בבית המשפט העליון בירושלים **בג"צ 23/________**

<u>בשבתו כבית המשפט הגבוה לצדק</u>

[נחתם ביום 25.6.23]

בעניין:

<u>העותרת</u>: גרינפיס ים תיכון בע"מ (חל"צ) 514340868

ע"י ב"כ עו"ד מתן גרפינקל (מ.ר. 45905)
כתובת להמצאת כתבי בי-דין ת.ד. 58132 תל אביב
טל': 03-6561505, פקס: 03-6561503

- נגד -

<u>המשיבים</u>:

1. **משרד האנרגיה והתשתיות**
2. **שר האנרגיה והתשתיות**
3. **הממונה על ענייני הנפט**
4. **מועצת הנפט**
5. **המשרד להגנת הסביבה**

ע"י פרקליטות המדינה
רח' צלאח א-דין 31, ירושלים
טל': 073-3925590; פקס: 02-6467011

<u>עתירה למתן צו על תנאי ולמתן צו ביניים</u>

העותרת מתכבדת להגיש בזאת עתירה, במסגרתה יתבקש בית המשפט הנכבד ליתן צו על תנאי המופנה אל המשיבים 1-3 המורה להם ליתן טעם כדלקמן:

א. מדוע לא יבוטל ההליך התחרותי הרביעי לקבלת רישיונות לחיפוש גז טבעי במימי ישראל (להלן: "**ההליך התחרותי הרביעי**" או "**ההליך התחרותי**")

ב. לחילופין – מדוע לא יתוקן ההליך התחרותי הרביעי ויפורסם מחדש באופן שיהיה בו כדי להתחשב בהשפעותיו על מחויבויותיה של מדינת ישראל להפחתת פליטות גזי חממה;

ג. לחילופי לחילופין - כל סעד אחר אשר יימצא כראוי ונכון בעיני בית המשפט הנכבד.

כן יתכבד בית המשפט הנכבד ליתן צו ביניים, כדלקמן:

צו המורה למשיבים להימנע מבחירה ו/או הכרזה על הזוכים בהליך התחרותי הרביעי, עד למתן פסק דין סופי בעתירה.

כמו כן, יתבקש בית המשפט הנכבד לחייב את המשיבים בהוצאות העתירה, בשכר- טרחת עו"ד ובמע"מ כדין.

(א) **פתח דבר**

1. משבר האקלים העולמי הוא מהמשברים החמורים ביותר איתם התמודדה האנושות מאז ומעולם. השנים האחרונות היו השנים החמות ביותר שנמדדו אי פעם והן מלוות באירועי מזג אוויר קיצוניים המשפיעים על העולם כולו.

2. למרבה הצער, לאדם השפעה מכרעת על משבר זה: העלייה בריכוז של גזי החממה באטמוספרה מיוחסת ברובה לפעילותו של האדם באמצעות הליכים תעשייתיים, חקלאיים ואחרים.

3. נוכח השפעות האנושות על משבר האקלים העולמי והצורך הדחוף להפחית בפליטה של גזי חממה, פעלו מדינות העולם בעשורים האחרונים וביתר שאת בשנים האחרונות על מנת להביא להפחתה בפליטות גזי החממה במדינותיהם.

4. כך, ובמסגרת ועידת האקלים ה- 21 של האו"ם בשנת 2015, הוצג הסכם פריז במטרה להביא להפחתת פליטות גזי חממה ברמה הגלובלית, והגבלת ההתחממות הגלובלית לפחות מ – 2 מעלות צלזיוס ביחס לתקופה הטרום תעשייתית וזאת עד לשנת 2050 (להלן: "**הסכם פריז**"). עסקינן בהתחייבות המשמעותית ביותר שנטלה על עצמה האנושות עד אותו מועד לשם מאבק בשינוי האקלים. ההסכם נחתם על ידי 195 מדינות וביניהם גם מדינת ישראל, שחתמה עליו ביום 22.4.16 ואשררה אותו ביום 14.11.16 (במסגרת החלטת ממשלה מס' 2041).

5. כפועל יוצא של הסכם פריז ואשרורו, התחייבה מדינת ישראל (כמו מדינות רבות אחרות) להפחית את פליטות גזי החממה שלה בשיעורים ניכרים בשנים הקרובות (להלן: "**יעדי ההפחתה**"). לצורך העמידה ביעדים אלה, נדרשת מדינת ישראל לשינוי של ממש של המשק הישראלי והרגלי החיים והצריכה של תושביה: החל ממעבר משמעותי של משק החשמל לשימוש באנרגיות מתחדשות, צמצום הטיפול בפסולת בדרך של הטמנה הגורמת לפליטה של גזי חממה, שינוי תהליכים תעשייתיים ועוד.

6. שינויים אלו והעמידה ביעדי ההפחתה הם משימה קשה ומורכבת לכל מדינה, ודאי למדינה כמו ישראל. על רקע האמור, ביום 13.12.22 פורסמו מסמכי ההליך התחרותי הרביעי לקבלת רישיונות לחיפושי גז טבעי במימי ישראל.

7. הליך זה הוא הליך מכרזי המבקש לאפשר לזוכים בו לחפש משאבי גז ונפט בשטח גדול במימי הים התיכון ולנצלם (אם אכן יימצאו משאבים כאלו). על פי ההערכות השמרניות עשוי ההליך התחרותי הרביעי להביא למציאה (והפקה) של מרבצי גז טבעי בהיקף גדול השקול לכמחצית היקף הגז שנמצא בישראל עד היום.

8. כאן המקום לציין, כי להליך פיתוח שדות גז והפקת הגז מהם (אף אם הגז עצמו מועבר בכולו לשימוש אל מחוץ לתחומי ישראל) תרומה משמעותית לפליטתם של גזי חממה. במסגרת פעולותיה בעניין, פנתה העותרת למומחה בעל שם על מנת שיכמת את שיעור פליטות גזי החממה העתיד להיפלט כתוצאה ממימושו של ההליך התחרותי הרביעי וזאת נעשה באמצעות חוות דעת מקיפה (להלן: "**חוות הדעת**" או "**חוות דעת המומחה**").

9. באמצעות שימוש במודל מדעי מיוחד אליו הוכנסו הנתונים הרלוונטיים, מצא המומחה כי תהליכי ההפקה והניצול של מאגרי גז חדשים מכוח ההליך התחרותי הרביעי יגדילו בצורה משמעותית את היקף פליטות גזי החממה בישראל באופן שיחייב את ישראל **<u>להכפיל פי 20-6</u>** (!) את שיעור הפחתת הפליטות הכולל על מנת לעמוד ביעדי ההפחתה שנטלה על עצמה.

10. **כפי העולה מחוות הדעת, תוספת הפליטות השנתית שתגרם כתוצאה ממימושו של ההליך התחרותי הרביעי <u>בלבד</u>, שוות ערך ל35% מסך פליטות גזי החממה <u>כולם</u> שנפלטו בישראל בשנת 2022 בישראל; 46% מסך פליטות גזי החממה שעל ישראל יהיה להפחית בשנת 2030, ו220% מסך פליטות גזי החממה שעל ישראל יהיה להפחית בשנת 2050. מדובר בשיעור עצום.**

11. ודוק. הלכה למעשה ונוכח הקושי הגדול בעמידה ביעדי ההפחתה גם כך, הרי שמטבע הדברים הצורך להגדיל בצורה כה משמעותית את שיעור הפחתת הפליטות כתוצאה ממימושו של ההליך התחרותי הרביעי יסכל למעשה כל סיכוי כי ישראל תוכל לעמוד ביעדי ההפחתה שנטלה על עצמה תוך הפרת התחייבויותיה בנושא ופגיעה במאמץ להילחם במשבר האקלים.

12. במילים אחרות, בעוד כי ממשלת ישראל התחייבה כי תפעל להפחית את גזי החממה שייווצרו בישראל פועלים המשיבים 1-4 כדי להרחיב באופן משמעותי את משק הגז בישראל באופן שיביא בהכרח להגדלה עצומה בכמות גזי החממה אותם נדרש להפחית.

13. ודוק. הלכה למעשה, לא נתקבלה החלטה סדורה להעדיף את ההליך התחרותי הרביעי והשלכותיו על פליטות של גזי חממה על פני העמידה ביעדי ההפחתה וממילא היציאה להליך התחרותי הרביעי לא נבחנה ביחס ליעדים אלו. כפי שיפורט בהרחבה להלן, ההחלטה לפרסם את ההליך התחרותי הרביעי נעשתה למעשה בהתעלם מהשפעותיו האפשריות על פליטות גזי החממה של ישראל, על כל המשתמע מכך.

14. דא עקא, כי למרות האמור לעיל וחשיבות העניין הרי שפניות העותרת למשיבים 1-4 בעניין זה זכו להתעלמות מוחלטת מצידן.

15. להשלמת פרק זה יצוין, כי ביום 24.4.23 הגישה החברה להגנת הטבע עתירה לבית משפט זה בעניין ההליך התחרותי הרביעי (בג"ץ 3143/23 החברה להגנת הטבע (ע"ר) נ' שר האנרגיה והתשתיות ואח') (להלן: "**העתירה הראשונה**") הנוגעת לטענות אחרות מאלה המובאות בעתירה דנן שעיקרן בהשלכות ההליך על שמירת הטבע בים התיכון וכן נימוקים אחרים.

(ב) הצדדים לעתירה

16. העותרת, גרינפיס ים תיכון בע"מ (חל"צ), היא הסניף הישראלי של ארגון גרינפיס העולמי – הארגון הגדול בעולם להגנת הסביבה הפועל ללא מטרות רווח.

17. המשיב 1, משרד האנרגיה והתשתיות (להלן: "**משרד האנרגיה**"), הוא הממונה מטעם ממשלת ישראל על משק האנרגיה ומשאבי הטבע בישראל ומפקח על הגופים הציבורים והפרטיים הפועלים בתחומים אלה. ההליך התחרותי הרביעי פורסם על ידי משרד האנרגיה.

18. המשיב 2, הוא שר האנרגיה והתשתיות והוא השר הממונה על יישומו של **חוק הנפט, תשי"ב – 1952** (להלן: "**חוק הנפט**") ועל התקנות שהותקנו מכוחו.

19. המשיב 3, הממונה על ענייני הנפט, אחראי על יישום הוראות חוק הנפט, ומתן רישיונות מכוחו לרבות רישיונות נשוא ההליך התחרותי.

20. המשיבה 4, מועצת הנפט, מייעצת למשיב 2 בענייני חוק הנפט ובכלל זה המליצה על פרסום ההליך התחרותי העומד במוקד עתירה זו.

21. המשיב 5, המשרד להגנת הסביבה, פועל לשמירה על הסביבה ועל בריאות הציבור באמצעות קידום חוקים, תקנות ותקנים ופיקוח על יישומם ואכיפתם. למשיב 5 נציגים במשיבה 4 ואלו הצביעו כנגד ההמלצה לקדם את ההליך התחרותי הרביעי.

(ג) רקע עובדתי

ג.1. משק הגז הישראלי וההליך התחרותי הרביעי

22. לאחר שנים רבות בהן משק האנרגיה הישראלי הסתמך כמעט לחלוטין על יבוא מחו"ל של הדלקים הדרושים לצורך פעילותו, הרי שהחל מתחילת המאה ה-21 חלו תמורות של ממש בעצמאותה האנרגטית של מדינת ישראל בדמות מציאתם ופיתוחם של מאגרי גז גדולים במימי ישראל.

23. בשנת 1999 נתגלה מאגר הגז "נועה" ובשנת 2000 מאגר "מרי – B" (שדה "ים תטיס") בעלי עתודות של כ- 40 BCM ((BCM היא יחידת מידת נפח לגז). הזרמת הגז ממאגרים אלה החלה בשנת 2004.

24. בשנת 2009 נתגלה מאגר הגז "תמר" בעל עתודה של 300 BCM. הזרמת הגז ממאגר זה החלה בשנת 2013.

25. בשנת 2010 נתגלה מאגר הגז "לוויתן", בעל עתודה של 500 BCM הזרמת הגז ממאגר זה החלה בשלהי שנת 2019.

26. בשנים 2012-2013 נתגלו מאגרי הגז "כריש" ו- "תנין" בעלי עתודה של 55 BCM. הזרמת הגז ממאגרים אלה החלה לאחרונה.

27. בשנת 2019 נתגלה מאגר "כריש צפון" בעל עתודה של 20 BCM.

28. סך היקפם של המאגרים שנתגלו עומד אפוא על כמות מוערכת של כ- 1,000 BCM.

29. בעקבות פיתוחו הענף של משק הגז בישראל, כמו גם ההבנה כי יש בפיתוח זה כדי לענות על הצרכים האנרגטיים של משק האנרגיה הישראלי עשרות שנים קדימה, ותוך הכרה בהשלכות הסביבתיות השליליות של פיתוח משק הגז על ישראל, בחודש דצמבר 2021 הודיעה שרת האנרגיה הקודמת על השהיית חיפושי גז חדשים בישראל:

> **"בשנה הקרובה נתמקד בעתיד, בחשמל הירוק, בהתייעלות האנרגטית ובאנרגיות המתחדשות – ובזמן שנעשה את זה נשים בצד את העיסוק בהרחבת פיתוח הגז הטבעי, שהוא, כידוע, דלק מעבר. בשנה הקרובה משרד האנרגיה לא יאמץ את מסקנות דו"ח בחינת מדיניות הגז הטבעי ולא ייצא להליך הרביעי למתן רישיונות לחיפושי גז טבעי. "**

--- העתק מדברי שרת האנרגיה מצ"ב כ **נספח 1**

30. למרות עמדתה זו של שרת האנרגיה הקודמת, הרי שבשלהי חודש מאי 2022 חזרה שרת האנרגיה מעמדתה והנחתה את אנשי משרדה להיערך ליציאה להליך התחרותי הרביעי המבקש להרחיב בצורה משמעותית את היקף הגז הטבעי שיופק במימיה הכלכליים של ישראל. ההנחיה החדשה, כך טענה השרה, נובעת מן המלחמה בין רוסיה לאוקראינה והשפעותיה על אספקת גז לאירופה.
--- העתק מעמדתה של שרת האנרגיה מחודש מאי 2022 מצ"ב כ**נספח 2**

31. כאן המקום לציין, כי שינוי עמדתה של שרת האנרגיה בדבר הצורך להמשיך ולפתח את משק הגז בישראל לצורכי ייצוא לא נשען על משנה סדורה: השלכותיו של ההליך התחרותי הרביעי בדמות ייצוא אפשרי של גז אל מחוץ לתחומי ישראל יתקיימו רק בעשור הבא, עת רוב רובה של יבשת אירופה תזנח את השימוש בגז ותעבור להסתמך על מקורות אנרגיה מתחדשת. בנסיבות אלה, לא ברור הצידוק שהביא את שרת האנרגיה לסגת מעמדתה שהובעה בעניין זה רק מספר חודשים קודם לכן.

32. כך או כך ובהתאם לעמדתו העדכנית (לפחות לעת הזו) של המשיב 1, ביום 13.12.22 פורסמו מסמכי ההליך התחרותי הרביעי לקבלת רישיונות לחיפושי גז טבעי במימי ישראל. כפי העולה מתגובת המדינה[1] לעתירת החברה להגנת הטבע שהוזכרה לעיל, מספר החברות שביקשו להשתתף בהליך גבוה משמעותית בהשוואה להליכים קודמים, ובכלל זה ביקשו להשתתף בהליך מספר חברות בינלאומיות גדולות שאינן פעילות כיום בישראל.
--- העתק מתגובת המדינה מצ"ב כ**נספח 3**

33. עוד עלה מתגובת המדינה[2], כי במסגרת הדיון שנערך במשיבה 4 עובר למועד פרסום ההליך התחרותי, נציגי המשיב 5 במשיבה 4 וכן נציג ציבור אחד **התנגדו** לפרסום ההליך התחרותי הרביעי כך שהמלצת המשיבה 4 לפתוח בהליך זה נתקבלה ברוב של חמישה כנגד שלושה.

34. כאן המקום לציין, כי מסמכי ההליך פורסמו בהתאם להוראות סעיף 5 לחוק הנפט ו-**תקנה 12 לתקנות הנפט (עקרונות פעולה לחיפושי נפט), התשע"ז 2016** המסדירות את סמכותם של המשיבים 1-3 לפעול לטובת קידומו של הליך תחרותי לטובת קידום הליכים לחיפושי גז ונפט והפקתם. מכאן גם סמכותו של בית המשפט הנכבד ולא של בית המשפט לעניינים מנהליים לדון בעתירה דנן.

35. על פי מסמכי ההליך התחרותי, אזור החיפוש המיועד משתרע על שטח גדול במימי הים התיכון כ- 5,888 קמ"ר הנחלקים לארבעה אזורים ובכל אזור מסומנים מספר "בלוקים".

36. על פי ההערכות השמרניות[3], פוטנציאל מימוש ההליך התחרותי הרביעי הוא למציאה של מרבצי גז בהיקף של כ 500 BCM. מדובר בהיקף עצום השקול לכמחצית כלל נפח הגז שנמצא בישראל עד היום במאגרים הקיימים. כאן המקום לציין כי עמדת הגורמים הנוגעים בדבר היא כי רובו

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[1] סעיף 27 לתגובת המדינה

[2] סעיף 47 לתגובה

[3] דו"ח הצוות המקצועי לבחינה תקופתית שנייה של מדיניות הממשלה בנושא משק הגז הטבעי (https://www.gov.il/BlobFolder/rfp/ng_210621/he/ng_report_2_draft.pdf)

ככולו של הגז שיופק בעקבות ההליך התחרותי הרביעי יועבר לייצוא אל מחוץ לישראל. כך למשל, במהלך הדיון שנערך ביום 29.11.22 במשיבה 4 ערב פרסום ההליך התחרותי ציין נציג המשיב 5 כי:

> **"כל גז שיימצא מיועד לייצוא ואינו לשוק מקומי כלל ועיקר, לכן תזמון ההליך אינו תואם את התחזיות הצפויות לירידת חשיבותו של הגז בשוק העולמי ולכן יש להבהיר את אפשרויות הייצוא של גז שיימצא במסגרת ההליך ואת העלות למדינה של הקמת תשתיות ייצוא"**

--- העתק מפרוטוקול הדיון מיום 29.11.22 מצ"ב כ**<u>נספח 4</u>**

37. למסמכי ההליך התחרותי צורפה טבלה המפרטת את לוחות הזמנים להשלמתו. על פי טבלה זו, המועד האחרון להגשת הצעות להליך התחרותי נקבע ליום 16.7.23 והמועד המשוער להכרזה על ההצעה או ההצעות הזוכות נקבע לסתיו 2023. הזוכה או הזוכים בהליך יקבלו מן המשיב 3 רישיון מתאים מכוחו של חוק הנפט על מנת שיוכלו לפעול לטובת מציאת משאבי הטבע והפקתם.
--- העתק ממסכי ההליך התחרותי מצ"ב כ**<u>נספח 5</u>**

38. כפי שיפורט להלן, העותרת סבורה כי אין מקום להמשיך ולקדם את הליכי ההליך התחרותי הרביעי בעת הזו ולמצער עד שיובהרו יחסי הגומלין שבין המשך פיתוחו של משק הגז מכוח ההליך התחרותי לבין התחייבויותיה של ישראל להפחית את פליטות גזי החממה שלה. זאת, נוכח העובדה כי הרחבת פיתוחו של משק הגז בישראל תביא בהכרח לכך כי ישראל לא תוכל לעמוד ביעדים והתחייבויות מקומיות ובין לאומית שנטלה על עצמה בכל הקשור להפחתת של פליטות גזי חממה.

39. בטרם נראה את הסתירה שבין קידומו ומימושו של ההליך התחרותי הרביעי לבין התחייבויותיה של מדינת ישראל בזירה הבין לאומית וזירות אחרות, נסקור בקצרה את משבר האקלים העולמי.

<u>ג.2. משבר האקלים העולמי</u>

40. לפי הארגון המטאורולוגי הבינלאומי[4], שבע השנים החולפות היו החמות ביותר שנמדדו אי פעם. לעוצמה ולתדירות של אירועים קיצוניים אלו קשר ישיר לשינוי האקלים מעשה ידי אדם אשר צפויים להחריף[5].

41. הגורם המרכזי להגברת אפקט החממה הוא פליטות פחמן מעשה ידי אדם, שמקורן בשריפה של דלקי מאובנים - נפט, גז מחצבי ופחם המשחררים גזי חממה בכמות המשפיעה באופן דרמטי על התחממות כדור הארץ. גלי חום אירעו אמנם בעבר, אך לא בתדירות ובעוצמה לה אנו עדים בעת

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[4] https://public.wmo.int/en/media/press-release/united-science-we-are-heading-wrong-direction

[5] United in Science: We are heading in the wrong direction

הנוכחית. שינויי טמפרטורה אלו משפיעים גם על טמפרטורת האוויר, הקרקע והים, היקף כיסוי הקרח וגודלם של קרחונים, שטחי יערות־ עד, חומציות האוקיינוסים, עוצמת זרם הגולף ועוד, אשר חווים שינויים הרי גורל בשנים האחרונות[6].

42. ודוק. קיים קונצנזוס מדעי בעניין משבר האקלים והשלכותיו על כדור הארץ והאנושות: כל עיכוב בפעולה גלובלית ביחס למשבר זה יביא להחמצת חלון ההזדמנויות המצטמצם, לטובת הבטחת עתיד בר קיימא של חיים על פני כדור הארץ.

<u>**ג.3. התחייבויות מדינת ישראל להפחתת פליטות של גזי חממה**</u>

<u>התחייבויות מדינת ישראל במסגרת הסכם פריז</u>

43. נוכח החשיבות העצומה שבטיפול במשבר האקלים, הצורך הדחוף בהפחתה משמעותית של פליטת גזי חממה המחוללים משבר זה, מתכנסות אחת לשנה ועידות האומות המאוחדות לשינוי אקלים (באנגלית: United Nations Climate Change conference; ידועה גם כ-"ועידת האקלים של האו"ם"), במסגרת אמנת המסגרת של האו"ם בנושא שינויי אקלים (UNFCCC).

44. במסגרת ועידות האקלים שהתכנסו בעשורים האחרונים, לקחו על עצמן מרבית מדינות העולם התחייבויות שונות לטובת התמודדות עם משבר האקלים. כך למשל, במהלך ועידת האקלים שנתכנסה בקיוטו ביפן בשנת 1997 נחתם פרוטוקול קיוטו המחייב את המדינות המפותחות לפעול להפחתה משותפת של פליטות גזי החממה שלהן.

45. עם המשך הצטברות העדויות וההשלכות הממשיות של משבר האקלים בדמות שינויי אקלים, אירועי קיצון של מזג האוויר, המסת קרחונים, שינוי בטמפרטורת האוקיאנוסים ועוד, החליטו מדינות העולם 'לעלות שלב' בטיפול במשבר.

46. כאמור לעיל, במסגרת ועידת האקלים ה- 21 של האו"ם בשנת 2015, הוצג הסכם פריז במטרה להביא להפחתת פליטות גזי חממה ברמה הגלובלית, והגבלת ההתחממות הגלובלית לפחות מ – 2 מעלות צלזיוס ביחס לתקופה הטרום תעשייתית וזאת עד לשנת 2050 עסקינן בהתחייבות המשמעותית ביותר שנטלה על עצמה האנושות עד אותו מועד לשם מאבק בשינוי האקלים. ההסכם נחתם על ידי 195 מדינות וביניהם גם מדינת ישראל, שחתמה עליו ביום 22.4.2016 ואשררה אותו ביום 14.11.2016 (במסגרת החלטת ממשלה מס' 2041).

--- העתק מהסכם פריז מצ"ב כ<u>**נספח 6**</u>

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[6] https://www.ipcc.ch/report/ar6/wg1/#FullReport

47. מאז נחתם ההסכם, הצטברו הראיות המדעיות המעידות על הצורך בהגבלת ההתחממות הגלובלית לפחות מ – 1.5 מעלות צלזיוס, על מנת למתן את ההשלכות הבלתי הפיכות של שינוי האקלים. לצורך כך, ובהתאם לפרסומים של הפאנל הבין-ממשלתי לשינויי האקלים (IPCC)[7], נדרשת הפחתת פליטות גלובלית של 50% מפליטות גזי החממה עד לשנת 2030, ואיפוס פליטות נטו עד לשנת 2050 (ביחס לשנת הבסיס 2015).

48. אחד מעקרונות היסוד בהסכם פריז, הוא ההתחייבות המדינות להעביר למזכירות ה UNFCC (אמנת המסגרת של האו״ם בנושא שינויי אקלים), נתונים בדבר פליטות גזי החממה השנתיות במדינה וכן להעביר, אחת ל 5 שנים, יעדים לאומיים של הפחתת פליטות גזי חממה.

49. בהתאם לכך, בשנת 2019 (שנת הדיווח האחרונה), דיווחה ישראל ל-UNFCC אודות כמות פליטות גזי חממה השנתית בישראל, שעמדה בשנה זו על כ-79 מיליון טון שווה ערך פחמן דו חמצני (MtCO2eq),

--- העתק מהדיווח האחרון שהעבירה ישראל מצ״ב כ**נספח 7**

50. כפי שיפורט להלן ממשלת ישראל קבעה יעדי הפחתה של פליטות גזי חממה ביחס לדיווחים שהעבירה למוסדות האו״ם. יעדים אלה מבוססים על הצורך בהפחתת הפליטות ובהגבלת ההתחממות הגלובאלית, כפי שצוין לעיל.

החלטת הממשלה מס׳ 171 בעניין מעבר לכלכלה דלת פחמן

51. בהתאם להוראות הסכם פריז, ביום 25.7.2021 החליטה ממשלת ישראל בהחלטה מס׳ 171 שכותרתה ״כלכלה דלת פחמן״ לקבוע יעדים להפחתת פליטות גזי החממה בישראל.

52. בפתח ההחלטה, צוינה החשיבות שבמעבר המשק הישראלי לכלכה דלת פחמן, בין היתר על מנת שמדינת ישראל תוכל לעמוד בהתחייבויות הבין לאומיות שנטלה על עצמה:

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[7] IPCC. (2021). Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou (eds.)]. Cambridge University Press. In Press.

> **"בהמשך להחלטת הממשלה מס' 542 מיום 20.9.2015 בעניין הפחתת פליטות גזי חממה וייעול צריכת האנרגיה במשק (להלן – החלטת ממשלה 542) ועל-מנת לעמוד במחויבותה של ישראל לפי החלטת הממשלה מס' 2041 בעניין אשרור הסכם פריז בדבר התמודדות בין-לאומית עם שינויי האקלים מיום 14.11.2016, להגיש למזכירות אמנת האקלים יעד לאומי מעודכן להפחתת פליטות גזי חממה לשנת 2030, וכן לפעול למעבר ישראל לכלכלה דלת פחמן עד לשנת 2050 מדינת ישראל מכירה בחשיבות ההגעה ליעד של אפס פליטת גזי חממה עד 2050 בהתאם להסכם פריז ומחויבותה הבין-לאומית ולמען מניעת חציית רף ההתחממות הגלובלית של מעלה וחצי צלזיוס. מכאן, שהממשלה תבחן מעת לעת את יעדי ההפחתה שהציבה לעצמה בהחלטה זו."**

--- העתק מהחלטת הממשלה 171 מצ"ב כ**<u>נספח 8</u>**

53. ואולם החלטה זו של ממשלת ישראל לא הייתה דקלרטיבית בלבד. החלטה 171 גם קבעה, ברחל בתך הקטנה, יעדים כמותיים ברורים להפחתת פליטות של גזי חממה בישראל:

> **"עדכון היעד הלאומי להפחתת פליטת גזי חממה לשנת 2030, כך שהכמות השנתית של פליטות גזי חממה בשנת 2030 תפחת ב-27% לפחות מהכמות השנתית שנמדדה בשנת 2015, אשר עמדה על 79 מיליון טון. בהתאם לאמור, הכמות השנתית של פליטות גזי חממה בשנת 2030 אמורה לעמוד על כ-58 מיליון טון.**
>
> **קביעת יעד לאומי להפחתת פליטות גזי חממה לשנת 2050, כך שהכמות השנתית של פליטות גזי חממה בשנת 2050 תפחת ב-85% לפחות מהכמות השנתית שנמדדה בשנת 2015. בהתאם לאמור, תעמוד הכמות השנתית של פליטות גזי חממה בשנת 2050 על כ-12 מיליון טון."**

54. היעדים שלעיל (קרי, פליטות של 58 מיליון טון גזי חממה בשנת 2030 ו- 12 מיליון טון בשנת 2050) נשוא החלטת הממשלה הוגשו למזכירות האו"ם (NDC Registry). יצוין כי יעדי ההפחתה שנקבעו הם יעדים אבסולוטיים (ולא פר נפש כפי שנקבע בעבר) והם נקבעו על ידי ממשלת ישראל על אף הגידול הצפוי באוכלוסיית ישראל בשיעור צפוי של בין 1.4% ל 2% בכל שנה.

--- העתק מיעדי ההפחתה שהעבירה ישראל לאו"ם מצ"ב כ**<u>נספח 9</u>**

55. זאת ועוד. בהתאם להחלטות הממשלה שצוינו לעיל ומחויבויותיה של ישראל בזירה הבין-לאומית להפחתת פליטות גזי חממה, ביום 26.10.21 פרסם המשיב 5 את "עיקרי האסטרטגיה הלאומית לישראל דלת פחמן ומשגשגת". במסמך זה צוין:

> **"משבר אקלים מאיים לפגוע בכדור הארץ בכלל, ובחברה האנושית בפרט. לאור כך, יש צורך בהרחבת והעמקת הצעדים להפחתת פליטות גזי חממה... לשם מניעת הסלמת המשבר והגדלת הפליטות שהוצגה במסגרת 'עסקים כרגיל', על ישראל מוטלת החובה לבצע שינויים מרחיקי לכת ולעבור לכלכלה דלת פחמן"**

--- העתק מעיקרי האסטרטגיה הלאומית לישראל דלת פחמן ומשגשגת מצ"ב כ**<u>נספח 10</u>**

56. כאן המקום להזכיר, כי בעוד בעבר הייתה ההתייחסות לגז הטבעי כדלק נקי יותר, בשל תרומתו לצמצום מזהמי אוויר מסוימים ובשל כמות הפחמן הדו החמצני המופחתת הנפלטת בעת שריפתו, בשנים האחרונות מדיניות האנרגיה העולמית עדכנה את יחסה לשימוש והפקת הגז, תוך מתן דגש לתרומתו לשינוי האקלים והצורך להפחית את התלות בדלקים פוסילים על מנת לאפשר את הגבלת ההתחממות הגלובלית מתחת למעלה וחצי.

57. עוד יצוין, כי מעבר לפליטות פחמן דו-חמצני הכרוכות בתהליך השריפה של הגז בתחנות הכוח, השלבים השונים בתהליך הפקת הגז כרוכים בשחרור לאוויר של המרכיב המרכזי בגז, הוא גז החממה מתאן.

58. כפי שיפורט בהמשך, פליטות מתאן אלו הוערכו בחסר לאורך השנים, והביאו ליצירת השוואה בלתי הגונה בין הדלקים השונים, שיצרה מצג לפיו הגז הוא דלק נקי בהרבה ביחס לדלקים האחרים. כך למשל, ועוד לפני הפרסום להערות הציבור של טיוטת של דו"ח ועדת אדירי 2 שעסק בבחינת מדיניות הגז הטבעי, דו"ח סוכנות האנרגיה הבינלאומית (IEA) שפורסם במאי 2021 קבע כי על מנת לעמוד ביעדי איפוס פחמן בשנת 2050, יש להפסיק פיתוח והשקעה בחיפוש שדות נפט וגז חדשים בשנת 2021. בנוסף, על פי דוח ה-IPCC, הפאנל הבין-ממשלתי לשינוי האקלים, שפורסם באוגוסט 2021, נקבע כי גז מתאן, המרכיב המרכזי בגז המחצבים, אחראי לבדו להתחממות של כ-0.5 מעלות צלזיוס (בהשוואה לפחמן דו-חמצני האחראי לעלייה של כ-0.8 מעלות צלזיוס).

--- העתק מדו"ח ה IEA ו- דו"ח ה IPPC מצ"ב כ**<u>נספח 11</u>**

59. בהתאם לכך, עמדת המשיב 5 שנשלחה כתגובה לדוח ועדת אדירי בספטמבר 2021, הציגה התנגדות להרחבת משק הגז, בשל העובדה כי זו מסכנת את יכולתה של ישראל להיגמל מהתלות בדלקים מזהמים, ולעבור לכלכלה דלת פחמן כמו שאר מדינות הOECD.

60. במסמך העמדה צוין כי מדיניות פיתוח משק הגז חייבת לעמוד בהלימה למחויבות ולאסטרטגיה להפחתת התלות בדלקים פוסיליים ולמעבר לכלכלת דלת פחמן. עוד צוין כי מתן תמריצים

כלכליים לדלקים פוסיליים עומד **בניגוד למחויבות ישראל להפחתת פליטות**, ובניגוד לקונצנזוס המדעי לפיו הפסקת הפיתוח של מאגרי דלקים פוסיליים היא הכרחית לבלימת שינויי האקלים.

--- העתק ממסמך העמדה של המשיב 5 מצ״ב כ**נספח 12**

61. להשלמת התמונה יצוין כי לקראת ועידת האקלים שנתכנסה בגלזגו בחודש נובמבר 2021, העבירה מדינת ישראל את יעדי הפחתת הפליטות המעודכנים לאותה השנה העומדים כאמור על על הפחתה של 27% לפחות עד לשנת 2030, והפחתה של 85% לפחות עד לשנת 2050, בהשוואה לכמות השנתית שנמדדה בשנת 2015.

--- העתק מיעדי הפחתת הפליטות המעודכנים שהעבירה ישראל מצ״ב כ**נספח 13**

62. כתוספת לאמור לעיל, בשל ההבנה הגלובלית אודות תרומתו המשמעותית של גז החממה מתאן, ובהתאם למסקנות דוח הפאנל הבין-ממשלתי לשינויי אקלים (IPCC) באוקטובר 2021 נחתמה יוזמה בין לאומית להפחתת פליטות המתאן הגלובליות. [8] מדינת ישראל היא אחת מ121 מדינות אשר חתמו על אמנת המתאן (Global Methane Pledge), והתחייבו להפחתה של לפחות 30% מפליטות המתאן הגלובליות עד לשנת 2030, ביחס לשנת הבסיס 2020.

63. ואולם, כפי שיפורט בהרחבה להלן ובהתבסס על חוות דעת מומחה המצ״ב לעתירה דנן, ככל שיושלמו הליכי ההליך התחרותי הרביעי העומד במרכזה של עתירה זו, יוכרז בו זוכה שיהא רשאי לפעול לגילוי מרבצי גז ונפט בים התיכון (ואם אכן יימצאו ויפתחו מרבצים אלה) **יביא הדבר בהכרח לכך כי ישראל לא תוכל לעמוד ביעדי ההפחתה שנטלה על עצמה תוך הפרת מחויבויותיה הבין לאומיות, החלטותיה ועמדותיה המקצועיות בעניין שרובן ככולן ניתנו רק לאחרונה והכל תוך החמרת תרומתה למשבר האקלים.**

ג.4. גז מתאן הוא גז חממה רב עצמה המהווה תוצר לוואי משמעותי של הפקה ושימוש בגז טבעי

64. המתאן הוא אחד מגזי החממה ומהווה את המרכיב המרכזי בגז הטבעי. בעוד שריכוז המתאן באטמוספירה נמוך בהרבה מזה של פחמן דו חמצני, הרכבו הכימי של המתאן הופך אותו ליעיל במיוחד בכליאת חום, ועל פי החישובים העדכניים, על פני 20 שנה הוא יוצר אפקט חממה גבוה פי 84-86 מזה של פחמן דו חמצני.[9]

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[8] Global Methane pledge (2021) https://www.globalmethanepledge.org/

[9] UNECE, Methange management https://unece.org/challenge

65. בהתחשב בהשפעה השלילית במיוחד של המתאן על אפקט החממה, ראוי להציג את מידת שכיחותו באטמוספירה והשפעתיו של האדם על כך. על פי דוח האו״ם שפורסם במאי 2021,[10] התעשיות הפוסיליות אחראיות על 35% מכלל פליטות המתאן האנושיות. תהליך הפקת הגז מביא לא רק לפליטות פחמן דו חמצני בתהליך השריפה, אלא גם לפליטות מתאן בהיקפים גדולים הנובעים באופן ישיר מהליך הפקת הגז: על פי ההערכה, כ- 3% מכלל הגז הטבעי שמופק אובד בכל שנה עקב דליפות, תקלות ובעירה בשלבי הייצור, בין היתר בעקבות פליטות בלתי מוקדיות.[11]

66. פליטות בלתי מוקדיות הן דליפות גז בלתי מכוונות שמקורן בייצור ועיבוד במתקני הגז והנפט השונים (בין היתר דרך פעולות או תקלות של נישוב ושריפת גז מכוונת בלפיד (פליירינג), ובמערך ההולכה והחלוקה. אלו הם הפסדי אנרגיה ממושכים בשיעור נמוך - פליטות לאוויר של גז אגרסיבי חסר צבע או ריח, מכל מרכיבי המערכת, דבר שמקשה מאוד על זיהוי שלהם באופן רציף ומקיף.

67. כפי העולה מחוות הדעת ועל פי ההערכות המדעיות המקובלות, פליטות המתאן המדווחות מכל השלבים בשימוש בגז מחצבי נמוכות בכ-70% ממספרן האמיתי.[12] מדידות בפועל שנעשו במקומות שונים בעולם, לטובת כימות פליטות המתאן (באמצעות לווינים או מצלמות תרמיות), הראו פליטות גבוהות בהרבה מההערכות שקדמו להן. בהתאם לכך, מספר עבודות מקצועיות שנערכו לאחרונה עבור המשיב 1 ו- המשיב 5 , ולא כללו מדידות בפועל, העריכו בחסר רב את שיעור פליטות המתאן כתוצאה מהפקת הגז בישראל (להלן: ״**חוות הדעת**״).

68. לא זו אף זו, אלא שגם בין העבודות השונות שביצעו משרדי הממשלה עצמם נתגלו פערים גדולים. בהתחשב בשיעור הגידול בכמות הגז המופקת לאורך השנים, נמצא פער של פי 5.7 בין העבודה האחרונה שבוצעה עבור המשיב 5 בספטמבר 2022, לבין העבודה שבוצעה במשיב 1 בפברואר 2021.

--- העתק מן העבודות שבוצעו לטובת כימות מתאן מצ״ב כ**<u>נספח 14</u>**

69. מן האמור בחוות הדעת המומחה עולה כי, מקורם של הנתונים עליהם התבססו חוות הדעת הוא במידע שהתקבל מחברות הגז, ולא נאסף באופן עצמאי מידע המשקף הערכת חסר של כמה סדרי גדול ביחס לנתונים המקובלים כיום. לצורך ההמחשה, חוות דעת המומחה העלתה כי בהתבסס על דיווחי חברות הגז למשיב 5, אחוז הפליטות ממאגרי הגז עומד על 0.014%, בעוד במחקר שבוצע

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[10] https://wedocs.unep.org/bitstream/handle/20.500.11822/35917/GMA_ES.pdf

[11] https://www.unep.org/news-and-stories/press-release/global-assessment-urgent-steps-must-be-taken-reduce-methane

[12] https://www.iea.org/news/methane-emissions-from-the-energy-sector-are-70-higher-than-official-figures

במסגרת חוות הדעת (ואשר מבוסס על נתונים והנחות מהימנים יותר) נמצא כי שיעור הפליטות עומד על 2.7%. מדובר בפער עצום של פי כ-200.

70. ודוק. ייתכן כי הערכת חסר זו היא אחד הגורמים המרכזיים לכך כי השפעותיו הדרמטיות של ההליך התחרותי הרביעי על יכולתה של מדינת ישראל לעמוד ביעדי ההפחתה לא נשקלו כנדרש על ידי הנוגעים בדבר או שנשקלו ביחס לשימוש בתשתית עובדתית רעועה.

ג.5. הגדלת הפקת הגז הטבעי כתוצאה מן ההליך התחרותי הרביעי תמנע מישראל לעמוד ביעדי הפחתת הפליטות שנטלה על עצמה

71. אין חולק כי קיים מתח מובנה בין פיתוח ושימוש בשדות גז שתוצריהם מיועדים בעיקר לייצוא, לבין הגברת פליטות גזי חממה. גם המשיב 2 בעצמו הכיר במתח זה. כך, בסעיף 23 לתגובת המדינה צוין מפורשות כי:

> **"במבט צופה פני עתיד, רואה משרד האנרגיה והתשתיות אתגר מדיניות מרכזי, באיזון שבין העובדה שמשק האנרגיה בישראל מבוסס בחלקו הגדול על גז טבעי, לבין מחויבותה של מדינת ישראל להתמודדות עם משבר האקלים".**

72. הנה כי כן, גם לשיטת המשיב 2 אין חולק כי יש צורך לאזן בין התחייבויותיה של מדינת ישראל להפחתת פליטות לבין שימוש והפקה של גז טבעי. כפי שיפורט מייד, איזון זה, שספק אם היה קיים ערב פרסומו של ההליך התחרותי הרביעי, יופר באופן מוחלט אם יקום הליך זה וימומש.

73. חשוב להדגיש, כי טענת העותרת בעתירה זו אינה קוראת תיגר על עמדתו המקצועית[13] של המשיב 2 הרואה בגז טבעי כ "דלק מעבר" בו ישתמש המשק הישראלי בעתיד הנראה לעין עד למעבר מלא של המשק הישראלי לשימוש באנרגיות מתחדשות ואף אינה מבקשת לבקר או לטעון כנגד עמדתו של המשיב 2 כי השימוש בגז טבעי המתבסס על שדות הגז שכבר נתגלו ופותחו נכון מבחינה כלכלית, סביבתית או אחרת (וממילא לא נתבקש כל סעד בגין כך).

74. טענת העותרת המבוססת על מחקר מדעי מקיף ועדכני היא, כאמור, כי קידום ההליך התחרותי הרביעי, המבקש לפתח מקורות חדשים של גז טבעי בעת הנוכחית, לא יאפשר לישראל לעמוד ביעדי ההפחתה שנטלה על עצמה. ונפרט.

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[13] סעיפים 20-25 לתגובת המדינה

75. כפי שצוין לעיל, על פי הערכותיו השמרניות של המשיב 1, הרחבתו של משק הגז הישראלי כתוצאה מן ההליך התחרותי הרביעי מוערכת ב כ- 500BCM. בחוות דעתו המקצועית, ניתח המומחה את תוספת פליטות גזי החממה הצפויה בישראל מכלל השלבים הנוגעים לניצולה של תוספת זו ובחן את השפעתה של תוספת זו על יכולתה של מדינת ישראל לעמוד ביעדי ההפחתה.

76. באמצעות שימוש במודל מדעי מיוחד ("מונטה קרלו") (להלן: "**המודל**") אליו הוכנסו הנתונים הרלוונטיים, מצא ד"ר לובצ'יק כי תהליכי ההפקה והניצול של מאגרי גז חדשים בהיקף של כ-500 BCM יגדילו בצורה משמעותית את היקף פליטות גזי החממה בישראל באופן שיחייב את ישראל כמעט ולהכפיל את שיעור הפחתת הפליטות הכולל על מנת לעמוד ביעדי ההפחתה שנטלה על עצמה. דר' לובצ'יק התייחס לכך בחוות הדעת בציינו:

> **"הרחבת משק הגז בהיקף של BCM500 (בהתאם להערכות השמרניות עליהן מתבסס משרד האנרגיה) תביא לתוספת פליטות גזי חממה כוללת בסך של Mton CO2eq 806.01, שיתפרסו לאורך 30 שנה מתחילת פיתוח המאגר. בהתאם, תוספת הפליטות השנתית צפויה לעמוד על Mton CO2eq 26.86 מדי שנה... אמנם, בהתבסס על הנתונים שמספקות חברות הגז למשרדי הממשלה (משרד האנרגיה והמשרד להגנת הסביבה), אחוז פליטות גזי החממה שמקורם במשק הגז בישראל עומד על 0.014% ו0.08% בהתאמה, במחקר זה נמצא שאחוז הפליטות עומד על 2.7%, כלומר מדובר בהערכת חסר של פי 192 ו-33 בהתאמה."**

--- העתק מחוות דעת המומחה מצ"ב כ**<u>נספח 15</u>**

77. הנה כי כן, קבע ד"ר לובצ'יק כי היקף פליטות גזי החממה כתוצאה מפיתוח של כ- 500 BCM הינו אדיר ועומד על Mton CO2eq 806.01 או Mton CO2eq 26.88 מדי שנה לתקופה של 30 שנה.

78. זאת ועוד. כפי שצוין לעיל, אחד הגורמים העיקריים להערכה השגויה של השפעת ההליך התחרותי הרביעי על יכולתה של ישראל לעמוד בעדי ההפחתה (אם בכלל נעשתה הערכה שכזו) נובע מהערכת חסר מהותית של הנוגעים בדבר במשרדי הממשלה ביחס לתרומת משק הגז לפליטות גזי חממה בישראל בכלל וביחס לשיעורו של גז המתאן מפליטות אלה בפרט.

79. במילים אחרות, גם אם ההחלטה להמשיך ולפתח את משק הגז באמצעות ההליך התחרותי הרביעי נעשתה בצורה מודעת, תוך לקיחת כל הפרמטרים הרלוונטיים בחשבון (וכפי שהראנו, לא כך הדבר), הרי שהיא התבססה על תשתית עובדתית שגויה לחלוטין, היורדת לשורשו של עניין.

80. כך או כך, בהתחשב בפיתוח משק הגז בהיקף נוסף של 500 BCM, בדק ד״ר לובצ׳יק את ההשפעה הצפויה של פיתוח זה, בדמות תוספת של פליטות גזי חממה כתוצאה מן ההליך התחרותי הרביעי, על יכולתה של ישראל לעמוד ביעדי ההפחתה שנטלה על עצמה:

> **״לצורך עמידה ביעד הפחתת פליטות גזי החממה שנקבע לשנת 2030, נדרשת מדינת ישראל לקצב הפחתה ממוצע של כ-8% מדי שנה לאורך 8 השנים הקרובות, עד להגעה לסך פליטות של 57.87 Mton CO2eq בשנת 2030. במידה והרחבת משק הגז תחל בין השנים 2023-2030, לרבות שלב החיפושים, היא צפויה להגביר את הקצב השנתי של הפחתת פליטות גזי החממה הנדרש לעמידה ביעד ההפחתה, כך שתידרש הפחתה ממוצעת של כ-52% מדי שנה.״**

81. הנה כי כן, המסקנה החד משמעית בחוות הדעת היא כי פיתוח מיידי של משק הגז בישראל בהיקף של 500 BCM יחייב את ישראל להכפיל פי 6 (!) את קצב הפחתת פליטות גזי החממה לשם עמידה ביעדי ההפחתה, מדי שנה. ואולם, נוכח ההנחה הסבירה כי ההליך התחרותי הרביעי יושלם ככל הנראה רק בשלהי שנת 2023, הליכי חיפוש הגז יחלו רק בסמוך לשנת 2024 והפקת הגז (אם יימצא) תחל לא לפני סוף העשור הנוכחי, בחן דר׳ לובצ׳יק את השפעת ההליך התחרותי על עמידת ישראל ביעדי הפחתה בהנחה כי הליכי הפיתוח בפועל יחלו בשנת 2030:

> **״בהנחה שמרנית ביותר לפיה ישראל תעמוד ביעדי ההפחתה לשנת 2030, לצורך עמידה ביעד שנקבע לשנת 2050, נדרש קצב הפחתה שנתי של כ-7.5% בממוצע לאורך 20 שנה, עד להגעה לסך פליטות של 11.96 Mton CO2eq בשנת 2050. במידה והרחבת משק הגז תתבצע בין השנים 2030-2050, היא צפויה להגביר את הקצב השנתי של הפחתת פליטות גזי חממה הנדרשות לעמידה ביעד, כך שתידרש הפחתה ממוצעת של כ-197% מדי שנה. בשל ההיערכות המוקדמת הנדרשת לטובת צמצום פליטות גזי חממה, הרחבת משק הגז בהיקף האמור תפגע בצורה משמעותית ביכולת העמידה של ישראל ביעדי הפחתת הפליטות אליהם התחייבה.״**

82. במילים אחרות, אם פיתוחו של משק הגז מכוח ההליך התחרותי הרביעי יחל בפועל רק בעשור הבא (וזו ההערכה הסבירה ביותר) שיעור הפחתת גזי החממה הדרוש לישראל על מנת שתוכל לעמוד ביעדי ההפחתה יעלה מ 10% ל 197% בשנה, מדי שנה עד לשנת 2050. מדובר בשיעור הפחתה אדיר, שספק רב, בלשון המעטה, שבכוחה של ישראל לעמוד בו גם אם תשתמש בטכנולוגיות הטובות ביותר ותנקוט במירב המאמצים לשם כך.

83. כאן המקום להבהיר את יחסי הגומלין שבין קידומו של ההליך התחרותי הרביעי, לבין צורכי משק הגז הישראלי והסעדים שנתבקשו בעתירה דנן. כפי שצוין בסעיף 17 לתשובת המדינה, ביום 12.10.21 פרסם משרד האנרגיה והתשתיות את מסמך "מפת הדרכים למשק אנרגיה דל פחמן עד שנת 2050" (להלן: "**מסמך מפת הדרכים**"), אשר מציג את האסטרטגיה ארוכת -הטווח של המשרד, תוך התמקדות בצמצום פליטות והתמודדות עם משבר האקלים.

--- העתק ממסמך מפת הדרכים מצ"ב כ**נספח 16**

84. על פי טענת המדינה, גם בתסריטים "האופטימיים" שנסקרו במסמך מפת הדרכים, קרי תסריטים לפיהם יעבור המשק הישראלי לשימוש המירבי האפשרי באנרגיות מתחדשות להפקת אנרגיה תוך השגת יעדי הפחתה מקסימליים של גזי חממה, יידרש המשק הישראלי לעשות שימוש בגז טבעי בהיקף בלתי זניח גם במהלך העשורים הקרובים באופן שיהווה אתגר של ממש לעמידתה של ישראל ביעדי ההפחתה. קל וחומר אפוא, כי ככל שהמעבר של המשק הישראלי לאנרגיות מתחדשות ייעשה בהיקף פחות מן המצופה היקף ההסתמכות על צריכת גז טבעי במשק רק יגבר ואיתו פליטת גזי חממה הנובעים מן השימוש בגז והאתגר להפחית פליטות אלה.

85. זאת ועוד, מדו"ח שפרסם המשרד להגנת הסביבה במאי 2023, עולה כי קצב היישום הנוכחי של התוכניות הלאומיות להפחתת פליטות בישראל, יביא להפחתה של כ12% בפליטות בשנת 2030 ביחס לרמתן בשנת 2015, זאת לעומת יעד משקי של 27% הפחתה שעליו התחייבה ישראל. יש לציין כי הדו"ח מתייחס למצב הנוכחי ביחס לעמידה ביעדי הפחתת פליטות, ואינו כולל התייחסות להרחבת משק הגז. השרה להגנת הסביבה התייחסה לכך בציינה:

86. **"כפי שהדוח שלנו מראה, ולמרות ההפחתה שבוצעה ב-2021, ישראל אינה צפויה לעמוד באף אחד מיעדי האקלים - הצנועים גם כך - שקבעה לעשור זה. נדרשת פעולה משמעותית שתשנה את האופן שבו ישראל תוביל להפחתת פליטות[14]..**"בנוסף, מדו"ח ה-OECD לסקירת הביצועים הסביבתיים של ישראל בעשור האחרון, שפורסם בסוף חודש מאי 2023, עולה כי עמידה ביעדים האקלים לשנים 2030 ו2050 תדרוש צעדים חדשים ומשמעותיים. ישראל אינה נמצאת בדרך להשגת יעדים אלה באמצעים הקיימים, ותצטרך ליישם אמצעים נוספים בכל המגזרים[15]:

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[14] https://www.gov.il/he/departments/news/special_report_climate_changes_2023

[15] https://www.oecd.org/environment/country-reviews/oecd-environmental-performance-reviews-israel-2023-0175ae95-en.htm

> **"בשנים האחרונות הגבירה ישראל את השאפתנות שלה בתחום האקלים. היא קבעה יעד הפחתה של 85% של פליטות גזי חממה עד 2050, כמו גם יעדים מגזריים לפליטות גזי חממה מייצור חשמל, פסולת מוצקה, תחבורה ותעשייה. כמו כן הצהירה על שאיפה כוללת של ניטרליות פחמנית (אפס פליטות נטו) עד לשנת 2050. ואולם ישראל אינה על המסלול להשגת יעדים אלה באמצעים הקיימים, ותצטרך לנקוט צעדים נוספים בכל המגזרים."**

ג.6 ההחלטה לפרסם את ההליך התחרותי הרביעי לא נעשתה על סמך בסיס עובדתי איתן ביחס להשפעת ההליך על יעדי ההפחתה

87. במסגרת המסמכים שנחשפו בעקבות הגשת העתירה הראשונה ובעקבות בקשה לפי חוק חופש המידע שהגישה, למדה העותרת לראשונה אודות הדיון המקצועי שנערך בפני המשיבה 4 ערב פרסום ההליך התחרותי. כפי העולה מתגובת המדינה, ביום 29.11.22 דנה המשיבה 4 בהצעה לפתוח בהליך התחרותי הרביעי[16]:

> **"לקראת הדיון הונח בפני המועצה מסמך המפרט את עקרונות ההליך התחרותי, לרבות ניתוח של ההיבטים הסביבתיים (להלן: "מסמך העקרונות") כפי שנעשה בהליכים תחרותיים קודמים, מסמך העקרונות שהונח בפני המועצה כלל את המסגרת החוקית; סעיפי הניקוד; פירוט בנושא ערבויות ושיווק במקבצים; וכן פירוט אודות שיקולי תחרות ונימוקים סביבתיים."**

--- העתק ממסמך העקרונות מצ"ב כ**נספח 17**

88. הנה כי כן, מתגובת המדינה עולה כי אותו מסמך עקרונות שהוצג בפני המשיבה 4 הוא המסמך המקצועי הרלוונטי שעל בסיסו התקבלה ההחלטה לפרסם את ההליך התחרותי.

89. במסמך העקרונות הוצגו כאמור גם הנימוקים או העקרונות הסביבתיים הרלוונטיים לעניין ובכלל זה אלה העוסקים (בצורה שטחית) ביעדי ההפחתה. מפאת חשיבות הדברים, נביא עקרונות אלה במלואם:

> **"שינויי האקלים הינם שינויים גלובליים ויש להתבונן בראיה גלובלית ולא מקומית. הפקת גז טבעי שייעודו להחליף דלקים מזהמים הרבה יותר, אם במצרים וירדן ואם באירופה, הינו תהליך מבורך שיסייע למדינות אלו לשמור על אספקת אנרגיה אמינה תוך שימוש בגז טבעי כאנרגיית מעבר. החלפת הדלקים המזהמים בתקופת המעבר תפחית את זיהום האוויר במדינות אלו, תשפר את בריאות האדם והסביבה ואף תפחית את פליטות גזי החממה שלהם**

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[16] סעיף 41 לתגובת המדינה

> **בעקבות הקרבה לאזורי ביקוש סמוכים, אזורי ביקוש ל LNG ובשל הפקת הגז הטבעי בשיטות קונבנציונליות ושיטות הטיפול הישראליות הנקיות באופן משמעותי מהנעשה במדינות אחרות.**
> **אין בתהליך החיפוש במים הכלכליים לפגוע ביעדי הפחתת הפליטות של מדינת ישראל, ואף לא בהחלטת הממשלה וביעדיה. הגז הטבעי כאמור, מחליף את השימוש בדלקים מזהמים יותר, ומהווה דלק מעבר עד אשר תמהיל מקורות האנרגיה בישראל יכלול מקורות אנרגיה נקייה בלבד, מה שלא צפוי בשנים הקרובות"**
> (ההדגשה אינה במקור – החי"מ)

90. קשה שלא להישאר אדישים למקרא מסמך העקרונות ולעמדות שהובעו בו ביחס להשפעת ההליך התחרותי על התחייבויותיה של ישראל לעמוד ביעדי ההפחתה. עיון בעמדה זו מלמד כי המשיבים 1-3 היו ערים היטב לעצם האפשרות כי המשך פיתוחו של משק הגז בישראל כפועל יוצא מן ההליך התחרותי הרביעי עלול לפגוע ביעדי ההפחתה, בהחלטת הממשלה בעניין וביעדיה.

91. דא עקא, כי למרות מודעות זו פטר מסמך העקרונות את החשש שהוא עלה באמרה סתמית כי "אין בתהליך החיפוש במים הכלכליים לפגוע ביעדי הפחתת הפליטות של מדינת ישראל". הא ותו לא. הדברים מקבלים משנה תוקף לאחר עיון בפרוטוקול ישיבתה של המשיבה 3 מיום 29.11.22 (נספח 4 לעיל) בה נידון ההליך התחרותי. כפי המשתקף בפרוטוקול זה, סוגיית השפעת ההליך על יעדי ההפחתה כלל לא נידונה ולו במעט במהלך הדיון שנערך, לא הובעו דעות נציגי המשיבה 4 בעניין ולא נסקר, הובא, נידון או נבחן שום נתון בעניין בשום צורה שהיא.

92. מן האמור עולה אפוא, כי מסמך העקרונות שהוצג בפני חברי המשיבה 3 שעל בסיסו ניתנה ההמלצה לפרסם את ההליך התחרותי הרביעי לא נימק, הסביר או התבסס על נתונים, מחקרים או אסמכתאות כלשהן עת קבע באופן חד משמעי כי ההליך התחרותי הרביעי לא יפגע בעמידת ישראל ביעדי ההפחתה. חומרת העניין מקבלת משנה תוקף נוכח חשיבות העניין אך גם נוכח מורכבות הסוגייה שעל הפרק שכפי שהוצג בחוות הדעת דורשת מארג מורכב של שימוש בכלים מדעיים מדיסציפלינות שונות.

93. במילים אחרות, וכפי שהוכח היטב מחוות הדעת שצורפה לעתירה, בחינת השפעת המשך פיתוחו של משק הגז על יעדי ההפחתה היא עניין סבוך ביותר, הדרוש מומחיות של ממש הנסמכת על בחינת מחקרים, ביצוע מודלים וכיו"ב כפי שנעשה בחוות הדעת. למעשה, ולמיטב ידיעתה של העותרת, עבודה מדעית בקנה מידה דומה טרם נעשתה בישראל ובכלל זה לא נעשתה עבור מי מהמשיבים. דומה כי אם הייתה נעשית עבודה שכזו הייתה המדינה מציגה את עיקריה זה מכבר.

94. נוכח האמור מובן כי המשיבים היו מודעים היטב לאפשרות כי המשך פיתוחו של משק הגז מכוח ההליך התחרותי הרביעי עלול לפגום בעמידתה של ישראל ביעדי ההפחתה, אך בחרו לפטור קושי זה בהתבסס על אמרה סתמית, בלתי מבוססת ובלתי מנומקת ובלא שהוצג לנוגעים בדבר ולו נתון, מחקר או בדיקה האחת התומכות באמרה זו.

95. לא זו אף זו, אלא שגם הערכות החסר ביחס לפליטות גזי החממה (פליטות מתאן בעיקרן) ממשק הגז הנוכחי בישראל שנידונה בחוות דעת העותרת, לא שימשו אפילו מצע לדיון בעניין. דומה כי הדברים מדברים בעד עצמם.

<u>ג.6 קידום ההליך התחרותי הרביעי אינו עולה בקנה אחד עם מסקנותיו של מבקר המדינה בעניין</u>

96. כאמור לעיל, חוות דעתו של מומחה העותרת קובעת באופן חד משמעי כי קידום ההליך התחרותי הרביעי יסכל את יכולה של מדינת ישראל לעמוד ביעדי ההפחתה שנטלה על עצמה. ואולם, אף עוד בטרם פורסם ההליך התחרותי הרביעי, קשייה של מדינת ישראל לעמוד ביעדי ההפחתה שנטלה על עצמה לא נעלמו מעיניו של מבקר המדינה.

97. ביום 26.10.21, כשנה עובר למועד בו פורסם ההליך התחרותי הרביעי, סקר מבקר המדינה את היערכות ויישום הצעדים הדרושים ביחס למשבר האקלים:

> **"13 שנים חלפו מאז הצטרפה ישראל ל-UNFCCC והיא החלה בפעולות אופרטיביות להפחתת פליטות גז"ח, אולם נכון לשנת 2021, אף שנרשמה ירידה בפליטות לנפש, הייתה עלייה בפליטות האבסולוטיות של ישראל. אשר לכל היעדים הסקטוריאליים שנקבעו בשנת 2015, <u>ההתקדמות בהשגתם נעה בטווח שבין ב"פיגור" לאפס</u>."**

(ההדגשה אינה במקור – החי"מ)

--- העתק מתקציר דו"ח מבקר המדינה מצ"ב כ**<u>נספח 18</u>**

98. ודוק. מובן כי אם מבקר המדינה מצא לנכון להעביר ביקורת חריפה על מידת הצלחתה של מדינת ישראל להביא להפחתה בגזי החממה הנפלטים בה, וזאת ביחס ליעדי מתונים יחסית שנקבעו בעבר, הרי שביקורת זו תהא רלוונטית ביתר שאת שעה שמדינת ישראל, באמצעות קידומו של ההליך התחרותי הרביעי, תסכל כל אפשרות לעמוד ביעדי ההפחתה המעודכנים.

99. זאת ועוד. דברים נכוחים אלה של מבקר המדינה מתחדדים עוד נוכח אמירתו החד משמעית ביחס ליחסי הגומלין שבין פיתוח והשקעה בתשתיות של דלקים פוסילים כפי בדיוק שמבקש לעשות ההליך התחרותי הרביעי, לבין היכולת לעמודי ביעדי הפחתת פליטות ובלשון המבקר:

> **"מדינות שנסקרו, לרבות מדינות ה-OECD, מציגות יעדים מעודכנים לאנרגיה מתחדשת לשנת 2030 שנעים בין 40% ל-100%, ואילו ישראל מציגה יעד חדש של 30% - הנמוך ביותר ממדינות ה-OECD אשר לפי הסכם פריז אמורות להציג יעדים בערכים מוחלטים ושאפתניים ולהוביל את הליך האיפוס הפחמני (דה-קרבוניזציה) העולמי. קביעת יעדים שיגדילו את ההשקעה בתשתיות אנרגיות פוסיליות עד שנת 2030 עלולה לסכן את הליך המעבר לכלכלה דלת פחמן עד שנת 2050."**

ובהמשך:

> **"קידום הפקת דלקים פוסיליים אינו מתיישב עם המדיניות המוצהרת של הממשלה, זה יותר מעשור, לצמצם פליטות גז"ח ומזהמי אוויר - ובעודה מקדמת מאבק בשינויי האקלים ולמען אוויר נקי, היא גם מקדמת מדיניות של "מיצוי פוטנציאל" משאבים שנדרש להתאימו למאמץ הלאומי להפחתת פליטות גז"ח ומזהמי אוויר. מומלץ אפוא שמשרדי האנרגייה והג"ס יגבשו מדיניות מוסכמת בעניין, המבוססת על ניתוח כלכלי המביא את מכלול התועלות והעלויות (לרבות החיצוניות) של החלופות השונות ועל ניתוח סביבתי-אקלימי, ובמידת הצורך יביאו אותה לדיון בממשלה"**

100.דומה כי הדברים מדברים בעד עצמם. אם עוד בטרם פרסומו של ההליך התחרותי הרביעי העלה מבקר המדינה ספק גדול ביחס ליכולתה של מדינת ישראל לקיים את מדיניותה ביחס להפחתת פליטה של גזי חממה, הרי שקל וחומר מימושו של הליך זה, על התוספת העצומה שהוא יביא בפליטות של גזי חממה בישראל, לא יאפשר באופן כליל לקיים מדיניות זו, על כל המשתמע מכך.

<u>ג.7. מיצוי ההליכים טרם הגשת העתירה</u>

101.כאמור לעיל, אחד מעיקרי עיסוקיה של העותרת הוא לפעול בכלים העומדים לרשותה על מנת להבטיח כי ישראל תתרום את חלקה במאבק בשינוי האקלים. ביום 29.12.21, חודשים ארוכים בטרם פרסומו של ההליך התחרותי הרביעי, פנתה העותרת אל שרת האנרגיה דאז בבקשה כי תבהיר כי לא תתיר עוד את המשך חיפושי גז ונפט.

--- העתק מפניית העותרת מיום 29.12.21 מצ"ב כ<u>**נספח 19**</u>

102.הפנייה נעשתה נוכח אי הבהירות ששררה באותו המועד ביחס לעמדתו של המשיב 1 ביחס לפיתוחו של משק הגז בישראל בעתיד הרחוק, שכן זמן קצר לפני פניית העותרת אל שרת האנרגיה, הודיעה השרה כי בכוונתה להשהות לתקופה של שנה חיפושי גז ונפט חדשים.

103.בפנייתה, פירטה העותרת את הסכנות הצפויות כתוצאה מהרחבת פיתוחו של משק הגז הישראלי ובכלל זה את הגברת פליטתם של גזי החממה. למרבה הצער, פנייה זו זכתה להתעלמות מוחלטת מצידה של שרת האנרגיה.

104.מספר חודשים לאחר מכן ובעקבות פתיחתה של מלחמת רוסיה אוקראינה שב ועלה החשש כי בכוונתו של משרד האנרגיה לשוב ולנקוט בצעדים לטובת פיתוחו והרחבתו של משק הגז הישראלי.

105.על רקע זה, ביום 19.9.22 שבה ופנתה העותרת אל שרת האנרגיה בדרישה ברורה כי לא תאפשר את קידומו של ההליך התחרותי הרביעי. בפנייה זו הביאה העותרת בפני שרת האנרגיה נתונים מהם ניתן ללמוד באופן ברור כי מימושו של ההליך התחרותי הרביעי לא יאפשר לישראל לעמוד ביעדי ההפחתה שנטלה על עצמה. למרבה הצער גם פנייה זו של העותרת הושבה ריקם.

--- העתק מן הפנייה מיום 19.9.22 מצ״ב כ**<u>נספח 20</u>**

106.להשלמת התמונה נזכיר כי ביום 13.12.22 פורסמו מסמכי ההליך התחרותי הרביעי. עם פרסומם של מסמכים אלה התחוור לעותרת, מלבד כמובן כי המשיב 1 בחר להמשיך ולפתח את משק הגז על אף התחייבויותיה הבין לאומיות של ישראל בעניין, כי מסמכי ההליך עצמו אינם משקללים כהלכה את כישורי המציעים בפן הסביבתי.

107.בהתאם לכך, ביום 1.2.23 פנתה העותרת אל המשיב 3 בדרישה כי ייערכו השינויים המתאימים במסמכי ההליך התחרותי על מנת להבטיח כי אם וכאשר ימומש ההליך התחרותי, הדבר יביא לפגיעה מינמאלית, ככל הניתן בסביבה. גם לפנייה זו לא טרח המשיב 3 או מי מנושאי המשרד במשרד האנרגיה להשיב.

--- העתק מן הפנייה מיום 1.2.23 מצ״ב כ**<u>נספח 21</u>**

108.לבסוף יצוין, כי ביום 29.3.2023 פנתה העותרת שוב אל הנוגעים בדבר בדרישה להורות על ביטולו של ההליך התחרותי הרביעי מן הטעם כי יש בו כדי לסכל את התחייבויותיה של ישראל להפחתה של פליטות גזי החממה שלה. גם פנייה זו, כמו כל אלו שקדמו לה, לא נענתה למרות מספר תזכורות בכתב ובעל פה שנשלחו לגורמים הנוגעים בדבר במשרד האנרגיה.

--- העתק מן הפנייה מיום 29.3.23 מצ״ב כ**<u>נספח 22</u>**

109.לאחר שכל פניותיה לא נענו באופן שיטתי, ועל מנת למצות כל דרך אפשרית בטרם פנייה לערכאות, פנה הח״מ אל נציג המשיב 1 במשיבה 4 באמצעות הטלפון וביקש כי המשיבים ישיבו

לפניותיה של העותרת. נציג המשיב 1 מסר כי פניותיה של העותרת ייענו לאחר מתן מענה המשיבים 1-5 לעתירה הראשונה. מענה זה ניתן ביום 24.5.23 אך גם לאחריו בחרו המשיבים 1-4 להתעלם מפניותיה של העותרת.

מכאן העתירה דנן.

(ד) __הטיעון המשפטי__

__ד.1 על המשיבים 1-3 היה לפעול בהתאם להחלטת הממשלה ולא לסכלה__

110.כאמור לעיל, ההליך התחרותי הרביעי המקודם על ידי המשיבים 1-2 מסכל את יכולתה של ישראל לעמוד ביעדי ההפחתה שנטלה על עצמה במסגרת החלטת הממשלה. יש לבחון איפוא את יחסי הגומלין בין החלטת ממשלה מחד ושר הפועל לקדם מדיניות המסכלת את אותה החלטה מאידך.

111.בספרו, הסמכות המינהלית קבע השופט זמיר כי:

> **"מבחינה משפטית, החלטת ממשלה מחייבת כל שר להפעיל את סמכותו, לרבות סמכות שהחוק העניק לו במישרין, בהתאם להחלטת ממשלה, אף אם ההחלטה נוגדת את דעתו."**

112.רוצה לומר, מחובתו של המשיב 2, בין אם סבור כי ההחלטת הממשלה בעניין יעדי הפחתה מקובלת על דעתו ובין אם לאו וכל עוד לא בוטלה או שונתה, הרי שמחובתו לפעול בהתאם לפיה. בהנחיית היועץ המשפטי לממשלה[17] ניתנה לכך התייחסות:

> **"כיוון שעדיין לא נפסקה הלכה בשאלה אם שר חייב לקבל את עמדת הממשלה בנוגע להפעלת סמכות שהחוק הקנה לו, כאשר עמדת הממשלה נוגדת את עמדתו, מן הראוי לברר שאלה זאת לגופה. הבירור מוביל למסקנה כי אכן חובה כזאת מוטלת על השר. נראה כי מסקנה זאת מקובלת על רוב המשפטנים שהביעו דעתם בשאלה זאת) ראו: יצחק זמיר הסמכות המינהלית 417-418 (כרך א', מהדורה שנייה, 2010); אמנון רובינשטיין וברק מדינה המשפט החוקתי של מדינת ישראל 862) כרך ב', מהדורה שישית, 2005(; חיים צדוק "האחריות המיניסטריאלית "ספר ברקת ,163 167) האגודה**

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[17] מספר הנחיה: 1.1001 (21.484)

> **הישראלית לבעיות הפרלמנטריזם, התשל״ז, להלן: צדוק (; צבי טרלו הרשות המבצעת בישראלאקדמון, התשל״ו))**

ובהמשך:

> **המסקנה העולה מכל האמור לעיל היא, שהממשלה רשאית לקבל החלטה גם בעניין שנמסר על-ידי חוק לסמכותו של שר מסוים, ואותו שר חייב לפעול באותו עניין על-פי החלטת הממשלה״**

113.בענייננו וכפי שפורט בהרחבה לעיל, אין ספק כי קידום ההליך התחרותי הרביעי יביא בהכרח לסיכולה של החלטת הממשלה התקפה. על פי עמדת היועץ המשפטי לממשלה שהובאה לעיל, מחובתו של המשיב 2 לנהוג בהתאם להחלטת הממשלה ומשלא עשה כן ואף פעל באופן אקטיבי על מנת לסכלה, הרי שהדבר מצדיק את התערבותו של בית המשפט הנכבד.

ד.2. אשרור הסכם פריז אינו מאפשר להתעלם ולסכל את הוראותיו

114.כפי שצוין לעיל, מחויבותה של ישראל לפעול להפחית את פליטות גזי החממה שלה נשענת על הוראות הסכם פריז, המחייב את הצדדים לו להגיש מעת לעת יעדי הפחתת פליטות של גזי חממה.

115.נושא התקשרות המדינה בהסכמים בין-לאומיים אינו מוסדר בישראל באמצעות חקיקה כי אם באמצעות הנחיות פנימיות וכללים מנהליים. באופן עקרוני, הסמכות להתחייב בשם המדינה בהסכמים בין-לאומיים נתונה לממשלה ונובעת מסמכותה השיורית הקבועה בסעיף 32 לחוק יסוד: הממשלה. על פי סעיף זה ״הממשלה מוסמכת לעשות בשם המדינה, בכפוף לכל דין, כל פעולה שעשייתה אינה מוטלת בדין על רשות אחרת"

116.בהנחיית היועץ המשפטי[18], נסקרו באופן רחב התחייבויותיה הבין לאומיות של מדינת ישראל:

> **״לאורך השנים שעברו מאז פורסמה ההנחיה האמורה חל גידול משמעותי במערך ההסכמים הבין -לאומיים בהם מתקשרת המדינה, הן מבחינת מספר ההתקשרויות והן מבחינת היקף הנושאים המטופלים במסגרתם. זאת, בין היתר, על רקע עליה משמעותית בהיקפי הפעילות הבין-לאומית של המדינה במישורים שונים ועל רקע התפתחויות כלליות במשפט הבין-לאומי. ההסכמים הבין -לאומיים בהם מתקשרת המדינה כוללים במקרים רבים**

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[18] מס׳ הנחייה: 10.300

> **מחויבויות משפטיות במגוון תחומים, והם משפיעים על התנהלות גורמים ממשלתיים בישראל ומחוצה לה, ולעיתים אף על הדין הפנימי."**

באשר ליחסי הגומלין שבין ההתחייבות הבין לאומית לבין הדין הפנימי נקבע:

> **"בהתאם להלכה הפסוקה, המשפט הבין-לאומי ההסכמי לא נקלט בדין הפנימי של ישראל אלא אם אומץ בו במפורש. במקרים בהם קיימת סתירה בין ההסכם הבין-לאומי ובין הוראה חקוקה, יש צורך בתיקון החקיקה לפני שניתן יהיה לאשרר את ההסכם, כדי שישראל לא תמצא עצמה במצב שבו היא לא יכולה לקיים את המחויבות המשפטית שקיבלה על עצמה במישור הבין-לאומי."**

117.יצוין, כי בהתאם להנחיית היועץ המשפטי שלעיל, במסגרת הליך אשרור של הסכם בין-לאומי על היועץ המשפטי המוביל של המשרד הרלוונטי לאשר כי ניתן ליישם בדין הפנימי את ההתחייבויות נשוא ההסכם:

> **"ככלל, הסכם בין-לאומי שיישומו דורש צעדים במישור הדין הפנימי, על מנת שניתן יהיה לעמוד בהתחייבויות המוטלות על המדינה במסגרתו, לרבות תיקוני חקיקה והתקנת תקנות, לא יובא לאשרור עד שיבוצעו הצעדים הנדרשים. חריגה מכלל זה תתאפשר רק באישור המשנה ליועץ המשפטי לממשלה (משפט בין-לאומי.)...**
>
> **יועץ המשפטי של המשרד המוביל, או מי מטעמו, יפנה ליועץ המשפטי של משרד החוץ ולמשנה ליועץ המשפטי לממשלה (משפט בין-לאומי), או מי מטעמם, לשם קבלת אישורם בכתב כי ניתן להביא את ההסכם לאשרור. לפנייה יצורף העתק ההסכם הבין -לאומי באנגלית ובעברית, אישור היועץ המשפטי של המשרד המוביל כי ניתן ליישם בדין הפנימי את ההתחייבויות הכלולות בהסכם ואישור על השלמתם של שינויי חקיקה, ככל שנדרשו, על מנת לאפשר את אשרור ההסכם".**

118.במילים אחרות, בטרם אשרור ההסכם הבין לאומי (כדוגמת הסכם פריז) יש להבטיח כי קיום הוראותיו אפשר ואינו סותר את הדין הישראלי. כידוע, הסכם פריז אושרר על ידי ממשלת ישראל ומכאן שאין כל מניעה ליישם הוראותיו בדין ופנימי ומנגד, מובן כי אין לפעול ולסכלו.

119.אמנם, נכון להיום טרם אומצו הוראותיו של הסכם פריז בחקיקה ספציפית בדין הישראלי והם נחשבים כ׳משפט רך׳ שעיקרם הכוונת מדיניות ויצירת סטנדרט פעולה בין לאומי אחיד ואולם, כבר כיום הוראותיו של חוק אוויר נקי, התשס"ח, 2008 (להלן: "**חוק אוויר נקי**") עולות בקנה

אחד עם הוראות הסכם פריז. כך, בסעיף 1 להוראות חוק אוויר נקי, שכותרתו "מטרות החוק" נקבע כי:

> **"חוק זה מטרתו להביא לשיפור של איכות האוויר וכן למנוע ולצמצם את זיהום האוויר, בין השאר על ידי קביעת איסורים וחובות בהתאם לעקרון הזהירות המונעת, והכל <u>לשם הגנה על חיי אדם, בריאותם ואיכות חייהם של בני אדם ולשם הגנה על הסביבה, לרבות משאבי הטבע, המערכות האקולוגיות והמגוון הביולוגי, למען הציבור ולמען הדורות הבאים ובהתחשב בצורכיהם</u>."**
>
> (ההדגשה אינה במקור – החי"מ)

120.אין כל חולק כי משבר האקלים העולמי כבר פוגע בערכים המוגנים בסייפא של הוראות מטרות חוק אוויר נקי. בהתאמה, החרפה של משבר האקלים העולמי כתוצאה מהעדר הפחתה מספיקה של גזי החממה תחמיר עוד יותר פגיעות אלה המוגנות הדין.

121.מן האמור עולה אפוא, כי סיכול התחייבויות ישראל לעמוד ביעדי ההפחתה יביא בין היתר לסיכול מטרותיו של חוק אוויר נקי המהווה חלק מן הדין הפנימי הישראלי מזה זמן, על כל המשתמע מכך.

122.לסיום פרק זה ראוי להזכיר את פרשת אורגנדה (urganda) שנדונה בבתי המשפט בהולנד[19]. ארגון ארוגנדה, עתר לבית המשפט המחוזי לאחר שבקשתו, כי המדינה תגביר את צעדיה להפחתת פליטות של גזי חממה משום שהצעדים שננקטו על ידי המדינה אינם מספיקים לשם עמידה ביעדי ההפחתה הרלוונטיים, סורבה.

123.בעתירתו, טען הארגון כי יעדי הפחתת גזי החממה שנקבעו אינם מספקים ופוגעים בהתחייבויותיה של הולנד במישור הבין לאומי כמו גם בדין הפנימי ההולנדי. במענה לטענות אלה, טענה המדינה כי הפחתת הפליטות הוא עניין פוליטי שאל לבית המשפט להתערב בו.

124. בית המשפט המחוזי ההולנדי קיבל את העתירה והורה למדינה להגביר את הצעדים להפחתת הפליטות. בית המשפט המחוזי דחה, בין היתר, את טענת ממשלת הולנד כי הפעולות העולמיות

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[19] "Urganda Foundation v. The State Of The Netherlands

להפחתת גזי החממה אינן תלויות רק בהולנד וכי עליה, כמו שאר המדינות, לתרום את תרומתה בעניין.

125.על החלטה זו הוגשו שני ערעורים על ידי המדינה אולם הם נדחו ובית המשפט העליון בהולנד[20] קבע כי על המדינה להרחיב את יעדי הפחתת פליטות גזי החממה שנטלה על עצמה. בית המשפט העליון ההולנדי קבע עוד כי מעשיהם ומחדליהם של מדינות אחרות ביחס למשבר האקלים אינן מורידות מחובתה של הולנד לפעול בעניין.

126.דומה כי התקדים ההולנדי יפה גם לענייננו – וביתר שאת. בעוד שההליך ההולנדי נסב בעיקר על **שיעור** קביעת יעדי ההפחתה של גזי החממה בידי המדינה, עניינו של הליך זה אינו בקביעת שיעור ההפחתה אלא בעניין פשוט בהרבה – העמידה בהם בהתאם להתחייבויות שהמדינה נטלה על עצמה.

<u>ד.3.ההחלטה לפרסם את ההליך התחרותי הרביעי נעשתה ללא תשתית עובדתית מספקת</u>

127.תנאי מוקדם לקבלת החלטה מינהלית תקינה הוא הביסוס העובדתי לה, בספרה משפט מנהלי[21], התייחסה לכך כב׳ השופטת דפנה ברק-ארז בציינה :

> **״תנאי מוקדם לקבלתה של החלטה מינהלית תקינה היא הביסוס העובדתית לה. אין טעם בהחלטה שנימוקיה סבירים וראויים אם אין היא מתאימה לנסיבות העובדתיות. על מנת לעמוד בדרישה זו, מוטלת על הרשות שתי חובות מצטברות: החובה לאסוף ראיות שישמשו כתשתית להחלטה והחובה לבסס את ההחלטה על ראיות מספיקות.״.**

128.בהתאם, בטרם קבלת החלטה לפרסם את ההליך התחרותי הרביעי היה על המשיבים 1-4 לוודא כי בפני מקבלי ההחלטה תשתית עובדתית ראויה ביחס להשפעות הליך זה על יכולה של ישראל לעמוד ביעדי ההפחתה, שכן, כמתחייב על פי דין כידוע -

> **״מושכלות יסוד הן כי כל החלטה של רשות מינהלית צריך שתתבסס על מלוא התשתית העובדתית הרלוונטית לשם קבלתה. לאחר איסוף התשתית על הרשות לבחון ולעבד את הנתונים שנאספו, ובסוף הליך זה לסכם ממצאיה ומסקנותיה בהחלטה מנומקת[22]״**

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[20] ***State of the Netherlands vs. Urgenda Foundation***

[21] כרך א עמ׳ 439

[22] (בג״ץ 8082/15 עמותת הל״ה נ׳ משרד הרווחה, פסקה 17 (10.7.2016)).

129.הלכה פסוקה היא שהחלטתה של רשות מנהלית שהתקבלה ללא בירור העובדות הנוגעות לעניין, אלא על יסוד החלטה של רשות אחרת, או שבגלל שדעת הרשות נחושה להשיג תוצאה מסוימת ללא תשתית עובדתית ראויה, הינה החלטה שרירותית שדינה פסלות.

בפרשת ברגר[23] נקבע כי:

> **"ההחלטה חייבת להיות בכל מקרה תוצאה של בדיקה עניינית, הוגנת ושיטתית...תהליך קבלת ההחלטה על ידי מי שהוקנתה לו סמכות על-פי חוק מן הראוי שיהיה מורכב, בדרך כלל, ממספר שלבים בסיסיים חיוניים, אשר הם הביטוי המוחשי להפעלת הסמכות המשפטית תוך התייחסות לנושא מוגדר, ואלו הם: איסוף וסיכום הנתונים (לרבות חוות הדעת המקצועיות הנוגדות, אם ישנן כאלה) בדיקת המשמעויות של הנתונים (דבר הכולל, במקרה של תיזות חלופות, גם את בדיקת מעלותיהן ומגרעותיהן של התיזות הנוגדות) ולבסוף סיכום ההחלטה המנומקת "**

ד.4 ההחלטה לפרסם את ההליך התחרותי הרביעי לא נומקה כנדרש

130.כידוע, חובת ההנמקה היא אחת מן החובות החשובות והמרכזיות החלות עת רשות מנהלית בעת מתן החלטותיה. חובה זה אף מעוגנת בסעיף 2(א) ל**חוק לתיקון סדרי המינהל (החלטות והנמקות), תשי"ט – 1958**.

131.כב' השופטת ברק-ארז התייחסה לכך בציינה[24]:

> **"ראשית, החובה לנמק מסייעת לקבלת החלטה רציונלית ולא שרירותית, משום שהיא מחייבת את הרשות לבסס את ההחלטה על תהליך מסודר בו נשקלים טעמיה. שנית, החלטה מנומקת מסייעת להסתמכות נכונה עליה, משום שהיא מאפשרת להבין טוב יותר את משמעותה של ההחלטה ואת השלכותיה התקדימיות לגבי מקרים אחרים. שלישית, ההנמקה מספקת תשתית עובדתית לביקורת על פעולתה של הרשות- הן ביקורת מנהלית (של גורמי ביקורת מנהליים), הן ביקורת שיפוטית והן ביקורת ציבורית. רביעית, ההנמקה מבטאת יחס אנושי ומכבד לפרט שההחלטה המינהלית עוסקת בו. חמישית, ההחלטה חשובה לביסוס אמון הציבור בשלטון, משום שיש בה כדי להסיר, ולו באופן חלקי, חשדות לשיקולים לא עניינים או לשרירות כמובן, על**

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[23] בג"ץ 297/82 **ברגר ואח' נ' שר הפנים**, פ"ד לז(3)29.
[24] דפנה ברק ארז, משפט מנהלי, בעמ' 424-423

> **מנת שההנמקה תוכל לשרת יעדים אלה, היא חייבת להיות מפורטת, ובכל אופן- להימנע מניסוחים כללים וסתמים"**

132.בנוסף, קבע בית המשפט העליון כי החלטות מנהליות שאינן מנומקות רק "דוחות את הקץ" עד לבחינתן בהליך שיפוטי[25]:

> **"מטבע הדברים, החלטת רשות מינהלית שאינה מנומקת, חשופה לביקורת שיפוטית ועל כן כל כולה "דוחה את הקץ" עד להליך השיפוטי אם יש, ובמסגרתו תתבקש ההנמקה"**

133.בעניינינו וביחס לסתירה שבין תוצאות ההליך התחרותי הרביעי ליעדי הפחתת הפליטות, החלטת המשיבה 4 לפרסם את ההליך התחרותי נעשתה למעשה ללא נימוק, הסבר או פירוט כלשהם (בניגוד למשל ביחס לנושאים אחרים להם נוגע ההליך התחרותי) תוך התבססות על אמרה לקונית וסתמית כי אין בהליך כדי לפגוע ביעדי ההפחתה. בנסיבות אלה, מובן כי החלטה זו לא נומקה כנדרש.

ד.5. __ההחלטה לפרסם את ההליך התחרותי הרביעי לוקה בחוסר סבירות קיצוני__

134.לדעת העותרת, מכלול הנסיבות שתואר מוביל למסקנה ברורה כי ההחלטה לפרסם את ההליך התחרותי הרביעי, אינה סבירה באופן קיצוני.

135.בפסיקה כבר נקבע, כי על הרשות המנהלית להפעיל את שיקול דעתה בתום לב, על יסוד שיקולים עניינים, במידתיות ובסבירות [26]

136.סבירותה של החלטה מינהלית טמונה לא רק בשקלול מכלול הנתונים הרלוונטיים, אלא גם באיזון הראוי ביניהם, כפי שנאמר בעניין המפקח על התעבורה[27]:

> **בקביעת גבולותיו של "מתחם סבירות" יש להתחשב, בין השאר, בשאלה, אם הרשות הציבורית נתנה משקל ראוי לגורמים הרלוואנטיים השונים שבהם עליה להתחשב. החלטתה של רשות מנהלית תיפסל בשל חוסר סבירות, אם**

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[25] רע"א 8996/04 עודד שכטר נ' נציגות הבית המשותף (פורסם בנבו)

[26] (בג"ץ 3057/09 מוחתסב נ' שר הפנים (פורסם בנבו); בג"ץ 6883/06 נאסר נ' שר הפנים (פורסם בנבו); עע"ם 9993/03 חמדאן נ' ממשלת ישראל (פורסם בנבו).

[27] בג"ץ 341/81 מושב בית עובד נ' המפקח על התעבורה (פ"ד לו)349 (3)

> **המשקל שניתן לגורמים השונים אינו ראוי בנסיבות העניין. אכן, שקלול ואיזון זה הם מעיקרי תפקידיה של הרשות הציבורית, והביקורת על אופן ביצועם נתונה לבית המשפט.**

כל אלה מחייבים לטעמה של העותרת את התערבותו של בית המשפט הנכבד.

(ה) סוף דבר

137.בשל כל הטעמים המפורטים לעיל מתבקש בית המשפט הנכבד להוציא צו על תנאי כמבוקש ברישא של העתירה ולאחר דיון להפוך צו זה למוחלט. כמו כן מתבקש בית המשפט הנכבד לחייב את המשיבים בתשלום הוצאות ושכר טרחת עורך דין בגין הגשת העתירה.

138.עתירה זו נתמכת בתצהירו של מר יונתן אייקנבאום, מנכ״ל העותרת.

מתן גרפינקל, עו״ד
ב״כ העותרת

<u>יפוי כוח כללי</u>

אנו הח״מ גרינפיס ים תיכון בע״מ (חל״צ) 514340868 ממנים בזה את **עו״ד מתן גרפינקל** להיות באי כחנו ולעשות בשמנו ובמקומנו את כל הפעולות המנויות להלן או מקצתן, **הכל בהקשר לעתירה לבית המשפט העליון בשבתו כבית המשפט הגבוה לצדק נ׳ שר האנרגיה ואח׳** לרבות:

1. לייצג ולהופיע בשמנו בפני בית המשפט בכל הנוגע לניהול עתירה ו/או בהליכי בוררות ו/או גישור ו/או דיונים אחרים המתנהלים במסגרתה, וכן לבצע כל פעולה הנדרשת בעניין עתירה זו כולן או כל חלק מהן.
2. להגיש בשמנו כתבי בי-דין, בקשות, הודעות, חוות דעת וכל מסמך אחר אשר נדרש לשם ייצוגנו בהליך המשפטי.
3. לעשות כל פעולה, לנקוט בכל צעד ולנהל כל משא ומתן בשמנו, ובכפוף לקבלת הסכמתנו מראש, בכל עניין ודבר שיימסר לטיפול עוה״ד הנ״ל.
4. לחתום על ו/או לשלוח התראות מכל סוג ולעשות כל הפעולות הקשורות והנובעות מכך.
5. לגבות כל הסכומים שיפסקו לטובתנו וכן כל סכום אחר המגיע לנו בכל עניין מהעניינים הנ״ל לרבות ריבית, הצמדה, הוצאות בית משפט, שכר טרחת עו״ד וכיוצא בזה.
6. להעביר ייפוי כוח זה על כל הסמכויות שבו או חלק מהן לעו״ד אחרים במשרד ולמנות אחרים במקומם ובכלל לעשות את כל הפעולות והצעדים שימצא לנכון ומועיל בקשר עם הביצוע של העניינים הנ״ל.
7. בייפוי כוח זה לשון יחיד גם לשון רבים במשמע ולהיפך, ולשון זכר גם לשון נקבה במשמע ולהיפך, הכל לפי המקרה.

ולראיה באתי על החתום, היום יום 13 לחודש 6 שנה 2023

חתימה .... **חותמת**....................

GREENPEACE
גרינפיס ים תיכון בע״מ (חל״צ)

הנני מאשר את חתימת מרשתי הנ״ל,

מתן גרפינקל, עורך דין
מס׳ רשיון 45905
License No. 45905
Matan Garfinkel, Advocate

עורך - דין

תצהיר

אני הח״מ, יונתן אייקנבאום, נושא ת.ז. מס׳ 314140724, לאחר שהוזהרתי כי עלי לומר את האמת, אחרת אהיה צפוי לעונשים הקבועים בחוק, מצהיר בזאת בכתב כדלקמן:

1. אני משמש כמנכ״ל גרינפיס ים תיכון בע״מ (חל״צ) (״**העותרת**״) ותצהירי זה ניתן לתמיכה בעתירה לבית המשפט הגבוה לצדק של העותרת כנגד שר האנרגיה ואח׳, המוגשת בבית המשפט העליון בירושלים בעניין ההליך התחרותי הרביעי.

2. העובדות המפורטות בעתירה הן בידיעתי האישית והן אמת למיטב ידיעתי.

3. הטיעון המשפטי המפורט בעתירה, בין אם הוא שזור בעובדות ובין אם לאו, מבוסס על חוות דעתו של ב״כ העותרת.

4. זה שמי, זו חתימתי, ותוכן תצהירי זה אמת.

יונתן אייקנבאום

אני הח״מ, עו״ד מתן גרפינקל מאשר בזאת כי בתאריך 16.6.23 הופיע בפני מר יונתן אייקנבאום, המוכר לי אישית, ולאחר שהזהרתיו כי עליו לומר את האמת, אחרת יהיה צפוי לעונשים הקבועים בחוק, אישר את תצהירו זה וחתם עליו בפני.

מתן גרפינקל, עורך דין
מס׳ רשיון 45905
Matan Garfinkel, Advocate
License No. 45905

תוכן עניינים

<u>נספח 1</u>

העתק מדברי שרת האנרגיה

עמ' 35

נספח 1

הודעות דוברות

"כדי להבטיח ששנת 2022 תהיה שנת האנרגיות המתחדשות, הגז הטבעי יחכה". שרת האנרגיה, קארין אלהרר, בפתיחת כנס אילת אילות לאנרגיות מתחדשות

נושא: גז טבעי , חיפוש והפקת נפט וגז טבעי
תאריך פרסום: 15.12.2021

שרת האנרגיה קארין אלהרר פתחה כעת את כנס אילת-אילות לאנרגיות מתחדשות וציינה את מחויבותה האישית ואת מחויבות משרד האנרגיה לנושא.

© צילום: דולב ארן

"קידום מאסיבי של אנרגיות מתחדשות לייצור חשמל במשק הישראלי זו המטרה שאני מקדמת בכל יום בחצי השנה האחרונה מאז כניסתי לתפקיד - מרמת המדיניות ועד הפרטים הכי קטנים. ביססתי ישיבות דו שבועיות עם כל גורמי המקצוע הרלוונטיים, בהן אנו מגרדים קילו וואט לקילו וואט של חיבורי מתקנים לייצור אנרגיות מתחדשות. בדיונים הללו הצלחנו לרתום את כולם למשימה ולהביא את המשק להכפלת החיבורים של אנרגיות מתחדשות לרשת, מאז כניסתי לתפקיד בחודש יוני.

אבל דיונים לא יספיקו כדי לעשות את השינוי האדיר הזה. כדי להבטיח ששנת 2022 תהיה שנת האנרגיות המתחדשות, הגז הטבעי יחכה.

בשנה הקרובה נתמקד בעתיד, בחשמל הירוק, בהתייעלות האנרגטית ובאנרגיות המתחדשות ובזמן שנעשה את זה נשים בצד את העיסוק בהרחבת פיתוח הגז הטבעי, שהוא, כידוע, דלק מעבר. בשנה הקרובה משרד האנרגיה לא יאמץ את מסקנות דו"ח בחינת מדיניות הגז הטבעי ולא יצא להליך הרביעי למתן רישיונות לחיפושי גז טבעי.

את השנה הקרובה ננצל לשורה של מהלכים שיקדמו את המעבר לאנרגיות מתחדשות. נקים אגף אנרגיות מתחדשות במשרד שיקבל את מירב הקשב והמשאבים, נקדם את התכנית הלאומית להתייעלות באנרגיה שאושרה בממשלה לאחרונה בעלות של כמיליארד שקלים, נשקיע במחקר ופיתוח, נקצה מענקים לקידום אנרגיה נקייה ופיתוחים טכנולוגיים משמעותיים ונסיר חסמים העומדים בפני יזמים."

דף זה עודכן לאחרונה בתאריך 15.12.2021

שירותים ומידע

אזרחות, תעודות ודרכונים
אכיפה, חוק וממשל
אנשים עם מוגבלות
בנייה, דיור ומקרקעין
בריאות ורווחה
תעשייה, מסחר ותקשורת
אנרגיה, סביבה וחקלאות
משפחה ומצב אישי
חינוך והשכלה
ביטחון וחירום
מסים ותשלומים
עבודה ותעסוקה
עלייה וקליטה
תחבורה
תרבות, ספורט ותיירות

מידע שימושי

העתק אישור תשלום
RSS
צרו קשר עם משרדי הממשלה

תמיכה

מוקד מענה ממשלתי מרכזי

התקשרו למוקד 1299

למענה אנושי בצ'אט - מוקד 1299

תמיכה טכנית בשירותים מקוונים

פנייה לאבטחת מידע

עקבו אחרינו

אודות האתר תנאי שימוש הצהרת נגישות תמיכה טכנית מפת האתר שימוש בקבצי "cookies" חופש המידע

<u>נספח 2</u>

העתק מעמדתה של שרת האנרגיה מחודש מאי 2022

עמ' 38

נספח 2

הודעות דוברות

יוצאים להליך התחרותי הרביעי לחיפושי גז טבעי במים הכלכליים של מדינת ישראל

יחידה: מינהל אוצרות טבע
נושא: חיפוש והפקת נפט וגז טבעי , גז טבעי
תאריך פרסום: 30.05.2022

"מדינת ישראל נרתמת לסיוע לאירופה בגיוון מקורות האנרגיה שלה. משבר האנרגיה העולמי מהווה הזדמנות למדינת ישראל לייצוא גז טבעי, זאת לצד הדאגה הכנה והאמיתית למתחולל באירופה", הסבירה שרת האנרגיה, קארין אלהרר.

© צילום: אלעד זגמן, לע"מ.

שרת האנרגיה, קארין אלהרר, הנחתה את אנשי משרדה להיערך ליציאה להליך התחרותי הרביעי לחיפושי גז טבעי במים הכלכליים של מדינת ישראל. כך אמרה במסיבת עיתונאים שערכה הבוקר במשרד האנרגיה.

נוכח המלחמה באוקראינה והשפעותיה על אספקת הגז הטבעי ליבשת אירופה, הנחתה שרת האנרגיה את אנשי משרדה להאיץ את ההערכות האסטרטגית ליציאה להליך רביעי של חיפושי גז טבעי. אתמול (ראשון) הודיעה השרה למנכ"ל משרדה ליאור שילת להוציא לדרך את ההליך התחרותי הרביעי לחיפושי גז טבעי במים הכלכליים של מדינת ישראל.

שרת האנרגיה קארין אלהרר: "בהתאם למדיניותי בשנה החולפת התמקד משרד האנרגיה בקידום האנרגיות המתחדשות ובהסרת חסמים בירוקרטיים ורגולטוריים, במטרה להקל על חיבור אנרגיות מתחדשות וליצוק בסיס איתן להמשך קידום מסיבי של חיבור אנרגיות מתחדשות.
מדינת ישראל נרתמת לסיוע לאירופה בגיוון מקורות האנרגיה שלה. משבר האנרגיה העולמי מהווה הזדמנות למדינת ישראל לייצוא גז טבעי, זאת לצד הדאגה הכנה והאמיתית למתחולל באירופה. משרד האנרגיה בראשותי פועל להבטיח את הביטחון האנרגטי של ישראל, את גיוון מקורות האנרגיה שלנו וההשקעה באנרגיות מתחדשות ואת עתודות הגז עבור המשק הישראלי לעשורים הקרובים".

מנכ"ל משרד האנרגיה ליאור שילת: "האירועים הגיאו פוליטיים בעולם, ומשבר האנרגיה העולמי שנגרם כתוצאה מהם, שינו לחלוטין את מצב שוק האנרגיה. בעקבותיו התחלנו בשיחות עם המקבילים הבין לאומיים שלנו, בעיקר באירופה, ארצות הברית ומצרים, בניסיון להבין את האסטרטגיה שלהם אל מול המשבר.
חשוב להדגיש כי אנחנו והאירופאים תמימי דעים שהמהלך האסטרטגי החשוב ביותר כדי להתגבר על המשבר הוא בהאצה של פיתוח האנרגיות המתחדשות. עם כל זאת, לא ניתן להתעלם מהצורך העולמי בגז טבעי גם בטווח המידי וגם בטווח הבינוני. האירופאים היו מאוד ברורים באמירה כי אם לא יאתרו די מקורות חלופיים לגז הטבעי שהם נזקקים לו, חלק מהמדינות החברות באיחוד ייאלצו לחזור ולהשתמש בפחם לייצור חשמל.
בנוסף, קשה להפריז בחשיבותו של הגז הטבעי בחיזוק הקשרים בין ישראל למצרים והשפעתו על המעמד הגיאופוליטי של ישראל במזרח התיכון".

דף זה עודכן לאחרונה בתאריך 30.05.2022

שירותים ומידע

- אזרחות, תעודות ודרכונים
- אכיפה, חוק וממשל
- אנשים עם מוגבלות
- בנייה, דיור ומקרקעין
- בריאות ורווחה
- תעשייה, מסחר ותקשורת
- אנרגיה, סביבה וחקלאות
- משפחה ומצב אישי
- חינוך והשכלה
- ביטחון וחירום
- מסים ותשלומים
- עבודה ותעסוקה
- עלייה וקליטה
- תחבורה
- תרבות, ספורט ותיירות

מידע שימושי

העתק אישור תשלום
RSS
צרו קשר עם משרדי הממשלה

תמיכה

מוקד מענה ממשלתי מרכזי
התקשרו למוקד 1299
למענה אנושי בצ'אט - מוקד 1299
תמיכה טכנית בשירותים מקוונים
פנייה לאבטחת מידע

עקבו אחרינו

אודות האתר תנאי שימוש הצהרת נגישות תמיכה טכנית מפת האתר שימוש בקבצי "cookies" חופש המידע

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נספח 3

העתק מתגובת המדינה

עמ' 41

בבית המשפט העליון **בג"ץ 3143/23**
בשבתו כבית משפט גבוה לצדק

החברה להגנת הטבע
על-ידי ב"כ עוה"ד אסף רוזנבלום ו/או אסף בן לוי
רח' הנגב 2, תל אביב
טלפון: 03-63887447; פקס': 03-6390580 **העותרת**

נגד

1. שר האנרגיה והתשתיות
2. הממונה על ענייני הנפט
3. משרד האנרגיה והתשתיות
4. מועצת הנפט
5. המשרד להגנת הסביבה
כולם על-ידי פרקליטות המדינה,
משרד המשפטים, ירושלים
טלפון: 0073-3925590; פקס': 02-6467011 **המשיבים**

תגובה מטעם המשיבים לבקשה למתן צו ביניים

1. בהתאם להחלטת כב' השופט סולברג מיום 24.4.23, ולארכה שניתנה, מתכבדים המשיבים להגיש את תגובתם לבקשת העותרת למתן צו ביניים, כדלקמן.

2. עניינה של העתירה בטענותיה של העותרת נגד ההליך התחרותי הרביעי במספר שפורסם על-ידי משרד האנרגיה והתשתיות (להלן גם: **המשרד**) להענקת רישיונות לפי חוק הנפט, התשי"ב-1952 (להלן: **חוק הנפט** או **החוק**). בתוך כך, תוקפת העותרת את ההודעות שפורסמו ברשומות ביום 14.12.22 בדבר העמדת שטחים לתחרות לפי סעיף 15א לחוק הנפט, ובדבר שינויים בשטחים לחיפושי נפט והפקתם בהתאם לסעיף 5 לחוק. במסגרת ההליך העומד במרכזה של העתירה, מקודם הליך תחרותי לבחירת מועמדים לחיפוש גז טבעי, באמצעות מנגנון רגולטורי שוויוני ושקוף, שתכליתו הקצאת רישיונות לחיפוש מאגרי גז טבעי נוספים הנדרשים לטובת האינטרסים האנרגטיים של מדינת ישראל.

   צילום ההודעה בדבר העמדת שטחים לתחרות לפי סעיף 15א לחוק הנפט, וצילום ההודעה בדבר שינויים בשטחים לחיפושי נפט והפקתם בהתאם לסעיף 5 לחוק הנפט מצורפים ומסומנים **מש/1**.

3. בעתירה, מבקשת העותרת כי בית המשפט הנכבד יוציא מלפניו צו-על-תנאי אשר יורה למשיבים לבוא וליתן טעם "מדוע לא יבוטל, ולמצער, יוקפא, ההליך התחרותי הרביעי לקבלת רישיונות לחיפושי גז טבעי במימי ישראל. זאת, כל עוד לא נתקבלה ההחלטה לקדמו על בסיס תשתית עובדתית נאותה, כנדרש על פי כללי המשפט המינהלי וכמפורט בגוף עתירה זו, והכל לאחר פרסום תשתית מידע זו וקיום הליך של שיתוף הציבור".

לחלופין, מבקשת העותרת כי בית המשפט הנכבד יורה למשיבים לבוא וליתן טעם ״מדוע לא תבוצע בחינה עדכנית של רגישות בתי הגידול והמצאי האקולוגי בתחומים המיועדים לשיווק, כולל הטמעת ידע עדכני, ויגרעו מהאזורים המיועדים לשיווק לחיפושי גז חדשים שטחים פרטניים אשר יש להם חשיבות אקולוגית, ובפרט תא השטח באזור E, בו אותרה בתצפיות צפיפות גבוהה יחסית של בתי גידול רגישים ובעבודת מודל יש צפי להימצאות בתי גידול רגישים נוספים, כמו גם פוטנציאל השפעה מרחבי על בתי גידול שהוכרזו כאזור מוגן ׳גלישת פלמחים׳, המצויים בטווח ההשפעה של חיפושי הגז״.

4. לצד העתירה ביקשה העותרת מבית המשפט הנכבד להוציא מלפניו צו-ביניים אשר יורה למשיבים 1-3 ״להימנע מכל פעולה אשר תוביל ליצירת הסתמכויות של המשתתפים במכרז, ובפרט, להימנע מבחירת הזוכים במכרז (המועד המשוער שנקבע לכך – 31.7.23), עד למתן פסק הדין בעתירה זו״; וכן צו שיורה למשיבים 1-3 ״לפרסם (לרבות באתר האינטרנט הייעודי למכרז), הודעה בדבר קיומה של העתירה ובדבר השלכותיה האפשריות על המשך קידום המכרז והסיכון אותו נוטלים המציעים (לרבות עיכובו, הקפאתו ואף ביטולו האפשרי של המכרז), וכן ליידע ישירות את הגורמים אשר הגישו מכתבי "Letters of Interest" בעניין זה, והכל כדי למנוע יצירת הסתמכויות אשר עלולות יהיו לסכל את בירורה של עתירה זו״.

לחלופין, ביקשה העותרת כי ״במידה שלא יינתן הצו המבוקש בסעיף (א) לעיל, יתבקש בכל מקרה כבוד בית המשפט ליתן צו כאמור בסעיף (ב) לעיל, ובנוסף, להורות למשיבים 1-3 להודיע לעותרת בדבר המועד בו הם מתכוונים להכריז על הזוכים במכרז, וזאת 14 ימים לפחות טרם ההכרזה, על מנת לאפשר לעותרת לשוב ולבקש סעד זמני מבית המשפט הנכבד בעניין זה״.

5. ביום 24.4.23 ניתנה החלטת בית המשפט הנכבד, המורה למשיבים להגיש תגובתם לבקשה למתן צו ביניים. עוד נקבע בהחלטה, כי ״על פני הדברים נראה, כי העתירה עוסקת בענייני מכרזים. המשיבים יתייחסו אפוא בתגובתם, גם לשאלת קיומו של סעד חלופי, בדמות הגשת העתירה לבית המשפט המחוזי, בשבתו כבית משפט לעניינים מינהליים (ראו: סעיף 5 לחוק בתי משפט לענינים מינהליים, התש״ס-2000, בצירוף פרט 5 לתוספת הראשונה של חוק זה)״.

6. כבר בפתח הדברים יצוין, כי ביום 18.5.23 פרסם משרד האנרגיה והתשתיות הודעה בדבר הגשת העתירה דנן. בנסיבות אלה, הראש השני של צו הביניים המבוקש בוצע הלכה למעשה על-ידי המשיבים, ולפיכך הדיון בו התייתר, ואין מקום שבית המשפט הנכבד יידרש לו עוד.

צילום הודעת משרד האנרגיה והתשתיות מיום 18.5.23 מצורף ומסומן **מש/2**.

7. אשר לראש הראשון של צו הביניים, המשיבים יטענו כי דינה של הבקשה למתן צו זה להידחות, תוך חיוב העותרת בהוצאות.

<u>ראשית</u>, יושם אל לב כי צו הביניים חופף בחלקים מהותיים שלו את הסעד הראשון המבוקש בעתירה, בכל הקשור לרצון העותרת לקבל סעד שיפוטי שיורה על הקפאת ההליך התחרותי. בהתאם להלכה הפסוקה בכגון דא, די בחפיפה זו כדי להצדיק את דחיית הבקשה למתן צו-ביניים על הסף.

<u>שנית</u>, עמדת המדינה היא כי דין הבקשה למתן צו ביניים להידחות גם לגופה. כפי שיפורט להלן, מאזן הנוחות בענייננו נוטה באופן מובהק לטובת דחיית הבקשה למתן צו הביניים המבוקש. ההחלטה לצאת להליך התחרותי בעיתוי הנוכחי נבעה מהצורך בהמשך ביסוסו ופיתוחו של משק האנרגיה הישראלי בכלל, ומשק הגז הטבעי בפרט. בהקשר זה, המשיבים יבהירו כי לשיטתם מתן הסעד המבוקש ועיכוב ההליך התחרותי עלולים להניא מציעים פוטנציאליים מלקחת בו חלק, באופן שיפגע קשות בהליך זה, וייתכן שאף בהליכים עתידיים. כל זאת, ללא הצדקה.

<u>שלישית</u>, המשיבים יטענו כי סיכויי העתירה להתקבל קלושים ביותר. לעמדת המשיבים, ועל כך עוד יורחב בהמשך, טענות העותרת בדבר פגמים שנפלו לכאורה בקידום ההליך נעדרות אחיזה במציאות, שכן העובדות מלמדות כי עסקינן בהחלטה שהתקבלה לאחר הליך מקצועי סדור ומעמיק, ובהתבסס על מידע מקצועי רחב ומגוון.

8. אשר לשאלת קיומו של סעד חלופי, יטענו המשיבים כבר עתה כי לשיטתם הערכאה לבירורה של העתירה היא בית המשפט הנכבד, **ולא** עומד לעותרת סעד חלופי בבית המשפט לעניינים מינהליים. שכן, ההליך התחרותי העומד במרכזה של העתירה מקודם מכח הוראות חוק הנפט, ולא מכוחו של חוק חובת המכרזים, תשנ"ב-1992 (להלן: **חוק חובת מכרזים**). ואכן, עתירות שהוגשו בעבר ועסקו בהליכים דומים נדונו אף הן בבית המשפט הנכבד (ראו, למשל, העתירה בבג"ץ 4015/20 **שברון מדיטרניאן לימיטד נ. שר האנרגיה**, שעודנה תלויה ועומדת).

9. ומן ההקדמה – למלאכה.

<u>א. עיקרי העובדות הצריכות לעניין</u>

<u>א.1 חיפושי גז טבעי בישראל – רקע ומדיניות המשרד</u>

<u>רקע היסטורי כללי</u>

10. בים התיכון, בשטח המים הכלכליים של מדינת ישראל, התגלו בשנים האחרונות מאגרי גז טבעי בהיקפים גדולים ביותר. על פי ההערכות, היקפם הכולל של המאגרים שהתגלו עומד על כ-1,000 BCM. כמו כן, על פי הערכות ישנה סבירות לקיומם של מאגרי גז טבעי משמעותיים נוספים, שהיקפם המדויק אינו ידוע.

11. חיפושי הגז הטבעי במימי ישראל הניבו פרי לראשונה עם גילויים של מספר שדות גז טבעי ימיים מול חופי אשקלון בסוף שנת 1999 ובתחילת שנות האלפיים. המאגר הראשון שהתגלה, "מארי B", סיפק בין השנים 2004-2018 גז טבעי לחברת החשמל (פרוייקט ים תטיס).

12. בעקבות התגליות הללו בוצעה סדרה של סקרים סיסמיים ברוב השטח הימי של מדינת ישראל. סקרים מתקדמים אלו מספקים הדמיה טובה של אגן הים התיכון עד לעומק רב וניתן לזהות בהם מבנים גיאולוגיים ומלכודות גז טבעי ונפט פוטנציאליים שונים. על בסיס אותם סקרים בוצעו בשנים שלאחר מכן קידוחים אשר הביאו לגילוי שדות הגז הטבעי המשמעותיים של מדינת ישראל – "תמר", "לוויתן" ו"כריש-תנין".

13. הצלחות אלו הגבירו את ההתעניינות באגן הימי שממערב לחופי ישראל. יצוין כי ביחס למרביתו של שטח זה כבר ניתנו זכויות נפט שונות לפי חוק הנפט. פעילות החיפוש המבוצעת במסגרת זכויות אלו כללה ביצוע סקרים סיסמיים נוספים ומחקרים גיאולוגיים, אשר מצביעים על פוטנציאל ניכר נוסף הקיים באגן.

<u>אחריות משרד האנרגיה והתשתיות לקיומו של משק אנרגיה יציב</u>

14. במסגרת תפקידיו, אמון משרד האנרגיה והתשתיות על קיומו של משק אנרגטי יציב ומקורות אספקה זמינים. בהקשר זה ראוי לציין, כי המלחמה בין רוסיה ואוקראינה, שהחלה בחודש פברואר 2022, החריפה במידה ניכרת את משבר האנרגיה העולמי שהחל עוד קודם לכן. משבר זה הוביל להבנה, באירופה ובמדינות רבות, כי קיימת חובה ליצירת מדיניות של יתירות במקורות אנרגיה, בשילוב קידומן של אנרגיות מתחדשות. המשבר הוביל לקשיים במציאת מקורות אספקה, דבר שהוביל לעליית שיא במחיר הגז הטבעי באירופה שעמד על פי 15 מערך הגז שנרשם בראשית שנת 2020, טרום התפרצות מגיפת הקורונה. אמנם מאז ירדו המחירים, ואולם הם עדיין ברמה הגבוהה פי שלושה לערך מאשר טרום המשבר.[1]

15. בחודש יוני 2021 פורסמה להערות הציבור טיוטת "דו"ח הצוות המקצועי לבחינה תקופתית שנייה של מדיניות הממשלה בנושא משק הגז הטבעי" (להלן: **טיוטת דוח אדירי 2**). במסגרת התרחיש אותו בחר לאמץ הצוות המקצועי במסגרת טיוטת הדוח, הוערך כי הצפי הוא שבשנת 2045 תידרש למשק הישראלי כמות של בין 19.5 ל-31.6 BCM של גז טבעי לשנה, המשקפים עלייה של 50-150% לעומת הביקוש בשנת 2022 (ראו תרשים בעמוד 58 לטיוטת דוח אדירי 2).

להלן קישור לטיוטת דוח אדירי 2:

<u>www.gov.il/BlobFolder/rfp/ng_210621/he/ng_report_2_draft.pdf</u>

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[1] מדד TTF, המייצג את מחירי הגז הטבעי באירופה, עומד נכון לאפריל 2023 על כ-13.5 דולר ארה"ב ליחידת חום, לעומת ממוצע של כ-4.8 דולר ארה"ב ליחידת חום בשנת 2019.

16. להשלמת התמונה יצוין, כי טרם פרסומה של טיוטת דוח אדירי 2 שלח המשרד להגנת הסביבה פניה מטעם מנכ״לית המשרד להגנת הסביבה למר אדירי (מכתבה של מנכ״לית המשרד צורף לעתירה כנספח 7). בתמצית ייאמר, כי לעמדת המשרד להגנת הסביבה, כפי שהוצגה במסמך, המתווה שהוצג במסגרת העבודה על דוח אדירי אינו תואם את צעדי המדיניות הנדרשים לשם השגת האסטרטגיה האקלימית של ישראל, ובתוך כך עמידה ביעדים להפחתת פליטות גזי חממה שנקבעו בהחלטת ממשלה מס. 171 – ״כלכלה דלת פחמן״. כן הצביעה המנכ״לית על כך שמאגרי הגז הקיימים מסוגלים לספק את צורכי המשק המקומי במשך עשורים קדימה, ככל שיופחת היקף הייצוא, וכי מעבר לייצור חשמל המבוסס על אנרגיות מתחדשות בשיעורים הנחוצים כדי לעמוד ביעדי הפחתת פליטות גזי החממה תמנע את הצורך בהסתמכות על יתירות גבוהה של גז טבעי כפי שהוערכה במסמך.

17. ביום 12.10.21 פרסם משרד האנרגיה והתשתיות את מסמך ״מפת הדרכים למשק אנרגיה דל פחמן עד שנת 2050״ (להלן: **מסמך מפת הדרכים**), אשר מציג את האסטרטגיה ארוכת-הטווח של המשרד, תוך התמקדות בצמצום פליטות והתמודדות עם משבר האקלים. גיבוש מסמך זה כלל גם הליך של קבלת והפנמת הערות ציבור.

להלן קישור למסמך מפת הדרכים:

www.gov.il/BlobFolder/reports/energy_121021/he/energy_2050_october_2021.pdf

מסמך מפת הדרכים מציג שלושה תרחישים אפשריים לעתיד משק האנרגיה: תרחיש ״עסקים כרגיל״; תרחיש ״טכנולוגיה״, המבטא שימוש בטכנולוגיות חדשות כגון תפיסת פחמן וגרעין; ותרחיש ״סולארי״, המבטא שימוש מקסימלי באנרגיה סולרית, לרבות אגירה. תרחישים אלו מביאים בחשבון אחוז חדירת אנרגיות מתחדשות בשנת 2050 העומד על 17%, 54% ועד 90%, בהתאמה (עמ׳ 119 למסמך מפת הדרכים).

לענייננו, המשיבים יבקשו להפנות לאמור במסמך מפת הדרכים, כדלקמן: ״**גם בשיעורי החדרה גבוהים ביותר של אנרגיה מתחדשת (מעל 80%) עדיין יהיה צורך בהספק גז טבעי של כ-GW 16 שיפעל ברציפות במשך כל היממה [...] סך ההספק הנדרש בגז טבעי בשנת 2050 יעמוד לכל הפחות על כ-GW 18 וזאת גם בתרחיש הכולל התבססות על אנרגיית שמש בשיעורים הגבוהים ביותר האפשריים**״ (עמ׳ 29-30 למסמך מפת הדרכים). כלומר, בהתאם להערכות המשרד, ***צרכי האנרגיה של המשק הישראלי מחייבים המשך שימוש בגז טבעי גם בעשורים הקרובים*** ואף במציאות של הפחתת פליטות מקסימלית, זאת בין השאר תוך הסתמכות על שיטות פעולה וטכנולוגיות שונות שיובילו להפחתה זו.

הנה כי כן, גם בתרחיש האופטימי ביותר, במסמך מפת הדרכים, המביא בחשבון כניסה מקסימלית של אנרגיה סולרית ושימוש מקסימלי בפתרונות אגירה, ואשר מבטא עמידה ביעדי מדינת ישראל להפחתה של 80% בפליטות גזי חממה עד לשנת 2050, נעשה שימוש בגז טבעי גם בשנת 2050 ומעבר לה (תרשים 40 בעמ׳ 123 למסמך מפת הדרכים).

18. בהקשר זה ראוי לציין גם את המגבלות הקיימות להסתמכות מוגברת על ייצור חשמל מאנרגיות מתחדשות. יפים לעניין זה הדברים הבאים מתוך מסמך מפת הדרכים (עמ' 19 למסמך מפת הדרכים):

> **"עמידה ביעדים משמעותיים של ייצור באנרגיות מתחדשות בישראל כרוכה באתגרים רבים הנוגעים בין השאר בהיבטים תכנוניים, סביבתיים, פיננסיים וטכנולוגיים, אשר מתאפיינים בהשפעה מכרעת על משק החשמל. בין ההשפעות הבולטות על המשק ניתן למנות את תוספת העלויות הישירות והעקיפות הנובעות משילוב אנרגיות מתחדשות במערכת ומגולמות בתעריף החשמל המשולם על ידי כלל הצרכנים, כמו גם את ההשפעות על יציבות ושרידות מערכת החשמל, על ביטחון האנרגיה, על הקצאת משאב הרשת ועוד.**
>
> [...]
>
> **למרות היתרונות הכלכליים של ייצור סולארי ומאפייני האקלים בישראל, קיימת מורכבות רבה בניהול מערכת חשמל המסתמכת באופן כמעט בלעדי על מקור אנרגיה מתחדשת אחד בלבד, בפרט סירוגי (שאינו ניתן לשליטה על ידי מנהלי הרשת ואינו בעל כושר אספקה רציף)".**

19. תפיסת משרד האנרגיה והתשתיות אפוא, על רקע אחריותו לשמירה על משק אנרגיה יציב, היא שדווקא מחויבותו להסתמכות עתידית על אנרגיות מתחדשות בכלל, ואנרגיה סולארית בפרט, מחייבת בנוסף את שימור האפשרות לייצור אנרגיה מגז טבעי. זאת, כאמצעי משלים בעל אמינות גבוהה, שפגיעתו בסביבה ובאקלים נמוכה לעומת דלקים פוסיליים אחרים.

<u>הגז הטבעי כ"דלק מעבר"</u>

20. משרד האנרגיה והתשתיות משקיע משאבים רבים לקידום פתרונות לסוגיית משבר האקלים והפחתת הפליטות של גזי חממה, ובכלל זה מקדם את תחום האנרגיה המקיימת. בין היתר, הוקמה על-ידי המשרד חטיבת אנרגיה מקיימת; פורסמו "קולות קוראים" להקמת מתקנים באנרגיה מתחדשת; קודם הפיילוט בנושא דו-שימוש בקרקע חקלאית לייצור חשמל; קודמו תוכניות מתאר ונוצרו תיאומים קריטיים למתקני יצור חשמל מרוח; קודמה הקמתן של עמדות טעינה לרכב חשמלי; וכן קודמו תקנים לתחנות תדלוק במימן. כל זאת, תוך השקעה של מאות מיליוני ש"ח, וכן תוך פעילות בארגונים בינלאומיים ובוועידת האקלים של האו"ם, מימון מחקרים ועוד.

21. לצד האמור, מתוקף אחריותו של המשרד, עליו לוודא כי ניתן מענה לצורך של מדינת ישראל במקורות אנרגיה זמינים, וכן עליו להביא בחשבון שיקולים נוספים, לרבות שיקולים כלכליים ושיקולים גיאו-פוליטיים. כפי שיפורט להלן, בשים לב לשיקולים אלה, **<u>גיבש משרד האנרגיה את תפיסתו של הגז הטבעי כ"דלק מעבר"</u>**, אשר יסייע לישראל ולעולם לצלוח את התקופה בת מספר עשורים עד למעבר להסתמכות כמעט מלאה על אנרגיות מתחדשות, תוך שימוש בגז טבעי כתחליף למקורות אנרגיה מזהמים יותר כגון פחם, סולר ומזוט.

22. כרקע לדברים יצוין כבר עתה, כי הגז הטבעי הוא **הדלק הפוסילי הנקי ביותר** בהשוואה לדלקים אחרים בהם נעשה שימוש. במובן זה, תורם השימוש בגז הטבעי כבר עתה לצמצום משמעותי של זיהום האוויר, כמו-גם של פליטות גזי החממה ומזהמים אחרים, לעומת השימוש בפחם לייצור חשמל, ובכך מסייע להתמודדות עם משבר האקלים (ראו התייחסות בעמודים 5 ו-23 לטיוטת דוח אדירי 2).

כך למשל, בדו״ח מצב משק החשמל לשנת 2021, אשר פורסם על-ידי רשות החשמל ביום 27.7.22 (להלן: **דו״ח משק החשמל**) צוין כי ״**על אף גידול ביצור החשמל פליטות המזהמים המקומיים במשק החשמל פחתו ביותר מ-75% בעשור האחרון. זאת, בעיקר בשל שינוי בתמהיל הדלקים (גז טבעי ואנרגיות מתחדשות חלף פחם) והתקנת סולקנים בתחנות הפחמיות**״.

צילום העמודים הרלוונטיים מתוך דו״ח משק החשמל מצורף ומסומן **מש/3**.

23. במבט צופה פני עתיד, רואה משרד האנרגיה והתשתיות אתגר מדיניות מרכזי, באיזון שבין העובדה שמשק האנרגיה בישראל מבוסס בחלקו הגדול על גז טבעי, לבין מחויבותה של מדינת ישראל להתמודדות עם משבר האקלים. כפי שיבואר להלן, ההסתמכות על אנרגיות מתחדשות, ובראשן אנרגיה סולרית, טומנת בחובה אתגרים טכניים, כלכליים ורגולטוריים משמעותיים.

לפיכך, לעמדת משרד האנרגיה והתשתיות, קיומו של מענה אנרגטי זמין, אמין ויציב בדמות הגז הטבעי, לא רק שאינו פוגע בכניסה של אנרגיות מתחדשות – שהן חלק ניכר מן המענה האסטרטגי ארוך-הטווח להתמודדות עם פליטות גזי חממה ומזהמים אחרים במשק החשמל, לצד התייעלות אנרגטית – אלא תומך בהן, תוך שמירה על הביטחון האנרגטי של מדינת ישראל. זאת, בניגוד לאופן בו מבקשת העותרת להציג את הדברים בעתירתה, כאילו פיתוח הגז הטבעי יבוא על חשבון הטמעתן של אנרגיות מתחדשות.

24. יתרה מכך, המשרד אף בוחן (כפי שבוחנות מדינות רבות אחרות בעולם) אפשרויות שונות לצמצום משמעותי של פליטת גזי החממה ומזהמים אחרים כתוצאה מהשימוש העתידי בגז טבעי, ובהן תפיסה והטמנה של פחמן דו-חמצני (CCS), וכן שימוש בגז טבעי לייצור ״מימן כחול״ מונח שמשמעותו שימוש בהליך היעיל ביותר ליצירת מימן, תוך תפיסת הפחמן הדוח חמצני הנפלט מהתהליך ולכידתו או שימוש משני בו (ראו עמודים 6 ו-20-21 למסמך מפת הדרכים). בהקשר זה יצוין גם דו״ח של סוכנות האנרגיה הבינלאומית, אשר קבע כי השקעה בתשתיות גז טבעי חדשות עשויה להוביל לצמצום פליטות. עוד נקבע, כי במקרים מסוימים, גז טבעי עשוי אף לספק מענה במקרים שלא ניתן לעשות בהם שימוש באלטרנטיבות מופחתות פחמן, כגון אחסון עונתי, או ייצור חום גבוה לשימוש בתעשיה.[2]

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[2] קישור לדוח של סוכנות האנרגיה הבינלאומית בעניין ״The Role of Gas in Today's Energy Transitions״:
https://www.iea.org/reports/the-role-of-gas-in-todays-energy-transitions

25. הנה כי כן, על אף האתגרים שבאיזון בין המשך השימוש בגז טבעי לבין ההתמודדות עם משבר האקלים, משרד האנרגיה והתשתיות פועל לגיבוש מדיניות ארוכת-טווח, במסגרתה ישמש הגז הטבעי בתקופת הביניים כ"דלק מעבר" עד לנקודה שבה ניתן יהיה לקיים משק אנרגטי יציב המסתמך על אנרגיות מתחדשות. כל זאת, תוך בחינת פתרונות המביאים בחשבון את כלל השיקולים הכלכליים, הסביבתיים והביטחוניים הרלוונטיים.

הביקוש העולמי לגז הטבעי והתועלת הכלכלית למדינה

26. כפי שיפורט להלן, עמדת משרד האנרגיה והתשתיות היא שהשפעות משבר האנרגיה בכלל, והיחסים המעורערים שבין אירופה לרוסיה בעקבות המלחמה בין רוסיה לאוקראינה בפרט, צפויות להימשך עשרות שנים ולהשפיע על הביקוש העולמי לגז טבעי.

בהקשר זה ראוי לציין את מזכר ההבנות בין ישראל, מצרים והאיחוד האירופי מיום 17.6.22, אשר קורא להגדיל את ייצוא הגז הטבעי הישראלי לאירופה דרך מצרים, ובפרט את מחויבות האיחוד האירופי לעודד חברות אירופיות להשתתף בהליכים תחרותיים בישראל ובמצרים.

27. עוד יוזכר כי על פי נתוני חברת הייעוץ הבינלאומית S&P Global שנמסרו למשרד האנרגיה והתשתיות, לגז הטבעי שמקורו במזרח הים התיכון, ובכלל זה בישראל, יהיה תפקיד משמעותי באספקת הגז הטבעי לאירופה גם בשנת 2040, בהיקף של כ-40 BCM לשנה, לעומת כ-10 BCM לשנה בלבד כיום.

השימוש בגז טבעי בשווקי אסיה אף צפוי להימשך זמן רב לאחר דעיכתו במדינות המערב, והדרישה לגז טבעי נוזלי (LNG) צפויה להגיע לכ-750 BCM בשנה בשווקים אלו גם בשנת 2050. הבנה זו, משתקפת גם במספר החברות המבקשות להשתתף בהליך התחרותי נושא העתירה דנן ואשר רכשו את מסמכי ההליך – מספר הגבוה משמעותית בהשוואה להליכים קודמים, ובכלל זה מספר חברות בינלאומיות גדולות שאינן פעילות כיום בישראל.

28. אשר להשקעה הציבורית והעלויות של פיתוח תשתיות גז טבעי, יודגש תחילה כי רובן המכריע של ההשקעות <u>בחיפוש והפקה</u> של גז טבעי, הנאמדות במיליארדי דולרים, והמתאפיינות ברמת סיכון גבוהה מאוד, נעשות על-ידי חברות פרטיות. פעילות החיפוש של גז טבעי מתאפיינת ברמת אי-ודאות גבוהה מאוד, ולכן לא ניתן להעריך בשלב זה אם וכמה גז טבעי יימצא בעקבות ההליך התחרותי, לא כל שכן את השפעותיו המשקיות.

כמו כן, ניסיון העבר מלמד כי כניסת הגז הטבעי הישראלי כמקור העיקרי לייצור חשמל בישראל הגנה על המשק מהעליות החדות של מחירי האנרגיה בעולם בשנת 2022. שכן, העלייה שהתרחשה במחירי החשמל נבעה דווקא מעליה חדה במחיר הפחם, אשר הוחלף ברובו על-ידי גז טבעי ישראלי בשנים האחרונות. ללא החלפה זו – שהתרחשה בעקבות גילוי מאגרי גז טבעי משמעותיים במימי ישראל – היו מחירי החשמל מזנקים בשיעור גבוה בהרבה. כן נבעה ההתייקרות מהעיכוב בבניית תחנות כוח גזיות נוספות ובהסבת יחידות פחמיות ליחידות העושות שימוש בגז טבעי.

.29 בכל הנוגע לתועלת הכלכלית מהגז הטבעי למדינת ישראל, ראוי להוסיף, כדלקמן:

א. החיסכון המשקי בשנים 2021-2014 מהמעבר לגז טבעי עומד על כ-116 מיליארד ש״ח.[3] חיסכון זה נובע מביטול הצורך בהקמת תחנות כוח פחמיות חדשות וחוסר הצורך בייצור משלים בסולר ובמזוט.[4]

ב. ההכנסות הכוללות של המדינה מגז טבעי (תמלוגים, מס חברות והיטל רווחי יתר) עד לסוף שנת 2022 עמדו על כ-20 מיליארד ש״ח,[5] וההכנסות מגביית היטל רווחי נפט וגז בלבד (ללא תמלוגים ומס חברות) ביחס למאגרים <u>הקיימים כיום</u>, עשויות להגיע ל-53-45 מיליארד דולר, מהם 12-10 מיליארד דולר רק בעשור הקרוב.[6]

<u>3.א קידום ההליך התחרותי נושא העתירה</u>

.30 ההליך התחרותי הרביעי להענקת רישיונות לפי חוק הנפט (להלן: **ההליך התחרותי**) הינו מנגנון רגולטורי שוויוני ושקוף, במסגרתו מוקצים רשיונות לחיפוש מאגרי גז טבעי נוספים בשטחי המים הכלכליים של מדינת ישראל. יצוין, כי הליכים תחרותיים דומים מתקיימים כיום במדינות רבות ברחבי העולם, כאשר בשנת 2022 פורסמו הליכים במדינות מתקדמות כאוסטרליה, בריטניה ונורבגיה.

.31 כפי שיפורט בסמוך, ההליך התחרותי מקודם מכוח הוראות חוק הנפט ולא מכוחו של חוק חובת המכרזים, שאינו חל על ההליך דנן (ראו: עע״ם 702/19 **צ׳יינה מוטורס בע״מ נ׳ משרד התחבורה והבטיחות בדרכים** (7.7.20), פסקאות 26-23 לפסק דינה של הנשיאה חיות (להלן: **עניין צ׳יינה מוטורס**). בנסיבות אלה, לעמדת המשיבים הערכאה המתאימה לבירורה של העתירה היא בית המשפט הנכבד, ולא עומד לעותרת סעד חלופי בבית המשפט לעניינים מינהליים. למען שלמות התמונה יצוין, כאמור בפתח הדברים, כי בפני בית המשפט הנכבד תלויה ועומדת עתירה נוספת הממתינה לפסק-דין, שבצד הסעדים העיקריים שהתבקשו בה ושלא עסקו בשאלה דומה לעתירה דנן, התבקש צו-ביניים **״שיאסור על המשיבים לפתוח בהליך תחרותי למתן רישיון חדש על שטח רישיון אלון D״** (בג״ץ 4015/20 **שברון מדיטרניאן לימיטד נ. שר האנרגיה**).

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[3] ראו לעניין זה מסמך סקירת התפתחויות במשק הגז הטבעי לשנת 2021, רשות הגז, אותו ניתן למצוא בקישור שלהלן: https://www.gov.il/BlobFolder/reports/ng_2021/he/ng_2021.pdf

[4] ראו לעניין זה מסמך סקירת התפתחויות במשק הגז הטבעי לשנת 2021, רשות הגז, אותו ניתן למצוא בקישור שלהלן: https://www.gov.il/BlobFolder/reports/ng_2021/he/ng_2021.pdf

[5] ראו לעניין זה דו״ח הכנסות מינהל אוצרות טבע לשנת 2022, אותו ניתן למצוא בקישור שלהלן: https://www.gov.il/BlobFolder/reports/income_reporte/he/revenue-report-2022.pdf

[6] ראו לעניין זה הדו״ח השנתי של הקרן לאזרחי ישראל לשנת 2022: https://www.gov.il/BlobFolder/news/press_04042023/he/israel-citizens-foundation_annual-report-2022-israel-citizens-foundation.pdf

32. אם כן, המסגרת הנורמטיבית לקידום ההליך התחרותי מצויה לנו בחוק הנפט, ובפרט בהוראת סעיף 5 הקובעת כדלהלן:

> "השר רשאי, לאחר התייעצות עם המועצה, לקבוע, בהודעה, שפורסמה ברשומות, כי שטח משטחי המדינה, יהיה שטח פתוח לחיפוש נפט ולהפקתו (להלן – שטח פתוח), ורשאי הוא באותה דרך עצמה, לחזור ולסגור שטח פתוח, כולו או מקצתו".

בהמשך לכך, קובע סעיף 15א(א) לחוק הנפט כדלקמן:

> "קרקע שאין עליה זכות קדימה או זכות נפט ונעשו בה על ידי החברה, שסעיף 80א דן בה בדיקות מוקדמות כדי לעמוד על הסיכויים לגלות בה נפט, ולאחר שפורסמו תוצאות הבדיקות נתבקשו עליה יותר מרישיון אחד, רשאי השר לאחר התייעצות עם המועצה, להודיע ברשומות כי אותה קרקע תועמד לתחרות וכל עוד הודעה זו בתוקפה לא תינתן עוד זכות קדימה או זכות נפט על אותה קרקע אלא על פי תחרות".

על הוראות אלו, מוסיפה תקנה 12 לתקנות הנפט (עקרונות פעולה לחיפושי נפט), התשע"ז-2016 כך:

> "12. (א) הודיע השר כי רישיון או חזקה בשטח שכולו או רובו בים יינתנו על פי תחרות, תיערך התחרות בהליך פומבי שיכוון להשגת מרב היתרונות למשק המדינה, ובכלל זה משק האנרגיה.
>
> (ב) הממונה יפרסם באתר האינטרנט של משרד התשתיות הלאומיות האנרגיה והמים, לכל הליך כאמור בתקנת משנה (א), את דבר קיום ההליך התחרותי, המועד האחרון להגשת הצעות, תנאי הסף, והסכום המזערי להצעת המחיר, אם נדרש, ואם יוחלט לבחון את ההצעות גם על בסיס טיבן – את אמות המידה לבחינה כאמור ואת המשקל של כל אחת מאמות המידה לבחירת הזוכה".

הנה כי כן, הסמכויות להחליט על פרסום ההליך התחרותי ולהעניק מכוחו רישיונות לחיפוש נפט והפקתו, נתונות לשר האנרגיה והתשתיות ולממונה על ענייני הנפט, בהתייעצות עם מועצת הנפט (להלן גם: **המועצה**).

33. עוד יצוין, כי מועצת הנפט קמה מכוח סעיף 3 לחוק הנפט, אשר קובע, בין היתר, כדלקמן:

> **"מועצה מייעצת**
> 3. (א) השר ימנה מועצה מייעצת של חמישה עשר חברים (להלן – המועצה), בהם לפחות שבעה מקרב הציבור וכן עובד אגף התקציבים ועובד אגף החשב הכללי במשרד האוצר, על פי הצעת שר האוצר, שני עובדי משרד האנרגיה והמים, על פי הצעת שר האנרגיה והמים, ושני עובדי המשרד להגנת הסביבה, על פי הצעת השר להגנת הסביבה; החברים יתמנו לשלוש שנים, ואפשר לחזור ולמנותם, ובלבד שלא יכהנו יותר משתי תקופות כהונה רצופות.
> (ב) השר ימנה את אחד מחברי המועצה ליושב ראש המועצה.
> (ג) הודעה על מינוי המועצה תפורסם ברשומות...".

.34 נושא ההליך התחרותי נידון במשרד האנרגיה והתשתיות במשך תקופה ארוכה ובאופן מעמיק. כבר בחודש ספטמבר 2020 הוצגו עקרונות ההליך התחרותי לשר האנרגיה והתשתיות דאז, ד"ר יובל שטייניץ. בהמשך לכך, ביום 5.1.21 החליטה מועצת הנפט להמליץ לשר האנרגיה והתשתיות דאז לפתוח לתחרות שטחים במים בהתאם לסעיף 5 לחוק הנפט. כעולה מפרוטוקול ישיבת מועצת הנפט מיום 5.1.21, ההמלצה התייחסה, בין היתר, לשטחים המשווקים במסגרת ההליך התחרותי נושא העתירה דנן, זאת, למעט שטח קטן בשולי מקבץ E. עם זאת, באותו שלב לא הבשילה המלצת המועצה לכדי פרסומו של הליך תחרותי.

צילום פרוטוקול הדיון במועצת הנפט מיום 5.1.21 מצורף ומסומן **<u>מש/4</u>**.

.35 כפי שפורט לעיל, בחודש אפריל 2021 פורסם להערות הציבור מסמך מפת הדרכים. בהמשך לכך, ביום 15.12.21, הודיעה שרת האנרגיה דאז, קארין אלהרר, כי היא מתכוונת למקד את פעילות המשרד בשנת 2022 באנרגיות מתחדשות, וכי לא יהיו חיפושי גז טבעי חדשים בשנה הקרובה. בדיון שנערך בוועדת הכלכלה של הכנסת ביום 16.2.22, הבהירה השרה את עמדתה וציינה כי "**לעולם לא אמרתי שאני עוצרת את כל חיפושי הגז, אלא שלא אתן רישיונות חדשים עד שלא נבין את מצב משק הגז, כשהשנה יהיו 3 קידוחים משמעותיים**".[7]

.36 כאמור, ביום 24.2.22 החלה המלחמה בין רוסיה ואוקראינה, אשר החריפה במידה ניכרת את משבר האנרגיה, שהחל עוד קודם לה; ושינתה במידה רבה את "כללי המשחק" בשוק האנרגיה.

.37 בעקבות שינוי הנסיבות, הודיעה השרה הקודמת ביום 30.5.22 כי היא מחליטה לחדש את היערכות המשרד ליציאה להליך תחרותי לחיפוש גז טבעי, בשים לב לביקוש הגובר לגז טבעי באירופה בשל המלחמה, והן בשל הצורך לגשר על תקופת הביניים עד למעבר מלא לאנרגיות מתחדשות. לפיכך, הנחתה השרה הקודמת את גורמי המקצוע במשרד האנרגיה והתשתיות לפעול לקידום פרסום הליך תחרותי רביעי לחיפוש גז טבעי.[8]

.38 ביום 31.5.22 פנו העותרת ועמותת "אדם, טבע ודין" לשרת האנרגיה והתשתיות הקודמת, בבקשה לעצור את קידום ההליך התחרותי הרביעי.

צילום פניית העותרת ועמותת אדם, טבע ודין מיום 31.5.22 מצורף ומסומן **<u>מש/5</u>**.

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[7] קישור לסיכום הדיון ועדת הכלכלה מיום 16.2.22 בחדשות הכנסת:
https://main.knesset.gov.il/news/pressreleases/pages/press16022022g.aspx

[8] ראו את הודעת הדוברות מטעם משרד האנרגיה " יוצאים להליך התחרותי הרביעי לחיפושי גז טבעי במים הכלכליים של מדינת ישראל" (30.5.22), בקישור הבא:
https://www.gov.il/he/departments/news/press_300522

39. ביום 20.6.22 פנתה העותרת לשרת האנרגיה והתשתיות הקודמת וליו״ר מועצת הנפט וביקשה, בין היתר, להציג טיעונים בפני מועצת הנפט נגד הכוונה לצאת בהליך תחרותי חדש. הפנייה הועברה לטיפול מנהל אגף סביבה במינהל אוצרות טבע דאז, מר אילן נסים, אשר השיב לעותרת ביום 5.9.22; **<u>תוך שציין, בין היתר, כי פניית העותרת תובא ככתבה וכלשונה במסגרת הדיון בפני מועצת הנפט</u>**, ואף ציין את הנימוקים המקצועיים התומכים ביציאה להליך התחרותי. ביום 24.10.22 שבה העותרת ופנתה בעניין ההליך הרביעי, תוך שביקשה, בין היתר, כי תינתן לה ולבעלי עניין נוספים, האפשרות להישמע בפני מועצת הנפט בדיון על חידוש חיפושי הגז הטבעי בים התיכון.

צילום מכתב העותרת מיום 20.6.22 צורף לעתירה כ<u>נספח 23</u>.
צילום המענה מטעם מנהל אגף סביבה במינהל אוצרות טבע מיום 5.9.22 צורף לעתירה כ<u>נספח 24</u>.
צילום מכתב העותר מיום 24.10.22 צורף לעתירה כ<u>נספח 25</u>.

40. ביני לביני, ביום 6.10.22, פנתה העותרת למשרד בבקשה לקבלת מידע לפי חוק חופש המידע, התשנ״ח-1998. במסגרת הפנייה, ביקשה העותרת, בין היתר, מידע בנוגע לתשתית המקצועית והעובדתית עליה התבססה ההחלטה על ״חידוש חיפושי הגז בים התיכון״. ביום 31.1.23 השיב המשרד לבקשת חופש המידע של העותרת.

צילום בקשת חופש המידע צורף לעתירה כ<u>נספח 26.</u>
צילום המענה לבקשת חופש המידע מיום 31.1.23 צורף לעתירה כ<u>נספח 29</u>.

41. ביום 29.11.22 דנה מועצת הנפט בהצעה לפתוח בהליך התחרותי הרביעי. לקראת הדיון הונח בפני המועצה מסמך המפרט את עקרונות ההליך התחרותי, לרבות ניתוח של ההיבטים הסביבתיים (להלן: **מסמך העקרונות**). כן הונח בפני חברי המועצה מכתב העותרת ועמותת אדם טבע ודין מיום 31.5.22, ומכתב העותרת מיום 20.6.22, שנזכרו לעיל. כפי שנעשה בהליכים תחרותיים קודמים, מסמך העקרונות שהונח בפני המועצה כלל את המסגרת החוקית; סעיפי הניקוד; פירוט בנושא ערבויות ושיווק במקבצים; וכן פירוט אודות שיקולי תחרות ונימוקים סביבתיים.

צילום מסמך העקרונות שהונח בפני מועצת הנפט מצורף ומסומן **<u>מש/6</u>**.

42. כפי שצוין לעיל, במכתבה מיום 20.6.22 ביקשה העותרת להופיע ולהציג טיעוניה מול חברי המועצה. כעולה מפרוטוקול הדיון במועצה, הוחלט לעניין זה להציג את פנייתה של העותרת ככתבה וכלשונה בפני חברי המועצה, על מנת שיוכלו לשקול את הטיעונים שהוצגו במסגרתה,וכך צוין לעניין זה בפרוטוקול הדיון:

> **״...הובהר כי ככלל, הנוהג לפיו פעלו עד כה הוא לא לזמן גורמים מבחוץ להצגת טיעונים בע״פ במסגרת דיוני המועצה. במקרה שלפנינו, לאור בקשת ארגוני סביבה להציג עמדתם בכל הנוגע להליך התחרותי, הוחלט שפנייתם הכתובה תוצג לחברי המועצה. לאור האמור, פנייתם צורפה לחומר אשר נשלח לכלל חברי המועצה, והובהר שככל שמי מהחברים ימצא לנכון הוא מוזמן להציג את עמדתו ביחס לפנייתם״.**

יוער בהקשר זה, כי הופעה בפני המועצה של גורמי חוץ מהווה חריגה מסדרי הדיון המקובלים במועצה. לפיכך, בעצם הבאת דבריה של העותרת, ככתבם וכלשונם בפני חברי המועצה, ניתנה לעותרת אפשרות להציג את טענותיה בפני חברי המועצה, אף שאיננה מבקשת לפי חוק הנפט (מי שרישיונו נדון בפני המועצה).

.43 במהלך הדיון במועצה הובאו עקרונות ההליך התחרותי, וכן פורטו עקרונות סביבתיים. בין היתר, צוין ביחס לעקרונות הסביבתיים, כי "הגז הטבעי המופק בישראל מחליף דלקים מזהמים יותר ... בנוסף הוא מהווה מקור אנרגיה משלים למקורות אנרגיה מתחדשת עקב השונות הגבוהה בזמינותם". עוד צוין בהקשר הסביבתי כי לפי המידע העדכני ביותר שבידי משרד האנרגיה "האזורים המשווקים במסגרת ההליך נמצאים במרחק למעלה מ-40 ק"מ מהחוף, ולא כוללים בתי גידול רגישים, קיימים אמצעי זהירות נוספים שמטרתם לוודא מניעת פגיעה בבתי גידול רגישים". לצד הערכה זו, שהתבססה על הסקר האסטרטגי הסביבתי, הובהר בעקרונות הסביבתיים שהוצגו בפני המועצה כי "קיימים אמצעי זהירות נוספים שמטרתם לוודא מניעת פגיעה בבתי גידול רגישים. במסגרת התנאים לאישור קדיחה נדרש מבעל רישיון לבצע סקר רקע מקדים, שמטרתו לוודא שאין בתי גידול רגישים במרחב המתוכנן לקידוח החיפוש, להכין מסמך סביבתי שאישורו נסמך על חוות דעת היחידה להגנת הסביבה הימית במשרד להגנת הסביבה, וכן לקבל היתר הזרמה לים, היתר רעלים ולקבל אישור לתכנית חירום מפעלית. אישורים והיתרים אלה נמצאים בסמכות הבלעדית של המשרד להגנת הסביבה".

.44 מנגד, נציגי המשרד להגנת הסביבה התנגדו לקבלת ההחלטה, בין היתר, מן הטעם שהמידע שהוצג בפני המועצה לא היה מספק לעמדתם, וזאת מאחר שלא בוצע באזורים המיועדים להיכלל בהליך התחרותי סקר סביבתי אסטרטגי מעמיק, הבוחן את נכסי הטבע באותו אזור לרבות חלופות ומגבלות שהמדינה תטיל על עצמה או על היזמים לאחר מכן. סקר מעין זה בוצע במדינות מתקדמות אשר פתחו בהליכים דומים כפי שנזכר לעיל, באוסטרליה, בריטניה ונורבגיה. בשונה מכך, הסקרים שנערכו בישראל בשנים 2016 ו-2021 לא כללו את האזורים המיועדים באופן מלא והמידע שנמצא בהם איננו מספק. בנוסף, התנגדו נציגי המשרד לקבלת ההחלטה מאחר שסברו כי תרומת מאגרי הגז הנוספים למשק האנרגיה הישראלי אינה הכרחית, בשל היקפי הייצוא הגדולים של גז טבעי.

.45 בתגובה, השיב נציג משרד האנרגיה והתשתיות כי "האזור מוגדר כאזור חדש לחיפוש ולכן טרם קידוח מבצעים סקר רקע כדי לוודא שהנחות הבסיס של הסא"ס מתקיימות ושלא קיימים במרחב הזה בתי גידול רגישים. במידה ומתגלה אזור רגיש, המגבלות למניעת פגיעה בבתי גידול רגישים חלות על בעל הזכות ומשנים את מיקום הקידוח כפי שכבר קרה בעבר. הסקר האסטרטגי הסביבתי לחיפוש ולהפקת גז טבעי מכסה את המרחבים שמוצעים לשיווק, מתעדכן באופן שוטף ותוצאות הניטור הלאומי שבוצע בשיתוף פעולה עם המשרד להגנ"ס תומכות בהנחות הבסיס שלו. סקר הרקע שמבוצע לפני אישור הקידוחה נותן מענה מספק למניעת פגיעה בבתי גידול רגישים במידה ויתגלו במהלך הבדיקות המקדימות. בנוסף, השטח המופר בעקבות קידוח הוא מצומצם ביותר ומשתרע על רדיוס של כמה מאות מטרים בודדים".

צילום פרוטוקול הדיון במועצת הנפט מיום 29.11.22 צורף לעתירה כ<u>נספח 31</u>.

46. בהמשך, נסוב הדיון גם על ההקשר הכלכלי והגיאופוליטי של ההחלטה, תוך שהוסבר כי בעולם יש ביקוש לגז טבעי נוסף, ולכן זכה הדבר לציון במזכר ההבנות המשולש בין ישראל, מצרים והאיחוד האירופאי. עוד עמד משרד האנרגיה והתשתיות על כך שאם **"יתגלה גז במסגרת ההליך, הוא עשוי לשמש הן לצרכי המשק המקומי והן לצרכי ייצוא, והכל בכפוף למדיניות הייצוא הקבועה בהחלטות ממשלה"**.

47. בסיומו של דיון מקיף, במסגרתו נשמעו כאמור דעות שונות, המליצה המועצה על קיומו של ההליך התחרותי, וזאת ברוב של חמישה תומכים מול שלושה מתנגדים (שני נציגי המשרד להגנת הסביבה במועצה המייעצת ונציג ציבור אחד).

48. ביום 13.12.22, בהמשך להמלצת מועצת הנפט, ומתוקף סמכותה לפי חוק הנפט, חתמה שרת האנרגיה והתשתיות הקודמת על הודעה בדבר העמדת שטחים לתחרות לפי סעיף 15א לחוק הנפט, ועל הודעה בדבר שינויים בשטחים לחיפושי נפט והפקתם לפי סעיף 5 לחוק הנפט. הודעות אלו פורסמו ברשומות ביום 14.12.22. במקביל לכך פורסמו מסמכי ההליך באתר הייעודי.[9]

במסגרת ההליך משווקים 20 בלוקים, המחולקים לארבעה מקבצים, בשטח של כ-5,900 קמ"ר. ההצעות מוגשות לפי מקבץ, הכולל בין שלושה לשישה "בלוקים". המועד האחרון לסגירת ההצעות נקבע ליום 29.6.23. לאחר קביעת הזוכים בהליך ואישורם בידי המועצה, יוכל הממונה על ענייני הנפט, בהיוועצות עם המועצה, להעניק רישיון לחברה או לשותפות שיעמדו בתנאי המכרז ויוכרזו כזוכים; כאשר לאותה חברה או שותפות יוענק רישיון לכל "בלוק" הכלול במקבץ שבו זכתה.

יצוין, כי בחינת ההשתתפות בהליך דורשת זמן למידה משמעותי וכן כרוכה בהשקעת משאבים ומאמצים ניכרים מצד החברות, הכוללים בין היתר: תשלום דמי השתתפות וחתימה על הצהרת סודיות; בחינה מעמיקה של המידע הגיאולוגי בידי צוות מקצועי; בחינת כלל ההיבטים הרגולטוריים והכלכליים הכרוכים בהשתתפות בהליך וכן בפעילות במסגרת רישיון עתידי; בחינת שותפות אפשרית עם חברות נוספות וגיבוש טיוטת הסכמי שותפות; ולבסוף קבלת החלטה סופית אודות ההשתתפות בהליך. עוד יצוין בהקשר זה, כי החלטה להיכנס לחיפוש גז טבעי במדינה חדשה היא החלטה מורכבת, בין היתר, עקב הצורך להקים תשתית חדשה לפעילות במדינה זו, ללמוד את הרגולציה הרלוונטית, לחתום הסכמי ייצוג עם משרדים מלווים מקומיים ועוד.

לבסוף, נבקש לעדכן כי על-פי הנמסר ממשרד האנרגיה והתשתיות, בשלב זה של התהליך ישנו מספר דו-ספרתי של חברות אשר שילמו את דמי ההשתתפות, לרבות חברות בינלאומיות אשר שוקלות להיכנס לפעילות בישראל בפעם הראשונה; ולמיטב ידיעת גורמי משרד האנרגיה והתשתיות החברות הללו מצויות בעיצומן של ההכנות להגשת הצעה, כמפורט לעיל.

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[9] להלן קישור לאתר הייעודי להליך התחרותי:
https://www.energy-sea.gov.il/ https://www.energy-sea.gov.il/

.49 ביום 19.12.22 פנתה העותרת ליועצת המשפטית של משרד האנרגיה והתשתיות, בעניין פרסום ההליך התחרותי.

בפנייה זו העלתה העותרת טענות לעניין מועד ההחלטה על פרסום ההליך התחרותי, וציינה כי "**מתעורר הרושם כי פרסום ההליך התחרותי בעת הזו, לא התאפיין במידת האיפוק אשר נדרשה על-יבי בית המשפט העליון**" בתקופת בחירות (סעיף 4 לפניית העותרת מיום 19.12.22).

צילום פניית העותרת מיום 19.12.22 צורף לעתירה כנספח 32.

.50 ביום 3.1.23 פנתה העותרת לשר האנרגיה והתשתיות הנוכחי, מר ישראל כ"ץ, בדרישה "**לבטל, ולמצער, להקפיא לאלתר, את ההליך התחרותי הרביעי לקבלת רישיונות גז טבעי**".

צילום פניית העותרת מיום 3.1.23 צורפה לעתירה כנספח 33.

.51 ביום 2.3.23 נשלח מענה מטעם מ"מ מנהל מינהל אוצרות הטבע והממונה על ענייני הנפט במשרד, מר חן בר יוסף. בין היתר, צוין במענה כי "**פרסום ההליך התחרותי שבנדון בתקופת ממשלת מעבר, נעשה לאחר היוועצות עם היועצת המשפטית של משרד האנרגיה יחד עם עורכי דין במשרדנו והגורמים הרלוונטיים במשרד המשפטים, לרבות צוות הבחירות בייעוץ וחקיקה**" (סעיף 3 למכתב המענה). כמו כן, פורטו במכתב מענים לטענות השונות שהעלתה העותרת במכתבה מיום 3.1.23, בין היתר לעניין יעדי האקלים של ישראל; הצורך בגז טבעי; ומאמצי המשרד לשימור ערכים סביבתיים.

צילום מכתב המענה מטעם מ"מ מנהל מינהל אוצרות הטבע והממונה על ענייני הנפט במשרד מיום 2.3.22 צורף לעתירה כנספח 34.

.52 ביום 9.3.23 פנתה העותרת בשנית לשר האנרגיה והתשתיות בפנייתה שכותרתה "**התראה טרם נקיטת הליכים – פגמים משפטיים בפרסום ההליך התחרותי הרביעי לקבלת רישיונות לחיפושי גז טבעי**". במסגרת פנייה זו שבה העותרת על טענותיה לעניין פגמים בפרסום ההליך התחרותי; וביקשה שוב לבטל או להקפיא את ההליך.

צילום פניית העותרת מיום 9.3.23 צורפה לעתירה כנספח 35.

.53 ביום 24.4.23 הוגשה העתירה דנן.

ב. עמדת המשיבים - דין הבקשה למתן צו ביניים להידחות

54. ראשית, כמפורט בפתח הדברים, ביום 18.5.23 פרסם המשרד הודעה בדבר הגשת העתירה דנן, וזאת באתר הייעודי של ההליך התחרותי. בנסיבות אלה, הרי שהראש השני של צו הביניים המבוקש, בוצע הלכה למעשה על-ידי המשיבים, ובנסיבות אלו אין כל עילה שבית המשפט הנכבד יידרש עוד לסעד ביניים זה.

55. שנית, המשיבים יטענו כי דינו של הראש הראשון של צו הביניים המבוקש – שעניינו הימנעות מכל פעולה שתוביל ליצירת הסתמכויות של המשתתפים בהליך התחרותי, ובפרט להימנע מבחירת הזוכים בהליך – להידחות על הסף ולגופו.

56. תחילה, המשיבים יטענו כי דינו של צו הביניים המבוקש להידחות על הסף, וזאת בשל העובדה שהוא **כונף בתוכו חלק מהותי מהסעד העיקרי המבוקש בעתירה**. שכן, העותרת מבקשת במסגרת העתירה, כי "יבוטל, ולמצער, **<u>יוקפא, ההליך התחרותי הרביעי לקבלת רישיונות לחיפוש גז טבעי במימי ישראל</u>**"; ובמסגרת צו הביניים, מבוקש באופן דומה "להימנע מכל פעולה אשר תוביל ליצירת הסתמכויות של המשתתפים".

כלומר, בקשת העותרת לקבל סעד שיפוטי שיורה על הקפאת ההליך התחרותי במסגרת צו הביניים חופפת במידה רבה את הצו-על-תנאי המבוקש במסגרת העתירה. בהתאם להלכה הפסוקה בכגון דא, די בחפיפה זו כדי להצדיק את דחיית הבקשה למתן צו-ביניים על הסף (ראו לעניין זה: בג"צ 2712/92 **מרכז השלטון המקומי נ' ראש הממשלה ואח'**, תק-על 92(2), 2001, עמ' 2002 (החלטה מיום 3.6.92).

57. כמו כן, סבורים המשיבים כי דינה של הבקשה למתן צו ביניים להידחות גם לגופה.

כידוע, שני מבחנים משמשים את בית המשפט הנכבד בבואו להכריע בבקשה למתן צו-ביניים: מאזן הנוחות מזה וסיכויי העתירה מזה. על בית המשפט לבחון האם עלה בידי המבקש לשכנע את בית המשפט כי סיכויי העתירה **<u>טובים</u>** דיים, וכי הניח תשתית איתנה לכך שמאזן הנוחות נוטה לטובתו באופן מובהק (ראו, למשל, עע"מ 10710/06 **בורשה נ' משרד הפנים**, תק-על 2007(1) 3677 (2007); עע"מ 3751/09 **פינקלשטיין נ' מדינת ישראל**, תק-על 2009(3) 1339 (2009); עע"מ 2914/09 **אגודת מגן דוד אדום בישראל נ' מדינת ישראל - משרד החינוך**, תק-על 2009(2) 434 (2009)).

עוד נקבע בפסיקה, כי בין שני השיקולים הללו מתקיימת "מקבילית כוחות", וככל שעוצמתו של אחד מהרכיבים עולה – כך משקלו של הרכיב השני פוחת, **<u>תוך שניתן משקל של ממש למבחן שעניינו נטיית מאזן הנוחות</u>**.

זאת ועוד – הלכה מושרשת היא כי הנטל להוכחת נחיצותו של צו-ביניים רובץ לפתחו של העותר המבקש אותו. נטל זה כפול הוא: ראשית, על העותר להניח תשתית עובדתית איתנה ועל בסיסה להצביע על נזק משמעותי שייגרם לו כתוצאה מאי-מתן הצו. שנית, על העותר להראות כי הנזק, בהנחה שייגרם, אינו ניתן לתיקון וכי "מאזן הנוחות" נוטה לטובתו באופן מובהק.

58. בית המשפט הנכבד אף הבהיר, בהזדמנויות שונות, כי יש להישמר מהוצאת צווי-ביניים, שכן אלו עלולים "לפגוע בפעילות התקינה של המינהל, וכתוצאה מכך לפגוע גם בטובת הציבור, **לעתים פגיעה קשה**" (בג"ץ 3330/97 **עיריית אור יהודה נ' ממשלת ישראל**, פ"ד נא(3) 472, 475 (1997) (להלן: "**פרשת עיריית אור יהודה**").

מן הטעם האמור, הוסיף בית המשפט הנכבד והבהיר כי "אין זכות קנויה בידי עותר לקבל צו-ביניים רק בשל כך שהגיש עתירה או רק על יסוד טענה שעד הדיון בעתירה עשוי לחול שינוי במצב" (בג"ץ 8242/99 **אורון, עו"ד נ' ועד מחוז תל אביב – לשכת עורכי-הדין בישראל**, פ"ד נג(5) 602, 603 (1999)).

ב.1 מאזן הנוחות נוטה באופן מובהק לטובת המשיבים

59. נקודת המוצא לבחינת שאלת מאזן הנוחות בענייננו מוסבת על החשש הממשי שמא העיכוב אותו מבקשת העותרת ליצור בהליך התחרותי, עלול להניא מציעים פוטנציאליים מהגשת הצעה, באופן שיפגע מהותית בהליך כולו ועל-ידי כך יפגע פגיעה משמעותית במשק האנרגיה בכלל, ובמשק הגז הטבעי בפרט – הן ביחס למשק המקומי והן ביחס ליצוא.

נסביר – ההחלטה בדבר השתתפות בהליך תחרותי של חיפוש גז טבעי דורשת השקעת משאבים ניכרת. כך למשל, כפי שעולה מהמסמך המפרט את עקרונות ההליך התחרותי, הגשת הצעה דורשת העמדת ערבויות בשווי מיליוני דולרים, בחינה של המידע הגאולוגי הרב, ובכלל זה בניית צוותי עבודה ייעודיים להתעמקות ובחינת פוטנציאל הגז וסיכויי ההפקה. זאת, לצד ההשקעות האדירות הקשורות בהליך מטבע הדברים, ובדיקות כדאיות עסקית שונות הנדרשות אף הן.

בנסיבות אלה, ישנו משקל משמעותי לקיומה של סביבה רגולטורית ומשפטית, שמקטינה את חוסר הוודאות ומגדילה את הביטחון והיציבות עבור המשתתפים בהליך. לעמדת משרד האנרגיה והתשתיות, אחת הסיבות העיקריות לכך שחברות רבות שוקלות בחיוב את השתתפותן בהליך התחרותי, לצד הפוטנציאל העסקי הגלום בו, היא היציבות הרגולטורית השוררת בשוק הגז הטבעי בישראל מאז החלטות הממשלה מס' 476 ו-1465 בעניין מתווה הגז.

60. הנה כי כן, מתן צו הביניים המבוקש על-ידי העותרת עשוי להטות את הכף כנגד השתתפות בהליך התחרותי בקרב משתתפים פוטנציאליים רבים. לעניין זה יודגש, כי השתתפותן של חברות בינלאומיות בקנה מידה גדול בהליך היא קריטית להצלחתו, ולהצלחת החיפושים של עתודות גז טבעי חדשות שצפויות להתחיל בעקבותיו.

61. אשר לחשיבות ההליך התחרותי, נדמה כי מספיק לשוב ולהפנות להתייחסות המפורטת שהובאה בפרק א.1 לתגובה זו, המלמדת כאלף מונים על הפוטנציאל המיטיב העצום שעשוי להיות להליך על האינטרסים האנרגטיים של ישראל, לצד התועלות הכלכליות והגיאו-פוליטיות של הגז הטבעי. נשוב ונזכיר את עיקרי הדברים.

62. כאמור, משרד האנרגיה והתשתיות רואה בגז הטבעי את "דלק המעבר", שיסייע לישראל להתקדם בעשורים הקרובים לעבר הסתמכות כמעט מלאה על אנרגיות מתחדשות. הגז הטבעי, בהיותו הדלק הפוסילי הנקי ביותר, מסייע כבר עתה לצמצם באופן משמעותי את זיהום האוויר ואת פליטות גזי החממה ומזהמים אחרים, ובעתיד יסייע לאזן בין היכולת להמשיך ולקיים משק אנרגטי מתפקד, לבין המאמצים למעבר להסתמכות על אנרגיות מתחדשות, ובראשן אנרגיה סולרית.

בהקשר זה נזכיר, כי המעבר לאנרגיות מתחדשות מביא עמו קשיים לא מעטים, ולפיכך העמדה המקצועית של משרד האנרגיה והתשתיות היא שיש צורך בגז הטבעי כדי לצלוח את תקופת המעבר. זאת, לצד המגבלות הקיימות להסתמכות מוגברת על ייצור חשמל מאנרגיות מתחדשות, כפי שפורטו במסמך מפת הדרכים.

63. כמו כן, הרי שנסיבות השנים האחרונות, ובהן משבר האנרגיה על רקע מלחמת רוסיה אוקראינה, מלמדות כי ישנה חשיבות עליונה בשמירה על **<u>יתירות במקורות אנרגיה.</u>** לעניין זה נזכיר, כי ההערכות בטיוטת דוח אדירי 2 מדברות על עלייה ניכרת בביקוש לגז טבעי עד שנת 2045. הנה כי כן, לקיומן של עתודות גז טבעי נוספות, יש חשיבות מכרעת, ועמדת המשיבים היא שאין לאפשר עיכוב ופגיעה בהליך התחרותי, שתכליתו, בסופו של דבר, לסייע בהשגתן.

לעניין זה יצוין, כי ניסיונה של העותרת לטעון כי "**עתודות הגז הקיימות יכולות לספק את צרכי המשק הישראלי המקומי למשך עשרות שנים**" (סעיף 60 לעתירה) – אינו יכול לעמוד. לעמדת גורמי המקצוע במשרד האנרגיה והתשתיות, החישוב שערכת העותרת בהקשר זה בסעיפים 61-59 לעתירה לוקה בפשטנות רבה, והוא אינו יכול להחליף את המודלים המקצועיים של המשרד, המעידים על הצורך באיתור עתודות גז טבעי נוספות, הן לצרכי המשק המקומי, לרבות יתירות לטובת הביטחון האנרגטי, והן לצרכי ייצוא. לעניין זה יצוין, כי נכון להיום נדרשים שלושת מאגרי הגז הטבעי של ישראל (תמר, לוויתן וכריש) לספק את כלל ביקושי הגז לחשמל במדינה. בנסיבות אלה, הפסקת בפעילות של כל אחד מהם, עלולה ליצור קושי תפעולי מהותי לאספקה רציפה של גז טבעי למשק. זאת, במיוחד בשים לב לביקושים הגדלים לגז טבעי. לבסוף יצוין, כי אספקת הגז הטבעי לייצוא לעומת המשק המקומי איננה משחק סכום אפס – מתן אפשרות לייצוא הינו קריטי למשיכת השקעות נוספות בחיפוש והפקה של גז טבעי, שיש להן ערך גם עבור המשק המקומי.

.64 לחשיבות בקידום ההליך התחרותי לחיפוש עתודות גז טבעי חדשות, יש להוסיף גם את התועלת הכלכלית העצומה הצפויה לישראל מהגז הטבעי בשנים הבאות, כפי שנלמד גם מניסיון העבר. כפי שפורט לעיל, ההערכה היא שהחיסכון המשקי בין השנים 2014-2021 מהמעבר לגז טבעי עומד על כ-116 מיליארד ש״ח. עוד יוזכר בהקשר הכלכלי, כי מרבית, אם לא כל ההשקעה הצפויה במסגרת ההליך התחרותי, נוגעת לעלויות החיפוש וההפקה של הגז הטבעי, ואלו תוטלנה על החברות הפרטיות שיזכו בהליך.

.65 לקידומו של ההליך התחרותי חשיבות גם בהיבט של גיוון השחקנים בשוק הגז הטבעי בישראל ולהגדלת התחרות. ההליך הרביעי מהווה אבן דרך חשובה לצורך הגדלת מספר הספקים והרחבת אפשרויות ההתקשרות של ספקי החשמל המרכזיים במדינה, כמו גם עשרות תעשיינים ולקוחות בינוניים בשוק הגז הטבעי בישראל.

.66 כן ראוי לציין, בין היתרונות של קידום ההליך התחרותי, את המשך חיזוק מעמדה הגיאו-פוליטי של מדינת ישראל. יוסבר – פיתוח משק הגז הטבעי בישראל, ובכלל זה ייצוא גז טבעי, סייע בקידום יחסים עם המדינות הגובלות, אשר מסתייעות במאגרים או במערכות הגז הטבעי שיוקמו במים הכלכליים של ישראל. לכל אלו השפעה ישירה על יחסי החוץ של מדינת ישראל, בין עם המדינות הקרובות אלינו ובין עם מדינות אירופה כולה, ומדובר בתהליך שנבנה והתעצם מאד בשנים האחרונות. כבר היום ניתן לראות שבהליך התחרותי הרביעי מביעות עניין חברות ענק בינלאומיות, אשר בעבר כלל לא שקלו פעילות בישראל. זאת על רקע השיפור במעמדה הגיאו-פוליטי של ישראל, אשר נובע בין היתר מתפקידו של הגז הטבעי הישראלי במערכת האזורית.[10]

.67 **הנה כי כן, לעמדת המשיבים מאז הנוחות בענייננו נוטה באופן מובהק להמשך קידום ההליך התחרותי ללא עיכובים, אשר עשויים להניא משתתפים פוטנציאליים מלהשתתף בו ובכך לפגום בו קשות. זאת, על רקע התועלות הפוטנציאליות האדירות למדינת ישראל ממציאת מאגרי גז טבעי נוספים.**

.68 בטרם סיום פרק זה יוזכר, כי ההודעה על קידום ההליך התחרותי פורסמה כבר לפני כארבעה חודשים, וכיום מצויים אנו כחודשיים לפני מועד הגשת ההצעות שנקבע בהליך. לעניין זה, המשיבים יזכירו כי ישנו מספר דו-ספרתי של חברות אשר שילמו את דמי ההשתתפות, וזאת לאחר השקעה של חודשי עבודה והכנה רבים, בהם למדו החברות בסיוע גאולוגים, גאו-פיסיקאים, כלכלנים, רואי חשבון וצוות ליווי משפטי את חבילת המידע הגאולוגית; כמו-גם את הסביבה החוקית והרגולציה הישראלית. עוד יובהר, כי חברות המבקשות לשמש כמפעילות, נדרשות בנוסף להגיש למשרד האנרגיה אסמכתאות המוכיחות את עמידתן בתנאים הנקובים בתקנות 6 ו-7 לתקנות הנפט (עקרונות פעולה

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[10] . לעניין זה ניתן לעיין בין היתר בחוות הדעת של משרד האנרגיה והתשתיות בנוגע להסכם הימי עם לבנון, אותה ניתן למצוא בקישור שלהלן:
https://www.gov.il/BlobFolder/reports/seder-gov271022/he/Seder_Gov_seder_gov271022_Natural%20Treasures%20Administration.pdf

לחיפושי נפט והפקתו בים), תשע״ז-2016. בהקשר זה יודגש, כי לפי תקנה 6(א)(4) חברה מפעילה נדרשת להוכיח ״ניסיון בפעולות לשמירת הבריאות והסביבה, קיום מערכת ניהול בטיחות וסביבה בקשר עם פעולות בזכויות נפט, לרבות הכנת תכניות בטיחות, ביצוע סקרי סיכונים, הכנת מסמכים סביבתיים וניטור סביבתי הנוגעים לפעולות בזכויות נפט, כולם בהתאם לאמות מידה בין-לאומיות מקובלות״.

.69 בנסיבות אלה, מתן צו הביניים המבוקש אף עשוי להוביל לאובדן הוצאות ניכרות של המבקשות להשתתף בהליך.

ב.2 סיכויי העתירה להתקבל נמוכים

.70 המשיבים יטענו כי סיכוייה של העתירה להתקבל נמוכים ביותר.

.71 במרכזה של העתירה, עומדת טענת העותרת לפיה ההחלטה על פרסום ההליך התחרותי הרביעי התקבלה בהיעדר תשתית עובדתית נאותה. כפי שיוסבר להלן, עמדת משרד האנרגיה היא כי דינה של טענה זו להידחות מכל וכל.

.72 ראשית, טרם הדיון במועצת הנפט מיום 29.11.22, התקיימו דיונים מקצועיים רבים, בהם הוצג ניתוח מקצועי מקיף של הסוגיות השונות והשיקולים השונים לקידום ההליך התחרותי, לרבות צרכי המשק המקומי; שיקולי תחרות; עקרונות סביבתיים (הפחתת מזהמי אוויר ופליטת גזי חממה); וחיזוק המעמד הגיאו-פוליטי של ישראל בשל ייצוא גז טבעי לירדן ולמצרים ולקהילה האירופית.

.73 אשר לשיקולים הסביבתיים, הרי שאלה נשקלו וקיבלו ביטוי ברור במסמך העקרונות שהוגש לחברי מועצת הנפט כמצע לדיון. לעניין זה נשוב ונפנה לסעיף ו׳ למסמך העקרונות, אשר מפרט אודות העקרונות הסביבתיים של ההליך התחרותי, אשר מבוססים על העקרונות הסביבתיים שאומצו בהליכים תחרותיים קודמים. בהקשר דנן יצוין, כי החלטת מועצת הנפט מצאה בדעת רוב, בניגוד לעמדתם החולקת של נציגי המשרד להגנת הסביבה, כי המידע שהוצג בפניה בהיבטים אלה היה מספק, שכן התבסס על עבודה מקצועית מעמיקה שארכה מספר שנים, במהלכה ערך משרד האנרגיה והתשתיות בשיתוף עם גורמים ממשלה נוספים ונציגי ציבור, בהם העותרת, סקר אסטרטגי סביבתי רחב ומעמיק לחיפוש והפקה של נפט וגז טבעי בים (להלן: **הסקר האסטרטגי** או **סא״ס**). במסגרת הסקר האסטרטגי, אשר בצוות שגיבש אותו נטלה חלק גם העותרת, נבחנו שטחי הים, הרגישות הסביבתית וקיומם של בתי גידול בשטח המים הכלכליים. במסגרת הסקר האסטרטגי נקבעו עקרונות לחיפוש גז במים הכלכליים בהיבט הסביבתי. כאמור, עקרונות אלה פורטו גם במסמך שהונח על שולחן מועצת הנפט טרם קיומו של הדיון במועצה בעניין ההליך התחרותי, והיוו בסיס להליך התחרותי.

בהתאם לסא״ס, האזורים המשווקים מוגדרים כבתיאל – אזור עם קרקעית בוצית אחידה עם כיתמיות. משמעות הכיתמיות היא שיתכן וקיימים בתי גידול נוספים במרחב זה, שלא זוהו בעת עריכת הסא״ס ועדכוניו שבוצעו בהמשך.

הדבר קיבל ביטוי בשני מישורים: א. ציון כי קיימים פערי מידע בנוגע להגדרת בתי הגידול; ב. חיוב בסגירת פערי המידע בטרם ביצוע פעולות בשטח. יובהר, כי כיוון שהגדרת בתי הגידול התבססה על נתונים שנאספו עד לאותה תקופה, אשר עודכנו בזמן, הוגדרו רמות פערי המידע שעליהם מתבסס מיפוי בתי הגידול וקביעת רמת רגישותם. רמת פערי המידע שהוספה למיפוי בית הגידול בתיאל ורגישותו סומנו כגבוה. בשל התייחסות זו, נדרשות, כאמור, פעולות מקדימות לפני קדיחה או פיתוח המותאמות לאזור חדש לפיתוח, במטרה למנוע פגיעה באותם בתי גידול המצויים ב״כתמים״ שעלולים להתגלות.

בנוסף, וכחלק מהסקר האסטרטגי, ולצורך סגירת פערי מידע שעדיין קיימים, משרד האנרגיה והתשתיות מקדם סקרים ותומך במחקרים רבים, התורמים להרחבת הידע המדעי על המרחב הימי של הים התיכון. כך למשל, כתוצאה מהמאמץ האמור, בתי הגידול צמודי הקרקע ובתי הגידול של גוף המים עודכנו מספר פעמים בשנים האחרונות. יצוין, כי הסא״ס מתעדכן מידי תקופה, ועודכן לאחרונה בדצמבר 2021. עדכון זה היווה את הבסיס להכרזה על ״ערכי טבע מוגנים״ (ולא ״שטח מוגן״ או ״אזור ימי מוגן״ כפי שכתבה העותרת) לפי חוק גנים לאומיים, שמורות טבע, אתרים לאומיים ואתרי הנצחה, התשנ״ח-1998, במרחב המכונה ״גלישת פלמחים״ (אכרזת גנים לאומיים, שמורות טבע, אתרים לאומיים ואתרי הנצחה (ערכי טבע מוגנים) (תיקון), התשפ״ג-2022). להשלמת התמונה יובהר, כי האכרזה אינה חלה באזורים נשוא ההליך התחרותי מושא העתירה, אלא באזור סמוך.

74. הנה כי כן, העקרונות לחיפוש גז טבעי שפורטו במסמך העקרונות נקבעו לאחר עבודה מקצועית ארוכה ומעמיקה במסגרת הסקר האסטרטגי הסביבתי. בין היתר, נקבעו העקרונות הבאים:

> "1. מניתוח המרחב הימי שנסקר בסא"ס עולה, כי יש הצדקה להתייחסות שונה לאזור הקרוב לחוף לעומת זה המרוחק ממנו. לפיכך, ההמלצה הכללית לעת הזאת היא לתת רישיונות על-פי חוק הנפט בשטחים המרוחקים מהחוף בלמעלה מ- 7 ק"מ.
> 2. בתחום בתי הגידול ברמת רגישות 4 בשטחים המרוחקים מהחוף, מומלץ להגביל פעולות קדיחה או הנחת צנרת, תשתיות ומתקנים אחרים בתחומם ולהגביל ביצוע קידוחים במרחק של 1 ק"מ מהם כדי להימנע מפגיעה באותם בתי גידול.
> 3. ביחס לבתי גידול ברמת רגישות 3, מוצע להגביל את הפעילות בהם ובסמיכות להם בדומה למוצע עבור בתי גידול ברמת רגישות 4 , וזאת עד להשלמת מידע נוסף, שיאפשר עדכון המדיניות ביחס לבתי גידול אלו.
> 4. בתחום בתי גידול בעלי רגישות גבוהה מאוד לפעולות בעלות הפרעה של קול מומלץ שלא לבצע סקרים סיסמיים.
> 5. בנוסף להמלצות אלו, מומלץ לתת עדיפות למתן זכויות באזורים בעלי רגישות אקולוגית נמוכה במסגרת מכלול השיקולים של הממונה בבואו להעניק זכויות".

בהתאם לאמור, פורט במסמך העקרונות כי יש להקפיד, בין השאר, על העקרונות הבאים במסגרת ההליך התחרותי:

> "6. במסגרת ההליך התחרותי אליו אנו יוצאים יינתנו רישיונות חיפוש רק בשטחים המרוחקים מהחוף (במרחק העולה על 30 ק"מ מהחוף), הואיל וברצועה הקרובה לחוף מתרכזים מירב השימושים הימיים הקיימים והמתוכננים, וברצועה הרחוקה יותר מהחוף השימושים הימיים מועטים.
>
> [...]
>
> 8 . יש לציין, כי בהענקת רישיון החיפוש ולאחריו במתן אישורים לסקרים, לקדיחה ולהקמת תשתיות אנו מיידעים את מבקשי רישיון החיפוש בדבר רגישות בתי הגידול המצויים בתחום הרישיון, על המגבלות האפשריות על רמת הפיתוח שתתאפשר, על אמצעים והפעולות שיידרשו ועל המגבלות שיוטלו לצורך שימור בתי הגידול.
>
> 9. במסגרת התנאים לאישור קדיחה נדרש מבעל רישיון לבצע סקר רקע מקדים, שמטרתו לוודא שאין בתי גידול רגישים במרחב המתוכנן לקידוח החיפוש, להכין מסמך סביבתי שאישורו נסמך על חוות דעת היחידה להגנת הסביבה הימית במשרד להגנת הסביבה, וכן לקבל היתר הזרמה לים, היתר רעלים ולקבל אישור לתכנית חירום מפעלית. אישורים והיתרים אלה נמצאים בסמכות הבלעדית של המשרד להגנת הסביבה".

75. למדים אנו, כי בניגוד לטענות העותרת, בהיבט הסביבתי התבססה מועצת הנפט בהמלצתה על תשתית עובדתית אותה מצאה כמספקת לקבלת ההחלטה, בתום דיון מעמיק בנושא אשר במסגרתו נשמעו עמדות מגוונות. בהתאם לכך, אף הוחלט על יצירת איזונים מתאימים שיאפשרו לבצע את חיפושי הגז הטבעי תוך שמירה על השטח הימי. המשרד השקיע מאמצים רבים במטרה לוודא כי פעילות החיפוש וההפקה של גז טבעי אינה פוגעת בסביבה הימית בכלל, ובבתי גידול ייחודיים ורגישים בפרט.

הנושא פורט בהרחבה במסמך העקרונות וכן במכתבו של מנהל אגף סביבה במינהל אוצרות טבע מיום 5.9.22, וכן נדון במועצת הנפט. ניתן לראות, כי משווקים במסגרת ההליך רק שטחים המרוחקים למעלה מ-40 ק"מ מהחוף (לעומת 7 ק"מ בהמלצת הסא"ס אשר פורסמה באוקטובר 2016), ואשר למיטב שיקול דעתו המקצועי של משרד האנרגיה והתשתיות גם אם מצויים בהם בתי גידול רגישים, ניתן לחפש את משאבי הגז הטבעי מבלי לפגוע בהם.

76. בנוסף, נציין כי יש להביא בחשבון גם את העובדה שלמרות גודל השטחים המשווקים במסגרת ההליך, הקידוחים משפיעים בפועל על שטח מצומצם ביותר, ברדיוס של עד מאות בודדות של מטרים. בנוסף, עוד בטרם ביצוע קידוח, בעל הזכות נדרש לבצע סקר רקע מקדים, כדי לוודא שאין בקרבת הקידוח המתוכנן (ק"מ אחד לכל הפחות) בתי גידול רגישים.

בנוסף לסקר זה, ועל בסיסו, בעל הזכות נדרש להכין מסמך השפעה על הסביבה שהנחיותיו מנוסחות בהסכמה עם המשרד להגנת הסביבה. במידה ומתגלים במהלך הסקר בתי גידול רגישים, כפי שכבר קרה בעבר, בעל הזכות נדרש להזיז את נקודת הקידוח. רק לאחר קבלת חוות דעת המשרד להגנת הסביבה למסמך הסביבתי ולפעולות המוצעות לצמצום הפגיעה בסביבה, וקבלת אישורים בלתי תלויים מהמשרד להגנת הסביבה, לרבות, היתר הזרמה לים, היתר רעלים ואישור תכנית מפעלית למניעת זיהום הים בשמן – ניתן על-ידי הממונה על ענייני הנפט אישור קדיחה.

היבט זה מלמד בתורו לא רק על כך שלא נפל כל פגם בהחלטה לקדם את ההליך התחרותי, אלא גם על היעדרה של פגיעה קונקרטית ועכשווית בערכי טבע כתוצאה מהמשך קידום ההליך התחרותי. הווה אומר, עדות נוספת לנו בדבר נטייתו המובהקת של מאזן הנוחות לעבר דחיית הבקשה למתן צו ביניים.

77. בכל הנוגע לטענות העותרת ביחס למקבץ E, הרי שהמידע הנזכר בעתירה (ראו למשל סעיפים 55-54 לעתירה) ידוע למשרד, ומבוסס על המידע הקיים היום לגבי השטח מסקרים וממחקר שנתמך על-ידי משרד האנרגיה והתשתיות. בהתאם למידע זה, קיימים אזורים מצומצמים שבהם יש תופעה הקרויה אבעבועים ("פוק מארקס"), שבחלק מהם, מתקיימים תנאים (נביעות מתאן טבעיות) המאפשרים התפתחות של אוכלוסיות כימו-סינטטיות.

כאמור לעיל, הפעולות הנדרשות טרם ביצוע קידוח, מאפשרות לבצע את חיפוש הגז הטבעי; ובשלב מאוחר יותר, במידה והחיפוש מסתיים בהצלחה, לפתח את המאגר – מבלי לפגוע באותן אוכלוסיות. כך למשל, במסגרת העבודות במאגר לוויתן הונחה צנרת במרחק של 20 מטרים בלבד מאבעבוע ומאוכלוסיות כימו-סינטטיות; ואף על פי כן לא נגרמה פגיעה לאותן אוכלוסיות.

78. העותרת מוסיפה וטוענת כי פגם נוסף שנפל בגיבוש התשתית העובדתית בהליך נוגע להיעדרה של חוות דעת כלכלית בבסיס ההחלטה על קידום ההליך. כאמור לעיל, לא ניתן לדעת ברמת ודאות כלשהי אם יתגלה גז טבעי בעקבות ההליך, ומה יהיה היקפו. עם זאת, לנוכח הביקושים הקיימים והעתידיים לגז טבעי, הן במשק המקומי והן בשווקי הייצוא, כפי שהוצג לעיל, עמדת גורמי המקצוע במשרד האנרגיה והתשתיות היא כי על אף חוסר הוודאות, קיים הגיון כלכלי מוכח בהחלטה על היציאה להליך. ראשית, למדינת ישראל צורך במקורות גז נוספים משלל הסיבות שנמנו לעיל; ובנוסף במבחן התוצאה מלמד אף הוא על ההיגיון הכלכלי – מספר רב של חברות עסקיות, הבוחנות את מהלכיהן בעיקר על בסיס כלכלי, בחרו לבחון את אפשרות השתתפותן בהליך. כמצוין לעיל, ההשקעה והסיכון בתהליך החיפוש מושתים על החברות המסחריות, ואילו המדינה נהנית מרווחים פוטנציאליים גבוהים במיוחד למול השקעה נוספת קטנה יחסית.

.79 המשיבים אף דוחים מכל וכל את הטענה בדבר "**ניגוד העניינים המוסדי בו מצוי דרך קבע משרד האנרגיה**" (סעיף 69 לעתירה). ראשית, גם המובן מאליו מוטב שייאמר – משרד האנרגיה והתשתיות כזרוע מזרועות המדינה פועל על מנת להשיג את התוצאה המיטבית עבור מדינת ישראל. בתוך כך, פועל המשרד במים הכלכליים של ישראל באחריות רבה, ובשיתוף פעולה עם יתר רשויות המדינה כמתחייב בדין. בהתאם לכך נערך דרך קבע תיאום עם משרד הביטחון, חיל הים, המשרד להגנת הסביבה, רשות התחרות ועם גורמים נוספים כנדרש.

.80 לצד זאת, המחוקק העניק את הסמכות בעניין פרסום הליך תחרותי בשטחה של מדינת ישראל, ובכלל זה בשטח המים הכלכליים שלה, לשר האנרגיה והתשתיות, בהיוועצות עם מועצת הנפט, בהתאם להוראות חוק הנפט. מתוקף סמכות זו פעלו שרת האנרגיה והתשתיות הקודמת והשר הנוכחי, תוך שימת לב למכלול השיקולים הרלבנטיים, כפי שפורט בהרחבה לעיל.

.81 העותרת מוסיפה וטוענת כי ההליך התחרותי פורסם ללא קיום של הליך שיתוף ציבור. בהקשר זה נשוב ונזכיר, כי במסגרת הדיון במועצה הוצגה פנייתה של העותרת ככתבה וכלשונה בפני חברי המועצה, על מנת שיוכלו לשקול את הטיעונים שהוצגו במסגרתה. ונזכיר, כי משרד האנרגיה פרסם להערות הציבור את הסקר האסטרטגי ומסמך מפת הדרכים, המהווים חלק מן התשתית העובדתית העומדת ביסוד החלטת השרה, ואף הטמיע חלק מההערות. יודגש כי ההליך התחרותי הוא כלי למימוש מדיניות המשרד כפי שמתבטאת במסמך מפת הדרכים, שפורסם להערות הציבור ונשלח לעותרת במסגרת פנייתה לפי חוק חופש המידע, וממחיש את הצורך במציאת גז טבעי נוסף, כמתואר לעיל.

.82 אשר לטענת העותרת בדבר קבלת ההחלטה על פרסום ההליך התחרותי על-ידי ממשלת מעבר, המשיבים יזכירו, כפי שצוין לעיל, כי טרם קבלת ההחלטה נבחן הנושא בהתאם לאמות המידה שנקבעו במכתבה של המשנה ליועצת המשפטית לממשלה גב' אביטל סומפלינסקי מיום 7.7.22 בנושא "היערכות משפטית לתקופת הבחירות לכנסת ה-25 בכל הנוגע לקבלת החלטות בתקופת בחירות".

צילום חוות דעתה של המשנה ליועצת המשפטית לממשלה גב' אביטל סומפלינסקי מיום 7.7.22 מצורף ומסומן **מש/7**.

.83 מעבר לכך, הרי שגם במובן המעשי אנו למדים כי ההחלטה על פרסום ההליך עולה בקנה אחד עם עמדת הממשלה הנוכחית. ולראייה, השר הנוכחי לא ראה לשנות מההחלטה, והמשרד ממשיך לקדם את ההליך התחרותי (לעניין זה, ראו והשוו: בג"ץ 8179/22 **לביא נ' שרת החינוך**, אר"ש 9.3.23).

84. לאור כלל האמור לעיל סבורים המשיבים כי סיכוי העתירה נמוכים ביותר, שכן כלל טענותיה של העותרת בדבר פגמים שנפלו לכאורה בפרסום ההליך התחרותי – דינן להידחות.

סוף דבר

85. לאור כל שפורט לעיל, עמדת המשיבים היא כי דין הבקשה למתן צו-ביניים להידחות על הסף ולגופה, תוך חיוב העותרת בהוצאות, וזאת בשל סיכויי העתירה הנמוכים ומאזן הנוחות הנוטה בבירור לטובת המשיבים ולעבר המשך קידום ההליך התחרותי.

86. העובדות המפורטות בסעיפים 2-15, 17-43, 45-84 לתגובה נתמכות בתצהירו של מר חן בר יוסף, הממונה על ענייני הנפט ומ״מ מנהל מינהל אוצרות טבע במשרד האנרגיה והתשתיות.

87. ד״ר גיל פרואקטור, ראש אגף בכיר שינוי אקלים ואנרגיה במשרד להגנת הסביבה, קרא ואישר את העובדות המפורטות בסעיפים 16 ו-44 לתגובה, אך מפאת קשיים טכניים יועבר תצהירו בימים הקרובים.

היום, ב׳ בסיון תשפ״ג
22 במאי 2023

רן רוזנבר

רן רוזנברג, עו״ד
סגן בכיר א׳ במחלקת הבג״צים
בפרקליטות המדינה

יונתן סיטון, עו״ד
עוזר במחלקת הבג״צים
בפרקליטות המדינה

תצהיר

אני הח"מ, חן בר יוסף, מצהיר בזאת כדלקמן:

1. אני מכהן בתפקיד הממונה על ענייני הנפט ומ"מ מנהל מינהל אוצרות טבע במשרד האנרגיה והתשתיות.
2. תצהירי זה ניתן כתמיכה לעובדות המפורטות בסעיפים 2-15, 17-43, 45-84 לתגובה מטעם המשיבים לבקשה למתן צו ביניים בבג"ץ **3143/23** (להלן "**התגובה**").
3. העובדות המפורטות בסעיפים 2-15, 17-43, 45-84 לתגובה זו הן אמת למיטב ידיעתי ואמונתי.
4. זה שמי, זו חתימתי, ותוכן תצהירי אמת.

חן בר יוסף

אישור

אני הח"מ, חביב ביטון, עו"ד, מאשר/ת בזאת כי ביום 22/05/2023 הופיע בפניי מר חן בר יוסף, [✓ המוכר לי אישית] / ~~שזיהיתיו לפי ת"ז מס'~~ ______, ולאחר שהזהרתיו כי עליו לומר את האמת, שאם לא יעשה כן יהא צפוי לעונשים הקבועים בחוק, חתם בפניי על תצהירו.

עו"ד חביב ביטון
מ.ר. 73742, עו"ד

תוכן עניינים

מש/1

צילום ההודעה בדבר העמדת שטחים לתחרות לפי סעיף 15א לחוק הנפט, וצילום ההודעה בדבר שינויים בשטחים לחיפושי נפט והפקתם בהתאם לסעיף 5 לחוק הנפט

עמ׳ 3

נספח מש/1

רשומות

ילקוט הפרסומים

כ׳ בכסלו התשפ״ג | 10969 | 14 בדצמבר 2022

הודעה בדבר העמדת שטחים לתחרות

לפי חוק הנפט, התשי״ב–1952

בתוקף סמכותי לפי סעיף 15א לחוק הנפט, התשי״ב–1952[1], ולאחר התייעצות עם המועצה המייעצת, אני מודיעה כי השטחים שגבולותיהם מפורטים להלן יועמדו לתחרות לצורך מתן רישיונות:

(א) ״מקבץ I״

(1) בלוק 4:

מס׳	Y	X
1	3700000.0000	559615.4752
2	3710746.4459	570497.1858
3	3703541.3711	590000.0000
4	3700000.0000	590000.0000

(2) בלוק 5:

מס׳	Y	X
1	3700000.0000	570000.0000
2	3680000.0000	570000.0000
3	3680000.0000	550000.0000
4	3690000.0000	550000.0000
5	3690562.4474	550000.0000
6	3700000.0000	559615.4752

(3) בלוק 6:

מס׳	Y	X
1	3700000.0000	570000.0000
2	3700000.0000	590000.0000
3	3680000.0000	590000.0000
4	3680000.0000	570000.0000

(4) בלוק 7:

מס׳	Y	X
1	3680000.0000	610000.0000
2	3680000.0000	590000.0000
3	3703541.3711	590000.0000
4	3703490.2076	590138.4871
5	3696152.2488	610000.0000

(5) בלוק 8:

מס׳	Y	X
1	3696152.2488	610000.0000
2	3689515.6230	628000.0000
3	3683100.0000	628000.0000
4	3683092.1284	626858.5403
5	3684738.0001	626823.3000
6	3684502.0000	619913.2999
7	3680000.0000	611087.4661
8	3679445.2905	610000.0000
9	3680000.0000	610000.0000

(5) בלוק 11:

מס׳	Y	X
1	3680000.0000	590000.0000
2	3674741.7149	590000.0000
3	3674741.7149	588085.1231
4	3673941.7150	588085.1231
5	3673777.8500	580369.9999
6	3669000.2789	572319.6298
7	3669000.2940	570000.0000
8	3680000.0000	570000.0000

(ב) ״מקבץ H״

(1) בלוק 9:

מס׳	Y	X
1	3665033.8143	530003.0821
2	3674911.4900	540172.7900
3	3677969.3067	537181.8585
4	3677981.2040	537170.2215
5	3690562.4474	550000.0000
6	3680000.0000	550000.0000
7	3659000.0000	550000.0000
8	3659000.0000	530000.0000

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[1] ס״ח התשי״ב, עמ׳ 322; התש״ן, עמ׳ 29.

(2) בלוק 10:

מס׳	Y	X
1	3680000.0000	550000.0000
2	3680000.0000	570000.0000
3	3669000.2940	570000.0000
4	3669000.3173	566432.7380
5	3661970.0612	554213.6076
6	3660000.0000	552325.3793
7	3659430.0170	551779.0723
8	3657525.0140	550000.0000

(3) בלוק 17:

מס׳	Y	X
1	3665033.8143	530003.0821
2	3640000.0000	530000.0000
3	3640000.0000	510000.0000
4	3651332.7618	510000.0000
5	3656412.1980	515159.3410
6	3664467.3899	523372.1712
7	3661446.5300	526309.7400
8	3661499.5937	526364.3724
9	3664812.7700	529775.5025

(4) בלוק 18:

מס׳	Y	X
1	3659000.0000	550000.0000
2	3657525.0140	550000.0000
3	3656412.1981	548960.7468
4	3655323.2741	550000.0000
5	3654819.8347	550480.4753
6	3654407.6730	550000.0000
7	3653376.1839	548797.5466
8	3645787.1623	548388.8212
9	3642674.2912	551335.6280
10	3641826.1514	554226.0817
11	3641295.6081	554666.9874
12	3636448.7136	550167.3465
13	3635971.7488	550000.0000
14	3636000.0001	550000.0000
15	3640000.0000	550000.0000
16	3640000.0000	530000.0000
17	3659000.0000	530000.0000

(5) בלוק 73:

מס׳	Y	X
1	3640000.0000	510000.0000
2	3640003.2420	498455.0645
3	3651332.7618	510000.0000

(ג) ״מקבץ G״

(1) בלוק 27:

מס׳	Y	X
1	3640000.0000	510000.0000
2	3640000.0000	530000.0000
3	3620000.0000	530000.0000
4	3620000.0000	510779.1905
5	3620052.0096	510742.5811
6	3621106.9629	510000.0000

(2) בלוק 28:

מס׳	Y	X
1	3640000.0000	530000.0000
2	3640000.0000	550000.0000
3	3635971.7488	550000.0000
4	3633789.4591	549234.3278
5	3633067.2513	550000.0000
6	3620000.0000	550000.0000
7	3620000.0000	530000.0000

(3) בלוק 36:

מס׳	Y	X
1	3620000.0000	530000.0000
2	3600000.0000	530000.0000
3	3600000.0000	524856.1235
4	3605037.0666	521311.5923
5	3620000.0000	510779.1905

(4) בלוק 37:

מס׳	Y	X
1	3620000.0000	530000.0000
2	3620000.0000	550000.0000
3	3600000.0000	550000.0000
4	3600000.0000	530000.0000

(5) בלוק 70:

מס׳	Y	X
1	3600000.0000	544461.9329
2	3582840.0399	535413.8825
3	3583516.8703	535028.3272
4	3584193.7006	534642.7719
5	3584882.1615	534237.0149
6	3585570.6224	533831.2580
7	3586259.0833	533425.5010
8	3586947.5442	533019.7440
9	3587636.0051	532613.9871
10	3588324.4660	532208.2301
11	3589012.9269	531802.4731
12	3589701.3878	531396.7162
13	3590389.8488	530990.9592
14	3591078.3097	530585.2023
15	3591766.7706	530179.4453
16	3592455.2315	529773.6883
17	3593143.6924	529367.9314
18	3593832.1533	528962.1744
19	3594520.6142	528556.4174
20	3595209.0751	528150.6605
21	3595897.5360	527744.9035
22	3596550.3596	527285.3813
23	3597203.1832	526825.8590
24	3597856.0068	526366.3368
25	3598508.8304	525906.8146
26	3599161.6541	525447.2924
27	3599814.4777	524987.7701
28	3600000.0000	524860.0000
29	3600000.0000	524856.1235

(6) בלוק 74:

מס׳	Y	X
1	3640000.0000	510000.0000
2	3621106.9629	510000.0000
3	3638983.8943	497416.4366
4	3638983.9532	497416.3952
5	3640003.2420	498455.0645

(ד) ״מקבץ E״

(1) בלוק 54:

מס׳	Y	X
1	3560000.0000	570000.0000
2	3580000.0000	570000.0000
3	3580000.0000	590000.0000
4	3560000.0000	590000.0000

(2) בלוק 60:

מס׳	Y	X
1	3560000.0000	590000.0000
2	3540000.0001	590000.0000
3	3540000.0000	573021.4884
4	3542165.6000	569907.4000
5	3552693.0000	575981.4000
6	3556936.7338	570001.1519
7	3558653.0000	570000.0000
8	3560000.0000	570000.0000

(3) בלוק 65:

מס׳	Y	X
1	3540000.0000	590000.0000
2	3540000.0001	611000.0000
3	3540000.0001	611913.7429
4	3536028.4072	610000.0000
5	3520784.7830	602654.7408
6	3520774.7036	602649.8837
7	3520778.3071	602644.3348
8	3521212.8479	601975.5481
9	3521647.3889	601306.7614
10	3522081.9297	600637.9746
11	3522516.4707	599969.1880

מס׳	Y	X
12	3522951.0116	599300.4013
13	3523385.5525	598631.6146
14	3523820.0934	597962.8279
15	3524254.6344	597294.0411
16	3524689.1753	596625.2545
17	3525123.7162	595956.4678
18	3525558.2572	595287.6811
19	3525992.7980	594618.8944
20	3526427.3388	593950.1078
21	3526861.8798	593281.3210
22	3527296.4206	592612.5343
23	3527730.9616	591943.7475
24	3528165.5025	591274.9607
25	3528600.0434	590606.1741
26	3528993.9021	590000.0000
27	3529034.5843	589937.3874
28	3529469.1253	589268.6008
29	3529903.6661	588599.8140
30	3530338.2069	587931.0272
31	3530772.7479	587262.2406
32	3531207.2889	586593.4539
33	3531641.8297	585924.6673
34	3532076.3707	585255.8805
35	3532510.9115	584587.0937
36	3532945.4525	583918.3071
37	3533379.9934	583249.5204
38	3533814.5343	582580.7337
39	3534249.0752	581911.9470
40	3539512.8798	573722.4815

י״ט בכסלו התשפ״ג (13 בדצמבר 2022)
(חמ 5344–3)

קארין אלהרר
שרת האנרגיה

הודעה בדבר שינויים בשטחים לחיפושי נפט והפקתם

לפי חוק הנפט, התשי״ב–1952

בתוקף סמכותי לפי סעיף 5 לחוק הנפט, התשי״ב–1952[1], ולאחר התייעצות עם המועצה המייעצת, אני מודיעה כי שטחי קרקע הים ותת־הקרקע של השטחים הימיים הסמוכים לחוף ושגבולותיהם מפורטים להלן יהיו פתוחים לחיפושי נפט והפקתו:

(1) ״מקבץ I״

מס׳	X	Y
1	570497.1858	3710746.4459
2	590000.0000	3703541.3711
3	590138.4871	3703490.2076
4	610000.0000	3696152.2488
5	628000.0000	3689515.6230
6	628000.0000	3683100.0000
7	626858.5403	3683092.1284
8	626823.3000	3684738.0001
9	619913.2999	3684502.0000
10	611087.4661	3680000.0000
11	610000.0000	3679445.2905
12	610000.0000	3680000.0000
13	590000.0000	3680000.0000
14	590000.0000	3674741.7149
15	588085.1231	3674741.7149
16	588085.1231	3673941.7150
17	580369.9999	3673777.8500
18	572319.6298	3669000.2789
19	570000.0000	3669000.2940
20	570000.0000	3680000.0000
21	550000.0000	3680000.0000
22	550000.0000	3690000.0000
23	550000.0000	3690562.4474
24	559615.4752	3700000.0000

(2) ״מקבץ H״

מס׳	X	Y
1	550000.0000	3690562.4474
2	550000.0000	3680000.0000
3	570000.0000	3680000.0000
4	570000.0000	3669000.2940
5	566432.7380	3669000.3173
6	554213.6076	3661970.0612
7	552325.3793	3660000.0000
8	551779.0723	3659430.0170

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[1] ס״ח התשי״ב, עמ׳ 322.

מס׳	X	Y
9	550000.0000	3657525.0140
10	548960.7468	3656412.1981
11	550000.0000	3655323.2741
12	550480.4753	3654819.8347
13	550000.0000	3654407.6730
14	548797.5466	3653376.1839
15	548388.8212	3645787.1623
16	551335.6280	3642674.2912
17	554226.0817	3641826.1514
18	554666.9874	3641295.6081
19	550167.3465	3636448.7136
20	550000.0000	3635971.7488
21	550000.0000	3636000.0001
22	550000.0000	3640000.0000
23	530000.0000	3640000.0000
24	510000.0000	3640000.0000
25	498455.0645	3640003.2420
26	510000.0000	3651332.7618
27	515159.3410	3656412.1980
28	523372.1712	3664467.3899
29	526309.7400	3661446.5300
30	526364.3724	3661499.5937
31	529775.5025	3664812.7700
32	530003.0821	3665033.8143
33	540172.7900	3674911.4900
34	537181.8585	3677969.3067
35	537170.2215	3677981.2040

(3) ״מקבץ G״

מס׳	X	Y
1	498455.0645	3640003.2420
2	510000.0000	3640000.0000
3	530000.0000	3640000.0000
4	550000.0000	3640000.0000
5	550000.0000	3635971.7488
6	549234.3278	3633789.4591
7	550000.0000	3633067.2513
8	550000.0000	3620000.0000
9	550000.0000	3600000.0000
10	544461.9329	3600000.0000
11	535413.8825	3582840.0399
12	535028.3272	3583516.8703
13	534642.7719	3584193.7006
14	534237.0149	3584882.1615
15	533831.2580	3585570.6224
16	533425.5010	3586259.0833
17	533019.7440	3586947.5442
18	532613.9871	3587636.0051
19	532208.2301	3588324.4660
20	531802.4731	3589012.9269
21	531396.7162	3589701.3878
22	530990.9592	3590389.8488
23	530585.2023	3591078.3097
24	530179.4453	3591766.7706
25	529773.6883	3592455.2315
26	529367.9314	3593143.6924
27	528962.1744	3593832.1533
28	528556.4174	3594520.6142
29	528150.6605	3595209.0751
30	527744.9035	3595897.5360
31	527285.3813	3596550.3596
32	526825.8590	3597203.1832
33	526366.3368	3597856.0068
34	525906.8146	3598508.8304
35	525447.2924	3599161.6541
36	524987.7701	3599814.4777
37	524860.0000	3600000.0000
38	524856.1235	3600000.0000
39	524856.1235	3600000.0000

(4) ״מקבץ E״

מס׳	X	Y
1	574995.2000	3541319.7000
2	573742.9000	3539538.5000
3	569909.7000	3542165.0000
4	571069.3000	3544177.0000

ההודעה בדבר שינויים בשטחים לחיפושי נפט והפקתם תתוקן לפי זה[2].

י״ט בכסלו התשפ״ג (13 בדצמבר 2022)

(חמ 1439–3)

קארין אלהרר
שרת האנרגיה

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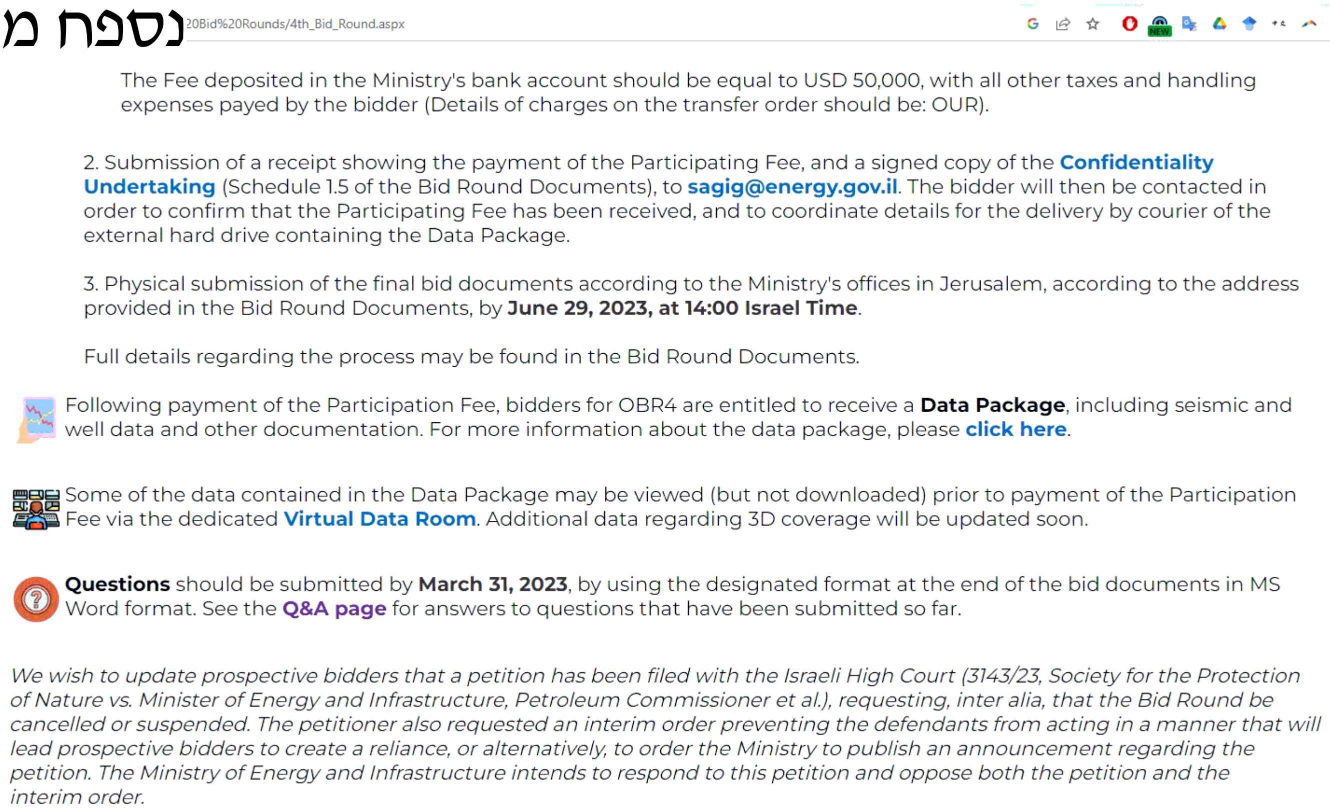
[2] י״פ התשע״ב, עמ׳ 5601; התשע״ז, עמ׳ 634; התשע״ט, עמ׳ 3544.

<u>מש/2</u>

צילום הודעת משרד האנרגיה והתשתיות מיום 18.5.23

עמ' 10

נספח מש/2



The Fee deposited in the Ministry's bank account should be equal to USD 50,000, with all other taxes and handling expenses payed by the bidder (Details of charges on the transfer order should be: OUR).

2. Submission of a receipt showing the payment of the Participating Fee, and a signed copy of the **Confidentiality Undertaking** (Schedule 1.5 of the Bid Round Documents), to **sagig@energy.gov.il**. The bidder will then be contacted in order to confirm that the Participating Fee has been received, and to coordinate details for the delivery by courier of the external hard drive containing the Data Package.

3. Physical submission of the final bid documents according to the Ministry's offices in Jerusalem, according to the address provided in the Bid Round Documents, by **June 29, 2023, at 14:00 Israel Time**.

Full details regarding the process may be found in the Bid Round Documents.

Following payment of the Participation Fee, bidders for OBR4 are entitled to receive a **Data Package**, including seismic and well data and other documentation. For more information about the data package, please **click here**.

Some of the data contained in the Data Package may be viewed (but not downloaded) prior to payment of the Participation Fee via the dedicated **Virtual Data Room**. Additional data regarding 3D coverage will be updated soon.

Questions should be submitted by **March 31, 2023**, by using the designated format at the end of the bid documents in MS Word format. See the **Q&A page** for answers to questions that have been submitted so far.

We wish to update prospective bidders that a petition has been filed with the Israeli High Court (3143/23, Society for the Protection of Nature vs. Minister of Energy and Infrastructure, Petroleum Commissioner et al.), requesting, inter alia, that the Bid Round be cancelled or suspended. The petitioner also requested an interim order preventing the defendants from acting in a manner that will lead prospective bidders to create a reliance, or alternatively, to order the Ministry to publish an announcement regarding the petition. The Ministry of Energy and Infrastructure intends to respond to this petition and oppose both the petition and the interim order.

מש/3

צילום העמודים הרלוונטיים מתוך דו״ח משק החשמל

עמ׳ 12

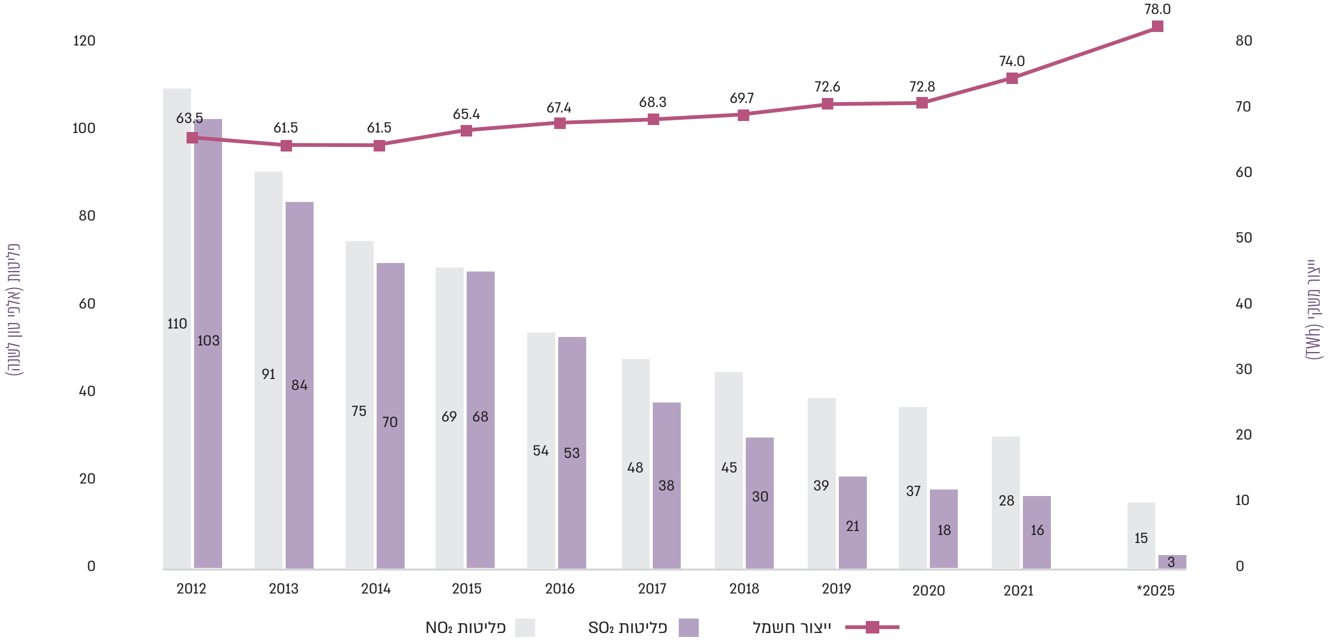
נספח מש/3

פרק חמישי

פליטות

פליטות מזהמים מקומיים מייצור חשמל ■ פליטות מזהמים מקומיים לנפש מייצור חשמל
■ פליטות CO_2 מייצור חשמל ■ פליטות CO_2 לנפש מייצור חשמל

5.1 | פליטות מזהמים מקומיים מייצור חשמל



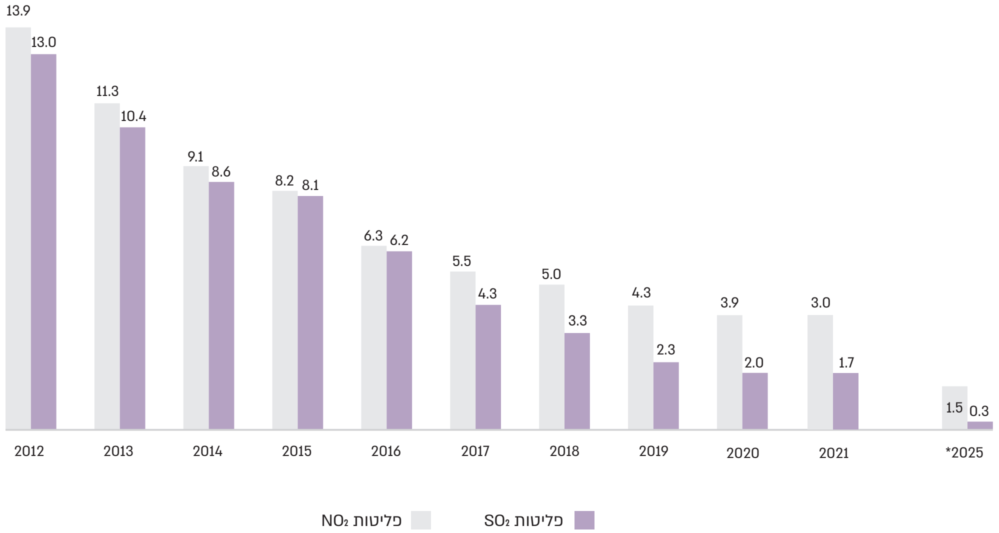
על אף גידול ביצור החשמל פליטות המזהמים המקומיים במשק החשמל פחתו ביותר מ-75% בעשור האחרון. זאת, בעיקר בשל שינוי בתמהיל הדלקים (גז טבעי ואנרגיות מתחדשות חלף פחם) והתקנת סולקנים בתחנות הפחמיות.

הערות

* התחזית מבוססת על היקף פליטות סגוליות לפי תמהיל דלקים צפוי.

** עלויות פליטות מזהמים מקומיים מחושבות ומפורסמות על ידי המשרד להגנת הסביבה בספר הירוק.

5.2 | פליטות מזהמים מקומיים לנפש מייצור חשמל (במונחי ק"ג לנפש לשנה)

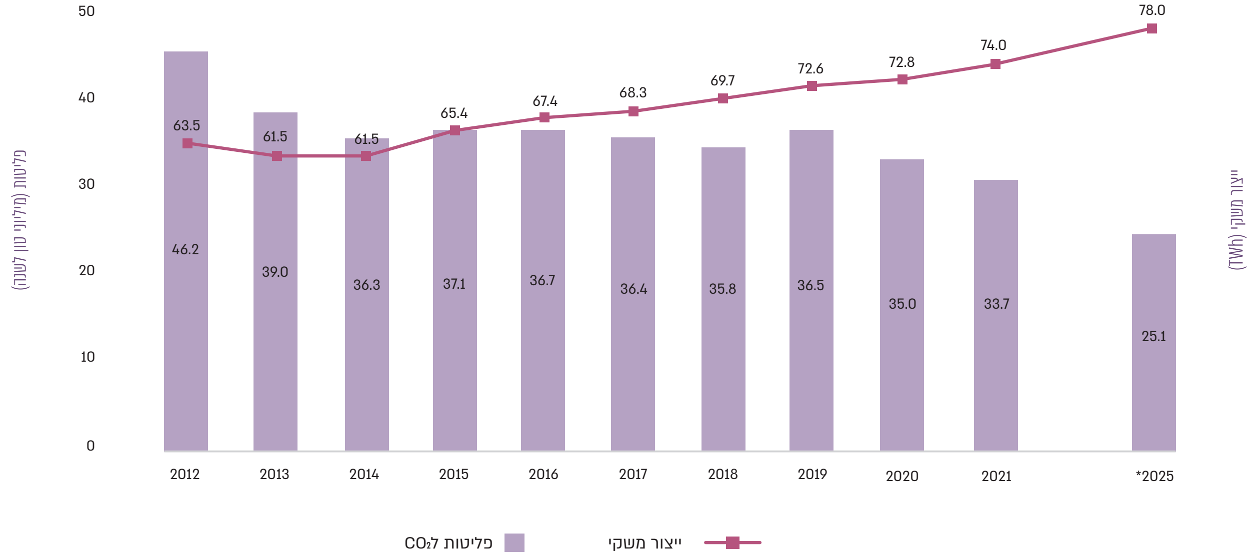


פליטות המזהמים המקומיים לנפש במשק החשמל פחתו ביותר מ-80% בעשור האחרון, בעיקר בשל שינוי בתמהיל הדלקים (גז טבעי ואנרגיות מתחדשות חלף פחם) והתקנת סולקנים בתחנות הפחמיות.

הערות

* תחזית.

5.3 | פליטות CO_2 מייצור חשמל

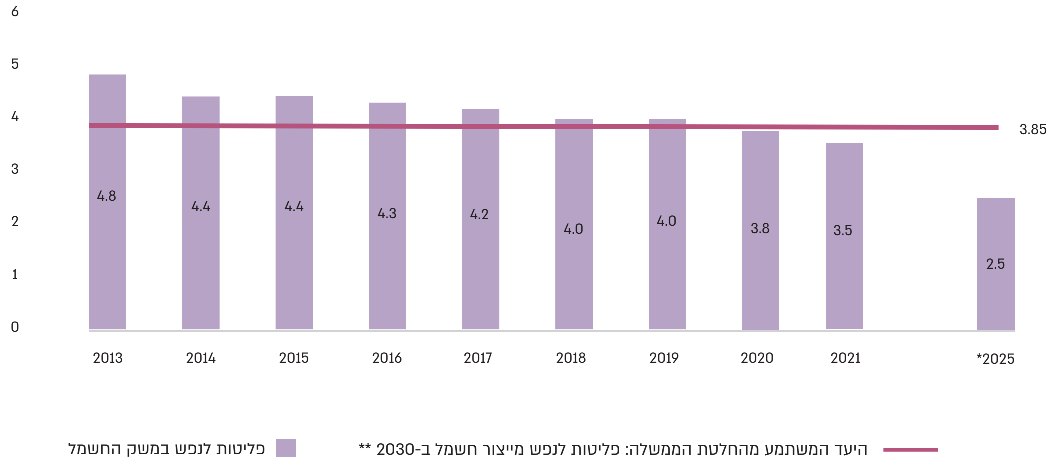


מגמת הירידה בפליטות CO_2 נמשכת על אף הגידול בייצור המשקי וצפויה להמשך בשנים הקרובות עם סגירת היחידות הפחמיות 1-4 באתר אורות רבין והסבת יתר התחנות הפחמיות לשימוש בגז טבעי.

הערות

- * התחזית מבוססת על היקף פליטות סגוליות לפי תמהיל דלקים צפוי.
- ** עלויות פליטות CO_2 מחושבות ומפורסמות על ידי המשרד להגנת הסביבה בספר הירוק.

5.4 | פליטות CO_2 לנפש מייצור חשמל (במונחי טון לנפש לשנה)



כבר בשנת 2020 עמד משק החשמל ביעד המשתמע למשק החשמל לשנת 2030 לפי החלטת הממשלה להפחתת פליטות.
ובשנים הקרובות צפויה הפחתה נוספת בשל הפחתת שימוש בפחם וגידול בשימוש באנרגיה מתחדשת.

הערות

* תחזית.
** החלטת ממשלה 542 מיום 20 בספטמבר 2015 קובעת יעד של 7.7 מיליון טון לנפש בשנת 2030. במועד קבלת ההחלטה משק החשמל היה אחראי ל 50% מפליטות גזי החממה, ולכן היעד המשתמע למשק החשמל מהווה 50% מהיעד שקבעה הממשלה ועומד על 3.85 מיליון טון לנפש.

מש/4

צילום פרוטוקול הדיון במועצת הנפט מיום 5.1.21

עמ' 18

נספח מש/4

משרד האנרגיה
מינהל אוצרות הטבע

כ״א טבת תשפ״א
05 ינואר 2021
נפט_2915_2021

הנדון: <u>פרוטוקול ישיבת מועצת נפט ראשונה לשנת 2021 מיום 5.1.21</u>

הישיבה התקיימה בזום.

משתתפים חברי המועצה: אלי גינזברג, אפי דלומי, עלא חטיב, בני גולדשטיין, אורלי טל, איתי חביליו, ראפת דיבסי, עירית הייטנר, אמיר זלצברג, רן עמיר, גלעד אורן.

נציגי משרד האנרגיה: יונית שרם-ונונו, יאיר אריאלי, ענת מיוחס יוסי וירצבורגר, שמעון כהן, מיקי גרדוש, אילן ניסים, אלעד גולן, שולי קליין.

<u>נושא מספר 3: המלצה לשר לפי סעיף 5 לחוק הנפט לפתוח שטחים לתחרות</u>

[redacted]: המשרד מבקש לצאת במהלך שנת 2021 להליך תחרותי רביעי במים הכלכליים של ישראל. מועד מדויק של היציאה להליך התחרותי טרם נקבעה.

מטרת ההמלצה הנוכחית הינה כפולה.

ראשונה לפרסם את המפה המצורפת כדיי להתחיל ליצור עניין אצל החברות הרלוונטיות אשר ידעו ויכירו כי המשרד מתכנון להליך תחרותי בקרוב. מטרה שניה, לפרסם את מיקום השטחים לציבור במידה ולמי מהציבור תהיה הסתייגות למי מהבלוקים נוכל לדון בכך מבעוד יום טרם יציאה להליך התחרותי הבא.

אנו ממשיכים במדיניות שלא להוציא את רישיונות חיפוש בסמיכות לקו החוף זאת בהתאם למדיניות הסקר האסטרטגי הסביבתי, הקובע כי יש להתרחק 7 ק״מ מקו החוף ובמפה זו אנו מרחיקים עוד יותר ויוצאים מעבר למים הריבוניים.

במפה המצורפת ניתן לראות את הכתמים המוכרים לנו כיום מבחינת בתי גידול. לא מוכרים בתי גידול בעלי רגישות בשטח שאנו מבקשים לפתוח.

נדגיש כי הבקשה כרגע היא רק להמליץ לשר ואנו נפרסם המלצה זו. השר ייפתח בפועל את השטחים לחיפוש בהתאם לתיזמון בו השר יחליט על מועד היציאה להליך התחרותי הרביעי.

כמו כן אנו מציעים שהמלצה זו תעמוד בתוקפה למשך 6 חודשים, כך שאם השר יחליט להתעכב את היציאה להליך התחרותי המועצה תוכל לדון בכך ולהמליץ לשר שוב.

[redacted]- פה אנחנו באים לציין שאלה השטחים המומלצים לשר, מה שמבקשים כרגע זה הגדרת השטחים ולא אישור על ההליך התחרותי.

[redacted]- מבקש להראות את המפה ביחד עם כולם, מבקש להסב את תשומת ליבכם לשטח הזה המקווקו, אולי יש בשטח זה שטח גיאולוגי אולי כדאי לגרוע שטח כזה?

[redacted]- אבקש להסביר מה מטרת שטח רישיון, משמעות הדבר כי הגז והנפט ככל ונמצאים בשטח הרישיון , בעל הרישיון זכאי להפיק את הנפט/גז. במידה ונגרע את השטח אזיי בעל הרישיון לא יוכל להפיק משם גז/נפט. יחד עם זאת אין בהענקת שטח הרישיון אישור לביצוע קידוח בכל שטח. על בעל הרישיון לבצע סקר סביבתי על מנת לבחון האם יש בתי גידול רגישים או שלא רגישים ולפי הממצאים לבחור את נקודת הקידוח המדוייקת. אציין כי גם אם נגרע את הבלוק בו מופיע השטח עליו [redacted] מדבר, עדיין יהיה ניתן לקדוח ממש בצמידות אליו מצפון. לכן עדיף כי כלל השטח יהיה ברישיון אבל נמשיך על פי המדיניות ונראה מה תוצאות הסקר הסביבתי ובהתאם לכך את נקודת הקידוח.

[redacted]- אני מבין כי יש שתי אפשרויות. הראשונה, לגרוע את השטח. השניה, לא לגעת בשטחים המקווקוים, וכאשר השר יאשר, יצויין שיש רגישות בשטח זה.

[redacted]- אנחנו לוקחים עוד מקדם ביטחון, וכבר היום אנו דואגים לכל בעל רישיון ונוהגים להודיע לו איזה בתי גידול יש באזורים רגישים, לכן אנו מבקשים סקרים.

[redacted] שאלה ל[redacted] לגבי שטחים רגישים שזה מאוד חשוב, אני רואה שבשטחים שכבר אושרו וישנם בהם שטחים רגישים, איך נהגתם בהם בעבר?

[redacted]- כפי שאתה רואה מרבית הים השטח גדול כמו כל שטח מדינת ישראל, אם מגלים בתי גידול, פועלים ומזיזים את הקידוח. פה אנו כבר יודעים מה יש ואיזה בתי גידול יש, ואז מתייחסים אליהם מלכתחילה.

[redacted]- אני חושבת שההתייחסות לבתי הגידול צריך להיות כמו ההתייחסות לעתיקות.

[redacted]- מתייחסים בהחלט ובודקים כל שטח ומוצאים שהכל בסדר מבחינת בתי גידול או עתיקות וכו', ורק אחרי כן מאשרים קידוח.

<u>המלצה:</u> להמליץ לשר לפתוח לתחרות את השטחים המצוינים במפה בהתאם לסעיף 5 לחוק הנפט.

הצבעה- הבקשה התקבלה פה אחד.

מש/5

צילום פניית העותרת ועמותת אדם, טבע ודין מיום 31.5.22

עמ' 21

נספח מש/5

31/5/2022

לכבוד :
גב' קארין אלהרר
<u>שרת האנרגיה</u>

שלום רב,

<u>הנידון: הכרזתך על היערכות לקראת הליך התחרותי לשיווק מחצית משטחה הימי של ישראל לחיפוש גז ונפט</u>

קיבלנו בתדהמה את הודעתך על הכוונה לקדם מכרז רביעי להרחבת חיפושי דלקים פוסיליים במרחב הימי של ישראל. אנו פונים אליך על מנת שתימנעי מלהוציא לפועל את ההליך התחרותי הרביעי לשיווק 25 בלוקים במים הכלכליים של ישראל, שהם כ-10,000 קמ"ר, ומהווים כמעט מחצית משטחה הימי של ישראל - לטובת חיפושי גז ונפט חדשים.
ביום 5.1.2021 החליטה מועצת הנפט לאשר את היציאה להליך התחרותי. בתגובה, פנינו לשר האנרגיה הקודם וביקשנו ממנו להימנע מלקדם הליך זה עד להשלמת תהליך בחינה שקוף ציבורית, אשר ישקלל בתוכו היבטים אקלימיים, סביבתיים וציבוריים. אכן, עם כניסתך לכהונת שרת האנרגיה, הודעת על הקפאת קידום ההליך.
אולם, לאור הודעתך מאתמול, נבקשך לעצור את קידום ההליך התחרותי הרביעי, שמשמעותו כבילת מדינת ישראל לעתיד של הפקה מאסיבית של גזי חממה, <u>ולקדם תהליך בחינה סדור, תוך שיתוף הציבור ושקלול היבטי אקלים וסביבה</u>, מהסיבות הבאות:

<u>1. חוסר הלימה עם המאבק במשבר האקלים</u>

ההחלטה הנוכחית, להוציא מחצית משטחה הימי לחיפוש והפקה של מאגרי גז ונפט חדשים, <u>שפיתוחם רלוונטי לעשורים הבאים</u> - היא החלטה שאינה עולה בקנה אחד עם התחייבות ישראל, והתחייבויותיך שלך כשרת האנרגיה, להפחית באופן משמעותי כבר בעשור הנוכחי את פליטת גזי החממה ולהתחיל במעבר מהיר, אחראי וצודק להפקת אנרגיה נקייה. זאת לרבות הצהרת ראש הממשלה בגלזגו על איפוס פליטות בשנת 2050. ההחלטה להוציא לפועל את ההליך התחרותי הרביעי לשיווק איננה החלטה שולית אשר מתירה את דחיית הבחינה האקלימית לשלב מאוחר יותר, אלא יש צורך להכריע בעניין זה כבר כעת.

א. **תשתית ידע נדרשת לקבלת החלטות -** לצורך קבלת החלטה מושכלת, וכחלק מהתנהלות סבירה של הממשלה, נדרשת הממשלה בביצוע הערכת סיכון סביבתית-אקלימית טרם קבלת החלטה זו. חשיבותה של הערכת סיכון סביבתית אקלימית היא בכך שהיא מאפשרת למקבלי ההחלטות לקבל את המידע הנדרש על-מנת לגבש דעה מבוססת, לגבי השפעת תכניות על משבר האקלים ועל היכולת של הממשלה ליישם את יעדי הפחתת גזי החממה ולהיערך לשינויי אקלים. החלטה לפתוח שטח עצום בגודלו לחיפוש (אשר משמעותו בפועל שלאחר מכן תתבצע הפקה) של דלקים פוסיליים היא בוודאי החלטה שהערכת סיכון כזו נדרשת לה, וזאת גם בהעדר הוראת חוק מפורשת על ממשלת ישראל לערוך הליך ראוי ושקוף של בחינת המשמעויות האקלימיות בבואה ליישם החלטה אסטרטגית בעלת השלכות ארוכות טווח מסוג זה, בין השאר כחלק מחובתה הבסיסית לקבל החלטות על סמך תשתית מידע הולמת. למותר לציין, כי כיום אפילו החלטות רגולטוריות מינוריות יחסית נדרשות לעבור

תהלידשל הערכת השפעות רגולטוריות (RIA)[1], ולא יעלה על הדעת כי דווקא מהלכים אסטרטגיים רחבים כאמור, יוכלו להתקדם ללא בחינה רחבה של משמעויות סביבתיות ואקלימיות.

ב. **תכניות ממשלתיות** להתמודדות עם משבר האקלים – החלטת הממשלה 171 בנושא כלכלה דלת פחמן כמו גם תזכיר חוק האקלים אשר עבר לאחרונה בממשלה מטילים על גורמי הממשלה להכין תכנית לאומית להערכות לשינוי האקלים וליישום יעדי כלכלה דלת פחמן. תכניות עבודה אלה צריכות להיות להיערך על ידי משרדי הממשלה האחראים לסקטורים השונים, ועליהן להיות הרמוניות למאמצים המבוצעים על ידי משרדי כלל משרדי הממשלה. בוודאי שלא הגיוני לקדם הליך שיגרום להפקה מאסיבית של דלקים פוסיליים, כששאר משרדי הממשלה נדרשים להפחית בפליטות בסקטורים אחרים כמו תחבורה, תכנון עירוני, תעשייה, ועוד. למעשה, ההחלטה הזו "מסנדלת" במידה רבה את משרדי הממשלה האחרים ואת התכנית הממשלתית כולה.

ג. **יעדים** - לא ברור כיצד ממשלת ישראל מצהירה בידה האחת על מחויבותה לאחריות אקלימית, המעוגנת ביעדים קונקרטיים, וביד השנייה מקדמת הפקה מאסיבית של גזי חממה. ונדגיש – המשמעות של גמילה הדרגתית מפליטת גזי חממה, עד שנת 2050, אינה להזדרז ולהפיק את כלל מאגרי הגז הזמינים ולהספיק לנצלם עד שנת 2050, אלא להיפך – לצמצם באופן הדרגתי את התלות המשקית (בארץ ובחו"ל) בדלקים פוסיליים.

2. צרכי המשק הישראלי והשוק העולמי

צרכי המשק הישראלי ושכנותיה של ישראל לגז טבעי – מובטחים. בתחומי המים הכלכליים של ישראל התגלו עד כה מצבורי גז גדולים אשר מכילים לפי הערכות משרדך במצטבר כ-1000 BCM. בשנת 2019, ישראל השתמשה במעט יותר מ-11 BCM סה"כ. גם אם השימוש בגז יעלה בשנים הקרובות, בשל הצריכה הגוברת וההפסקה המבורכת של השימוש בפחם ומזוט, לישראל יש די והותר גז לשימוש עצמי, כמו גם לייצוא משמעותי במסגרת ההסכמים הקיימים למצרים וירדן - עד לשנת היעד 2050, בה השימוש בגז עתיד להיות מזערי מאוד. החל משנת 2050 ישראל תפחית את השימוש בדלקים פוסיליים כמעט לחלוטין, לטובת שימוש באנרגיה נקייה.

יש לציין כי אנו מתקשים להבין את הקשר, שצוין בהודעתך לעיתונות, בין המלחמה באוקראינה (שכולנו מקווים שתפסק בקרוב) והרצון האירופי להפחתת התלות בגז הרוסי, לבין מהלך שיווק של בלוקים, אשר גם אם יקודם בצורה מואצת, ויתממש, יניב הפקה של דלקים פוסיליים בטווח **זמן של לפחות עשור מהיום, קרי אחרי שנת 2030**. גם מדינות אירופאיות אשר מבקשות להקטין או להפסיק את התלות בגז הרוסי אינן מכוונות, כך על פי פרסומים, להעביר את תלותן מרוסיה למדינה מייצאת גז אחרת, אלא מכוונות להאיץ את המעבר לאנרגיות מתחדשות, תוך מילוי מצבורי הגז והפחם ממקורות שונים טווח הקצר בלבד.[2] רבות מהמדינות יהיו בשנת 2030 בשלבים מתקדמים של מעבר לאנרגיה מתחדשת (כך למשל גרמניה הציבה יעד של הפחתת 55 אחוז לפחות מפליטות גז חממה עד 2030[3]); ממילא מרבית הסיכויים שמדינות אלו לא ידרשו למקור אנרגיה פוסילית בשנים הרלוונטיות להליך הנוכחי.
במילים אחרות - המצב הגיאופוליטי העכשווי הוא נזיל ונדרשות למדינות מסוימות רזרבות של דלקים פוסיליים **לטווח הקצר**, אולם תכנון בראייה לטווח קצר של תהליך שיבשיל בעוד כעשור אינו הגיוני, – וזאת במיוחד על רקע משבר ודאי, קונקרטי, המשפיע על האנושות כולה – משבר האקלים.

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[2] https://ec.europa.eu/commission/presscorner/detail/en/IP_22_3131
[3] https://www.bmuv.de/en/topics/climate-adaptation/climate-protection/national-climate-policy/climate-action-plan-2050-germanys-long-term-low-greenhouse-gas-emission-development-strategy

3. שיווק מחצית משטחה הימי של ישראל מבלי להשלים את הבחינה הסביבתית הנדרשת בים העמוק הוא בכיה לדורות

א. נכון להיום, מדינת ישראל מפרה במפגיע את התחייבותה הבינלאומית ליעד שימור של 10% לפחות מן המרחב הימי שלה, לרבות המים הכלכליים. בהקשר זה, מדינת ישראל מדורגת במקום האחרון מבין מדינות ה-OECD בכל הנוגע לקידום אזורים ימיים מוגנים בכלל, ובמים הכלכליים בפרט. הסקר הסביבתי האסטרטגי שמוביל משרד האנרגיה מאז שנת 2013, הכיר בעובדה שמעט מאוד ידוע על בתי הגידול והמגוון הביולוגי בים העמוק, בתחום המים הכלכליים של ישראל, וכי פערי הידע הם גדולים עד גדולים מאוד. למעשה, מלבד אתר אחד משמעותי, הידוע כ׳הפרעת פלמחים׳[4], ובו נמצאו גני אלמוגי עומק, נביעות מתאן, בו מצוי אזור רבייה של טונה כחולת סנפיר, המים הכלכליים של ישראל כמעט ולא נחקרו ומעט מאוד ידוע עליהם. מהלך של שיווק היקף אדיר של שטח לחיפושי גז ונפט, משול לגישוש באפלה בחדר שמצויים בו חפצים עדינים ונדירים.

ב. החברה להגנת הטבע עוסקת כיום, בשיתוף עם צוות חוקרים רב תחומי, באיתור ואיפיון השטחים הראויים לשימור במים הכלכליים, וזאת על רקע היעדר היוזמה הממשלתית לפעולות שימור במרחב זה, כמו גם האיתור הדל במסגרת הסא״ס, במסגרתו אותרו רק שטחים מצומצמים שאופיינו עד כה כרגישים. וזאת, כשברור שבמרחב זה קיימים שטחים רבים הראויים לשימור, ולהרחקה של פעולות לחיפוש, קידוח והפקה של דלקים פוסיליים מהם.

ג. במצב הדברים הזה, לא מתקבל על הדעת לצאת להליך תחרותי נוסף, בהעדר מידע עקרוני והכרחי כל כך. בוודאי כך, כשבהליך התחרותי הקודם, בשנת 2018, מצא משרד האנרגיה לנכון לתת רישיון חיפוש על האזור, שהוא בעצמו מכיר בכך שהוא האתר הרגיש ביותר שנמצא עד היום בסביבה הימית בישראל – הפרעת פלמחים, אשר מודלים של החוקרים המובילים בתחום חוזים כי היקף השטח הרגיש בה מגיע למאות קמ״ר. ואכן, בעת שיווק השטח טען משרד האנרגיה כי השטחים הרגישים בו הם בהיקף של **עשרות** קמ״ר בלבד, ורק בתקופה האחרונה הכיר משרד האנרגיה כי מדובר על מרחב רגיש בהיקף של **מאות** קמ״ר – וזאת כשברור שהמשך מחקר באזור ירחיב את היקף השטח הראוי לשימור.

4. לא נבחנה הפגיעה המצטברת כתוצאה ממכלול פעולות החיפוש וההפקה בים

ההחלטה לצאת להליך תחרותי נוסף, לשיווק מחצית משטחה הימי של ישראל, משמעותי גם מבחינת הפגיעה המצטברת של מכלול פעולות הפיתוח באזור. נגמרו הימים שהסתכלנו מערבה וסברנו שמדובר במרחב פתוח ובלתי מופרע. הפעילות הכלכלית באזור המים הכלכליים של ישראל הולכת ונהיית אינטנסיבית וצפופה. לכל אלו יש השפעה על הסביבה הימית וכך גם השפעה אקלימית – דבר אשר גם הוא לא נבחן במסגרת הסא״ס. החלטה בסדר גודל כזה חייבת להתחשב בתוספת הפיתוח ובמשמעויותיו, ולא רק כל קידוח בפני עצמו.

למרות בקשת ארגוני הסביבה, הסא״ס שפורסם בשנת 2016 לא בחן את נושא ההשפעות המצטברות של פעילות החיפוש וההפקה של גז ונפט במים הכלכליים של ישראל. עם הכוונה להכפיל(!) את היקף השטחים שבהם צפויה פעילות כזו, ופרישתה על כלל שטח המים הכלכליים, מתבקש היה שבחינה מקדימה של השפעות מצטברות היתה נערכת כתנאי מקדים להחלטה על פתיחת שטח עצום נוסף לחיפושים. אולם, בדיקה כזו לא נערכה ולא פורסמה עד היום.

5. תקינות הליכים ושיתוף ציבור

החלטה להוציא לשיווק מחצית משטחה הימי של ישראל, שתקבע מסמרות לעשרות שנים קדימה, אינה החלטה שצריכה להתקבל ע״י גורם ממשלתי אחד, ללא מעורבות גורמי ממשלה אחרים, ובראשם, המשרד להגנת הסביבה ורשות הטבע

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[4] https://bit.ly/3wgBmS3

והגנים. כאמור בחלק הראשון לפניה זו, ההחלטה לצאת לדרך עם עשרות רבות של שטחי חיפוש חדשים אינה עומדת בקנה אחד עם ההתחייבויות האקלימיות של ישראל, ועם פעולותיו של המשרד להגנת הסביבה בנושא. החלטה כזו חייבת גם להתבסס על תשתית עובדתית ראויה הכוללת, כמפורט לעיל - איתור בתי גידול רגישים ופרישתם המרחבית, באמצעות מודלים, סימון מרחבי של 30% משטח המים הכלכליים כאזור המיועד לשטח מוגן, ניתוח ההשפעות המצטברות ועוד.

ההחלטה להוציא לשיווק מחצית משטחה הימי של ישראל לחיפוש גז ונפט אינה יכולה לצאת לדרך ללא הליך כלשהו של שיתוף ציבור. משאבי הגז והנפט הם משאבים ציבוריים, כמו גם משאבי הטבע בסביבה הימית, שעלולים ועתידים להיפגע מן ההחלטה.

חמור מכך - ההחלטה להוציא לשיווק מחצית משטחה הימי של ישראל לחיפושי גז ונפט, ובכך להשלים את ״ניכוס״ מרבית השטח הימי לטובת פעילות חיפוש והפקת גז ונפט - בעוד החקיקה הרלוונטית לתכנון וניהול המרחב הימי על כלל משתמשיו – זו שאמורה לאזן בין פיתוח ושימור - חוק אזורים ימיים, מתעכבת כבר מעל 15 שנה, היא בעייתית בלשון המעטה.

לאור כל האמור, אנחנו סבורים שעליך לעצור את היציאה להליך תחרותי רביעי במספר, ולפעול במקום זה, ליצירת יעדים ישימים ויעילים למעבר מלא של המשק הישראלי לאנרגיה נקייה עד שנת 2050. החלטה לאשר את ההליך התחרותי, ולצאת לשיווק של מחצית משטחה הימי של ישראל לפיתוח שדות גז ונפט חדשים, היא החלטה פגומה, לא מידתית, שאינה מבוססת על מידע נדרש ורלוונטי לקבלת החלטה ובלתי סבירה בנסיבות העניין.

החלטה כזו, צריכה – אם כבר – להתקבל על בסיס תהליך בחינה רחב, במסגרתו יבחנו כלל הסוגיות לרבות האקלימיות, הסביבתיות, הכלכליות, תוך שיתוף משרדי הממשלה והציבור כולו.

נודה לתשובתך בהקדם,

בכבוד רב,

איריס האן, מנכ״ל
החברה להגנת הטבע

עמית ברכה, מנכ״ל
אדם טבע ודין

העתקים:
ראש הממשלה, מר נפתלי בנט
שר החוץ וראש הממשלה החלופי, מר יאיר לפיד
גב׳ תמר זנדברג, השרה להגנת הסביבה
מר ליאור שילת, מנכ״ל משרד האנרגיה
גב׳ גלית כהן, מנכ״לית המשרד להגנת הסביבה
גב׳ רעיה שורקי, מנכ״לית רשות הטבע והגנים
מר גיא סמט, הממונה על אוצרות הטבע , משרד האנרגיה
עו״ד דוד קופל, היועץ המשפטי, משרד האנרגיה
עו״ד דלית דרור, היועצת המשפטית, המשרד להגנת הסביבה

<u>מש/6</u>

צילום מסמך העקרונות שהונח בפני מועצת הנפט

עמ' 26

נספח מש/6

מדינת ישראל
משרד האנרגיה
מינהל אוצרות טבע

נפט וגז
ל׳ בחשוון התשפ״ג
24 בנובמבר 2022

לכבוד:
חברי מועצת הנפט

הנדון: עקרונות ההליך התחרותי הרביעי 2022

מצורפים בזאת העקרונות המרכזיים של ההליך התחרותי הרביעי למתן רישיונות לחיפוש גז ונפט בים.

בדומה להליכים התחרותיים הקודמים, תנאי סף להשתתפות להליך הינו עמידת הקבוצה כולה ובפרט המפעיל בדרישות המפורטות ב״תקנות הנפט (עקרונות פעולה לחיפושי נפט והפקתו בים), תשע״ז-2016״ (מצ״ב).

א. משך זמן הרישיון וחובת קדיחה

סעיף 18 (א) לחוק הנפט, קובע כי רישיון לחיפוש נפט ניתן לתקופה של 3 שנים, וסעיף 18 (ב) קובע כי הממונה רשאי להאריך את תוקף רישיון החיפוש עד לתקופה של 7 שנים. על פי סעיף 21 לחוק הנפט בעל רישיון חיפוש חייב להתחיל לקדוח תוך 24 חודשים מיום קבלת הרישיון. יחד עם זאת, סעיף 51 לחוק קובע הממונה רשאי להאריך את מועד הביצוע של פעולה שיש לבצעה לפי זכות נפט. כלומר, לממונה קיימת סמכות להאריך את התקופה בה חובה על בעל רישיון לקדוח בשטח רישיון, לתקופה של מעבר ל- 24 חודשים.
ההליך התחרותי נסוב על הזכות לקבל רישיון חיפוש לתקופה של 3 שנים, בהתאם לתכנית עבודה שתוגש עם ההצעה. הדרישות לתוכנית העבודה אינן כוללות חובה לבצע קידוח חיפוש בתקופה זו של 3 השנים הראשונות.
עם זאת, כפי שיוסבר בהמשך, התחייבות בתכנית עבודה של מציע, לביצוע קידוח חיפוש במהלך 3 השנים הראשונות תעניק משקל משמעותי בהערכת ההצעה ובניקודה, וממילא לסיכוי לזכייה ברישיון החיפוש.
בהליך התחרותי נקבע, כי קבוצה אשר תבצע את תכנית העבודה לה היא התחייבה, רישיון החיפוש שלה יוארך בשנתיים נוספות, וככל שתעמוד בכל הדרישות, רישיון החיפוש יוארך בשנתיים נוספות עד למקסימום 7 השנים האפשריות להחזקה ברישיון חיפוש.
מי שיקבל במסגרת ההליך רישיון החיפוש, מבלי שהתחייב לקדיחה ב-3 שנים הראשונות, יחליט לקראת סיומה של תכנית העבודה של ה-3 שנים הראשונות, האם לאור הסקרים אשר ביצע קיימת מטרה מבטיחה לקדיחה. היה ויחליט בעל הרישיון כי אין מטרה כאמור, יחזיר את רישיון החיפוש למדינה וזאת ללא נקיטת סנקציות מאת המדינה. היה וימצא כי ישנה מטרה ראויה ומתאימה לקדיחה יגיש לממונה תכנית עבודה הכוללת התחייבות לקדיחה במשך השנתיים הבאות ותכנית עבודה לשאר הרישיונות.

הרעיון העומד מאחורי תקופות רישיון אלו של 3+2+2, הוא שב-3 השנים הראשונות בעל הרישיון לומד את שטח הרישיון שקיבל, ולאחר מכן, בהתאם לבדיקות שיבצע על פי תכנית העבודה, מחליט האם יש מטרה המצדיקה קידוח. מעבר לכך, כיוון שמדובר רק על מבנה שבעל הרישיון טרם קדח בו עומדת בפני בעל הרישיון אפשרות ללימוד שטח הרישיון באופן הדוק ומעמיק על ידי קידוח, אשר כתוצאה ממנו יידע האם גם בשאר הרישיונות המצויים ברשותו מצויות מטרות גז או שמא מדובר על מטרות "יבשות".

חשוב להדגיש כי במקרה בו זוכה בשטח בהליך התחרותי אשר במהלך הצעת תכנית העבודה התחייב לבצע קידוח במהלך 3 השנים הראשונות, יחליט שלא לבצע קידוח לאחר שהגיע למסקנה כי אין מטרת גז/נפט בשטח הרישיון, או מכל סיבה שהיא, הערבויות אשר העמיד יחולטו.

ב. סעיפי ניקוד

אזור G					
נושא התיחור			יחידת מדידה	ניקוד	משקל
תכנית עבודה מחייבת במהלך 3 השנים הראשונות	ביצוע קידוח חיפוש (במהלך 3 השנים הראשונות)		מספר קידוחים	70	85
	ביצוע סקר סייסמי 3D		שטח (קמ"ר)	20	
	ביצוע סקר סייסמי 2D		אורך כולל (ק"מ)	0	
	עיבוד חוזר של סקרים סייסמיים קיימים	עיבוד חוזר של סקר סייסמי 3D	שטח (קמ"ר)	7	
		עיבוד חוזר של סקר סייסמי 2D	אורך כולל (ק"מ)	0	
	סקרים גיאופיסיים נוספים או מחקרים גיאולוגים שונים		סכום התחייבות להשקעה כספית	3	
מענק חתימה			סכום מענק	100	15
סה"כ					100

אזורים H+E					
נושא התיחור			יחידת מדידה	ניקוד	משקל
תכנית עבודה מחייבת במהלך 3 השנים הראשונות	ביצוע קידוח חיפוש (במהלך 3 השנים הראשונות)		מספר קידוחים	50	85
	ביצוע סקר סייסמי 3D		שטח (קמ״ר)	30	
	ביצוע סקר סייסמי 2D		אורך כולל (ק״מ)	5	
	עיבוד חוזר של סקרים סייסמיים קיימים	עיבוד חוזר של סקר סייסמי 3D	שטח (קמ״ר)	10	
		עיבוד חוזר של סקר סייסמי 2D	אורך כולל (ק״מ)	2	
	סקרים גיאופיסיים נוספים או מחקרים גיאולוגים שונים		סכום התחייבות להשקעה כספית	3	
מענק חתימה			סכום מענק	100	15
	סה״כ				100

אזור I					
נושא התיחור			יחידת מדידה	ניקוד	משקל
תכנית עבודה מחייבת במהלך 3 השנים הראשונות	ביצוע קידוח חיפוש (במהלך 3 השנים הראשונות)		מספר קידוחים	0	85
	ביצוע סקר סייסמי 3D		שטח (קמ״ר)	65	
	ביצוע סקר סייסמי 2D		אורך כולל (ק״מ)	25	
	עיבוד חוזר של סקרים סייסמיים קיימים	עיבוד חוזר של סקר סייסמי 3D	שטח (קמ״ר)	0	
		עיבוד חוזר של סקר סייסמי 2D	אורך כולל (ק״מ)	6	
	סקרים גיאופיסיים נוספים או מחקרים גיאולוגים שונים		סכום התחייבות להשקעה כספית	4	
מענק חתימה			סכום מענק	100	15
	סה״כ				100

תכנית עבודה – 85%

העיקרון המנחה של הניקוד הוא שקבוצות אשר יעברו את תנאי הסף כאמור לעיל, ראויות לקבל זכויות נפט בישראל מבחינה מקצועית ומבחינה כלכלית.

התחרות היא בעיקרה על תכנית העבודה אשר הקבוצה מתחייבת לבצע ברישיון החיפוש, ולכן נקבע כי תכנית העבודה תקבל 85 נקודות מתוך 100.

הניקוד בתוך 85 הנקודות מתחלק בהתאמה להשקעה הכספית המשוערת אשר בעל רישיון החיפוש צריך להשקיע. עלותו של קידוח חיפוש מוערכת בכ -80-100 מיליון דולר, עלות סקר סייסמי 3D מוערכת בכ- 5-10 מיליון דולר, עלות סקר 2D מוערכת בכ 1-5 מיליון דולר, עלותו של עיבוד חוזר של סקר D3 מוערכת בכ 1-2 מיליון דולר ועלותו של עיבוד חוזר סקר D2 מוערכת בכ- 0.5-1 מיליון דולר.

בכל מקבץ בלוקים התיחור שנקבע הוא שונה, בהתאם למידע הגאולוגי הקיים ביחס לאותו מקבץ, ולכן המשקל של כל רכיב שונה בהתאם לבשלות המידע הקיים במקבץ זה. במקבץ בו לא קיים עדיין סקר D3 יינתן ניקוד גבוה יותר לביצוע סקר חדש D3 מאשר במקבץ בו כבר קיים סקר D3. וכן בהתאמה לגבי שאר הסקרים המתוחרים בטבלה.

<u>מענק חתימה- 15%</u>

עיקר ההכנסות של המדינה מגז ונפט הינו בשלב ההפקה. לצורך כך נחקק חוק מס רווחי יתר (חוק ששינסקי) אשר מתווסף למס חברות/מס הכנסה ולתמלוגים על פי חוק הנפט. מטרתו של סעיף זה היא הכנסת רכיב נוסף, כלכלי, בתחרות אשר לגביו יתחרו קבוצות המבקשות לקבל זכות נפט. משקלו של פרמטר זה קטן יחסית במטרה שלא להרתיע חברות אשר לא יהיו מוכנות להשקיע כספים רבים בשלב המקדמי של כניסה לרישיון.

סיבה נוספת למשקל הנמוך יחסית של מענק החתימה היא הסיכון הגבוה של שלב הרישיון בו קיים חוסר וודאות משמעותי ביחס לכלכליות ההשקעה. מצב זה שונה מהמצב בענפים אחרים כגון הקמת תחנת כוח, הקמת בניין משרדים, תפעול רשת סלולארית וכיו״ב, כאשר בענף חיפושי הנפט והגז שיעור ההצלחות באתרים בהם כבר הוחלט על ביצוע קידוח הינו כ-20% בלבד.

ג. ערבויות ועידוד חבילות בלוקים

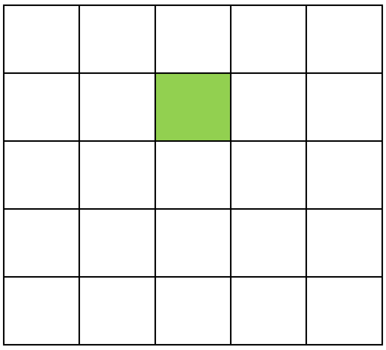
ע״פ חוק הנפט, השטח המקסימלי שניתן לתת לגביו רישיון חיפוש הוא 400 קמ״ר, וזאת לעומת שטחים נרחבים וגדולים בהרבה, הקבועים במדינות הגובלות עם ישראל.

ישנה עדיפות וקיים יתרון לכך שקבוצה תקבל רישיון חיפוש בכמה בלוקים גובלים וזאת משתי סיבות עיקריות. הראשונה, היא שמבנה המאגרים בדרך כלל לא תואם לגבולות רישיון ועשויים להיות מאגרים גדולים אשר משתרעים על פני מספר שטחי רישיונות. לכן ישנה עדיפות כי מבנה אחד יוחזק ע״י קבוצה אחת, על מנת לצמצם את הצורך בביצוע איחוד פעולות בין מספר קבוצות שונות המחזיקות ומפיקות נפט/גז מאותו המאגר. קבלה של מספר רישיונות בשטחים סמוכים מגדילה את הסיכויים לכך. בנוסף, ביצוע סקרים סייסמיים גדולים על פני שטחי מספר בלוקים הינו כלכלי יותר לעומת ביצוע סקרים סייסמיים קטנים על ידי מספר קבוצות, כל אחת בבלוק בודד שברשותה.

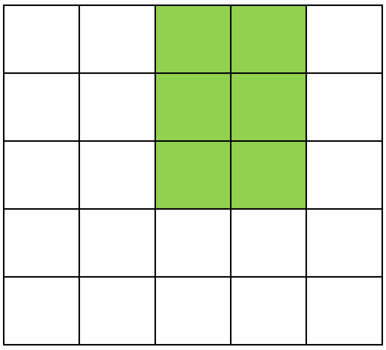
לאור ההבנה כי נכון יותר להעניק רישיונות חיפוש בשטחים רציפים וגדולים יותר לקבוצה אחת, הוחלט גם לתמרץ זאת באמצעות הדרישות להפקדת ערבויות. הערבויות משמשות בעיקר כערבות ביצוע, על מנת לוודא כי בעל רישיון החיפוש אשר קיבל מהמדינה את השטח לטובת חיפוש אכן מבצע את המוטל עליו בשקידה ראויה לטובת חיפוש נפט וגז. חשוב להבין כי מטרת הערבות אינה תשלום ובטחון למקרה של אסון. לצורך זאת קיים מערך ביטוחים אשר בעל רישיון החיפוש מעמיד לפי דרישות הממונה.

גובה הערבות הבסיסית לכל רישיון הינה 2.5 מיליון דולר. כאשר יזם מבקש זכות לקבל מספר רישיונות בשטחים רציפים, אזי גובה הערבות על השטח הנוסף הינו תוספת של 0.5 מיליון דולר לכל רישיון נוסף במקום 2.5 מיליון דולר, כך עד גובה ערבות מרבי של 5 מיליון דולר (לערבות בגין 6 רישיונות השטחים רציפים שהיא הכמות המירבית במסגרת ההליך התחרותי הנוכחי).

בשלב השני, כאשר בעל רישיון חיפוש יבקש לבצע קידוח ב-3 השנים השניות לפני ביצוע הקידוח עליו יהיה להעמיד בנוסף לערבות הבסיס שהעמיד (2.5 מיליון דולר), עוד ערבות בנקאית בגובה 5 מיליון דולר לקידוח, כפי שנקבע בהנחיות הערבויות המפורסמות באתר המשרד. דוגמאות:



בקשת רישיון בודד – 2.5 מיליון דולר.



בקשת רישיון ב-6 שטחים צמודים, ערבות - 5 מיליון דולר.

ד. **אגרות ותשלומים**

לצורך השתתפות בהליך התחרותי, מוצע למשתתפים להירשם תחילה באתר האינטרנט המיוחד שהוקם לצורך ההליך, וזאת לצורך קבלת אפשרות להגשת וקבלת מידע רציף- שאלות, תשובות והבהרות אשר יעלו במהלך התקופה בה מסמכי ההליך יפורסמו.

בנוסף לכך כל קבוצה מחויבת, כתנאי להשתתפות בתהליך התחרותי והגשת הצעות ומסמכי ההליך, בתשלום עבור אגרת בקשה הכוללת רכישת חבילת המידע שהוכנה על ידי הצוות המקצועי במשרד. חבילה זו כוללת דוחות ונתונים גיאולוגיים וגיאופסיים מקידוחים וסקרים, בכלל זה תוצאת המחקר האגני והערכת העתודות שבוצעה על ידי המשרד, וכן מידע סביבתי על האזורים המוצעים המצוי בידי המשרד. מטרת החבילה היא לספק מידע על כלל השטח העומד לתחרות וזאת כדי לאפשר ליזמים לזהות את הבלוקים אשר מעניינים אותם במיוחד ולגביהם ירצו להגיש הצעות. עלות הרכישה של אגרת הבקשה וחבילת המידע היא 50,000$ וזאת לצורך כיסוי עלויות אחסון, טיפול והכנת חבילת המידע.

ה. שיקולי תחרות

בתהליכים שקדמו להכנת מסמכי ההליך ניתנה חשיבות רבה לנושא התחרות. המשרד מעוניין לעודד את התחרות והשתתפות של מספר חברות גבוה ככל האפשר, על מנת לפתח את המשאבים הנמצאים בשטח הימי של ישראל, באופן אופטימאלי. בהתאם, להערכת היועצים הבינלאומיים המלווים את ההליך התחרותי, יש קושי לא מבוטל לעניין חברות באקספלורציה בהשתתפות. בנוסף, אירוע של כניסה למדינה חדשה הוא משמעותי עבור חברה ולכן, על אף המאמצים המשרד משקיע וישקיע לעידוד כניסת שחקנים חדשים, ייתכן ועיקר התחרות תהיה בין חברות הפעילות כבר בישראל. לאור זאת המשרד מעוניין שלא להגביל חברות הפעילות בישראל מההשתתפות בהליך התחרותי אך עם זאת מבקש לקבוע הוראות שונות בנושא התחרות כדי למקסם את התחרות על הרשיונות החדשים.

לאור חוות דעת שהתקבלה מטעם רשות התחרות, מסמכי ההליך מחילים את המגבלות הבאות על בעלי חזקות קיימות:

- המחזיק ביותר מחזקה מפיקה אחת (=שברון) רשאי להגיש הצעה לכל אזור, אולם היא תתקבל רק במקרה שמדובר בהצעה יחידה לאזור זה, וכי קיים הסדר למכר בנפרד של הגז ע"י כל אחד מבעלי הרשיון שיתקבל.
- המחזיק בחזקה מפיקה אחת (=ניו מד, רציו) רשאי להגיש הצעה לכל אזור, אולם ההצעה תתקבל רק בהתקיים **אחד** מהתנאים הבאים:
  - המחזיק הקיים חובר לשחקן חדש מחזיק לפחות ב-50% מההצעה.
  - המחזיק הקיים חובר לשחקן חדש המוגדר כמפעיל עבור ההצעה.
  - אין הצעות נוספות לאזור זה, או שההצעה היחידה הנוספת היא של מחזיק ביותר מחזקה אחת, **ובנוסף** קיים הסדר למכר בנפרד.
- מספר שחקנים המחזיקים כיום באותה חזקה אינם רשאים להגיש הצעה משותפת.

ו. עקרונות סביבתיים

שינויי האקלים הינם שינויים גלובליים ויש להתבונן בראיה גלובלית ולא מקומית. הפקת גז טבעי שייעודו להחליף דלקים מזהמים הרבה יותר, אם במצריים וירדן ואם באירופה, הינו תהליך מבורך שיסייע למדינות אלו לשמור על אספקת אנרגיה אמינה תוך שימוש בגז טבעי כאנרגיית מעבר. החלפת הדלקים המזהמים בתקופת המעבר תפחית את זיהום האוויר במדינות אלו, תשפר את בריאות האדם והסביבה ואף תפחית את פליטות גזי החממה שלהן בעקבות הקרבה לאזורי ביקוש סמוכים, אזורי ביקוש ל- LNG ובשל הפקת הגז הטבעי בשיטות קונבנציונאליות ושיטות הטיפול הישראליות הנקיות באופן משמעותי מהנעשה במדינות אחרות.

אין בתהליך החיפוש במים הכלכליים לפגוע בייעדי הפחתת הפליטות של מדינת ישראל, ואף לא בהחלטות הממשלה וביעדיה. הגז הטבעי כאמור, מחליף את השימוש בדלקים מזהמים יותר, ומהווה דלק מעבר עד אשר תמהיל מקורות האנרגיה בישראל יכלול מקורות אנרגיה נקייה בלבד, מה שלא צפוי בשנים הקרובות.

העקרונות הסביבתיים בהליך התחרותי הרביעי מבוססים על העקרונות הסביבתיים שאומצו בהליכים תחרותיים קודמים שנקבעו לאחר סיומו המוצלח של הסקר האסטרטגי הסביבתי, עדכוניו ואימוץ המלצותיו.

להלן פירוט העקרונות:

1. מניתוח המרחב הימי שנסקר בסא״ס עולה, כי יש הצדקה להתייחסות שונה לאזור הקרוב לחוף לעומת זה המרוחק ממנו. לפיכך, ההמלצה הכללית לעת הזאת היא לתת רישיונות על-פי חוק הנפט בשטחים המרוחקים מהחוף בלמעלה מ-7 ק״מ.
2. בתחום בתי הגידול ברמת רגישות 4 בשטחים המרוחקים מהחוף, מומלץ להגביל פעולות קדיחה או הנחת צנרת, תשתיות ומתקנים אחרים בתחומם ולהגביל ביצוע קידוחים במרחק של 1 ק״מ מהם כדי להימנע מפגיעה באותם בתי גידול.
3. ביחס לבתי גידול ברמת רגישות 3, מוצע להגביל את הפעילות בהם ובסמיכות להם בדומה למוצע עבור בתי גידול ברמת רגישות 4, וזאת עד להשלמת מידע נוסף, שיאפשר עדכון המדיניות ביחס לבתי גידול אלו.
4. בתחום בתי גידול בעלי רגישות גבוהה מאוד לפעולות בעלות הפרעה של קול מומלץ שלא לבצע סקרים סיסמיים.
5. בנוסף להמלצות אלו, מומלץ לתת עדיפות למתן זכויות באזורים בעלי רגישות אקולוגית נמוכה במסגרת מכלול השיקולים של הממונה בבואו להעניק זכויות.

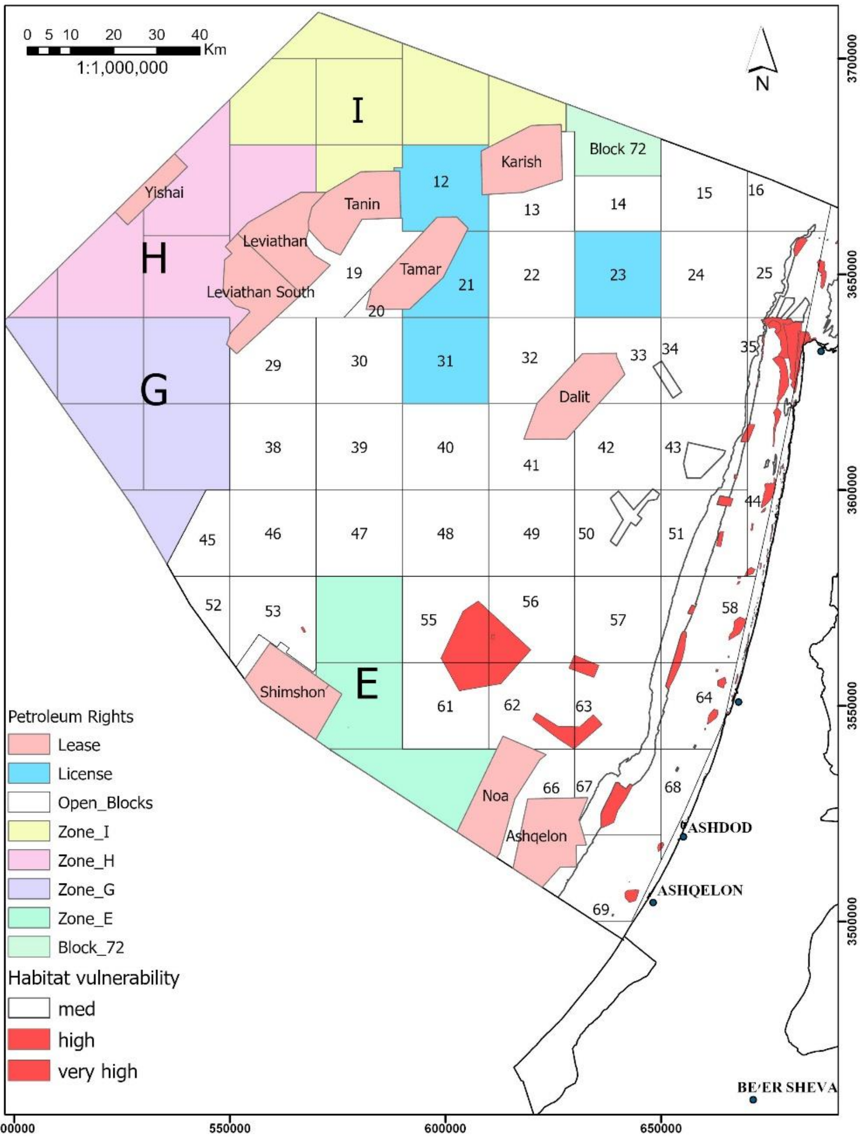
לפיכך:

6. במסגרת ההליך התחרותי אליו אנו יוצאים יינתנו רישיונות חיפוש רק בשטחים המרוחקים מהחוף (במרחק העולה על 30 ק״מ מהחוף), הואיל וברצועה הקרובה לחוף מתרכזים מירב השימושים הימיים הקיימים והמתוכננים, וברצועה הרחוקה יותר מהחוף השימושים הימיים מועטים.
7. המידע על בתי הגידול במרחב הימי נכלל בחבילת המידע של ההליך התחרותי (מפת בתי הגידול ורגישותם – עדכון דצמבר 2021 מצורפת בהמשך).
8. יש לציין, כי בהענקת רישיון החיפוש ולאחריו במתן אישורים לסקרים, לקדיחה ולהקמת תשתיות אנו מיידעים את מבקשי רישיון החיפוש בדבר רגישות בתי הגידול המצויים בתחום הרישיון, על המגבלות האפשריות על רמת הפיתוח שתתאפשר, על אמצעים והפעולות שיידרשו ועל המגבלות שיוטלו לצורך שימור בתי הגידול.
9. במסגרת התנאים לאישור קדיחה נדרש מבעל רישיון לבצע סקר רקע מקדים, שמטרתו לוודא שאין בתי גידול רגישים במרחב המתוכנן לקידוח החיפוש, להכין מסמך סביבתי שאישורו נסמך על חוות דעת היחידה להגנת הסביבה הימית במשרד להגנת הסביבה, וכן לקבל היתר הזרמה לים, היתר רעלים ולקבל אישור לתכנית חירום מפעלית. אישורים והיתרים אלה נמצאים בסמכות הבלעדית של המשרד להגנת הסביבה.

יוער, כי במסגרת בחינת מפעיל על ידי הממונה נדרש ממבקשי הזכות להציג את הנאותות הסביבתית (Environmental Appropriateness Report) של מבקש הזכות ונאותות זו נבחנת טרם מתן הרישיון.

State of Israel

Petroleum rights with habitats Nov. 2022



איור 1. מפת בתי הגידול הרגישים והבלוקים המיועדים לשיווק במסגרת ההליך התחרותי הרביעי.

בכבוד רב

חן בר יוסף
הממונה על ענייני הנפט

<u>מש/7</u>

צילום חוות דעתה של המשנה ליועצת המשפטית לממשלה גבי אביטל סומפלינסקי מיום 7.7.22

עמ׳ 35

נספח מש/7

מדינת ישראל
משרד המשפטים

המשנה ליועצת המשפטית לממשלה
(משפט ציבורי-חוקתי)

ירושלים: ח' תמוז תשפ"ב
07 יולי 2022
תיקנו: 803-98-2022-000055
סימוכין: 803-99-2022-049000

אל: היועצים המשפטיים למשרדי הממשלה

שלום רב,

הנדון: **<u>היערכות משפטית לתקופת הבחירות לכנסת ה-25</u>**

א. ביום א' בתמוז התשפ"ב, 30 ביוני 2022 קיבלה מליאת הכנסת בקריאה שלישית את חוק התפזרות הכנסת העשרים וארבע ומימון מפלגות, התשפ"ב-2022, לפיו הכנסת העשרים וארבע תתפזר לפני גמר תקופת כהונתה והבחירות לכנסת העשרים וחמש יתקיימו ביום ז' בחשוון התשפ"ג (1 בנובמבר 2022). החוק אף פורסם ברשומות ביום זה. בהתאם לכך, החל מיום 30.6.2022 הפכה הממשלה המכהנת (הממשלה ה - 36) לממשלה יוצאת, ולאחר הבחירות העתידות להיערך ביום 1.11.2022 - תהפוך ממשלה זו ל"ממשלת מעבר".

יוזכר גם כי עוד קודם לקבלת החוק להתפזרות הכנסת העשרים וארבע, ביום כ"א בסיון התשפ"ב (20 ביוני 2022), הודיעו ראש הממשלה וראש הממשלה החלופי בהודעה משותפת על החלטתם להקדים את מועד הבחירות תוך שהכנסת העשרים וארבע תתפזר לפני גמר כהונתה. כפי שצוין במכתבה של היועצת המשפטית לממשלה, יש לראות במועד מוקדם זה כמועד שבו התחילה תקופת הבחירות לצורך תחולת ההנחיות הנזכרות להלן לפי העניין, כיוון שהחל ממועד זה התקיימו התנאים המהותיים המצדיקים להביא בחשבון את השיקולים ואמות-המידה שנקבעו ביחס לתקופת הבחירות.

ב. בהתאם לפסיקה, בצד הרצון לאפשר לממשלה היוצאת להמשיך ולפעול במסגרת סמכויותיה מכוח עקרון הרציפות השלטונית, תקופת הבחירות מחייבת את הממשלה היוצאת, השרים המכהנים בה ומשרדי הממשלה לנהוג בריסון ובאיפוק בכל הנוגע להחלטות המתקבלות, הקצאת המשאבים ויוזמות החקיקה (ראו לעניין זה מכתבה של היועצת המשפטית לממשלה אל מזכיר הממשלה מיום 30.6.2022). הטעם לכך כפול - ראשית, על הממשלה היוצאת להימנע, כשהדבר לא נדרש, מהכרעות בלתי הפיכות שיקשו על הממשלה החדשה שתכהן מכוח אמון הכנסת הבאה לממש את מדיניותה לפי רצון הבוחר; שנית, יש להיזהר מפני שימוש לא ראוי בכוח השלטוני ובמשאבי המדינה לתעמולה או להשגת יתרון לא הוגן למפלגה או למועמד.

ג. נוכח האמור, מוטלת עלינו – היועצים המשפטיים הפועלים מטעמה של היועצת המשפטית לממשלה במשרדי הממשלה ובייעוץ וחקיקה – החובה לסייע בידי הממשלה, השרים ובעלי התפקידים במשרדים כך שההחלטות שתתקבלנה ייבחנו גם על רקע ההוראות המיוחדות הנוגעות לתקופת בחירות, ויעמדו במגבלות הרלבנטיות, מקום בו הדבר נדרש; זאת, במסגרת תפקידנו המרכזי לסייע לממשלה לממש את מדיניותה בגבולות הדין. בהתאם לכך, על היועץ המשפטי בכל משרד, אשר דרך שגרה מעניק ייעוץ משפטי שוטף ואמון על סיוע לקידום פעילות המשרד והבטחת החוקיות של פעילות זו, להוסיף בימים אלה בחינה נוספת בהיבט הייחודי של התאמת הפעילות לתקופת הבחירות, על כל המשתמע מכך.

נדגיש, כי ניתן כמובן – ואף נדרש – להמשיך בביצוע הפעילות הרגילה והשוטפת שמבטיחה את המשכיות עבודת הרשות המבצעת, ובהתאם לכך אין צורך לבדוק כל פעולה ופעולה שאינה מעוררת על פניה חשש בקשר לשתי התכליות האמורות.

ד. מבלי למצות את מארג השיקולים שיש לשקול בהקשר זה על מנת להבטיח את האיזון שבין חובת האיפוק והריסון לצורך בעשייה ובשמירה על רציפות הפעילות הממשלתית, נזכיר מספר שאלות מנחות בולטות שיכולות לסייע בידיכם בבחינה זו.

1. עד כמה קיימים דחיפות וכורח אובייקטיביים בביצוע הפעולה דווקא במועד זה? האם הימנעות מביצועה יפגע באינטרס ציבורי? יש לבחון, למשל, אם התוצאה של ההחלטה תבוא לידי ביטוי עוד בתקופה שלפני כינונה של הממשלה החדשה, כסממן של חיוניות. ככלל, קיומה של חובה משפטית (למשל בשל התחייבות בינלאומית, הוראה בחוק, צו שיפוטי או מחויבות חוזית) תצביע על כך שמתקיים מבחן "הדחיפות והכורח".

2. ככל שמידת החיוניות פוחתת וככל שמועד הבחירות קרב, יש לבחון ביתר שאת את השיקולים האחרים.

3. האם הפעולה תביא לקביעת עובדות מוגמרות אשר אותן יקשה על הממשלה הנכנסת לשנות? הקושי יכול שיהיה מסוגים שונים, כגון קושי משפטי, כלכלי, תקציבי או מנהלי.

4. האם הפעולה נוגעת למדיניות המתאפיינת ברגישות פוליטית או ציבורית בולטת שאין לגביה קונצנזוס ציבורי, אשר סביר להניח כי ממשלה חדשה עשויה לרצות לנקוט בה עמדה אחרת?

5. האם הפעולה היא תוצר של עבודת מטה מקצועית מקובלת שהחלה טרם תקופת הבחירות ומבשילה במקרה עתה? אם מדובר ביוזמה חדשה, האם מקור היוזמה הוא בדרג המקצועי ומה מידת המעורבות של הדרג הפוליטי בתהליך קבלת ההחלטה?

6. עד כמה היקף ההשפעה של הפעולה גדול ומשמעותי? האם יש בה משום שינוי משמעותי בסדרי העדיפות של הפעילות הממשלתית, למשל בתחום התקציבי?

7. עד כמה יש בפעולה משום הטבה או תועלת לציבור הבוחרים ויש חשש, לאור השיקולים האחרים, שהיא עלולה להיות מונעת, או להיראות כמונעת, משיקולים של ההתמודדות בבחירות הקרובות?

כאמור, שאלות אלו אינן ממצות את כלל השיקולים שעשויים להיות רלבנטיים, והן פורטו כאן ככלי עזר בידיכם לשם בחינה קונקרטית בסיטואציות הנדרשות.

ה. בכל הנוגע לקידום חקיקה בתקופה זו, יובהר כי, ככלל, אין מניעה להפיץ להערות הציבור תזכירי חוק או טיוטת תקנות שהבשילו לאחר עבודת מטה שהחלה טרם תקופת הבחירות, בשל השלב המקדמי של פעולה זו (יחד עם זאת, יש לבחון אם בנסיבות העניין ולפי תוכנו של החיקוק המוצע יש בכל זאת משום חשש בולט לתעמולת בחירות). כן יובהר בהקשר זה כי ככלל, בשונה מפעולה מנהלית רגילה, דבר חקיקה שעשוי ממילא להגיע לדיון ואישור בכנסת, מעורר, מטבע הדברים, פחות בעייתיות בהיבטים אלו.

ו. בכל הנוגע לחתימה ואשרור הסכמים בין-לאומיים בתקופת בחירות, ראו את מכתבו של המשנה ליועצת המשפטית לממשלה (משפט בין-לאומי), המצורף למכתבי זה.

ז. כדי לייעל את ממשקי העבודה בין משרדי הממשלה לייעוץ וחקיקה ולאפשר מתן שירות מהיר ויעיל, נבקש להבהיר את דרכי העבודה הבאות לפיהן ננהג בתקופת הבחירות:

1. צוות הבחירות במחלקה למשפט ציבורי-חוקתי ירכז ויוביל את הטיפול בענייני הבחירות עצמן. הצוות יטפל במכלול השאלות הקשורות בדיני הבחירות ובכלל זה תעמולה (לרבות פעילות של שרים ומשרדים שמעלה חשש לתעמולה), קידום חקיקה ראשית ומשנית בתקופת בחירות ובכלל זאת גם שאלות באשר לסעיף 38 לחוק-יסוד: הכנסת, רשימות מועמדים והקשר עם ועדת הבחירות המרכזית (בשיתוף ובתיאום עם מחלקת הבג"צים ככל הנדרש). אציין כי חברי הצוות אמונים בשוטף על דיני הכנסת, דיני החקיקה, דיני המפלגות ודיני מימון המפלגות, וכן חופש הביטוי, סוגיות אשר עשויות להיות רלבנטיות בתקופת הבחירות. צוות הבחירות הוא בראשות איל זנדברג. פניות בנושא תעמולת בחירות יש להפנות לעמי ברקוביץ ולרבקה ליפשיץ. פניות בנושא קידום חקיקה בתקופת בחירות יש להפנות לשלומית גרינפילד גילת.

2. סוגיות הנוגעות למינויים בתקופת בחירות יטופלו בידי צוות בחירות - מינויים, במחלקה למשפט ציבורי-מנהלי בראשות אורן פונו יחד עם דרור כהנר ועמרי בן צבי, ובכל הנוגע למינויים בתאגידים ציבוריים ובחברות ממשלתיות, בידי סמדר דולב.

3. שאלות בדבר היבטי תקופת הבחירות של החלטות ממשלה, החלטות ועדות שרים והחלטות מנהליות של שרים או גורמים אחרים במשרדי הממשלה, כמו גם ביחס ליתר הפעילות המקצועית-מנהלית של משרדי הממשלה לתקופה זו, יטופלו בידי צוות בחירות – עבודת ממשלה, במחלקה למשפט ציבורי-מינהלי, בראשות ענת אסיף, יחד עם חיליק מרציק ונעמה רוט.

4. שאלות הנוגעות למתן תמיכות ולקידום מבחני תמיכה בתקופת הבחירות יטופלו בידי שרה גולד מהמחלקה למשפט ציבורי-מינהלי.

5. סוגיות הנוגעות לחתימה ואשרור הסכמים בין-לאומיים בתקופת בחירות יטופלו בהתאם למכתבו של המשנה ליועצת המשפטית לממשלה (משפט בין-לאומי), הנזכר לעיל.

ח. ככלל, יועץ משפטי של משרד ממשלתי או יחידת סמך הנתקל בסוגיה הראויה לדעתו להתייעצות עם ייעוץ וחקיקה בשל תקופת הבחירות, בעיקר כאשר מדובר בחקיקה, החלטות ממשלה, החלטות מינהליות משמעותיות, תמיכות והסכמים שונים, לרבות הסכמי שכר, יפנה אל הרפרנט האחראי על המשרד במחלקה הרלוונטית בייעוץ וחקיקה, אשר יעביר בכל עניין כאמור פנייה סדורה לצוותי הבחירות הרלוונטיים.

ט. כמקובל, קידום חקיקה, החלטות ממשלה וועדות שרים מצריך בדיקה מוקדמת עם הגורמים הרלוונטיים לעניין בייעוץ וחקיקה וממילא כעת אף לעניין היבטי תקופת הבחירות. על הפניה לכלול פירוט העובדות, ניתוח משפטי של הסוגיה וחיווי דעה משפטית לגבי השאלה שעל הפרק. כאשר הצעת ההחלטה (או הסוגיה האחרת העומדת על הפרק) מערבת מספר משרדי ממשלה, על המשרד המוביל לכלול בהתייחסותו גם את עמדות המשרדים הרלוונטיים האחרים בהיבטי בחירות. מובן כי בנסיבות של דחיפות יכולה הפניה הכתובה להיות תמציתית.

נדגיש כי יישום אמות-המידה תלוי עד מאד בנסיבותיו של כל מקרה ומקרה, ועל כן תיאור הנסיבות והעובדות הרלבנטיות הוא בעל חשיבות רבה למתן ייעוץ משפטי מדויק ומענה מהיר מטעם ייעוץ וחקיקה בכל הנושאים שבהם עוסק מכתב זה.

י. בפנייה מטעמו של שר למזכירות הממשלה בבקשה להניח על סדר היום הצעת החלטה או טיוטת חוק, יש לכלול בחוות הדעת המשפטית המצורפת, כמקובל, מאת היועץ המשפטי של המשרד או של יחידת הסמך, התייחסות גם לשאלת קידום ההחלטה או החקיקה בתקופת הבחירות, בין היתר לאור האמור לעיל. כך גם יש לפעול בפנייה מטעמו של שר למחלקת חקיקת משנה בייעוץ וחקיקה לפרסם חקיקת משנה, והפניה תשלח במקביל גם לרפרנט של המשרד המגיש במחלקת ייעוץ וחקיקה, שיצרף התייחסותו להיבט זה.

נא הקפידו על פנייה מסודרת באופן האמור על מנת שניתן יהיה לתת מענה מקצועי מהיר ומדויק ככל הניתן.

יא. בכדי לייעל את דרכי העבודה, כאשר מדובר בנושאים של ייעוץ משפטי שוטף שאינם נזכרים בסעיף ח' שלעיל וכאשר מדובר בחקיקת משנה, כשמקרה אינו מעורר שאלה בעלת השלכות רוחב והיועץ המשפטי של המשרד הרלוונטי והרפרנט הנוגע בדבר בייעוץ וחקיקה תמימי דעים שהמקרה אינו מגלה קושי משפטי שמצדיק את הידרשות צוות הבחירות, לא יהיה הכרח לפנות לצוות הבחירות.

יב. אני מקווה, כי עבודה משותפת של כולנו ברוח האמור במכתב זה, יחד עם הניסיון הרב שצברנו בארבע מערכות הבחירות האחרונות, יאפשרו לצלוח את תקופת הבחירות המורכבת והרגישה, תוך שמירה על האיזון הראוי הנדרש בין הצורך בהמשך העשייה הממשלתית והרציפות השלטונית לבין חשיבות השמירה על האיפוק והריסון הנדרשים בתקופת מעבר זו.

יג. לבסוף אציין, כי ביום 17.7.2022 נקיים יום עיון מרוכז בהשתתפות הלשכות המשפטיות של משרדי הממשלה וגורמי ייעוץ וחקיקה המעורבים בנושא, על מנת לרענן ולחדד את השיקולים הרלוונטיים וצורת העבודה בתקופת הבחירות.

בברכה,

אביטל סומפולינסקי, עו״ד

המשנה ליועצת המשפטית לממשלה (משפט ציבורי-חוקתי)

העתק:

היועצת המשפטית לממשלה

המשנים ליועצת המשפטית לממשלה

מנהל מחלקת הבג״צים, פרקליטות המדינה

משפטני ייעוץ וחקיקה

<u>נספח 4</u>

העתק מפרוטוקול הדיון מיום 29.11.22

עמ' 107

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משרד האנרגיה

מינהל אוצרות הטבע

ל' בסיון התשפ"ב
29 בנובמבר 2022

הנדון: <u>פרוטוקול מועצת נפט חמישית לשנת 2022 מיום 29 בנובמבר 2022</u>

<u>חברי המועצה:</u> אפי דלומי, אבי קדיש, רני עמיר, מיכל אוגולניק, אמיר זלצברג, הלאל חילאילה, אורלי טל, ראפת דיבסי

<u>נציגי המשרד:</u> חן בר יוסף, ד"ר מיקי גרדוש, אלעד גולן, שגיא גנות, ד"ר מיכאל דנון, רו"ח שמעון כהן, שארבל שחאדה, אילן נסים

<u>לשכה משפטית</u>: עו"ד יונית שרם-ונונו, עו"ד יאיר אריאלי, עו"ד חגית אייזנמן מלכה

הישיבה התקיימה באמצעות ה-ZOOM.

מברכים את מיכל אוגולניק על הצטרפותה למועצת הנפט כנציגת ציבור.
חברי המועצה מסכימים פה אחד למינוי אפי דלומי כיו"ר הישיבה.

לשאלת [redacted], הובהר כי ככלל, הנוהג לפיו פעלו עד כה הוא לא לזמן גורמים מבחוץ להצגת טיעונים בע"פ במסגרת דיוני המועצה. במקרה שלפנינו, לאור בקשת ארגוני סביבה להציג עמדתם בכל הנוגע להליך התחרותי, הוחלט שפנייתם הכתובה תוצג לחברי המועצה. לאור האמור, פנייתם צורפה לחומר אשר נשלח לכל חברי המועצה, והובהר שככל שמי מהחברים ימצא לנכון הוא מוזמן להציג את עמדתו בדיון ביחס לפנייתם.

<u>הליך תחרותי רביעי</u>

<u>רקע</u>:

יחידת הגז הטבעי והנפט נערכת ליציאה להליך תחרותי רביעי לחיפושי גז טבעי בים התיכון.

להלן הנימוקים העיקריים ליציאה להליך:

- הצורך של המשק הישראלי במקורות גז נוספים, הן לצרכי הגברת התחרות הורדת יוקר המחיה והן לצרכי גיבוי ומתן מענה למשק במצבי הפסקה שונים באסדות הקיימות. כל הצלחה תיצור יתירות החיונית למשק הגז עליו מתבסס מרבית משק החשמל בישראל ותעשיות קריטיות נוספות.

- משבר האנרגיה באירופה והחלטת האיחוד האירופי בעקבותיה לפעול לצמצום התלות בגז הרוסי ולגיוון משמעותי של מקורות הייבוא.
- מזכר ההבנות המשולש שנחתם בין ישראל, מצרים והאיחוד האירופי ב-15.6.2022 להגדלת ייצוא הגז מישראל דרך מצרים לאירופה, אשר כולל גם התחייבות של האיחוד לעידוד חברות אירופיות לגשת להליך התחרותי.
- העלייה החדה במחירי הנפט והגז בשוק העולמי.
- ההתחממות ביחסים עם מדינות ערב ושיתופי הפעולה המשמעותיים עמן שהחלו בעקבות החתימה על הסכמי אברהם, והביאו בין היתר לכניסה של חברה מאיחוד האמירויות כשותפה במאגר תמר. עובדה זו צפויה לתרום להצלחת ההליך, הן לאור האפשרות להשתתפות חברות מהעולם הערבי והן לאור צמצום הרגישות עבור חברות בינלאומיות.
- חתימת ההסכם הימי עם לבנון, אשר מגביר את היציבות הגיאופוליטית באזור ומקטין את הסיכונים של מציעים פוטנציאליים.
- עניין גובר בהשתתפות בהליך מצד חברות מרחבי העולם.

להלן עקרונות ההליך התחרותי:

- במסגרת ההליך משווקים ארבעה מקבצים ובהם סה"כ 20 בלוקים, בשטח כולל של 5,888 קמ"ר.
- כל מציע יוכל לזכות בשני מקבצים לכל היותר, ויוענקו לו רישיונות עבור כל אחד מהבלוקים הכלולים במקבץ בו זכה.
- בדומה להליכים התחרותיים הקודמים, הרישיונות יוענקו בתנאים, לתקופות של 3+2+2:
    - רישיון יוענק ל-3 שנים, בהתאם לתכנית עבודה שתוגש עם ההצעה הזוכה.
    - הרישיון יוארך לשנתיים כנגד תכנית עבודה מעודכנת הכוללת התחייבות לקדיחה, במהלך אותן שנתיים.
    - ניתן במקרה הצורך להאריך את הרשיון בשנתיים נוספות, בהתאם לפעילות בעל הרישיון ולפי שיקול דעת הממונה.
    - ככל שיסבור בעל הרישיון כי אין מטרה המצדיקה קדיחה בשטח הרישיון, או שלאחר קדיחה יוחלט שלא לפתח את שטח הרישיון, הרישיון יוחזר למדינה.
- הקריטריונים לניקוד שיינתן למציעים ביחס לכל מקבץ, הם תכנית העבודה שתוגש ע"י המציע (משקל 85%), ומענק חתימה (משקל 15%). לכל מקבץ בלוקים, הותאמו קריטריונים פנימיים לניקוד תכנית העבודה, בהתאם למידע הגאולוגי הקיים ביחס לאותו מקבץ. במקבצים עליהם קיים מידע רב ניתן דגש להתחייבות לקדיחה, בעוד במקבצים שטרם נחקרו לעומק ניתן דגש לביצוע סקרים סייסמיים. בנוסף, יישקל להעניק ניקוד נוסף לשחקנים חדשים ובהתאם ישתנה משקל הניקוד המוענק לתכנית העבודה.

- מתן הרישיונות עפ״י מקבצים נועד לוודא כי הרישיונות הניתנים תואמים את המבנים הגאולוגיים המוערכים בשטח, שאינם תואמים בד״כ את גבולותיו של רישיון בודד, אשר מוגבל עפ״י חוק הנפט ל-400 קמ״ר.
- מציע זוכה יידרש להעמיד ערבות בסיס בגובה של 2.5-5 מיליון דולר, וככל שיתחייב במסגרת הצעתו לבצע קידוח או קידוחים בשטח הרישיונות, יידרש להגיש ערבות נוספת בגובה 5 מיליון דולר בגין כל קידוח.
- עפ״י התייחסות רשות התחרות, שחקנים קיימים רשאים להגיש הצעות במסגרת ההליך, אולם הוחלו מגבלות שמטרתן עידוד התחרות כאשר ניתנת עדיפות לשחקנים חדשים המציעים הצעה לבדם או חוברים לשחקנים קיימים (במועד הדיון לא התקבל עדיין נוסח סופי של ההתייחסות, אולם התקבלה טיוטה סופית של ההתייחסות אשר ההתייחסות הסופית זהה לה.)
- במסמכי ההליך יובהר כי טרם קבלת החלטה בדבר הענקת רישיון לגורם כלשהו, רשאי הממונה לשקול שיקולים של ביטחון המדינה, יחסי חוץ, וקשרי מסחר בינלאומיים וכי הוא רשאי שלא להעניק זכות נפט לאור שיקולים אלה.
- עקרונות סביבתיים:
  - הגז הטבעי המופק בישראל מחליף דלקים מזהמים יותר, הן בשוק המקומי והן בשווקי היצוא. בנוסף, הוא מהווה מקור אנרגיה משלים למקורות אנרגיה מתחדשת עקב השונות הגבוהה בזמינותם.
  - האזורים המשווקים במסגרת ההליך נמצאים במרחק למעלה מ-40 ק״מ מהחוף, ולא כוללים בתי גידול רגישים, עפ״י עדכון מפת בתי גידול שבוצע בחודשים האחרונים.
  - מכל מקום, במסגרת הענקת רישיון החיפוש ולאחריו במתן אישורים לביצוע סקרים, לקדיחה ולהקמת תשתיות, מבקשי רישיון החיפוש ייודעו בדבר רגישות בתי הגידול המצויים בתחום הרישיון ככל שקיימים, על המגבלות האפשריות על רמת הפיתוח שתתאפשר, על אמצעים והפעולות שיידרשו לנקוט בהם ועל המגבלות שיוטלו לצורך שימור בתי הגידול.
  - לצד ההערכה המבוססת על הסא״ס כי בשטחים המשווקים במסגרת ההליך לא קיימים בתי גידול רגישים, קיימים אמצעי זהירות נוספים שמטרתם לוודא מניעת פגיעה בבתי גידול רגישים. במסגרת התנאים לאישור קדיחה נדרש מבעל רישיון לבצע סקר רקע מקדים, שמטרתו לוודא שאין בתי גידול רגישים במרחב המתוכנן לקידוח החיפוש, להכין מסמך סביבתי שאישורו נסמך על חוות דעת היחידה להגנת הסביבה הימית במשרד להגנת הסביבה, וכן לקבל היתר הזרמה לים, היתר רעלים ולקבל אישור לתכנית חירום מפעלית. אישורים והיתרים אלה נמצאים בסמכות הבלעדית של המשרד להגנת הסביבה.
- לחומר שהועבר לעיון חברי המועצה צורפו שני מכתבים מטעם החברה להגנת הטבע ועמותת אדם טבע ודין המייצגים את עמדתם ביחס להליך. מצ״ב בנוסף תשובות המשרד לחברה להגנת הטבע.

<u>דיון</u>:

- לשאלה בנושא מאגרים חוצי גבולות, צוין כי [redacted], וכן כי במסמכי ההליך מעוגנות הוראות כלליות הנוגעות לאזורים סמוכי גבול וכן הוראות ספציפיות ביחס להסכמים עם לבנון וקפריסין.
- צוין כי הבלוקים המשווקים במסגרת ההליך נבחרו בתהליך מקצועי בסיוע חברת ייעוץ וקיימות בהם עשרות מטרות פוטנציאליות, שחלקן כבר אותרו בידי מפעילים קודמים. מעריכים כי עשויה להימצא במסגרת ההליך כמות כוללת של [redacted].
- כחלק ממסקנות הסא״ס הוחרגו ולא ייפתחו להגשת הצעות במסגרת ההליך הנוכחי שטחים שיש בהם פוטנציאל למציאת גז אך הם רגישים מבחינה סביבתית וקרובים יותר לחוף – במרחק של פחות מ-7 ק״מ.
- הובהר כי תקנות הנפט (עקרונות פעולה לחיפושי נפט והפקתו בים), תשע״ז-2016 (״תקנות מפעילים״) קובעות תנאי סף גבוהים יחסית הן למפעיל והן לקבוצה כולה, מבחינת יכולת מקצועית וכלכלית. מנגנון הניקוד במקרה שתהיה יותר מהצעה אחת מדגיש את תכנית העבודה שתוגש – סקרים וקידוחים (בהתאם למידת הבשלות של החומר הקיים בנוגע למקבץ).
- כלקח מההליך השני, הוחלט לאפשר בתנאים מסוימים השתתפות של חברות מקומיות המחזיקות בחלק מחזקה קיימת, בעדיפות משמעותית לחברה המביאה מפעיל חדש או שחקן חדש המחזיק ב-50% ומעלה. כמו כן נשקל להעניק ניקוד נוסף לשחקן חדש.
- [redacted] ציין כי היה מקום לתת לנציגי החברה להגנת הטבע להביא את טיעוניהם בפני המועצה. הוא הציג את עמדת המשרד להגנ״ס בשלוש נקודות:

1. כל גז שיימצא מיועד לייצוא ואינו לשוק מקומי כלל ועיקר, לכן תזמון ההליך אינו תואם את התחזיות הצפויות לירידת חשיבותו של הגז בשוק העולמי ולכן יש להבהיר את אפשרויות הייצוא של גז שיימצא במסגרת ההליך ואת העלות למדינה של הקמת תשתיות ייצוא. (ר׳ תשובת המשרד לעניין זה בהמשך – הגז מיועד הן למשק המקומי והן לייצוא)
2. ידוע לנו מעט מאוד על המערכות האקולוגיות בעומק הים ובאזורים המוצעים למכרז. זוהי חובת המדינה כנהוג בכל המדינות המפותחות וזאת בנוסף לחובות על המפעילים. לכן חובה לעדכן ולהרחיב את הסקר האסטרטגי הסביבתי (סא״ס) לארבעת המקבצים טרום ההליך, כדי לוודא שלא קיימים אזורים רגישים.
3. לא סביר כלל להמליץ על הרחבת פעילות לחיפוש והפקת גז ללא מתן מענה מקביל באמצעים לזרוע של המשרד להגנת הסביבה האמונה על הפיקוח וההיערכות לסיכונים נוספים כאלו.

- [redacted] הוסיף שלשיטתם יש להמתין לממשלה החדשה ולתת מענה הוליסטי לאתגרים שיוצר ההליך.

- [redacted] הציג את עמדת משרד האנרגיה שלגז טבעי יש הרבה תועלות סביבתיות בהפחתת מזהמי אוויר ופליטות גזי חממה. תכנית הניטור הלאומית כוללת גם את האזורים המרוחקים מהחוף, וכל הממצאים מצביעים על כך שהים העמוק הוא אחיד מבחינת בתי גידול, ולהערכת המשרד לא מצויים אזורים רגישים באזורים המשווקים במסגרת ההליך. האזור מוגדר כאזור חדש לחיפוש ולכן טרם קידוח מבצעים סקר רקע כדי לוודא שהנחות הבסיס של הסא״ס מתקיימות ושלא קיימים במרחב הזה בתי גידול רגישים. במידה ומתגלה אזור רגיש, המגבלות למניעת פגיעה בבתי גידול רגישים חלות על בעל הזכות ומשנים את מיקום הקידוח כפי שכבר קרה בעבר. הסקר האסטרטגי הסביבתי לחיפוש ולהפקת גז טבעי מכסה את המרחבים שמוצעים לשיווק, מתעדכן באופן שוטף ותוצאות הניטור הלאומי שבוצע בשיתוף פעולה עם המשרד להגנ״ס תומכות בהנחות הבסיס שלו. סקר הרקע שמבוצע לפני אישור הקידחה נותן מענה מספק למניעת פגיעה בבתי גידול רגישים במידה ויתגלו במהלך הבדיקות המקדימות. בנוסף, השטח המופר בעקבות קידוח הוא מצומצם ביותר ומשתרע על רדיוס של כמה מאות מטרים בודדים. להרחבה ראו תשובת המשרד לחברה להגנת הטבע שנזכרה לעיל, וכן:
    1. פירוט המידע שהצטבר בסא״ס ועדכוניו בשנים 2016-2021
    2. סא״ס 2016 – דו״ח סופי
    3. עדכון ראשון לסא״ס (2018)
    4. עדכון שני לסא״ס (2020)
    5. עדכון בתי גידול (2021)
- [redacted] הציגו כי בעולם יש ביקוש לגז טבעי נוסף, ולכן נושא זה צוין במזכר ההבנות המשולש בין ישראל, מצרים והאיחוד האירופאי. בנוסף, בהתאם להערכות שקדמו למשבר האנרגיה, לפיהן תמהיל מקורות האנרגיה העולמי בשנת 2050 עדיין יכלול גז טבעי בשימושיו השונים, וודאי בישראל ובאזורים הסמוכים לה, יהיה ככל הנראה צורך וביקוש לגז הטבעי מספר עשורים קדימה. הודגש כי ההשקעות הנחוצות הן של גורמים פרטיים, וכי לעניין השימוש בגז הטבעי בישראל, המשרד מקדם גם יישומים מופחתי פליטות כגון תפיסת והטמנת פחמן וייצור מימן ״כחול״ (הנוצר מגז טבעי תוך לכידת והטמנת הפחמן הנוצר מהתהליך). לבסוף יש לציין כי במידה ויתגלה גז במסגרת ההליך, הוא עשוי לשמש הן לצרכי המשק המקומי והן לצרכי ייצוא, והכל בכפוף למדיניות הייצוא הקבועה בהחלטות ממשלה.
- [redacted] הציג את עמדת משרד האוצר לפיה קיימת מדיניות ייצוא אשר נועדה לאזן את צרכי השוק המקומי עם התרומה הכלכלית של הייצוא למשק. צוין כי עקב העובדה שמדובר ביוזמה והשקעה של השוק הפרטי, לא יתרחשו מאמצי חיפוש והפקה ללא כלכליות. יש מקום לתת עדיפות לשחקן חדש גם בניקוד ולא רק בתנאי הסף.

המלצה:

- להמליץ בפני שרת האנרגיה לפתוח את הבלוקים הבאים באזורים לחיפוש, בהתאם לסמכותה לפי סעיף 5 לחוק הנפט:
  - ○ קטע מתוך בלוקים 60 ו-65 (חלק מ"מקבץ E") – יתר שטחי המקבץ נפתחו בעבר[1]
  - ○ 27, 28, 36, 37, 70, 74 ("מקבץ G")
  - ○ 9, 10, 17, 18, 73 ("מקבץ H")
  - ○ 4, 5, 6, 7, 8, 11 ("מקבץ I")
- להמליץ בפני שרת האנרגיה להעמיד את שטחי הבלוקים הבאים לתחרות, בהתאם לסמכותה לפי סעיף 15א לחוק הנפט:
  - ○ 54, 60, 65 ("מקבץ E")
  - ○ 27, 28, 36, 37, 70, 74 ("מקבץ G")
  - ○ 9, 10, 17, 18, 73 ("מקבץ H")
  - ○ 4, 5, 6, 7, 8, 11 ("מקבץ I")

כל זאת, במסגרת ההליך התחרותי הרביעי שבנדון, ובהתאם לעקרונות ההליך אשר הוצגו בפני המועצה.

ההמלצה אושרה ברוב של חמישה קולות בעד מול שלושה קולות נגד.

חברי המועצה מבקשים להמליץ לשרת האנרגיה להמשיך ולהרחיב את ביצוע הסקר האסטרטגי הסביבתי לצורך העמקת הידע הסביבתי הנוגע לשטח הימי של מדינת ישראל.

רשם: שגיא גנות

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[1] ההמלצה בנוגע למקטע ספציפי זה (כ-13 קמ"ר) נשמטה בטעות מהחומר שהוצג למועצה ולא נדונה במהלך הדיון. לאחר הבהרת הנושא, פנה הממונה ביום 8.12.22 לחברי המועצה לקבלת אישורם לתיקון. במענה אישרו שבעת חברי המועצה באמצעות דוא"ל את התיקון הטכני ואת הכללת ההמלצה בפרוטוקול ובהמלצות המועצה. יודגש כי האישור הוא לתיקון ההמלצה בלבד ואין הדבר משנה את תוצאות ההצבעה אודותיה.

נספח 5

העתק ממסכי החליך התחרותי

עמ' 114

נספח 5

State of Israel

Ministry of Energy and Infrastructure

Call for Bids

4th Offshore
Bidding Round

2022

Natural Resources Administration

7 Bank Israel St., PO Box 36148

Jerusalem, 9195021

Phone: +972 74 7681569

energy-sea.gov.il

TABLE OF CONTENTS

1. INTRODUCTION

1.1. The Ministry of Energy and Infrastructure of the State of Israel (**the Ministry**) invites bids for certain defined areas (**the Zones**) in the Israeli Mediterranean offshore area to be granted under the Petroleum Law 5712-1952 (**the Law**) including regulations and guidelines promulgated thereunder, through this 4th Offshore Bidding Round (**OBR4**).

a. The Ministry is responsible for the management and stewardship of Israel's petroleum resources.

b. The Natural Resources Administration is the unit of the Ministry charged with managing all aspects related to the award of licences to participate in the upstream petroleum sector.

c. OBR4 is administered by the Petroleum Commissioner (**the Commissioner**).

1.2. This Call for Bids (CFB) is published pursuant to the Law, the Petroleum Regulations 5713-1953 and the Petroleum Regulations (Principles of Operation for Offshore Petroleum Exploration and Production) 5777-2016 (together: **the Regulations**).

a. This CFB describes the offshore areas offered in OBR4, the process for bid submissions, the information required to be submitted with bids, the necessary qualifications for participating companies, bid evaluation criteria, and other information for prospective bidders. Detailed information about the requirements for the licence round are available at **www.energy-sea.gov.il** (4th Offshore Bidding Round).

b. In case of any discrepancy between this CFB and the Law and Regulations, the Law and Regulations will prevail. Before preparing and submitting bids, participating companies should familiarise themselves with Israel's regulatory regime for the allocation, management and regulation of rights to explore and produce petroleum, including any legislation that may apply to petroleum rights and right holders and any applicable regulation.

c. This CFB may be updated from time to time and an updated CFB will be published prior to the deadline for the submission of bids.

d. Mandatory Tenders Law 5752-1992 does not apply to this CFB, and this CFB shall not be regarded as a Tender under said law.

1.3. The timetable below highlights the main coming events of this 4th Offshore Bidding Round 2022. This table is indicative only and the Commissioner may change any of these dates.

Event	**Date**
Publication of Initial Call For Bids	December 13, 2022
Data Packages Available	December 13, 2022
Prequalification of Operators	From February 1, 2023
Submission of Letters of Interest (All Companies)	By February 1, 2023
End of Q&A	March 31, 2023
Publication of Updated Call For Bids & Opening Date for Submission of Bids	June 6, 2023
Closing Date for Submission of Bids	July 16, 2023 14:00 (IL time)
Estimated Date for Announcement of Successful Bids	Fall 2023
Execution of Licenses	TBD

1.4 In order to participate in OBR4, a company wishing to bid as an operator must have pre-qualified individually. The qualifications required for participating in OBR4 as an operator are detailed in Schedule 4.

1.5 All activities in a Zone must be conducted by an entity that qualifies as an operator, which has the minimum experience and capability requirements outlined in Schedule 4, all in accordance with the principles set out in the Petroleum Regulations (Principles of Operation for Offshore Petroleum Exploration and Production) 5777-2016 (the **Offshore Regulations**). In case of a bidder that is a consortium, one of its members that is the proposed operator must comply with the experience and capability requirements outlined in Schedule 4 and must hold at least a 25% interest in the consortium. Holding a

25% interest in the consortium means holding 25% of the rights and obligations therein specified in Article 5(a)(2) of the Offshore Regulations.

1.6 Bids may be submitted from June 6, 2023. The deadline for the submission of bids is **July 16, 2023, 14:00 (IL time)** (the **Closing Date**).

1.7 Bids must contain all the forms and documents listed in Schedules 3 to 5, completed and signed, including the proposed work programme and signature bonus for each bid.

1.8 Bids for each Zone will be evaluated separately, and separate bids should be submitted for each Zone.

1.9 In order to participate in OBR4 a company must pay US$ 50,000 participation fee and sign a Confidentiality Undertaking in the form included in Schedule 1.5. A company may pay the Participation Fee in its own name, and subsequently submit the bid using an affiliate company, subject to a written notice by the former, it being made clear that each paid Participation Fee applies to a single bidder/consortium member.

1.10 Each of the Zones offered in OBR4 consists of multiple licences and the individual blocks associated therewith as described in Schedule 9 of this CFB. Bids may be submitted only for a Zone, as a whole, and the successful bidder for a Zone will be granted the licences for all the blocks included in the Zone.

1.11 The petroleum licences applicable to the Zones allow for an initial phase of three (3) years, with extensions for two successive periods of two (2) years, subject to the satisfaction of certain conditions. Further, where a discovery made, the Commissioner may extend the term of the licence for such time as will give the licence holder a sufficient period, not exceeding two (2) years, within which to define the petroleum field. The term and phasing of the licences are described in more detail in Article 5 of this CFB.

1.12 The rights and obligations of a licence holder are set out in the relevant legislation, including the licence deed. A model licence of the licences that will be granted following OBR4 (in Hebrew) will be published on the OBR4 website, and a non-binding convenience translation into English of the model licence is included in Schedule 6 (**the Model Licence**).

1.13 A petroleum licence granted following OBR4 will be based on the Model Licence, and the work programme committed by the successful bidder.

2. BIDDING ROUND PROCESS

2.1. Companies that are interested in participating in OBR4 are encouraged, but not obliged, to submit a Letter of Interest (LOI) to the Ministry via the e-mail address sagig@energy.gov.il, by **February 1, 2023**. A form of LOI is included in Schedule 10.

2.2. In order to submit a bid and to be awarded for a data package, a company must pay a Participation Fee of US$ 50,000. The payment instructions are specified in Article 9.2 below. A company may pay the Participation Fee in its own name, and subsequently submit the bid using an affiliate company, subject to a written notice by the former, it being made clear that each paid Participation Fee applies to a single bidder/consortium member.

2.3. Companies should be aware that the Offshore Regulations include terms and conditions that refer to the operator (financial and technical qualifications) and to the financial capacity of the bidder. The Offshore Regulations (Hebrew version) can be found in this **link** and an unofficial English translation of the Offshore Regulations can be found in this **link**. Please note that:

2.4. Each company seeking to qualify as an operator must submit to the Ministry the Financial Competence Forms of Schedule 4 and Experience Requirements Forms of Schedule 4, as appropriate.

   a) Applications to qualify as an operator may be submitted at any time up to and including the Closing Date.

   b) Where an application to qualify as an operator is submitted sufficiently in advance of bidding (as determined by the Ministry), the Ministry will review such applications and advise the applicant whether it has qualified, and where appropriate, allow for the re-submission of the application with such corrections or supplemental information as the Ministry may have requested.

   c) Where an application to qualify as an operator is submitted less than seven (7) business days before bidding, or with bids at the Closing Date, the Ministry's review of the application and determination of qualification will be made in advance of bid evaluations. In such event, if the proposed operator is determined not to qualify, the bidder will be notified and the bid returned unopened to the bidder.

   d) The Commissioner may exercise his discretionary powers under Regulations 3(f), 6(b), 7(c), and 10(d) of the Offshore Regulations.

   e) The Ministry will consider applications for the pre-qualification of operators from February 1, 2023.

f) The Ministry will not publish the identity of companies submitting applications to qualify as an operator, except in the context of announcing the successful bidder and subject to Israeli law. This does not preclude the transfer of information regarding the identity of companies submitting applications, as specified in Articles 12.4 and 12.5.

g) The pre-qualification of an operator may be cancelled (i) in the event of a declaration of bankruptcy, dissolution or sale of the company, (ii) a material adverse change in the circumstances of the company, (iii) a material misrepresentation by the company, (iv) a failure by the company to comply with the requirements of the bidding process, or (v) in the circumstances contemplated by Regulation 11 of the Offshore Regulations.

2.5. A bidder must also demonstrate that it has adequate financial competence in accordance with the requirements of Schedule 4. Any bid submitted should include all documents necessary to demonstrate the financial competence of the bidder.

2.6. Bids must be submitted in forms included in Schedules 3 to 5 and must be delivered in a sealed envelope marked 'Confidential: 4th OFFSHORE BID ROUND 2022: ZONE #'.

2.7. Bids must be submitted no later than the Closing Date, at the following address:

4th OFFSHORE BIDDING ROUND 2022
The Petroleum Commissioner Office
Natural Resources Administration
Ministry of Energy and Infrastructure
Generi #2 Building, Floor -1, Box #1
7 Bank Israel St.
Jerusalem, Israel

2.8. Bids should be submitted in both hardcopy (1 copy) and digital, text-searchable format (1 copy). The digital copy should be stored on a CD-ROM, DVD-ROM or memory stick, or other commonly used electronic media compatible with a Windows operating system.

2.9. Bids received later than the Closing Date will not be accepted.

2.10. Each Bid must include a sealed envelope containing:

i. completed registration forms (Schedule 1) completed and signed by the bidder or, when in consortium, by each of the consortium members ;

ii. a completed bid form (Schedule 3), signed by the bidder or, when in consortium, by each of the consortium members;

iii. detailed work programme according to the requirements set out in Schedule 5.

iv. A bid bond as detailed at Article 9.3 below.

v. Documentation establishing that the bidder (and in the case of a consortium, each member of the consortium) has paid the participation fee of US$ 50,000.

2.11. All bids should fully comply with this CFB. Any bid that does not comply with the terms and conditions of this CFB may not be accepted. If a bid is not accepted, the bidder will be notified.

3. THE ZONES OFFERED IN OBR4

3.1. Each of the Zones consists of multiple licences as described in Schedule 9 of this CFB. In respect of a Zone, bids must be submitted for the Zone, as a whole, and the successful bidder will be granted licences for all the blocks included in the Zone. For OBR4, the Ministry has created multi-block, multi-licence Zones to provide companies with an opportunity to explore larger areas with various types of potential targets, while complying with the requirement in the Law limiting the size of licence area to 400 km^2 each.

3.2. A bidder may bid for more than one of the Zones individually or as a part of a consortium.

3.3. Each company, whether applying individually or as part of a consortium, may be part of a successful bid and be granted licences for a maximum of two (2) Zones. For the purpose of applying this restriction, a company will be deemed the grantee of a licence awarded to any consortium in which the company holds more than a twenty-five per cent (25%) interest in the consortium. Holding more than a twenty-five per cent (25%) interest in the consortium means holding more than a twenty-five per cent (25%) as specified in Article 5(a)(2) of the Offshore Regulations.

3.4. A map indicating the location and graticular area of each one of the Zones is presented in Schedule 9. This map, and all maps published as part of OBR4, are provided for illustration only. In case any of these maps contradicts the coordinates published in the official government gazette ("Rashumot") under Section 15A of the Petroleum Law, the coordinates shall prevail.

3.5. By submitting its bid, the bidder acknowledges that the Zones are adjacent to the outer limits of Israel's exclusive economic zone ("EEZ"), which has not yet been fully delimited. In light of these facts, the bidder acknowledges the information and agrees to comply with the obligations as set forth in Article 17 of the Model Licence, which forms an integral part of the terms and conditions for submitting a bid under this CFB, as applicable to a bidder, whether or not the bid is successful and/or a licence has been granted, and agrees to waive any future claim or demand in this regard. The binding Hebrew version of the Model Licence will be published on the OBR4 website, and a non-binding English convenience translation is presented in Schedule 6.

4. STRATEGIC ENVIRONMENTAL ASSESSMENT

4.1. A Strategic Environmental Assessment (SEA) was completed for all offshore areas in 2016, and the last biannual update was made in 2020.

4.2. The blocks included in the Zones offered in OBR4 were delineated in line with the SEA conclusions, which consider these areas to be of low environmental vulnerability.

4.3. A summary of the SEA (in English) and a full report (in Hebrew) are available on the OBR4 website at this **link**. Bidders should familiarize themselves with the summary as part of their bidding preparations.

4.4. The information and materials provided by the Ministry regarding the SEA and its conclusions are brought to the bidders' attention for informational purposes only, and the bidders acknowledge and agree that the Ministry is not responsible or liable for the accuracy or completeness of the information provided.

5. TERMS OF LICENCES AND LEASES

5.1. According to Section 13 of the Law, a petroleum licence confers upon the holder, subject to the provisions of the Law and the regulations promulgated thereunder, *inter alia*:

a) the right to explore for petroleum in the licenced area;

b) the exclusive right to conduct exploration and development drilling in the licenced area and to produce petroleum therefrom; and

c) the right to obtain a lease after having made a discovery in the licenced area.

5.2. A petroleum licence will have a term of three (3) years, with extensions for two successive periods of two (2) years, subject to the satisfaction of certain conditions, as follows:

- An initial phase (the **Initial Phase**) of three (3) years, during which the licence holder is obligated to perform the work programme submitted as a part of its bid.

  i. The Initial Phase has a first decision point, no later than three (3) months prior to the expiry of the Initial Phase (the **First Decision Point**). By that time, the licence holder has to notify the Commissioner whether it undertakes to drill a well or wells, and in which of the licences within the Zone is the planned well located, or perform other exploratory work in the licences during the ensuing two (2) year period (the **Second Phase**).

  ii. If a licence holder has not drilled at least one (1) exploration well in the Initial Phase pursuant to its work programme commitment, and has not, by the end of the initial phase, committed to drill at least one (1) exploration well within one of the licences in the Zone in the Second Phase, all licences within the Zone will automatically terminate at the end of the Initial Phase.

iii. If a licence holder has drilled an exploration well or wells in the Initial Phase in accordance with its work programme commitment, or committed to drill at least one (1) exploration well within one of the undrilled licences in the Zone during the Second Phase, the licence holder will retain any licence on which an exploration well has been drilled or committed, as the case may be.

iv. The licence holder may retain other licences within the Zone on which an exploratory well has not been drilled, or committed to, by committing to perform an additional work programme in the Second Phase. Such additional work programme must be submitted by the licence holder to the Commissioner for approval prior to the First Decision Point. The Commissioner will base his approval or rejection of the additional work programme on whether the additional work programme was prepared diligently in accordance with good industry practice and promotes the understanding of the retained licences or the Zone as a whole. The Commissioner may reject an additional work programme in whole, or in respect of any licence, in the exercise of his discretion and such decision will be final. Any such licence with no commitment for exploration activity during the Second Phase, approved by the commissioner, will automatically terminate at the end of the Initial Phase.

- An extension phase of two (2) years (the Second Phase) during which the licence holder is obligated to perform the exploratory drilling or other exploration commitments made in respect of the Second Phase

i. The Second Phase has a second decision point, no later than 3 months prior to the expiry of the Second Phase (the **Second Decision Point**). By that time, the licence holder has to notify the Commissioner whether it undertakes to drill a well in undrilled licences in the Zone during the ensuing 2-year period (the **Third Phase**).

ii. Any undrilled licence with no commitment for drilling during the Third Phase will automatically terminate at the end of the Second Phase.

- A further extension phase of two (2) years (the **Third Phase**) during which the licence holder is obligated to perform the exploratory drilling commitments made in respect of the Third Phase.
- In addition to the phases described above, where the licence holder has made a discovery in the licenced area, the Commissioner may extend the term of

the licence for such time as will give the licence holder a sufficient period, not exceeding two (2) years, within which to define the petroleum field.

- Extensions of the term into the Second Phase, Third Phase or the additional two (2) year period referenced above are determined by the Commissioner in accordance with the requirements of the licence and the Law.

5.3. A licence holder that finds hydrocarbons within a drilled well in the licenced area, is entitled, subject to the conditions of the licence and of the Law, and any other relevant law, to be granted a lease for 30 years, extendable, subject to the conditions of Section 29 of the Law, for an additional period of 20 years, provided that:

a) the Commissioner approves the Discovery of a hydrocarbon field;

b) the licence holder has applied for a lease in accordance with the Law and its regulations during the period of the licence; and

c) the lease is in respect of any area chosen by the licence holder within the licence area and up to 250 km^2, subject to Section 27 of the Law.

d) where an approved Discovery(s) may extend beyond the licence area, the licence holder may apply to the Ministry to have the boundaries of the development area drawn to accommodate the approved Discovery(s) according to Article 49 of the Law. In such event, whether and how the boundaries are drawn shall be determined by the Ministry in its discretion.

5.4. A lease confers upon the lease holder the exclusive right to explore for and produce petroleum in the area of the lease so long as the lease is in force.

5.5. The lease will be subject to the conditions stipulated in the Law and the regulations promulgated thereunder, the licence and the lease deed and its conditions. Upon the granting thereof, the licence will expire.

6. COMMUNICATIONS

6.1 Potential bidders for OBR4 may submit questions by means of the Questions Form included in Schedule 2, by email to sagig@energy.gov.il by the date mentioned in the timetable in Article 1.3 above.

6.2 The Ministry is not obliged to answer any question.

6.3 Questions that the Ministry decides to answer, and the responses to such questions, will be posted on the OBR4 website. The identity of the companies asking the questions will remain anonymous.

6.4 Should there be variations or modifications to the CFB, an updated CFB will be posted on the OBR4 website.

6.5 Bidders will be notified before any public statements are made about the outcome of their bids. Details of unsuccessful bidders and the bids themselves will not be made public, unless it is legally required, or otherwise disclosed by the bidder itself.

7. WORK PROGRAMME

7.1. Each bid should include a detailed work programme proposed by the bidder, according to the guidelines specified in Schedule 5.

7.2. The proposed work programme should include details of the exploration work which the bidder proposes to carry out during the Initial Phase of the licence.

7.3. A summary of the proposed work programme should be submitted in a form included in Schedule 3.1. Except with respect to the general impression criterion, bids will be scored on the basis of the proposed work programme summary included in Schedule 3.1, and in case of any discrepancy between the detailed work programme and the summary, the latter will prevail.

7.4. The bidder may propose to carry out an exploration drilling programme during the Initial Phase of the licence. In such case, details of the planned exploration well should be included in the proposed work programme as prescribed in Schedule 5.

7.5. The work programme committed to in the successful bid will form an integral part of the licence, and the licence holder will be obliged to carry it out diligently, and according to good oil field practices.

8. DATA PACKAGE

8.1. As part of OBR4, a data package has been prepared with technical evaluation material relating to the Zones.

8.2. The data package includes location maps, geological reports, well files and logs, seismic, gravimetric, magnetic data and general information, as described in Schedule 8. The data package includes materials for all the Zones; however, type, quantity and quality of data may vary between Zones.

8.3. Companies that have paid the participation fee and signed the Confidentiality Undertaking may receive the data package. To obtain the data package, companies should contact Mr. Sagi Ganot at sagig@energy.gov.il and provide proof of payment and a signed Confidentiality Undertaking in the form included in Schedule 1.5 (a MS WORD version of the Confidentiality Undertaking can be found also at OBR4 website at this **link**). Following the submission of the said documents the applicant will be contacted by a Ministry representative and will receive directions regarding access to the data package.

8.4. The Ministry is not responsible or liable for the accuracy or completeness of the information provided in the data package.

8.5. Data included in the data package is provided to participating companies for purposes of their potential or actual participation in OBR4 and submission of bids only. It may not be sold, published or used for any purpose other than participation in OBR4.

8.6. Additional data not included in the data package may be acquired via the PRIME National Database for Oil and Natural Gas, which is available for all users, regardless of participation in OBR4. The address of the PRIME website is https://prime.energy.gov.il/.

9. PAYMENT OF PARTICIPATION FEE, GUARANTEES AND SIGNATURE BONUS

9.1. Each company must pay a participation fee of US$ 50,000 to participate in OBR4.

9.2. The payment shall be made to the Ministry of Energy and Infrastructure by a bank transfer as follows:

<u>Correspondent bank:</u>
Federal Reserve Bank of New York, New York
Swift code: FRNYUS33
ABA/FW: 0210-0120-8
Acc: 021084393 ISRAEA

<u>Final Beneficiary Bank:</u>
Bank of Israel, Jerusalem
Swift code: ISRAILIJ
Beneficiary Name: MINISTRY OF ENERGY.
Beneficiary IBAN: IL700990011317120084582
Held in Bank of Israel's books

9.3. A separate bid bond in the amount of **<u>US$ 70,000</u>** must be submitted with each Bid for each Zone. The bid bond shall be an independent payment obligation, unconditional and irrevocable, in the form prescribed in <u>Schedule 7.1</u>. The bond shall be **<u>valid until December 31, 2023</u>**, and extendable by an additional 120 days upon a notice by the Commissioner. The issuer of the bond must be a commercial bank, whether domestic or foreign, provided that such bank is licenced to operate in Israel. In the event of postponement of the award of licences in OBR4, bidders will be requested to extend the bid bond period.

9.4. The Bid Bond may be drawn by the Ministry in the event that:

  a. the successful bidder withdraws its bid after the Closing Date;

  b. the successful bidder fails to meet the requirements following notice of award, such as payment of the signature bonus, submission of the licence guarantee and payment of the licence fees according to the conditions and dates as set forth in this CFB;

  c. the successful bidder is found to have withheld material information or provided misleading or incorrect information;

9.5. Each successful bidder will be required to provide an unconditional and irrevocable bank guarantees according to the Law, the Commissioner's Guidelines for Providing Securities in Relation to Petroleum Rights, and the licence terms.

a. The successful bidder must provide a licence guarantee, in the form prescribed in Schedule 7.2, within 60 days of being notified that its bid was successful, as a condition for the issuance of the petroleum licence.

b. The bidder will be required to provide a guarantee of US$ 2,500,000 for the first block and US$ 500,000 for each additional block within the Zone. For each one of the zones G and I, the amount of the guarantee will be US$ 5,000,000, for Zone H the amount of the guarantee will be US$ 4,500,000 and for Zone E the amount of the guarantee will be US$ 3,500,000.

   Following a relinquishment of a licence, the licence holder will be entitled to reduce the licence guarantee in the amount of US$ 500,000 per licence assuming that the Ministry is not entitled to make a draw on the guarantee(s) at the time of relinquishment.

c. In addition to the guarantee provided for in Article 9.5(b), a guarantee of US$ 5,000,000 per well shall be required in order to ensure a commitment to drill exploration well(s) during the first 3-year period by a successful bidder, as included in the Work Programme submitted as part of the bid. Such a guarantee shall be valid until replaced by a guarantee given ahead of actual drilling, in accordance with Section 2 of the Commissioner's Guidelines for Providing Securities in Relation to Petroleum Rights. Either of the two guarantees may be forfeit if the commitment to drill according to the Work Programme is not fulfilled, without derogating from other causes for forfeiture included in the Guidelines.

9.6. The bank guarantee shall be issued by a commercial bank, whether domestic or foreign, provided that such bank is licenced to operate in Israel.

9.7. Bidders submitting a bid as a consortium may submit separate bid bonds and/or bank guarantees, representing their proportionate shares of the required guarantee, as provided for in Articles 9.3 and 9.5. For example, if a consortium has three members holding 50%, 30% and 20%, they may submit bid bonds as specified under Article 9.5 in the amount of US$ 35,000, US$ 21,000 and US$ 14,000 respectively, it being made clear that the total amount of the bid bonds and/or bank guarantees must equal the amount required for the entire bid.

9.8. A guarantee will be released at the expiration of validity stated therein assuming no claims are pending in respect of the guarantee.

9.9. A successful bidder will pay the signature bonus included as part of its bid, which will be not less than US$ 400,000 per Zone, within 60 days of being notified that its bid was successful.

9.10. Failure to pay the signature bonus or submit the bank guarantee within 60-days period from the notice that the bidder won the bid will result in disqualification of the bid, and forfeiture of the bid bond.

10.CONSORTIUM

10.1. Companies will be free to form bidding consortia up to the Closing Date. The following restrictions shall apply:

a. Each consortium must designate as operator a company qualified as such;

b. The operator must have a minimum 25% interest in the consortium as specified in Article 5(a)(2) of the Offshore Regulations);

c. The members of a consortium should be the same in all bids; provided that an operator can participate in different consortia in order to make offers for different Zones. No company, or any of its affiliates or otherwise related companies, will be permitted to make more than one offer for the same Zone, whether individually or in consortia; and

d. In the event a company wishes to withdraw from a consortium following submission of a successful bid but before execution of the licences, the remaining consortium member(s) must assume the obligations of the withdrawing company. In no circumstances will new companies be permitted into the consortium during this period.

In case of any discrepancy between this Article and the Offshore Regulations, the Offshore Regulations will prevail.

10.2. Under the Law for Promotion of Competition and Reduction of Concentration 5774-2013 (the Reduction of Concentration Law) the granting of petroleum licences to entities which are included in the List of Concentrated Entities (the List)[1] requires the regulator's consideration, after consultation with the Committee to Reduce Concentration, of the possible effects of such granting on the concentration of the Israeli market. This consideration may cause a bid to be disregarded, as provided for in Article 12.11(g)(ii).

10.3. Potential bidders included in the List may apply, as soon as possible during the bidding term and **no later than February 1, 2023**, to the Commissioner, via the e-mail address sagig@energy.gov.il, regarding their qualification to participate as bidders in OBR4, and the Commissioner will consult with the Committee to Reduce Concentration. Best efforts will be made by the Committee to Reduce Concentration to reply to the Commissioner within 30 days on the result of the application.

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[1] https://www.gov.il/BlobFolder/unit/centralization_decrease_committee/he/Vaadot_ahchud_CentralizationDecreaseCommittee_GormimRikuzim_List-new.pdf Updated August 2022

10.4. Bidders should take into account the schedule of this consultation procedure as part of the preparation of the bid. Any bidder that is included in the List and which failed to receive the aforementioned approval may be disqualified.

11.BIDS AND THE BID EVALUATION PROCESS

11.1. Bids will only be evaluated after the Closing Date.

11.2. All bids must comply with the requirements of this CFB and its schedules.

11.3. Bids will be evaluated on the basis of the following criteria:

ZONE G

Component		Determining criteria		Weight (%)
Work programme	Exploration well	Number of exploration wells the bidder commits to drill during the first 3-year period	70	**85%**
	New 3D seismic survey	Area (km²)	20	
	New 2D seismic survey	Length (km)	0	
	3D reprocessing	Area (km²)	7	
	2D reprocessing	Length (km)	0	
	Other surveys/studies	Estimated total expense (US$)	3	
	New entrants	See Article 11.8(c) below	5	
Signature bonus [Not less than US$ 400,000]			100	**15%**

ZONES E AND H

Component		Determining criteria		Weight (%)
Work programme	Exploration well	Number of exploration wells the bidder commits to drill during the first 3-year period	50	**85%**
	New 3D seismic survey	Area (km^2)	30	
	New 2D seismic survey	Length (km)	5	
	3D reprocessing	Area (km^2)	10	
	2D reprocessing	Length (km)	2	
	Other surveys/studies	Estimated total expense (US$)	3	
	New entrants	See Article 11.8(c) below	5	
Signature bonus [Not less than US$ 400,000]			100	**15%**

ZONE I

Component		Determining criteria		Weight (%)
Work programme	New 3D seismic survey	Area (km^2)	65	**85%**
	New 2D seismic survey	Length (km)	25	
	3D reprocessing	Area (km^2)	0	
	2D reprocessing	Length (km)	6	
	Other surveys/studies	Estimated total expense (US$)	4	
	New entrants	See Article 11.8(c) below	5	
Signature bonus [Not less than US$ 400,000]			100	**15%**

11.4. Bids will be scored relatively to the highest proposal for each criterion.

For example: if the highest proposal for signature bonus was US$ 10,000,000 and the second highest proposal for signature bonus was US$ 5,000,000, the bid with the highest proposal will get 100 points and the bid with the second highest proposal will get 50 points (100*5,000,000/10,000,000= 50 points).

11.5. Bids will be ranked in descending order, from the overall highest to the overall lowest.

11.6. A company may bid for more than one of the Zones individually or as a part of a consortium.

11.7.

a. Each company, whether bidding individually or as part of a consortium, may be part of a successful bid and be granted licences for a maximum of two (2) Zones in OBR4. For the purposes of applying this restriction, a company will be deemed the grantee of a licence awarded to any consortium in which the company holds more than a twenty-five per cent (25%) interest in the consortium, in accordance with Article 5(a)(2) of the Offshore Regulations.

b. Following the evaluation of the bids, if the bids submitted by any bidder are determined to be the best bids for more than two Zones, the Zones awarded to the bidder will be determined in accordance with the priority list submitted by the bidder in accordance with <u>Schedule 3.2</u>.

c. If an operator submits bids as a member of more than one consortium, for more than two (2) Zones, it shall submit an Operator Priority Announcement as part of each bid (<u>Schedule 3.3</u>). The operator shall assign a priority for each bid, with the highest-ranking bid marked as 1, and indicate the priority of each bid on its Operator Priority Announcement. If the operator forms part of successful bids for more than two (2) Zones, the bids for the two top-ranked Zones according to the Operator Priority Announcements will be accepted, and the rest will be disregarded. This ranking takes precedence over the consortium's Priority List described in sub-section (b).

11.8.

a. For the purpose of this Article:

   i. A **producing lease holder** will be defined as a company holding an existing interest in <u>a current</u> producing lease under the Petroleum Law.
   ii. A **new entrant** will be defined as a company <u>not</u> currently holding an existing interest in any producing lease.
   iii. A **separate sale arrangement** is defined as an arrangement by which each member of a consortium that has successfully bid for a Zone, and received a licence, is not prevented from selling its share of the natural gas produced from the Zone independently of one or more other members of the consortium.

b. In order to encourage the competition within the domestic natural gas market, the following restrictions shall apply for holders of interests in a producing lease:
   i. One or more producing lease holders may submit a bid, individually or as part of a consortium, provided that if two or more producing lease holders hold an existing interest in different producing fields,

they may not form part of the same consortium. However, the bid may not be declared successful unless **one** of the following conditions is met:

    a) A new entrant has a share of 50% or more in the bid; or
    b) A new entrant is defined as the operator by the consortium; or
    c) No additional bids are submitted for the relevant Zone, and, in case of a consortium, a separate sale arrangement is concluded; or
    d) The only additional bid or bids are made by one or more existing producing lease holders, and, in case of a consortium, a separate sale arrangement is concluded.

  ii. A producing lease holder that holds an existing interest in 50% or more of the number of producing leases under the Petroleum Law will be subject to additional restrictions that result from these holdings.

c. A bid submitted by a single new entrant, or a bid submitted by a consortium in which one or more new entrants hold a cumulative interest of 90% or more, will receive five (5) additional points for the Work Programme score.

11.9. The Commissioner will evaluate the bids and present the evaluation to the Petroleum Council, according to Section 15A of the Law. The Petroleum Council will review the results of the bid evaluation and will make recommendations to the Commissioner, who will then take the final decision on the winning bidders.

11.10.

a. A company submitting a bid, whether individually or as part of a consortium, may indicate in a letter attached to its bid its intention to incorporate an affiliate company (the **Designated Affiliate**) to receive the licences awarded in case of a successful bid.

b. The Designated Affiliate must be:

    i. 100% owned (directly or indirectly) by the bidding company;

    ii. under the control of the bidding company, as defined in Regulation 1 of the Offshore Regulations.

c. Subject to the approval of the Petroleum Council, and provided that all other conditions included in this CFB and in the relevant laws and regulations are met, including the qualification of the Designated Affiliate as an operator if relevant, the bidding company's share of each licence will be granted to the Designated Affiliate in place of the bidding company. The bid bond and/or bank guarantees provided by the bidding company will remain in effect until replaced by equivalent documents signed by the Designated Affiliate.

11.11. The Commissioner, with the Minister's approval, will have the right to disregard a bid in the circumstances specified in Regulation 11 of the Offshore Regulations, i.e, “for reasons of state security, foreign relations or international commercial ties (…) [including] the event that the controlling shareholder in the applicant for the petroleum right or the applicant for authorization as an operator is a foreign country or if there are other special circumstances with respect to which authorization of the application would not benefit the public interest or the energy market in Israel".

The Commissioner reserves the right to consult with the relevant authorities in applying these considerations.

11.12. The Commissioner may exercise his discretionary powers under Regulations 3(f), 6(b), 7(c), and 10(d) of the Offshore Regulations.

11.13. All bidders will be informed about the final outcome of their bids.

11.14. The successful bidder for each Zone will be granted the number of licences as per the number of blocks included in such Zone (i.e. 3 licences for Zone E, 5 licences for Zone G, 4 licences for Zone H, and 6 licences for Zone I).

12. GENERAL CONDITIONS

12.1. By submitting a bid, the bidder warrants and represents that the bid is final and binding and it will not be changed or rescinded after its submission. Bids and any other documents and information submitted by participants will become the property of the Ministry on receipt, and they will not be returned.

12.2. The Ministry will treat all submitted information as confidential and will not disclose any information unless it is required to do so under any law, under the provisions of this CFB, or where the information is in the public domain.

12.3. The Ministry will publish the winning bidders’ names and may publish their environmental due diligence reports. The identity of the bidders that will not be granted licences will not be disclosed except as required by law or under the provisions of this CFB, or if previously disclosed by the bidder itself. Licences issued following the OBR4 will be published on the OBR4 and/or the Ministry's website.

12.4. The Ministry reserves the right to request, in writing, additional information as he deems necessary to carry out professional inquiries regarding any participant in the OBR4, including by contacting third parties.

12.5. The Commissioner may use any information received from participants, bidders or any third party for any purpose he deems fit and at his sole discretion, and he may transfer any such information to any relevant governmental authorities and to any of his consultants or any person acting on his behalf. In addition, the Ministry may engage external experts in the examination of the bids and in carrying out the OBR4 process. Upon registration, participants authorise the release of any and all information submitted by them to all the above mentioned for the aforesaid purpose.

12.6. The Commissioner may communicate in writing with bidders after the Closing Date if and to the extent that their bid requires clarifications.

12.7. If a winning bidder fails to comply with the licence granting requirements, including the submission of the licence guarantee or the payment of the signature bonus, the Commissioner, at his discretion, may grant the licence to the second ranked bidder, all according to Section 15A (c) of the Law.

12.8. The publication of this CFB, including all information included in the CFB or shared as part of the bidding process, is not intended to give rise to or create any representation, undertaking or warranty on behalf of the Ministry, or anyone on its behalf with respect to OBR4. The publication of this CFB is not intended to warrant the initiation, execution or the implementation of OBR4, its scope, its components or any part thereof.

12.9. The Ministry does not represent or warrant that the information contained in this CFB or any other information which is made available to participants is either complete or accurate. The bidder acknowledges and agrees that the Ministry shall not be held responsible or liable in case of any incompleteness or inaccuracy, and waives any claim or demand of any kind in this regard.

12.10. Participation in OBR4 does not and will not provide a participant or any other entity any advantage, nor will it confer upon a participant any right with respect to any future proceedings which will be conducted with respect to the grant of exploration licences, if and to the extent conducted. Participation in the CFB does not and will not constitute or be interpreted as constituting recognition of a bidder or any other entity's eligibility, qualification or competence to participate in any such future proceedings, to the extent conducted.

12.11. The Ministry and the Commissioner reserve the right, at their sole discretion, to:

a) Institute a new CFB and/or other procedure with respect to the grant of offshore exploration licences;

b) institute a different CFB, inviting or not the current participants to take part in such process, or execute any other licencing process they deem appropriate, all subject to and in accordance with the applicable legislation;

c) modify this CFB at any stage prior to the Closing Date. Modifications will be posted on the OBR4 website and will become part of this CFB;

d) cancel OBR4, with respect to all blocks or part of them at any time, including after the Closing Date;

e) accept a bid despite of any minor irregularity or failure of a bidder to comply with the terms and conditions of this CFB;

f) change any date that has been set for this CFB. The date change will be posted on the OBR4 website;

g) cause a bid to be disregarded, *inter alia* under the following circumstances:

  i. in the circumstances specified in Regulation 11 of the Offshore Regulations;

  ii. for reasons pertaining to competition, including in accordance with the Reduction of Concentration Law (see Article 10.2);

  iii. when the winning bidder fails to comply with the licence award requirements;

and in case any of the bids so disregarded is the highest-scoring, to declare successful the next highest-scoring bid, if such a bid exists.

12.12. Participants will not be entitled to any payment for the information provided by them in this process.

12.13. All expenses incurred by a participant or anyone on its behalf will be borne solely by the participant. Participants will not be entitled to any reimbursement or compensation for expenses with respect to their participation in OBR4.

12.14. The Ministry will not be responsible or liable towards a participant or anyone acting on its behalf in connection with OBR4, including in connection with the accuracy or completeness of the information provided, including information contained in the Data Package.

12.15. This CFB is governed by and will be construed in accordance with Israeli law and each participant agrees to submit to the exclusive jurisdiction of the Israeli courts.

SCHEDULE 1 – REGISTRATION FORM

Registration forms shall be submitted in 2 text-searchable PDF files as shown in Schedules 1.1 and 1.2 and 3 scanned PDF files as shown in Schedules 1.3 to 1.5.

[***Note:*** *If the bidder is a consortium, the* registration *form should be completed* ***by each consortium member separately****]*

If the bidder is a body of persons, whether corporate or unincorporated, and a person holds, either directly or indirectly, more than 25 percent of the shares or the voting power or the power of control or the power of appointing directors in that body, within the meaning of these terms in the Petroleum Law, including Article 56 thereof, the same details and documents with respect to such person should be submitted as if he too were a bidder.

Schedule 1.1 – Contact Details

Bidder	
Name	
Tax or ID number	
Date of incorporation	
Country of incorporation	
Nature of incorporation (company, partnership…)	
Corporate purpose	[*as listed in articles of incorporation, memorandum of association or equivalent*]
List of shareholders/partners holding more than 25% in the bidder*	[*List of shareholders/partners or person/group with their respective holdings*]
Address	
Telephone	
Fax	
E-mail	
Website	
* more than 25% of the shares or the voting power or the power of control or the power of appointing directors in that body, within the meaning of these terms in the Petroleum Law, including Article 56 thereof.	
Representative	
Full name	
Job title	
Division\department\unit	
Address	
Telephone	
Fax	
Mobile phone	
E-mail	

Schedule 1.2 – Ownership Chart

Business ownership chart detailing the shareholding structure of the bidder.

If the bidder is a body of persons, whether corporate or unincorporated, and a person holds, either directly or indirectly, more than 25 % of the shares or the voting power or the power of control or the power of appointing directors in that body, within the meaning of these terms in the Petroleum Law, including Article 56 thereof, the same details and documents to such person should be submitted.

Bidder will highlight any entity which shareholding structure contains a shareholder owning more than 25% of the aforesaid rights.

Schedule 1.3 – Payment Receipt

Copy of payment receipt in respect of the participation fee, as prescribed by Articles 8 and 9 of the CFB.

When a bidder is a consortium, receipt of payment should be submitted by each member of the consortium.

Schedule 1.4 – Constitutional Documents

1. Certificate issued by a registrar of companies, or equivalent, with information concerning the participant's incorporation and a current company extract. Certificate should not be dated more than 90 days before its submission. Certificate issued in a language other than English or Hebrew must be accompanied by a notarised translation into English or Hebrew.
2. If a bidder is registered in Israel as a foreign company according to Article 346 of the Companies Law, 5729-1999, a certificate from the Israeli Registrar of Companies confirming said registration.
3. Updated copy of constitutional documents (*i.e.* articles of incorporation, memorandum of association or equivalent). Constitutional documents in a language other than English or Hebrew must be accompanied by a notarised translation into English or Hebrew.
4. If the bidder is a body of persons, whether corporate or unincorporated, and a person holds, either directly or indirectly, more than 25 percent of the shares or the voting power or the power of control or the power of appointing directors in that body, within the meaning of these terms in the Petroleum Law, including Article 56 thereof, the same details and documents to such person should be submitted with respect thereto.

Schedule 1.5 – Confidentiality Undertaking

[When a bidder is a consortium, each member of the consortium should submit receipt of payment].

Executed Confidentiality undertaking by [Name of Company] as a condition to receiving access to data from the Ministry in connection with the 4th Offshore Bidding Round conducted by the Ministry of Energy and Infrastructure of the State of Israel

[***note:*** *text to be printed in full, signed, certified and scanned*]

The undersigned, ___________, (hereinafter: the "**Receiving Party**"), hereby confirms and undertakes towards the State of Israel (hereinafter: the "**Disclosing Party**") that:

1. The Receiving Party has received and/or will receive Confidential Information as defined hereinafter in connection with its participation as a potential bidder in the 4th Offshore Bidding Round 2022, and in accordance with the Call For Bids (hereinafter: the "**CFB**") published by the Ministry of Energy and Infrastructure of the State of Israel (hereinafter: the "**Permitted Purpose**")

   "**Confidential Information**" means, without limiting the generality of the term, geological, geophysical, geochemical and engineering data, environmental information and other reports, studies and analyses contained in the data package, within its meaning in the CFB, but excluding information or data which is lawfully in the public domain at the time of disclosure to the Receiving Party; or subsequently becomes lawfully part of the public domain by publication or otherwise.

2. The Receiving Party undertakes and confirms:

   2.1 not to disclose, or use the Confidential Information for any reason or purpose, other than for the Permitted Purpose; and

   2.2 to restrict the dissemination of the Confidential Information to only those of its personnel who are involved in its activities related to the Permitted Purpose, to take practical steps to impress upon those personnel who need to be given access to Confidential Information, the confidential nature thereof.

   2.3 All the Confidential information is acknowledged by the Receiving Party to be proprietary to the Disclosing Party, and the disclosure thereof to the Receiving Party does not confer any rights of whatsoever nature in such information to the Receiving Party.

2.4 The Receiving Party shall protect the Confidential Information in the same manner and with the same endeavour which it uses to protect his own confidential information. Should the Receiving Party become aware of any unauthorized copying, disclosure or use of Confidential Information, it shall notify the Disclosing Party thereof and take reasonable steps to prevent a recurrence thereof.

2.5 This Obligation to Confidentiality and Non-Disclosure will be governed by and construed in accordance with the laws of the State of Israel and all disputes actions and other matters relating thereto will be determined in accordance with such law.

2.6 All disputes, actions and other matters relating to this Obligation to Confidentiality and Non-Disclosure shall be brought before the authorized courts in Jerusalem.

2.7 This Obligation to Confidentiality and Non-Disclosure shall not be restricted in time.

SIGNED AT ……………… ON THIS ………. DAY OF ……………. 202_.

[___________________________________]

By __________________________ [name and title]

__ _______________________ [name and title]

Attorney Certification

I, the undersigned, confirm that [bidders' representatives' names] proved their identities with their [identity cards or passport numbers] and signed before me at [attorney's office address or place of signature] on [date].

_______________________________ [signature]

_______________________________ [attorney's full name]

SCHEDULE 2 - QUESTIONS FORM

In accordance with Article 6 of the CFB, questions should be submitted by e-mail to sagig@energy.gov.il with the subject line: **4th Offshore Bidding Round 2022 –** [*Applicant's name*]

The e-mail must contain a text-searchable PDF file attached to it as shown below:

4th Offshore Bidding Round

Applicant

Applicant:

Representative's name:

Representative's e-mail address:

Questions

Question Number	**Document** (CFB/Schedule)	**Item Number**	**Query**
1			
(…)			

SCHEDULE 3 - BID FORM

By submitting the bid, the bidder warrants and represents that all the information contained in the in the bid is complete and accurate in all material respects.

The bid form below must be initialled by the bidder's representative(s) (if the bidder is a consortium, by each of the consortium members' representatives) on each page and placed inside a sealed envelope along with all applicable Schedules.

BID FOR ZONE [*ALPHABETICAL DESIGNATION*]	
Bidder	**Proposed interest**
Operator	xx% **(operator)*** [*not less than 25%*]
Non-operator A	xx%
Non-operator B	xx%

Schedule 3.1 - Summary of the Proposed Work Programme and Signature Bonus

BID FOR ZONE [*ALPHABETICAL DESIGNATION*] **SUMMARY OF THE PROPOSED WORK PROGRAMME**	
Exploration well	[*specify whether there is a drilling commitment within the first 3-year period*]
3D seismic survey	[*in* km^2]
2D seismic survey	[*in km*]
3D reprocessing	[*in* km^2]
2D reprocessing	[*in km*]
Other surveys/studies	[*specify the proposed expenditure for any other activity proposed as part of the work programme*]
PROPOSED SIGNATURE BONUS [*not less than US$ 400,000*]	
US$ xxxxxx,00	
By ______________________________ [name and title] __ ___________________________ [name and title]	

Schedule 3.2 – Consortium Priority List

Priority List according to Article 11.7 of the CFB:

Order of priority	Zone
1.	
2.	
3.	
4.	
By ______________________________ [name and title] __ ___________________________ [name and title]	

Schedule 3.3 – Operator Priority Announcement

Operator Priority Announcement according to Article 11.7(c) of the CFB:

The priority for this bid among all bids submitted by [Company] as Operator, as part of OBR 2022, is: _____

By ____________________________ [name and title]

__ _________________________ [name and title]

Schedule 3.4 - Confirmation of Verification of Identity

[***note:*** *If the bidder is a consortium, the form should be completed by each consortium member separately]*

I, the undersigned [*attorney or CPA*], certify to the Ministry of Energy and Infrastructure that the representatives listed below are allowed to commit and sign, on behalf of [*bidder's name*], any one or all of the documents related to the 4th Offshore Licensing Round.

__________________________________ [*bidder's representative 1 full name*]

__________________________________ [*bidder's representative 1 title*]

__________________________________ [*bidder's representative 1 ID or passport number*]

__________________________________ [*bidder's representative 1 signature*]

__________________________________ [*bidder's representative 2 full name*]

__________________________________ [*bidder's representative 2 title*]

__________________________________ [*bidder's representative 2 ID or passport number*]

__________________________________ [*bidder's representative 2 signature*]

Signed before me on [*date*],

__________________________________ [*attorney or CPA signature*]

__________________________________ [*attorney or CPA full name*]

__________________________________ [*attorney or CPA licence number*]

__________________________________ [*attorney or CPA telephone*]

__________________________________ [*attorney or CPA address*]

Schedule 3.5 - Designation and Authorization of Operator

[***note:** If the bidder is a consortium, the form should be filled by all consortium members]*

We, the undersigned, hereby notify that [*name*] was designated by us as operator, with a proposed ___% interest* in the licence, and is authorized to act as a lead negotiator for the consortium and to bind other members.

Witnesses of our signatures on [*date*]

_________________________________ [*signature*]
__________________________________ [*bidder A's representative full name*]
__________________________________ [*identity card or passport no.*]
__________________________________ [*title*]

_________________________________ [*signature*]
__________________________________ [*bidder B's representative full name*]
__________________________________ [*identity card or passport no.*]
__________________________________ [*title*]

_________________________________ [*signature*]
__________________________________ [*bidder C's representative full name*]
__________________________________ [*identity card or passport no.*]
__________________________________ [*title*]

Attorney Certification

I, the undersigned, confirm that [*bidders' representatives' names*] proved their identities with their [*identity cards or passport numbers*] and signed before me at [*attorney's office address or place of signature*] on [*date*].

__________________________________ [*signature*]
__________________________________ [*attorney's full name*]

* Within its meaning in Regulation 5(a)(2) of the Offshore Regulations

Schedule 3.6 – Bid Envelope

Each bid must be placed inside a sealed envelope labelled as follows:

State of Israel

Ministry of Energy and Infrastructure

The Petroleum Commissioner

Natural Resources Administration

7 Bank Israel St., PO Box 36148

Jerusalem, 9195021

Israel

Confidential: 4th Offshore Bidding Round

ZONE [ALPHABETICAL DESIGNATION]

The sealed envelope(s) must contain a covering letter as follows:

CONFIDENTIAL

To: Petroleum Commissioner

From: [*bidder A, bidder B and bidder C*]

We hereby submit our bid for ZONE [*Alphabetical Designation.*] in the 4th Offshore Bidding Round 2022.

We agree to all terms and conditions of the Call for Bids.

We understand and accept the obligations that shall be applicable to us if our bid is accepted.

We comply, to the best of our knowledge, with the conditions of the Call for Bids and qualify as bidders.

Upon the announcement of the winning bids, we undertake to timely submit all documents and meet all requirements necessary for licence awarding and issuance. We understand that if we fail to comply with this undertaking, we will not receive the Licence and we may be subject to legal sanctions.

Yours sincerely,

[*signature of the bidders' representatives*]

[*name*]

[*job title*]

[*e-mail address*]

SCHEDULE 4 - PREQUALIFICATION OF PARTICIPATING COMPANIES

The pre qualifications criteria specified herein are based on the Petroleum Regulations (Principles of Operation for Offshore Petroleum Exploration and Production) 5777-2016 (the **Offshore Regulations**). Words and Phrases used in this SCHEDULE 4 shall have the same meaning if any, given to them in the Offshore Regulations.

In case of any discrepancy between this SCHEDULE 4 and the Offshore Regulations, the Offshore Regulations will prevail.

Any submission should include all the documents, forms and certifications prescribed under the Offshore Regulations.

Financial Capacity of a Bidder

1. A bidder for a petroleum right will be considered as having adequate financial competence if:
   a) The total assets in its balance sheet, and for a consortium - the total assets of all members together, are at least US$ 400 million; and
   b) The total equity in its balance sheet, and for a consortium - the total equity of all members together, are at least US$ 100 million.
2. For purposes of section 1, the total assets and total equity will be as stated in the bidder/s audited financial statements. Compliance with this criterion shall be determined according to the higher of:
   - The figures stated in most recently available audited financial statements; and
   - The average of the figures stated in the audited financial statements for the two most recent years for which audited financial statements are available.
3. A bidder may prove financial competence in reliance on its controlling shareholder financial competence, in accordance with Regulation 3(c) or Regulation 9(a) of the Offshore Regulations. In such case, irrevocable letters in accordance with Regulations 3(d) and 3(e), and/or Regulation 9 of the Offshore Regulations should be submitted with the bid.

Prequalification of Operator

A. Proportional Holding

The Commissioner will not approve an operator unless the bidder complies with the provisions of Regulation 5 of the Offshore Regulations.

B. Technical experience

1. Experience of at least 5 years in performing roles of an operator during the 10 years preceding the submission of the bid, including experience in operations carried out by contractors hired by the proposed operator, under the supervision

and responsibility of the proposed operator, as specified in subsections (a) to (d), below:

- **a)** Experience in offshore petroleum exploration, including the following operations: planning and management of geological and geophysical surveys including data processing, geological and geophysical analysis of exploration targets, identification and description of geological structures that form petroleum traps, preparation of drilling prospects and resource evaluation reports;
- **b)** Experience in offshore drilling, including the following operations: detailed engineering design of wells, employing contractors to perform drilling operations, purchasing of drilling equipment, engineering and geological supervision of drilling activities, wireline logging and well testing, analysis of drilling results, planning and execution of well abandonment operations and preparation of end-of-well reports;
- **c)** Experience in offshore development and production of oil and gas fields, including the following operations: preparation of field development plans, design and construction of oil and gas production and transmission facilities, including subsea facilities, installation of subsea transmission pipeline and floating systems, management and operation of manned production platforms; and
- **d)** Experience in HSE activities and maintenance of a safety and environmental management system for petroleum operations, including preparation of safety programs, conduction of HSE risk assessment, preparation of environmental documents and environmental monitoring programs relating to petroleum rights activities, all in accordance with internationally accepted standards.

4. A proposed operator may prove compliance with the aforesaid requirements in reliance on its controlling shareholder competence, in accordance with regulation 6(e), and subject to the conditions of regulation 6(e) of the Offshore Regulations. In such case, irrevocable letters in accordance with Regulation 9 of the Offshore Regulations should be submitted with the bid.

5. The Commissioner will not approve an operator unless it directly employs experienced employees who have at least 5 years of training and experience in fields specified in sub-section 3(a) and in sub-section 3(c).

C. Financial competence and financial robustness

1. The Commissioner will not approve an operator unless it has sufficient financial competence and robustness.
   - **a)** Financial competence is considered sufficient if the total assets in the operator's balance sheet is at least US$ 200 million and its total equity is at least US$ 50 million;

b) Financial robustness shall be proved by:

I) at least two of the three following ratios:

- the current ratio of current assets to current liabilities is greater than 1;
- the ratio of total equity to total balance is greater than 25%; and
- the ratio of cash flow from operating activities to annual financing expenses is greater than 1.2.; and

II) The auditor's report attached to the applicant's financial statements does not contain drawing attention clauses with respect to the financial condition of the applicant or to significant doubts on the applicant's ability to continue as a going concern;

2. For purposes of Section b(1)(I), the total assets and total equity will be as stated in the proposed operator audited financial statements. Compliance with this criterion shall be determined according to the higher of:

- The figures stated in most recently available audited financial statements; and
- The average of the figures stated in the audited financial statements for the two most recent years for which audited financial statements are available.

3. A proposed operator may prove financial competence and robustness in reliance on its controlling shareholder financial competence and robustness, in accordance with Regulation 7(a) of the Offshore Regulations. In such case, irrevocable letters in accordance with Regulation 9 of the Offshore Regulations should be submitted with the bid.

Schedule 4.1 – Technical Capability Form

[***note:** form to filled only by the proposed operator]*

To enable the assessment of the proposed operator’s technical experience, and in addition to the documents and certifications required under the Offshore Regulations, the following form should be submitted to the Ministry in connection with qualification and followed by a letter signed by the proposed operator's authorized signatories confirming the provided information.

1. Experience in offshore petroleum exploration, including the following operations: planning and management of geological and geophysical surveys including data processing, geological and geophysical analysis of the exploration targets, identification and description of geological structures that form petroleum traps, preparation of drilling prospects and resource evaluation reports.	
a.	Detailed description of the operator experience in offshore petroleum exploration.
b.	CV’s of employees holding key positions in the proposed operator with at least 5 years' training and experience in offshore petroleum exploration.
2. Experience in offshore drilling, including the following operations: detailed engineering design of wells, employing contractors to perform drilling operations, purchasing of drilling equipment, engineering and geological supervision of drilling activities, wireline logging and well testing, analysis of drilling results, planning and execution of well abandonment operations and preparation of end-of-well reports.	
a.	Detailed description of the operator experience in offshore drilling.
b.	CV’s of employees holding key positions in the proposed operator with at least 5 years' training and experience in offshore drilling.
3. Experience in offshore development and production of oil and gas fields, including the following operations: preparation of field development plans, design and construction of oil and gas production and transmission facilities, including subsea facilities, installations of subsea transmission pipeline and floating systems, production management and operation of manned production platforms.	
a.	Detailed description of the operator experience in offshore development and production of oil and gas fields
b.	CV’s of employees holding key positions in the proposed operator with at least 5 years' training and experience in offshore development and production of oil and gas fields.
4. Description of the offshore petroleum rights in which the proposed operator held rights and in which it served as operator during the 10 years preceding the bid application. For each of the said petroleum rights list the following information:	
a.	The petroleum right and the proposed operator's percentage of rights in it;
b.	Location of the petroleum right;

c.	Water depth in the places where wells were drilled and development work was conducted;
d.	Description of the proposed operator's activity as operator in the petroleum right;
e.	Duration of activity;
f.	Scope of proposed operator's investments;
g.	Proven reserves in the petroleum right;
h.	Amount of petroleum production from the petroleum rights area (total amount and current daily amount); and
i.	List of accidents and environmental pollution incidents, and claims submitted against the proposed operator for these incidents during the 10 years preceding the bid;
5. HSE experience	
a.	Operator's experience in protecting health, safety and the environment (HSE) in the petroleum rights where operator served as an operator, including the information requested under Regulation 6(a)(3) of the Offshore Regulations.
b.	Relevant information pertaining to the experience listed in subsection (a) should be provided in the bid documents, including: (1) Description of operator's organizational structure, internal procedures and supervision and control systems; (2) Operator's performance record based on recognized indices such as lost time injury (LTI) and injury severity rate; and (3) environmental due diligence report;

Schedule 4.2 – Financial Capability Form

In addition to the documents and certifications required under the Offshore Regulations, the following form should be submitted to the Ministry to enable assessment of the prospective bidder's financial capabilities. The following information must be based on the data of the audited financial statements of the last 2 years that shall be attached to this form.

1. **Financial capability of each of the consortium members:**

*[**note:** information to be presented in US$ MM]*

FINANCIAL COMPETENCE		
	202_	**202_**
Total assets		
Total equity		

2. **Financial capability of all consortium members together:**

*[**note:** information to be presented in US$ MM]*

FINANCIAL COMPETENCE		
	202_	**202_**
Total assets		
Total equity		

3. **Financial capability for the proposed operator**

*[**note:** information to be presented in US$ MM]*

FINANCIAL COMPETENCE		
Summary Balance Sheet		
	202_	**202_**

Total assets		
Total stockholders’ equity		
The following data and ratios should be accompanied by a document signed by the applicant's auditor or by the applicant's authorized signatories.		
Current Ratio		
	202_	**202_**
Current assets		
Current liabilities		
Current ratio		
Capital to Balance Sheet Ratio		
	202_	**202_**
Total Equity		
Total Balance		
Total Equity to Total Balance ratio		
Cash Flow to Financial Expenses Ratio		
	202_	**202_**
Cash flow from operating activities		
Financial expenses		
Cash flow from operating activities to financial expenses ratio		

SCHEDULE 5 – WORK PROGRAMME

1. The bidder shall propose for the Zone a work programme that the bidder commits to carry out if it is to be awarded licences. The work programme will indicate its overall duration, the duration of each of its activities and the relevance of each activity to assess the prospectivity of the Zone.
2. The activities proposed in the work program must be described clearly and with sufficient details to avoid ambiguity.
3. The work program included in the bid documents shall refer to the Initial Phase.
4. The proposed work programme must be consistent with bidder's exploration strategy and it must be underpinned by the technical evaluation of the Zone.
5. The proposed work programme should include work activities that will be undertaken within the Zone. Any work, studies, surveys and seismic reprocessing proposed outside the Zone, must be clearly defined.
6. It is expected that the proposed work programme will enable a play, lead or prospect to be identified and developed toward maturing a drillable target and should contain:

   a. New operational activities such as data acquisition.

   b. Reprocessing of existing seismic data and/or other geophysical and geological studies.

7. It is expected that the proposed work programme should include the following items:

   a. Acquisition of new 2D/3D seismic data:

      i. A map showing the outline area of the planned new survey. In case of a 3D survey, both acquisition area and full-fold coverage should be presented. All existing seismic surveys should be identified on this map;

      ii. The cumulative length in kilometres (2D) or area in square kilometres (3D) of the acquired survey;

      iii. The initial acquisition parameters and survey design; and

      iv. The main survey deliverables after processing.

   b. Reprocessing of existing 2D/3D seismic data:

      i. The name of the survey (3D) or lines (2D) to be reprocessed;

      ii. A map showing the location of the 2D lines or 3D survey outline. All existing seismic surveys should be identified on this map;

      iii. The cumulative length in kilometres (2D) or area in square kilometres (3D) of the reprocessed survey or surveys;

iv. The main steps of the reprocessing flow, highlighting new processes or algorithms to be applied; and

v. The main survey deliverables expected after processing.

c. Acquisition of other geophysical data:

i. A map showing the location of the new survey;

ii. The area in square kilometres of the acquired survey; and

iii. Main acquisition parameters and survey design.

d. Other surveys and studies:

i. Type of the new survey or study to be carried out such as geological, petro physical and geochemical analysis of well data, interpretation, mapping and modelling of geologic and geophysical data;

ii. The main steps of the planned activity, presented for each survey or study separately;

iii. The estimated total expenditure in US Dollars for all the planned surveys and studies in current market value;

e. Drilling of an exploration well during the Initial Phase (if proposed)

i. The location of wells;

ii. An initial drilling plan presenting the geologic concept, drilling target(s) and resource estimates for the well; and

iii. An initial engineering plan with the main drilling parameters including well total depth, casing design and mud plan.

8. A summary of the work programme should be set out for the Zone in accordance with the form included in Schedule 3.1. The summary will be used for bid evaluation and in any case of discrepancy between the detailed work programme and the summary, the later will prevail.

State of Israel

Licence

Licence No. [ ]

By virtue of my authority under Section 16 of the Petroleum Law, 5712-1952

This Licence is granted to –

[ ] …………………[ ]%

[ ] …………………[ ]%

[ ] …………………[ ]%

The Licence is issued with respect to the areas described in the First Addendum.

The Licence is issued in accordance with the provisions set forth in the Petroleum Law, 5712-1952, the regulations promulgated thereunder, and the special conditions set forth in the Second Addendum that constitutes an integral part of this Licence.

Issued in Jerusalem on the _____ day in the month of ___________ 577_

The _______ day in the month of ___________, 202_

Petroleum Commissioner

This Licence was registered in the Petroleum Registry on the_____ day in the month of ___________ 577_

The _______ day in the month of ___________, 202_

State of Israel

Licence No. [ ]

First Addendum

Description of the area:

From the [ ] coordinate in the east to coordinate [ ]

From the [ ] coordinate in the south to coordinate [ ]

………………

- **The total area is approximately [ ] dunams (approximately [ ] km², coordinates are based upon the Universal Transverse Mercator.**
- **The Licence area is defined by the coordinates specified above only. It is hereby clarified that in the event of a lack of conformity between the maps that were submitted by the licence holder and that which is stated above, the coordinates shall be used to determine the area.**
- **Issue of this Licence shall not render redundant any permit, certificate or licence that are required by law from any public or other body, and this Licence does not render redundant the regulation of all other aspects that are required by law towards any public or private body.**

State of Israel

Licence No. [ ]

Second Addendum

Special Conditions

This Licence is granted for the period from the [ ] day in [ ] **202_** until the

[ ] day in [ ] 202_.

During the Term of Licence the licence holder shall execute the work programme as follows:

	Task	Period for performance of task
1.		
2.		
3.		
4.		
5.		
6.		
7.		

1. Interpretation

1.1. Words and expressions that were defined in the Petroleum Law, 5712-1952 (hereinafter: "**the Law**") or the Petroleum Regulations 5713-1953 (hereinafter: "**Petroleum Regulations**") or the Petroleum Regulations (Principles for Off-shore Petroleum Exploration and Production) 5777-2016 (hereinafter: "**Offshore Exploration Regulations**") (the Petroleum Regulations and the Offshore Exploration Regulations shall be referred hereinafter collectively: "**the Regulations**") or in the Natural Gas Sector Law 5762-2002 (hereinafter: "**Natural Gas Sector Law**") shall have the meaning assigned to them in the Law or the Petroleum Regulations or the Offshore Exploration Regulations or in the Natural Gas Sector Law, as the case may be, unless otherwise stated expressly or in case another meaning is implied in the language of the text or context thereof.

1.2. For the avoidance of doubt, "licence holder" shall mean any of the licence holders that are specified above, individually and collectively, including their substitutes as approved by the Law. The obligations that are imposed on the licence holder in the Licence shall apply to each of the licence holders or substitutes thereof as aforesaid, individually and collectively.

1.3. The term “Zone” shall mean the graticular area consisting of the block covered by this licence and other blocks and licences granted under the Law, within this area, as delineated in OBR4, as published by the Ministry of Energy and Infrastructure.

2. Term of Licence

2.1. The Term of Licence is three (3) years as stated in the Second Addendum of this Licence (hereinafter respectively: "**Second Addendum**," "**Initial Phase**").

2.2. The licence may be extended for additional two (2) successive periods of two 2 years each (hereinafter: "**Second Phase**" and **“Third Phase”**), subject to fulfilment of the provisions of the Law, the regulations and the following conditions.

2.3. An initial phase (the **Initial Phase**) of three (3) years, during which the licence holder is obligated to perform the work programme submitted as a part of its bid.

2.3.1. The Initial Phase has a first decision point, no later than three (3) months prior to the expiry of the Initial Phase (the **First Decision Point**). By that time, for each licence in the Zone, the licence holder has to notify the Commissioner whether it undertakes to drill a well or wells, and in which of the licences within the Zone is the planned well located, or perform other exploratory work in the licences during the ensuing two (2) year period (the **Second Phase**).

2.3.2. If a licence holder has not drilled at least one (1) exploration well in the Initial Phase, and has not committed to drill at least one (1) exploration well within one of the licences in the Zone in the Second Phase, all licences within the Zone will automatically terminate at the end of the Initial Phase.

2.3.3. If a licence holder has drilled an exploration well or wells in the Initial Phase, or committed to drill at least one (1) exploration well within one of the undrilled licences in the Zone during the Second Phase, the licence holder will retain any licence on which an exploration well has been drilled or committed, as the case may be.

2.3.4. With regard to the situation described in Section 2.3.3, the licence holder may retain other licences within the Zone on which an exploratory well has not been drilled during the Initial Phase, or committed to drill in the Second Phase, by committing to perform an additional work programme in the Second Phase. Such additional work programme must be submitted by the licence holder to the Commissioner for approval prior to the First Decision Point. The Commissioner will base his approval or rejection of the additional work programme on whether the additional work programme was prepared diligently in accordance with good industry practice and promotes the understanding of the area of the retained licences or the area of the Zone as a whole. The Commissioner may reject an additional work programme in whole, or in respect of any licence, in the exercise of his discretion and such decision will be final. Any such licence with no approved commitment approved by the commissioner, for exploration activity during the Second Phase, will automatically terminate at the end of the Initial Phase.

2.4. The Second Phase, during which the licence holder is obligated to perform the exploratory drilling or other exploration commitments made in respect to this Phase

2.4.1. The Second Phase has a second decision point, up to 3 months prior to the expiry of the Second Phase. By that time, the licence holder has to notify the Commissioner whether it undertakes to drill a well in licences undrilled during the Initial Phase or Second Phase in the Zone during the ensuing 2-year period (the **Third Phase**).

2.4.2. Any undrilled licence with no commitment for drilling during the Third Phase will automatically terminate at the end of the Second Phase.

2.5. In the event of an extension of the licence to the Third Phase, the licence holder will be obligated to perform the exploratory drilling commitments made in respect of this Phase.

2.6. In the event that the licence holder finds hydrocarbons in a well drilled in the licence area; and the Commissioner approves the Discovery of a hydrocarbon field; the Commissioner may extend the term of the licence for such time as will give the licence holder a sufficient period, not exceeding two (2) years, within which to define the petroleum field, in accordance with the provisions set forth in section 18(B)(2) of the Law.

2.7. The licence holder will comply with the terms set forth in the Offshore Exploration Regulations, and any other relevant legislation.

2.8. Applications for the extension of the Term of Licence for the additional Second and Third Phases after expiration of the Initial Phase, shall be submitted in three copies, at least three (3) months prior to expiration of the relevant Phase , and shall include the details that are required in accordance with the Law and the Petroleum Regulations, including details regarding the licence holder's technical and financial ability to comply with the proposed work programme.

3. <u>Rights of the licence holder</u>

3.1. The licence grants to its holder, subject to the provisions set forth by the Law:

3.1.1. The right to explore for petroleum in the licenced area;

3.1.2. The right to conduct, in accordance with the conditions set forth by the Commissioner, if any, exploration activities outside the licenced area that can provide an estimate regarding the chances of finding petroleum in the licenced area;

3.1.3. The exclusive right to perform test or development drilling in the licenced area and produce petroleum therefrom;

3.1.4. The right to obtain a lease after having made a discovery in the licenced area.

4. Duties of the licence holder; application of laws and provisions

4.1. The licence holder shall act with due diligence for the purpose of performing exploration activities in the potential petroleum resource in the area subject matter of the Licence by way of initiative and in an efficient manner in accordance with the Licence and customary professional practice.

4.2. When performing the actions of the licence holder in connection with the Licence, the licence holder shall act in accordance with the following:

4.2.1. The provisions of the Law, Petroleum Regulations, Offshore Exploration Regulations, safety at work legislation, environmental protection and hazardous materials laws, provisions set forth in the Natural Gas Sector Law and the Gas (Safety and Licensing) Law 5749-1989 and any other relevant law that is in effect from time to time to the extent that these laws are applicable to the licence holder or pertain to the Licence or activities that are performed in connection with the Licence.

4.2.2. The instructions set forth by the Minister pursuant to his powers in accordance with the Law and in accordance with the provisions set forth in any law and the instructions set forth by the Commissioner by virtue of his statutory powers or by virtue of the provisions set forth in the Licence, including provisions and conditions that are set forth in the letters of approval and demands and instructions on behalf of any competent authority by law;

4.2.3. International treaties to which Israel is a party and that apply to the licence holder or to its activities, in accordance with the provisions set forth in any law;

4.3. The licence holder shall act for the purpose of obtaining any approval and certificate that are required from any government entity and in accordance with the provisions set forth in any law.

4.4. The Operator at the Licence granting date is ______________________________

5. The work programme

5.1. The work programme as stated in the Second Addendum as amended at any time (hereinafter: "**Work Programme**") constitutes an integral part of the Licence.

5.2. The licence holder shall implement the Work Programme in due diligence and in accordance with "good oilfield practice" that is to say – the practice, methods, standards and procedures that are customary in competent and experienced operators in the oil and gas sector and that act with due diligence and care and that, during relevant times, and after exercising reasonable judgment and in light of the facts known at the time of making decisions, are those that will attain the desirable outcomes and objectives.

5.3. The licence holder is required to plug and abandon any well that is performed or any well in which re-entry is made as part of the Licence and in accordance with "good oilfield practice."

6. Drilling a well, approvals for drilling, plugging and abandonment

6.1. The licence holder will operate in accordance with the Guidelines of the Petroleum Commissioner with Regard to Petroleum Exploration Drilling Activities.

6.2. It is made clear that the performance of any drilling requires prior and written approval of the Commissioner.

6.3. Where the licence holder undertook to drill a well, the drilling shall be performed in accordance with the objective that was defined in the Work Programme or for a purpose that will be approved by the Commissioner prior to performance of drilling

6.4. The licence holder shall request the Commissioner's approval for any commencement or re-entry to the well and for plugging or abandonment of each well.

6.5. The application shall include specifications and information in accordance with the instructions set forth by the Commissioner.

6.6. The Commissioner shall be entitled to approve the work under conditions.

6.7. Any temporary or permanent plugging or abandonment of a drill shall be performed in accordance with the requirements set forth by the

Commissioner and in such manner that will leave the drill in good condition and will allow continuation of the works in the drill.

6.8. Prior to expiration of the Term of Licence, the licence holder shall plug and abandon any drilling that is performed or any drilling in which a re-entry is made as part of the Licence and that was not yet plugged and abandoned in accordance with "good oilfield practice," unless otherwise agreed with the Commissioner.

7. Reaching a Discovery and Granting a lease

7.1. The licence holder shall notify the Commissioner regarding having made discovery immediately after becoming allegedly aware of such discovery in accordance with the Petroleum Law, Petroleum Regulations, and Guidelines of the Petroleum Commissioner on Discovery Approval.

7.2. The notice shall include details and information as determined by the Commissioner.

7.3. In the event that the Commissioner confirms that the licence holder made a discovery, and the licence holder submits to the Commissioner an application for granting a lease in accordance with the Law and the Regulations during the Term of Licence, with relation to an area whose area shall not be greater than 250km^2 that is included in the Licence area and where the discovery was made.

7.4. Where an approved discovery(s) may extend beyond the Licence, the licence area holder may apply to add areas to the licence area such that the development area will accommodate the approved discovery(s), and the Minister of Energy and Infrastructure (the **Minister**) may approve such application, in accordance with Article 49 of the Law.

7.5. The lease deed shall set out additional conditions those set forth in the Licence and that are relevant to the granting of a lease and the stage of commercial petroleum production.

7.6. Upon granting a lease, the Licence shall expire and the rights regarding the area that is not included in the lease will be returned to the State.

7.7. In the event that the licence holder made a discovery in the Licenced area, the licence holder shall be obligated, unless there is a reason to contradict this obligation to produce petroleum, to set the boundaries of the field and develop it – and all in due diligence as if it were a lease holder and the licence holder shall bear all obligations of a lease holder with respect to these actions and with respect to the petroleum that is produced; this provision shall not derogate from its obligations as a licence holder.

8. Reports and records

8.1. The licence holder shall keep samples in accordance with the provisions set forth in the Petroleum Law and the guidelines set forth by the Commissioner.

8.2. The licence holder shall submit to the Commissioner records, reports and documents as required by the Law, Regulations, provisions set forth in the Licence and guidelines set forth by the Commissioner.

8.3. The licence holder shall submit to the Commissioner an immediate report regarding any irregular and material event, including an event in which damage was caused or might be caused to any person, property or the environment, and will operate in accordance with the Guidelines of the Petroleum Commissioner on this issue.

8.4. The licence holder shall submit to the Commissioner reports in accordance with the Law, Regulations and guidelines set forth by the Commissioner; any information and data in its possession and any agreement, report or any other document that is required, in the opinion of the Commissioner, for the purpose of supervising the licence holder and actions thereof in connection with the Licence.

8.5. All data and information submitted to the Commissioner shall be kept by the Commissioner and shall be handled in accordance with the provisions set forth in any law, Regulations and guidelines set forth by the Commissioner. The Commissioner shall be entitled to use the data and information as he deems fit for the optimal development of petroleum resources in Israel.

9. Security

9.1. The licence holder shall observe strictly the instructions it is given by an authorized representative of the IDF with respect to any security issue pertaining to the Licence area and the actions of the licence holder.

9.2. Without derogating from that which is stated in Section 9.1, the licence holder shall act in security issues in accordance with the instructions set forth by the Commissioner or the Security Officer in the Ministry of Energy and Infrastructure (hereinafter: "**the Ministry**") or anyone authorized by said entities.

9.3. Without derogating the above, the licence holder should be aware that the licence area may be located in proximity to the boundaries of Israel's exclusive economic zone and/or areas of special sensitivity from a security and/or foreign relations perspective, and will take special care not to take any action in the licence area without specific approval by the security authorities and by the Commissioner, and if approved, will take special care to carry out the action in accordance with the instructions given in the approval.

10. <u>Supervision and obligation of coordination with the authorities</u>

10.1. The licence holder shall be responsible for obtaining all licences, permits and approvals that are required by law and shall act with due diligence to obtain them on dates that will facilitate performance of the Work Programme in accordance with the schedule set forth therein.

10.2. The licence holder shall act in coordination with the Administration of Shipping and Ports in the Ministry of Transport and Road Safety in anything related to shipping.

10.3. Without derogating from the provisions of Section 50 of the Law, the licence holder will allow the Commissioner or whoever is authorized by the Commissioner to be present during the performance of any action in accordance with this Licence and, in this regard, will grant to the Commissioner or its authorized representatives immediate access to any location where such activities of the licence holder are performed and access to any data, document or any other information that are required for the purpose of filling their position.

10.4. Supervision and inspection authorities that were exercised by law or the right to demand the submission of reports as aforesaid shall not impose on the State, the Commissioner or any other entity on their behalf any obligation or liability or give rise to an argument of preclusion or estoppel in connection with the performance of actions in accordance with the Licence.

10.5. The supervision and inspection authorities and the right to request reports shall not derogate from the responsibility of the licence holder regarding the manner of performance of the works and the fulfilment of its obligations in accordance with the instructions set forth in the Licence and any law.

10.6. Without derogating from the provisions set forth in the Licence and the statutory provisions, the Commissioner shall be entitled to instruct the licence holder to perform actions and conduct inspections that are required in its opinion for the purpose of supervising the performance of the instructions set forth in the Licence and the certificates, including statutory provisions, documents, standards and procedures specified therein; in the event that the licence holder failed to take said action within a reasonable time as prescribed by the Commissioner, the Commissioner shall be entitled to perform said action or conduct said inspection by anyone authorized by the Commissioner for that purpose and shall be entitled to demand from the licence holder to provide equipment for that purpose.

10.7. In the event that the licence holder became aware of a demand made by a competent authority that may, in its opinion, harm its compliance with the requirements set forth in the Licence, the licence holder shall notify the Commissioner promptly of such.

11. <u>Employment of Israeli employees, purchase of goods and services from Israel</u>

11.1. The licence holder shall give priority to hiring local Israeli workforce to the extent that there is in Israel a suitable workforce possessing skills and competence to fill in the professional and administrative positions that are required for the purpose of the Licence and for the customary costs with respect to positions as aforesaid, and will propose actions that will help to increase the quantity and quality of such a suitable workforce in the future.

11.2. When purchasing goods and services for the purpose of performing actions in the Licence area, the licence holder shall give priority to goods and services that are produced in Israel, to the extent that their quality, availability and costs are commensurate with the goods and services that are produced outside Israel.

11.3. The licence holder shall inquire whether there are local manufacturers and service providers that can provide the goods and the services that are required for the purpose of performing the works in the Licence. Such an inquiry as aforesaid may be conducted directly or in relevant government ministries, industrialist associations or the Industrial Cooperation Authority (ICA). The licence holder shall afford a fair and equal opportunity to local manufacturers and service providers to become integrated in its activities that are performed in accordance with the Licence.

11.4. Upon the granting of the lease, insofar as one is awarded, the licence holder shall present to the Commissioner a local content plan. This plan will include, as a minimum, a plan for professional training and employment of local workers in the oil and gas professions, the purchase of local goods and services for the purpose of performing the actions in the lease and supporting research and development in the oil and gas sector in Israel. This plan will include provisions relating to the employment of sub-contractors, which will follow the same principles as mentioned in this Section.

12. Environmental protection

12.1. The licence holder shall act in accordance with the Environmental guidelines for Offshore Petroleum and Natural-Gas Exploration and Production and all instructions set forth by the Commissioner and any government authority regarding environmental protection.

12.2. The licence holder shall not perform a drilling before obtaining any approval or permit required for the purpose of its performance from the Ministry of Environmental Protection, including approval regarding a contingent emergency plan, poisons permit and discharge, permit and shall act in accordance with their provisions.

13. Fees and royalties

13.1. The licence holder shall pay annual fees in accordance with the provisions set forth in the Law and the Regulations that is in effect from time to time.

13.2. In the event that the licence holder produces oil or natural gas from the Licenced area, the licence holder shall pay royalties to the State of Israel in accordance with the provisions set forth in Section 32 of the Law and the guidelines set forth by the Commissioner in this matter.

14. Guarantees

14.1. As a condition for the issue of the Licence, the licence holder shall provide an autonomous, unconditional and irrevocable bank guarantee in the amount of US$ [______________] a copy of which is enclosed as an appendix (hereinafter: "**the Guarantee**").

14.2. Performance of drilling shall be subject to providing of the securities as required in accordance with the guidelines set forth by the Commissioner Guidelines for Providing Securities Associated with Petroleum Rights.

14.3. Guarantee amounts and amounts of securities shall not limit the scope of liability of the licence holder towards the State for payments whose obligation applies to the licence holder in accordance with the Licence or in accordance with the provisions set forth in any law or compensation for damages caused to the State (including any authority thereof).

14.4. The Commissioner shall forfeit the Guarantee upon the occurrence of any event specified in the Guidelines for Providing Securities Associated with Petroleum Rights and the provisions set forth in these guidelines shall apply to such forfeiture as aforesaid.

15. Liability, indemnification and insurance

15.1. An instruction that was delivered in accordance with authorization and in accordance with the law, including instructions, permits, licences and certificates, the instructions set forth in the Licence and letters of approval, statutory provisions and any other instruction, shall not impose on the State or any authority thereof or any employee thereof any responsibility or liability towards the licence holder, its employees, contractors, customers and any other third party and shall not serve as grounds for a claim of any thereof towards the same, or cause the removal of the licence holder's full statutory liability in accordance with the Licence and the letters of approval in respect of the performance of actions in the Licence area in a safe and standard manner.

15.2. The powers of approval or supervision in accordance with the Law or the Licence or an approval or the use of any other power that is granted in accordance with the Licence, an approval or any law to the State or any authority thereof or any employee thereof shall not impose on any of the same any responsibility that is imposed on the licence holder or eliminate or derogate from this responsibility.

15.3. The licence holder shall indemnify the State, including any authority thereof and employee thereof, for any damage, pecuniary and non-pecuniary, or any monetary obligation including legal and other expenses said entities are obligated to pay to a third party as a result of a negligent act or omission or in violation of the instructions set forth in the Licence or an approval of the licence holder in connection with the

Licence, and the obligation of the licence holder in accordance with the Licence as per a peremptory judgment in a proceeding in which the licence holder was a party or was afforded to join as a party and in case of settlement – after its approval by the licence holder that shall not be unreasonably withheld.

15.4. The licence holder shall acquire at its expense and shall maintain during the entire Term of Licence all insurance coverage specified in Chapter B regarding Guidelines for Providing Securities Associated with Petroleum Rights and all of said instructions shall apply to the licence holder, *mutatis mutandis*.

16. <u>Transfer or charge of the Licence</u>

16.1. The provisions set forth in the Law shall apply to transfer of the Licence or a benefit thereof and the charge of a licence. A licence or benefit thereof may not be charged or transferred in any manner without obtaining the Commissioner's approval.

16.2. The provisions of Guidelines for Providing Securities Associated with Petroleum Rights shall apply to the application for transfer or charge of the Licence or any benefit thereof.

17. Exclusive Conditions

17.1. The licence holder acknowledges and agrees that the area described in the First Addendum is part of the Exclusive Economic Zone of the State of Israel, which has not yet been fully delimited. If during the term of the Licence or during the period of any petroleum right granted following issue of this Licence (licence or lease) an area or areas are deducted from the area described above, the licence area or the other right area will be decreased accordingly without any compensation to the rights holder.

17.2. By receiving this licence, the licence holder hereby affirms that he knows that the licence area is located near the outer limits of Exclusive Economic Zone (EEZ) of the State of Israel. This fact, along with Israel's political and security interests, may impact potential activities in the Zones.

17.3. Without derogating from the above:

17.3.1. in the event that any arrangement and/or agreement is made by the State of Israel, including, inter alia, regarding:

i. the extent of the Israeli Exclusive Economic Zone (EEZ);

ii. transboundary reservoirs or prospects, including the rights to explore, develop and produce such reservoirs or prospects, as well as requirements to provide information regarding exploration, development and production activities related to such reservoirs or prospects, including to a third party;

The licence holder agrees to comply with the Ministry's instructions regarding such agreement and/or arrangement and waive any claim, demand or cause of action, of any kind towards the State of Israel in this regard.

17.3.2. In the event of the existence of a transboundary reservoir or prospect in the licence area, the licence holder acknowledges that in addition to the right of Israel to make any agreement/arrangement regarding such a reservoir or prospect, the Commissioner may issue specific instructions regarding such reservoir or prospect, including conditions or limitations to activities in relation to it. Such instructions, as well as agreements or arrangement made by the state of Israel regarding such a reservoir or prospect, may take into account the political, security and economic interests of the State of Israel, alongside the need to ensure the economic viability of the development of such a reservoir or prospect. The licence holder agrees to comply with such instructions and waive any claim,demand or cause of action, of any kind towards the State of Israel in this regard.

17.4. Without derogating from the provisions of Articles 17.1 to 17.3 above, the licence holder further acknowledges and agrees that:

17.4.1. It is aware of the Maritime Agreement between the State of Israel and the Republic of Lebanon, signed and entered into force on October 27, 2022, via exchange of letters between the State of Israel and the United States of America, and between the Republic of Lebanon and the United States of America (hereinafter: the Maritime Agreement).

17.4.2. It is aware, inter alia, of Section 3A and 3B of the Maritime Agreement, which read:

"A. If there is identification of any other single accumulation or deposit of natural resources, including liquid hydrocarbon, natural gas, or other mineral extending across the [Maritime Boundary Line] other than the [Saida] Prospect, and if one Party by exploiting that accumulation or deposit would withdraw, deplete, or draw down the portion of the accumulation or deposit that is on the other Party's side of the [Maritime Boundary Line], then before the accumulation or deposit is exploited, the Parties intend to request the United States to facilitate between the Parties (including any operators with relevant domestic rights to explore and exploit resources), with a view to reaching an understanding on the allocation of rights and the manner in which the accumulation or deposit may be most effectively explored and exploited.

B. Each Party shall share data on all currently known, and any later identified, cross--[Maritime Boundary Line] resources with the United States, including expecting the relevant operators that operate on either side of the MBL to share such data with the United States. The Parties understand that the United States intends to share this data with the Parties in a timely manner after receipt."

17.4.3. It is aware that the licence area borders on the maritime boundary line between Israel and Lebanon as delimited in the Maritime Agreement.

17.4.4. The licence holder waives any claim, demand, or cause of action of any kind in connection with the Maritime Agreement or any arrangement that may result from it, and agrees to comply with the Ministry's instructions regarding its implementation. Inter alia, the licence holder agrees and commits to share with the Ministry any information it requires, and consent to the sharing of such information with third parties, to the extent required by Section 3B of the Maritime Agreement.

17.4.5. Nothing in the above shall derogate from the right of the Parties to the Maritime Agreement to agree to amend said agreement or any of its terms, as well as to sign another or different agreement or any arrangement concerning transboundary reservoirs or prospects, in general or regarding a specific reservoir, and the licence holder waives any claim, demand, or cause of action of any kind in connection with such amendment, agreement or arrangement.

17.5. Without derogating from the provisions of Articles 17.1 to 17.3 above, the licence holder further acknowledges and agrees that:

17.5.1. It is aware of the Agreement Between the Government of the State of Israel and the Government of the Republic of Cyprus on Delimitation of the Exclusive Economic Zone, signed on December 17, 2010 (hereinafter: the Delimitation Agreement).

17.5.2. It is aware, inter alia, of Article 2 of the Maritime Boundary Agreement, which reads: "In case there are natural resources, including hydrocarbons reservoirs, extending from the Exclusive Economic Zone of one Party to the Exclusive Economic Zone of the other, the two Parties shall cooperate in order to reach a framework unitization agreement on the modalities of the joint development and exploitation of such resources."

17.5.3. It is aware that the licence area is located near the delimitation line between Israel and Cyprus as delimited in the Delimitation Agreement.

17.5.4. The licence holder waives any claim or demand or cause of action of any kind in connection with the Delimitation Agreement or any arrangement that may result from it, and agrees to comply with the Ministry's instructions regarding its implementation.

17.5.5. Nothing in the above shall derogate from the right of the Parties to the Delimitation Agreement to amend said agreement or any of its terms, as well as to sign another or different agreement or any arrangement concerning transboundary reservoirs or prospects, in general or regarding a specific reservoir, and the licence holder waives any claim, demand, or cause of action of any kind in connection with such amendment, agreement or arrangement.

18. General

18.1. Anything stated in this Licence shall not derogate from the obligations of the licence holder in accordance with the Law and in accordance with any applicable law at the time.

18.2. The licence holder shall be obligated to uphold different guidelines that are published by the Commissioner from time to time on the Internet website of the Ministry.

18.3. Conditions and requirements set forth in this Licence shall come in addition to any regulatory requirement made by the Commissioner or any other competent authority.

18.4. Where the Licence is held by more than one entity, each of the licence holders shall be responsible, individually and collectively, to uphold the terms set forth in the Licence.

18.5. The licence holder shall be capable of performing all its obligations in accordance with the Licence and any other relevant law during the entire Term of the Licence

18.6. The Appendices to this Licence shall constitute an integral part thereof.

18.7. The Licence shall be public and shall be published on the Internet website of the Ministry.

18.8. Applications, reports, representations, data or other document that should be prepared and submitted to the Commissioner shall be compiled and prepared professionally and clearly and in accordance with customary practice in the field and shall be submitted to the Commissioner in writing, by mail, by courier, or as a scanned document that will be transmitted by email or in any other electronic format as requested by the Commissioner. In the event that the licence holder found that there is a mistake in a material detail it submitted to the Commissioner, or that no material detail was included therein, the licence holder shall notify the Commissioner immediately after becoming aware of same.

18.9. Applications and reports shall be submitted when they are signed by the authorized persons on behalf of the licence holder.

18.10. Israeli law shall govern anything related to the Licence, and the Israeli courts shall have sole jurisdiction in anything relating to and arising out of this Licence.

Schedule 7.1 - Form of Bid bond

Name of bank _______________

Phone no. _______________________

Fax no. _______________________

Letter of Guarantee

To

Petroleum Commissioner

The Ministry of Energy and Infrastructure

Re: Guarantee No. ___________

We hereby guarantee that we will pay you any amount up to a total of **US$ 70,000** (in words seventy thousand US$) that you will demand from: _________ (referred to as: the Bidder) in connection with Israel 4th offshore bid round 2022.

We will pay you the aforesaid amount within 15 days of the date of your first written demand sent to us by registered mail, without requiring you to provide reasons for your demand and without asserting against you any defence available to the Bidder in relation to the Bidder's obligation to you, and without requiring that you first demand payment from the Bidder.

This guarantee is valid starting __________ until __________

This guarantee is extendable by an additional [120 days] upon a notice that will be submitted to us by the Petroleum Commissioner.

Demands based on this guarantee must be addressed to the bank branch at (address) __________

Name of bank __________________________________

Bank number and branch number __________________________________

Bank branch address __________________________

This guarantee is non transferrable

_______________ _______________

Name of bank _______________

Phone no. _______________________

Fax no. _______________________

Letter of Guarantee

To

Petroleum Commissioner

The Ministry of Energy and Infrastructure

Re: Guarantee No. ____________

We hereby guarantee that we will pay you any amount up to a total of **US$** _______________ (in words _______________) that you will demand from: __________ (hereinafter: The Debtor) in connection with licence _________________, granted according to the Petroleum Law 5712-1952, and in connection with compliance with the licence's terms, provisions of the Petroleum Law 5712-1952, and the Petroleum Commissioner's guidelines, and with any damage that may be caused in connection with the activity or inactivity in the licence area, including in connection with performing an abandonment plan or failing to perform it.

We will pay you the amount listed above within 15 days of the date of your first written claim sent to us by registered mail, without requiring you to provide reasons for your demand and without asserting against you any defence available to the Debtor in relation to the Debtor's obligation to you, and without requiring that you first demand payment from the Debtor.

This guarantee is valid starting ___________ until ___________

Claims based on this guarantee must be addressed to the bank branch/insurance company at (address) ___________

Name of bank ___________________________________

Bank number and branch number ___________________________________

Bank branch address ___________________________

This guarantee is non transferrable

________________ ________________

SCHEDULE 8 – DATA PACKAGE CONTENTS

The following data sets have been made available for reviewing the prospectively of the zones offered in OBR4.

Well Data

The well package comprises information and data from 22 wells that were drilled offshore Israel between the 1970 and 2013. The package includes well log data in LAS format, composite logs, End of Well reports and for certain wells additional technical reports and information, as described in the table below.

	Offshore Israel wells	**LAS files**		**Reports**					
			Velocity Survey	EOWR	Composite Log	Reservoir Characterization EOWR	Formation Evaluation	Stratigraphy/ Paleontology	Geochemistry
1	ANDROMEDA EAST 01	V	V		V	V	V		
2	APHRODITE 02 (ISHAI)	V	V	V	V				
3	ASHER YAM 01	V	V	V	V		V		
4	BRAVO 01	V	V	V	V			V	
5	DELTA 01 & 01A	V	V	V	V				
6	DOLPHIN 01	V	V	V	V			V	V
7	FOXTROT 01	V		V	V			V	
8	GAD 01	V	V	V	V		V		
9	HANNAH 01	V	V	V	V			V	
10	MYRA 01	V	V	V	V		V	V	V
11	NIR 01	V		V	V		V		
12	OR 01	V		V	V				
13	OR SOUTH 01/01A/01B	V		V	V				
14	QISHON YAM 01	V		V	V		V	V	
15	SARA 01	V		V	V		V	V	V
16	SHIMSHON 01/01A	V	V	V	V			V	V
17	YAM 01 (+SIDETRACK)	V		V	V			V	
18	YAM 02	V	V	V	V	V		V	
19	YAM 03	V		V	V		V	V	
20	YAM WEST 01	V	V	V	V				

21	YAM WEST 02/02A	V		V	V		V		
22	YAM YAFO 01	V	V	V	V				

Seismic Data

2D Data Set -

The 2D seismic data comprises of regional high-quality 2D seismic reflection lines (in SEGY format) that were acquired by Spectrum Geophysical in 2000 and TGS-NOPEC in 2001 and in 2008. These surveys that are processed in time domain cover the entire bid area. X/Y coordinates are edited within the trace headers and the lines are ready to be loaded into any standard interpretation station.

Additional, raw, field tapes may be purchased separately. See the line list in the table below.

Spectrum Geophysical 2000 survey consists of 51 lines (3943 km)

1	emed-03.sgy	27	emed-58.sgy
2	emed-07.sgy	28	emed-60.sgy
3	emed-09.sgy	29	emed-62.sgy
4	emed-11.sgy	30	emed-64.sgy
5	emed-13.sgy	31	emed-66.sgy
6	emed-16.sgy	32	emed-68.sgy
7	emed-18.sgy	33	emed-96.sgy
8	emed-20.sgy	34	FMIG_EMED-00-003-EDIT.SGY
9	emed-22.sgy	35	FMIG_EMED-00-007-EDIT.SGY
10	emed-24.sgy	36	FMIG_EMED-00-011-EDIT.SGY
11	emed-27.sgy	37	FMIG_EMED-00-013-EDIT.SGY
12	emed-29.sgy	38	FMIG_EMED-00-014-EDIT.SGY
13	emed-33.sgy	39	FMIG_EMED-00-016-EDIT.SGY

14	emed-35.sgy	40	FMIG_EMED-00-029-EDIT.SGY
15	emed-37.sgy	41	FMIG_EMED-00-031-EDIT.SGY
16	emed-39.sgy	42	FMIG_EMED-00-033-EDIT.SGY
17	emed-41.sgy	43	FMIG_EMED-00-039-EDIT.SGY
18	emed-43.sgy	44	FMIG_EMED-00-041-EDIT.SGY
19	emed-48.sgy	45	FMIG_EMED-00-046-EDIT.SGY
20	emed-50-1.sgy	46	FMIG_EMED-00-047-EDIT.SGY
21	emed-50-2.sgy	47	FMIG_EMED-00-048-EDIT.SGY
22	emed-52.sgy	48	FMIG_EMED-00-049-EDIT.SGY
23	emed-54.sgy	49	FMIG_EMED-00-051-EDIT.SGY
24	emed-56-1.sgy	50	FMIG_EMED-00-057-EDIT.SGY
25	emed-56-2.sgy	51	FMIG_EMED-00-096-EDIT.SGY
26	emed-57.sgy		

TGS-NOPEC 2001 survey consists of 62 lines (6481 km) –

1	1004-IS.sgy	17	1052-IS.sgy	33	2035-IS.sgy	49	4003-IS.sgy
2	1010-IS.sgy	18	1060-IS.sgy	34	2039-IS.sgy	50	4004-IS.sgy
3	1016-IS.sgy	19	1064-IS.sgy	35	2041-IS.sgy	51	4005-IS.sgy
4	1019-IS.sgy	20	1070-IS.sgy	36	2045-IS.sgy	52	4006-IS.sgy
5	1020-IS.sgy	21	1076-IS.sgy	37	2051-IS.sgy	53	4007-IS.sgy
6	1021-IS.sgy	22	1086-IS.sgy	38	2053-IS.sgy	54	4033-IS.sgy
7	1024-IS.sgy	23	1094-IS.sgy	39	2057-IS.sgy	55	4035-IS.sgy
8	1028-IS.sgy	24	2003A-IS.sgy	40	2061-IS.sgy	56	4037-IS.sgy
9	1032-IS.sgy	25	2003B-IS.sgy	41	2065-IS.sgy	57	4041-IS.sgy
10	1034-IS.sgy	26	2007-IS.sgy	42	2069-IS.sgy	58	4043-IS.sgy
11	1036-IS.sgy	27	2011-IS.sgy	43	2073-IS.sgy	59	4045-IS.sgy

12	1040-IS.sgy	28	2015-IS.sgy	44	2077-IS.sgy	60	4047-IS.sgy
13	1042-IS.sgy	29	2017-IS.sgy	45	2081-IS.sgy	61	4053-IS.sgy
14	1044-IS.sgy	30	2023-IS.sgy	46	2085-IS.sgy	62	4059-IS.sgy
15	1048-IS.sgy	31	2027-IS.sgy	47	4001-IS.sgy		
16	1050-IS.sgy	32	2031-IS.sgy	48	4002-IS.sgy		

TGS-NOPEC 2001 survey consists of 19 lines (1204 km) –

1	25-ISY.108918.sgy	**11**	75-ISY.108929.sgy
2	28-ISY.108920.sgy	**12**	78-ISY.108930.sgy
3	35-ISY.108921.sgy	**13**	85-ISY.108931.sgy
4	38-ISY.108922.sgy	**14**	88-ISY.108932.sgy
5	45-ISY.108923.sgy	**15**	95-ISY.108933.sgy
6	48-ISY.108924.sgy	**16**	98-ISY.108934.sgy
7	55-ISY.108925.sgy	**17**	105-ISY.108915.sgy
8	58-ISY.108926.sgy	**18**	125-ISY.108916.sgy
9	65-ISY.108927.sgy	**19**	135-ISY.108917.sgy
10	68-ISY.108928.sgy		

3D Data Set -

The 3D seismic reflection data comprises of 6 surveys acquired by previous license operators between 2000 to 2013. The package includes time and depth (where available) migrated volumes (in SEGY format) that can be loaded into any standard interpretation station.

Additional, raw, field tapes, velocity data and stacked offset data can be purchased separately. See list of 3D volumes in the table below.

No.	Survey Name	TWT	Depth	Survey Outline km^2
1	EXP00302	X		2810
2	EXP00303	X		2745
3	ISR13300	X	X	2845
4	NBL09301	X	X	2800
5	NBL13301	X	X	1920
6	PEL12M001	X	X	2345
7	PET09302	X	X	1540
8	RTI10308	X	X	510

Gravity and Magnetic Data

A regional set of gravity and magnetic measurements was acquired during the seismic acquisition of TGS-NOPEC in 2001.

The data set comprises of –

1. Information file (README.asc)
2. Survey line data (archive.asc)
3. Bathymetry grid (dep.grd.asc)
4. Free air gravity grid (fag.grd.asc)
5. Bouguer gravity grid (bgrv.grd.asc)
6. Magnetic anomaly grid (mag.grd.asc)
7. Offshore Israel 2001 East Mediterranean Sea Phase 1 2D Gravity and Magnetic Survey Processing Report
8. IAGC Industry Code of Practice - Data Use

Bathymetry

A New Multibeam Bathymetric Map of the Israeli Exclusive Economic Zone is included in the data package.

Culture Data

The culture data included in the data package comprises the following –

1. Active Petroleum Rights
2. Zones Offered in the 4th Bid Round
3. Open Blocks

Petrel 2019 E&P Software Platform Project

For easy access all well and seismic data included in the data package was loaded into Petrel 2019 E&P project named – Israel 4th Offshore Bid Round.pet. The contents of the Petrel projects are described below.

1. 2D seismic data
2. 3D seismic data in .zgy format
3. Well location and well log data
4. Culture data
5. Bathymetry map

Previous Operators Reports

A selection of reports compiled by previous operators in the zones of interest are listed below.

Zone E

1. NSAI_Og Prospect_Prospective Resources
2. Og Gas Prospect
3. 2013-08-01 MEWR Qeren
4. Qeren License: Miocene Play Concepts
5. Qeren Deep # 1 Drilling Prospect (Revised)
6. Re-evaluation of Mesozoic Seismic Markers in the Aviah and Qeren Licenses, offshore Israel
7. Re-evaluation of Mesozoic Seismic Markers in the Aviah and Qeren Licenses, offshore Israel – Figures

Zone E

1. MEWR Block Extension Summary Report - Hannah - 12 5 14

Zone G & H

1. Pelagic Project License Technical Report - 1 Nov 2011 milestone - Final[1]
2. Pelagic_Project_License_Technical_Report_-_1_oct2012_milestone_AGR_V5_Final
3. Pelagic Consortium - CPR Final - MWE
4. Pelagic Consortium - SRR Filing 6-14-2012 (REVISED FINAL) (2)
5. 2014_03_15_Neta_and_Royee _G&G_Report (Maps)
6. 2014_12_15_Neta_and_Royee_AVO_Seismic_Inversion_Report
7. 2014_12_15_Neta_and_Royee_Seismic_Attributes_Report

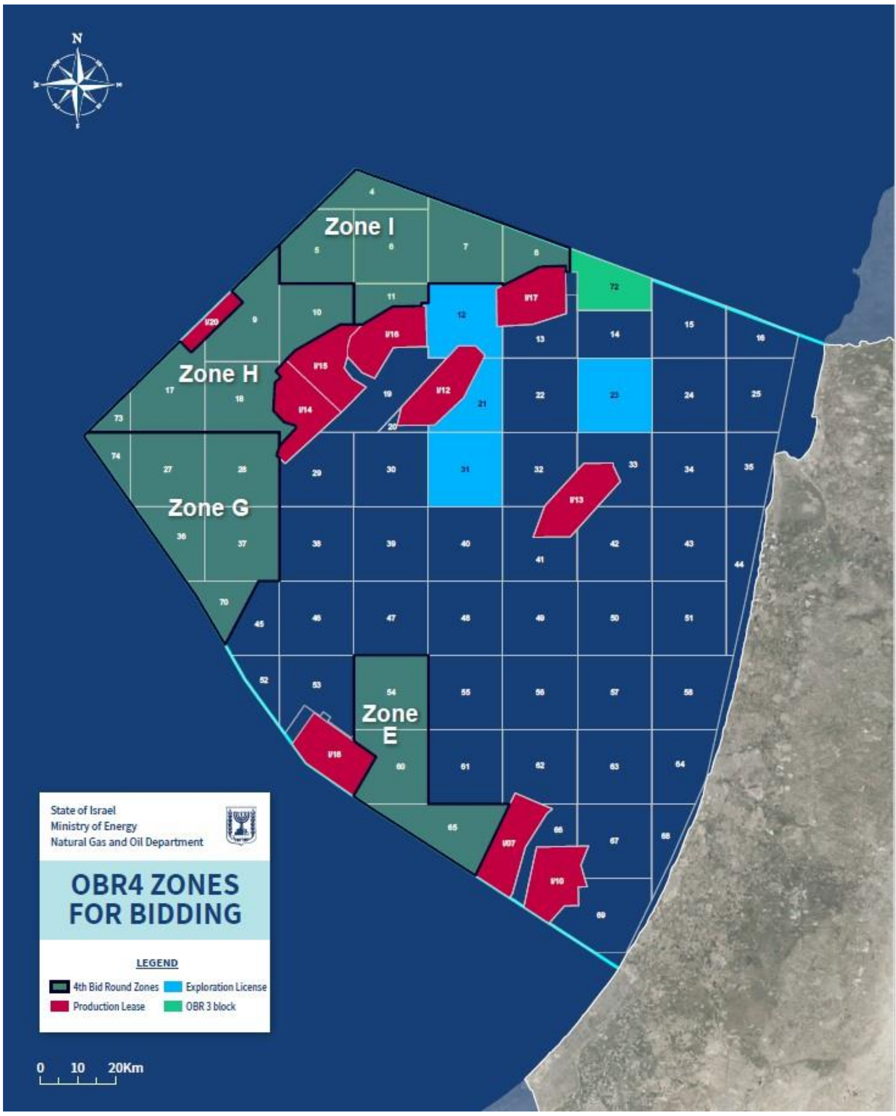
8. Royee_Neta_2015_09_15_Depthing_Report
9. AMEL_Report_11122015
10. AMEL_Report_Figures_Part_A_11122015_lr
11. AMEL_Report_Figures_Part_B_11122015_lr
12. 2015_02_11_Royee_Prospect_Report_withNSAI
13. 2016_06_15_Royee_Geol&Eng_Report_rev02

Regional Reports

1. Prospectivity Summary
2. Geochemical Evaluation of Mesozoic Source Rocks and their Potential to Support Petroleum Systems, Israel Continental Shelf
3. Highlights of Basin Analysis of the Levantine Basin Offshore – Extracted from BeiCip FranLab Final Report (2015), (RE 2141132)
4. The Levant Basin Offshore Israel: Stratigraphy, Structure, Tectonic Evolution and Implications for Hydrocarbon Exploration. Revised Addition – Gardosh et al., (2008), (RE GSI 1/4/2008, GII 429/328/08)
5. The Oligo-Miocene Deepwater System of the Levant Basin - Gardosh et al., (2008), (RE GSI 33/2008, GII 446/426/08)
6. Reference to additional articles

SCHEDULE 9 - MAP OF ZONES OFFERED IN OBR4

The map of the Zones offered for bidding in OBR4 is shown below. Coordinate system is **WGS 84/UTM Zone 36N (EPSG: 32636).**



Zone Area, No. of Blocks and Average Water Depth

# Zone	Zone Area (km²)	No. of Blocks	Average Water Depth (m)
E	1127	3	-1130
G	1732	6	-1380
H	1527	5	1643-
I	1677	6	

SCHEDULE 10 – LETTER OF INTEREST FORM

LETTERHEAD
ADDRESS

DATE
XXXX ADDRESS

Letter of Interest

The Ministry of Energy and Infrastructure of the State of Israel (the Ministry) has invited bids for certain defined areas (the Zones) in the Israeli, Mediterranean offshore area to be granted under the Petroleum Law 5712-1952 pursuant to the 4th Offshore Bidding Round 2022 (**OBR4**). [Corporate Name] ("Company") has reviewed the Call for Bids published on the Ministry's website that describes the offshore areas offered in OBR4, the process for bid submissions, the necessary qualifications for participating companies, bid evaluation criteria, and other matters relevant to prospective bidders. The Company wishes to express its interest in participating in OBR4.

We understand that questions concerning OBR4 should be addressed by email to. Please be advised that, until further notice, the Company's representative for matters related to OBR4 is as follows:

[Contact Details for Company Representative]

This letter of interest is non-binding and nothing contained herein represents a commitment on the part of the Company or the Ministry in respect of OBR4 or otherwise.

Very truly yours,

[Company – Authorized Representative]

נספח 6

העתק מהסכם פריז

עמ' 196

United Nations

FCCC/CP/2015/L.9/Rev.1

Framework Convention on
Climate Change

Distr.: Limited
12 December 2015

Original: English

Conference of the Parties
Twenty-first session
Paris, 30 November to 11 December 2015

Agenda item 4(b)
Durban Platform for Enhanced Action (decision 1/CP.17)
Adoption of a protocol, another legal instrument, or an agreed outcome with legal force under the Convention applicable to all Parties

ADOPTION OF THE PARIS AGREEMENT

Proposal by the President

Draft decision -/CP.21

The *Conference of the Parties,*

Recalling decision 1/CP.17 on the establishment of the Ad Hoc Working Group on the Durban Platform for Enhanced Action,

Also recalling Articles 2, 3 and 4 of the Convention,

Further recalling relevant decisions of the Conference of the Parties, including decisions 1/CP.16, 2/CP.18, 1/CP.19 and 1/CP.20,

Welcoming the adoption of United Nations General Assembly resolution A/RES/70/1, “Transforming our world: the 2030 Agenda for Sustainable Development”, in particular its goal 13, and the adoption of the Addis Ababa Action Agenda of the third International Conference on Financing for Development and the adoption of the Sendai Framework for Disaster Risk Reduction,

Recognizing that climate change represents an urgent and potentially irreversible threat to human societies and the planet and thus requires the widest possible cooperation by all countries, and their participation in an effective and appropriate international response, with a view to accelerating the reduction of global greenhouse gas emissions,

Also recognizing that deep reductions in global emissions will be required in order to achieve the ultimate objective of the Convention and emphasizing the need for urgency in addressing climate change,

Acknowledging that climate change is a common concern of humankind, Parties should, when taking action to address climate change, respect, promote and consider their respective obligations on human rights, the right to health, the rights of indigenous peoples, local communities, migrants, children, persons with disabilities and people in vulnerable situations and the right to development, as well as gender equality, empowerment of women and intergenerational equity,

Also acknowledging the specific needs and concerns of developing country Parties arising from the impact of the implementation of response measures and, in this regard, decisions 5/CP.7, 1/CP.10, 1/CP.16 and 8/CP.17,

Emphasizing with serious concern the urgent need to address the significant gap between the aggregate effect of Parties' mitigation pledges in terms of global annual emissions of greenhouse gases by 2020 and aggregate emission pathways consistent with holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels,

Also emphasizing that enhanced pre-2020 ambition can lay a solid foundation for enhanced post-2020 ambition,

Stressing the urgency of accelerating the implementation of the Convention and its Kyoto Protocol in order to enhance pre-2020 ambition,

Recognizing the urgent need to enhance the provision of finance, technology and capacity-building support by developed country Parties, in a predictable manner, to enable enhanced pre-2020 action by developing country Parties,

Emphasizing the enduring benefits of ambitious and early action, including major reductions in the cost of future mitigation and adaptation efforts,

Acknowledging the need to promote universal access to sustainable energy in developing countries, in particular in Africa, through the enhanced deployment of renewable energy,

Agreeing to uphold and promote regional and international cooperation in order to mobilize stronger and more ambitious climate action by all Parties and non-Party stakeholders, including civil society, the private sector, financial institutions, cities and other subnational authorities, local communities and indigenous peoples,

I. ADOPTION

1. *Decides* to adopt the Paris Agreement under the United Nations Framework Convention on Climate Change (hereinafter referred to as "the Agreement") as contained in the annex;

2. *Requests* the Secretary-General of the United Nations to be the Depositary of the Agreement and to have it open for signature in New York, United States of America, from 22 April 2016 to 21 April 2017;

3. *Invites* the Secretary-General to convene a high-level signature ceremony for the Agreement on 22 April 2016;

4. *Also invites* all Parties to the Convention to sign the Agreement at the ceremony to be convened by the Secretary-General, or at their earliest opportunity, and to deposit their respective instruments of ratification, acceptance, approval or accession, where appropriate, as soon as possible;

5. *Recognizes* that Parties to the Convention may provisionally apply all of the provisions of the Agreement pending its entry into force, and *requests* Parties to provide notification of any such provisional application to the Depositary;

6. *Notes* that the work of the Ad Hoc Working Group on the Durban Platform for Enhanced Action, in accordance with decision 1/CP.17, paragraph 4, has been completed;

7. *Decides* to establish the Ad Hoc Working Group on the Paris Agreement under the same arrangement, mutatis mutandis, as those concerning the election of officers to the Bureau of the Ad Hoc Working Group on the Durban Platform for Enhanced Action;[1]

8. *Also decides* that the Ad Hoc Working Group on the Paris Agreement shall prepare for the entry into force of the Agreement and for the convening of the first session of the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement;

9. *Further decides* to oversee the implementation of the work programme resulting from the relevant requests contained in this decision;

10. *Requests* the Ad Hoc Working Group on the Paris Agreement to report regularly to the Conference of the Parties on the progress of its work and to complete its work by the first session of the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement;

11. *Decides* that the Ad Hoc Working Group on the Paris Agreement shall hold its sessions starting in 2016 in conjunction with the sessions of the Convention subsidiary bodies and shall prepare draft decisions to be recommended through the Conference of the Parties to the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement for consideration and adoption at its first session;

II. INTENDED NATIONALLY DETERMINED CONTRIBUTIONS

12. *Welcomes* the intended nationally determined contributions that have been communicated by Parties in accordance with decision 1/CP.19, paragraph 2(b);

13. *Reiterates* its invitation to all Parties that have not yet done so to communicate to the secretariat their intended nationally determined contributions towards achieving the objective of the Convention as set out in its Article 2 as soon as possible and well in advance of the twenty-second session of the Conference of the Parties (November 2016) and in a manner that facilitates the clarity, transparency and understanding of the intended nationally determined contributions;

14. *Requests* the secretariat to continue to publish the intended nationally determined contributions communicated by Parties on the UNFCCC website;

15. *Reiterates* its call to developed country Parties, the operating entities of the Financial Mechanism and any other organizations in a position to do so to provide support for the preparation and communication of the intended nationally determined contributions of Parties that may need such support;

16. *Takes note* of the synthesis report on the aggregate effect of intended nationally determined contributions communicated by Parties by 1 October 2015, contained in document FCCC/CP/2015/7;

17. *Notes* with concern that the estimated aggregate greenhouse gas emission levels in 2025 and 2030 resulting from the intended nationally determined contributions do not fall within least-cost 2 ˚C scenarios but rather lead to a projected level of 55 gigatonnes in 2030, and *also notes* that much greater emission reduction efforts will be required than those associated with the intended nationally determined contributions in order to hold the increase in the global average temperature to below 2 ˚C above pre-industrial levels by

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[1] Endorsed by decision 2/CP.18, paragraph 2.

reducing emissions to 40 gigatonnes or to 1.5 ˚C above pre-industrial levels by reducing to a level to be identified in the special report referred to in paragraph 21 below;

18. *Also notes, in this context,* the adaptation needs expressed by many developing country Parties in their intended nationally determined contributions;

19. *Requests* the secretariat to update the synthesis report referred to in paragraph 16 above so as to cover all the information in the intended nationally determined contributions communicated by Parties pursuant to decision 1/CP.20 by 4 April 2016 and to make it available by 2 May 2016;

20. *Decides* to convene a facilitative dialogue among Parties in 2018 to take stock of the collective efforts of Parties in relation to progress towards the long-term goal referred to in Article 4, paragraph 1, of the Agreement and to inform the preparation of nationally determined contributions pursuant to Article 4, paragraph 8, of the Agreement;

21. *Invites* the Intergovernmental Panel on Climate Change to provide a special report in 2018 on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways;

III. DECISIONS TO GIVE EFFECT TO THE AGREEMENT

MITIGATION

22. *Invites* Parties to communicate their first nationally determined contribution no later than when the Party submits its respective instrument of ratification, accession, or approval of the Paris Agreement. If a Party has communicated an intended nationally determined contribution prior to joining the Agreement, that Party shall be considered to have satisfied this provision unless that Party decides otherwise;

23. *Urges* those Parties whose intended nationally determined contribution pursuant to decision 1/CP.20 contains a time frame up to 2025 to communicate by 2020 a new nationally determined contribution and to do so every five years thereafter pursuant to Article 4, paragraph 9, of the Agreement;

24. *Requests* those Parties whose intended nationally determined contribution pursuant to decision 1/CP.20 contains a time frame up to 2030 to communicate or update by 2020 these contributions and to do so every five years thereafter pursuant to Article 4, paragraph 9, of the Agreement;

25. *Decides* that Parties shall submit to the secretariat their nationally determined contributions referred to in Article 4 of the Agreement at least 9 to 12 months in advance of the relevant meeting of the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement with a view to facilitating the clarity, transparency and understanding of these contributions, including through a synthesis report prepared by the secretariat;

26. *Requests* the Ad Hoc Working Group on the Paris Agreement to develop further guidance on features of the nationally determined contributions for consideration and adoption by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement at its first session;

27. *Agrees* that the information to be provided by Parties communicating their nationally determined contributions, in order to facilitate clarity, transparency and understanding, may include, as appropriate, inter alia, quantifiable information on the reference point (including, as appropriate, a base year), time frames and/or periods for implementation, scope and coverage, planning processes, assumptions and methodological approaches including those for estimating and accounting for anthropogenic greenhouse gas

emissions and, as appropriate, removals, and how the Party considers that its nationally determined contribution is fair and ambitious, in the light of its national circumstances, and how it contributes towards achieving the objective of the Convention as set out in its Article 2;

28. *Requests* the Ad Hoc Working Group on the Paris Agreement to develop further guidance for the information to be provided by Parties in order to facilitate clarity, transparency and understanding of nationally determined contributions for consideration and adoption by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement at its first session;

29. *Also requests* the Subsidiary Body for Implementation to develop modalities and procedures for the operation and use of the public registry referred to in Article 4, paragraph 12, of the Agreement, for consideration and adoption by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement at its first session;

30. *Further requests* the secretariat to make available an interim public registry in the first half of 2016 for the recording of nationally determined contributions submitted in accordance with Article 4 of the Agreement, pending the adoption by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement of the modalities and procedures referred to in paragraph 29 above;

31. *Requests* the Ad Hoc Working Group on the Paris Agreement to elaborate, drawing from approaches established under the Convention and its related legal instruments as appropriate, guidance for accounting for Parties' nationally determined contributions, as referred to in Article 4, paragraph 13, of the Agreement, for consideration and adoption by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement at its first session, which ensures that:

(a) Parties account for anthropogenic emissions and removals in accordance with methodologies and common metrics assessed by the Intergovernmental Panel on Climate Change and adopted by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement;

(b) Parties ensure methodological consistency, including on baselines, between the communication and implementation of nationally determined contributions;

(c) Parties strive to include all categories of anthropogenic emissions or removals in their nationally determined contributions and, once a source, sink or activity is included, continue to include it;

(d) Parties shall provide an explanation of why any categories of anthropogenic emissions or removals are excluded;

32. *Decides* that Parties shall apply the guidance mentioned in paragraph 31 above to the second and subsequent nationally determined contributions and that Parties may elect to apply such guidance to their first nationally determined contribution;

33. *Also decides* that the Forum on the Impact of the Implementation of response measures, under the subsidiary bodies, shall continue, and shall serve the Agreement;

34. *Further decides* that the Subsidiary Body for Scientific and Technological Advice and the Subsidiary Body for Implementation shall recommend, for consideration and adoption by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement at its first session, the modalities, work programme and functions of the Forum on the Impact of the Implementation of response measures to address the effects of the implementation of response measures under the Agreement by enhancing cooperation amongst Parties on understanding the impacts of mitigation actions under the Agreement

and the exchange of information, experiences, and best practices amongst Parties to raise their resilience to these impacts;*

36. *Invites* Parties to communicate, by 2020, to the secretariat mid-century, long-term low greenhouse gas emission development strategies in accordance with Article 4, paragraph 19, of the Agreement, and *requests* the secretariat to publish on the UNFCCC website Parties' low greenhouse gas emission development strategies as communicated;

37. *Requests* the Subsidiary Body for Scientific and Technological Advice to develop and recommend the guidance referred to under Article 6, paragraph 2, of the Agreement for adoption by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement at its first session, including guidance to ensure that double counting is avoided on the basis of a corresponding adjustment by Parties for both anthropogenic emissions by sources and removals by sinks covered by their nationally determined contributions under the Agreement;

38. *Recommends* that the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement adopt rules, modalities and procedures for the mechanism established by Article 6, paragraph 4, of the Agreement on the basis of:

(a) Voluntary participation authorized by each Party involved;

(b) Real, measurable, and long-term benefits related to the mitigation of climate change;

(c) Specific scopes of activities;

(d) Reductions in emissions that are additional to any that would otherwise occur;

(e) Verification and certification of emission reductions resulting from mitigation activities by designated operational entities;

(f) Experience gained with and lessons learned from existing mechanisms and approaches adopted under the Convention and its related legal instruments;

39. *Requests* the Subsidiary Body for Scientific and Technological Advice to develop and recommend rules, modalities and procedures for the mechanism referred to in paragraph 38 above for consideration and adoption by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement at its first session;

40. *Also requests* the Subsidiary Body for Scientific and Technological Advice to undertake a work programme under the framework for non-market approaches to sustainable development referred to in Article 6, paragraph 8, of the Agreement, with the objective of considering how to enhance linkages and create synergy between, inter alia, mitigation, adaptation, finance, technology transfer and capacity-building, and how to facilitate the implementation and coordination of non-market approaches;

41. *Further requests* the Subsidiary Body for Scientific and Technological Advice to recommend a draft decision on the work programme referred to in paragraph 40 above, taking into account the views of Parties, for consideration and adoption by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement at its first session;

ADAPTATION

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* Paragraph 35 has been deleted, and subsequent paragraph numbering and cross references to other paragraphs within the document will be amended at a later stage.

42. *Requests* the Adaptation Committee and the Least Developed Countries Expert Group to jointly develop modalities to recognize the adaptation efforts of developing country Parties, as referred to in Article 7, paragraph 3, of the Agreement, and make recommendations for consideration and adoption by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement at its first session;

43. *Also requests* the Adaptation Committee, taking into account its mandate and its second three-year workplan, and with a view to preparing recommendations for consideration and adoption by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement at its first session:

(a) To review, in 2017, the work of adaptation-related institutional arrangements under the Convention, with a view to identifying ways to enhance the coherence of their work, as appropriate, in order to respond adequately to the needs of Parties;

(b) To consider methodologies for assessing adaptation needs with a view to assisting developing countries, without placing an undue burden on them;

44. *Invites* all relevant United Nations agencies and international, regional and national financial institutions to provide information to Parties through the secretariat on how their development assistance and climate finance programmes incorporate climate-proofing and climate resilience measures;

45. *Requests* Parties to strengthen regional cooperation on adaptation where appropriate and, where necessary, establish regional centres and networks, in particular in developing countries, taking into account decision 1/CP.16, paragraph 13;

46. *Also requests* the Adaptation Committee and the Least Developed Countries Expert Group, in collaboration with the Standing Committee on Finance and other relevant institutions, to develop methodologies, and make recommendations for consideration and adoption by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement at its first session on:

(a) Taking the necessary steps to facilitate the mobilization of support for adaptation in developing countries in the context of the limit to global average temperature increase referred to in Article 2 of the Agreement;

(b) Reviewing the adequacy and effectiveness of adaptation and support referred to in Article 7, paragraph 14(c), of the Agreement;

47. *Further requests* the Green Climate Fund to expedite support for the least developed countries and other developing country Parties for the formulation of national adaptation plans, consistent with decisions 1/CP.16 and 5/CP.17, and for the subsequent implementation of policies, projects and programmes identified by them;

LOSS AND DAMAGE

48. *Decides* on the continuation of the Warsaw International Mechanism for Loss and Damage associated with Climate Change Impacts, following the review in 2016;

49. *Requests* the Executive Committee of the Warsaw International Mechanism to establish a clearinghouse for risk transfer that serves as a repository for information on insurance and risk transfer, in order to facilitate the efforts of Parties to develop and implement comprehensive risk management strategies;

50. *Also requests* the Executive Committee of the Warsaw International Mechanism to establish, according to its procedures and mandate, a task force to complement, draw upon the work of and involve, as appropriate, existing bodies and expert groups under the Convention including the Adaptation Committee and the Least Developed Countries Expert Group, as well as relevant organizations and expert bodies outside the Convention, to

develop recommendations for integrated approaches to avert, minimize and address displacement related to the adverse impacts of climate change;

51. *Further requests* the Executive Committee of the Warsaw International Mechanism to initiate its work, at its next meeting, to operationalize the provisions referred to in paragraphs 49 and 50 above, and to report on progress thereon in its annual report;

52. *Agrees* that Article 8 of the Agreement does not involve or provide a basis for any liability or compensation;

FINANCE

53. *Decides* that, in the implementation of the Agreement, financial resources provided to developing countries should enhance the implementation of their policies, strategies, regulations and action plans and their climate change actions with respect to both mitigation and adaptation to contribute to the achievement of the purpose of the Agreement as defined in Article 2;

54. *Also decides* that, in accordance with Article 9, paragraph 3, of the Agreement, developed countries intend to continue their existing collective mobilization goal through 2025 in the context of meaningful mitigation actions and transparency on implementation; prior to 2025 the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement shall set a new collective quantified goal from a floor of USD 100 billion per year, taking into account the needs and priorities of developing countries;

55. *Recognizes* the importance of adequate and predictable financial resources, including for results-based payments, as appropriate, for the implementation of policy approaches and positive incentives for reducing emissions from deforestation and forest degradation, and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks; as well as alternative policy approaches, such as joint mitigation and adaptation approaches for the integral and sustainable management of forests; while reaffirming the importance of non-carbon benefits associated with such approaches; encouraging the coordination of support from, inter alia, public and private, bilateral and multilateral sources, such as the Green Climate Fund, and alternative sources in accordance with relevant decisions by the Conference of the Parties;

56. *Decides* to initiate, at its twenty-second session, a process to identify the information to be provided by Parties, in accordance with Article 9, paragraph 5, of the Agreement with the view to providing a recommendation for consideration and adoption by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement at its first session;

57. *Also decides* to ensure that the provision of information in accordance with Article 9, paragraph 7 of the Agreement shall be undertaken in accordance with modalities, procedures and guidelines referred to in paragraph 96 below;

58. *Requests* Subsidiary Body for Scientific and Technological Advice to develop modalities for the accounting of financial resources provided and mobilized through public interventions in accordance with Article 9, paragraph 7, of the Agreement for consideration by the Conference of the Parties at its twenty-fourth session (November 2018), with the view to making a recommendation for consideration and adoption by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement at its first session;

59. *Decides* that the Green Climate Fund and the Global Environment Facility, the entities entrusted with the operation of the Financial Mechanism of the Convention, as well as the Least Developed Countries Fund and the Special Climate Change Fund, administered by the Global Environment Facility, shall serve the Agreement;

60. *Recognizes* that the Adaptation Fund may serve the Agreement, subject to relevant decisions by the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol and the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement;

61. *Invites* the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol to consider the issue referred to in paragraph 60 above and make a recommendation to the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement at its first session;

62. *Recommends* that the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement shall provide guidance to the entities entrusted with the operation of the Financial Mechanism of the Convention on the policies, programme priorities and eligibility criteria related to the Agreement for transmission by the Conference of the Parties;

63. *Decides* that the guidance to the entities entrusted with the operations of the Financial Mechanism of the Convention in relevant decisions of the Conference of the Parties, including those agreed before adoption of the Agreement, shall apply mutatis mutandis;

64. *Also decides* that the Standing Committee on Finance shall serve the Agreement in line with its functions and responsibilities established under the Conference of the Parties;

65. *Urges* the institutions serving the Agreement to enhance the coordination and delivery of resources to support country-driven strategies through simplified and efficient application and approval procedures, and through continued readiness support to developing country Parties, including the least developed countries and small island developing States, as appropriate;

TECHNOLOGY DEVELOPMENT AND TRANSFER

66. *Takes note of* the interim report of the Technology Executive Committee on guidance on enhanced implementation of the results of technology needs assessments as referred to in document FCCC/SB/2015/INF.3;

67. *Decides* to strengthen the Technology Mechanism and requests the Technology Executive Committee and the Climate Technology Centre and Network, in supporting the implementation of the Agreement, to undertake further work relating to, inter alia:

(a) Technology research, development and demonstration;

(b) The development and enhancement of endogenous capacities and technologies;

68. *Requests* the Subsidiary Body for Scientific and Technological Advice to initiate, at its forty-fourth session (May 2016), the elaboration of the technology framework established under Article 10, paragraph 4, of the Agreement and to report on its findings to the Conference of the Parties, with a view to the Conference of the Parties making a recommendation on the framework to the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement for consideration and adoption at its first session, taking into consideration that the framework should facilitate, inter alia:

(a) The undertaking and updating of technology needs assessments, as well as the *enhanced* implementation of their results, particularly technology action plans and project ideas, through the preparation of bankable projects;

(b) The provision of enhanced financial and technical support for the implementation of the results of the technology needs assessments;

(c) The assessment of technologies that are ready for transfer;

(d) The enhancement of enabling environments for and the addressing of barriers to the development and transfer of socially and environmentally sound technologies*;*

69. *Decides* that the Technology Executive Committee and the Climate Technology Centre and Network shall report to the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement, through the subsidiary bodies, on their activities to support the implementation of the Agreement;

70. *Also decides* to undertake a periodic assessment of the effectiveness of and the adequacy of the support provided to the Technology Mechanism in supporting the implementation of the Agreement on matters relating to technology development and transfer;

71. *Requests* the Subsidiary Body for Implementation to initiate, at its forty-fourth session , the elaboration of the scope of and modalities for the periodic assessment referred to in paragraph 70 above, taking into account the review of the Climate Technology Centre and Network as referred to in decision 2/CP.17, annex VII, paragraph 20 and the modalities for the global stocktake referred to in Article 14 of the Agreement, for consideration and adoption by the Conference of the Parties at its twenty-fifth session (November 2019);

CAPACITY-BUILDING

72. *Decides* to establish the Paris Committee on Capacity-building whose aim will be to address gaps and needs, both current and emerging, in implementing capacity-building in developing country Parties and further enhancing capacity-building efforts, including with regard to coherence and coordination in capacity-building activities under the Convention;

73. *Also decides* that the Paris Committee on Capacity-building will manage and oversee the work plan mentioned in paragraph 74 below;

74. *Further decides* to launch a work plan for the period 2016–2020 with the following activities:

(a) Assessing how to increase synergies through cooperation and avoid duplication among existing bodies established under the Convention that implement capacity-building activities, including through collaborating with institutions under and outside the Convention;

(b) Identifying capacity gaps and needs and recommending ways to address them;

(c) Promoting the development and dissemination of tools and methodologies for the implementation of capacity-building;

(d) Fostering global, regional, national and subnational cooperation;

(e) Identifying and collecting good practices, challenges, experiences, and lessons learned from work on capacity-building by bodies established under the Convention;

(f) Exploring how developing country Parties can take ownership of building and maintaining capacity over time and spac*e;*

(g) Identifying opportunities to strengthen capacity at the national, regional, and subnational level;

(h) Fostering dialogue, coordination, collaboration and coherence among relevant processes and initiatives under the Convention, including through exchanging information on capacity-building activities and strategies of bodies established under the Convention;

(i) Providing guidance to the secretariat on the maintenance and further development of the web-based capacity-building portal;

75. *Decides* that the Paris Committee on Capacity-building will annually focus on an area or theme related to enhanced technical exchange on capacity-building, with the purpose of maintaining up-to-date knowledge on the successes and challenges in building capacity effectively in a particular area;

76. *Requests* the Subsidiary Body for Implementation to organize annual in-session meetings of the Paris Committee on Capacity-building;

77. *Also requests* the Subsidiary Body for Implementation to develop the terms of reference for the Paris Committee on Capacity-building, in the context of the third comprehensive review of the implementation of the capacity-building framework, also taking into account paragraphs 75, 76, 77 and 78 above and paragraphs 82 and 83 below, with a view to recommending a draft decision on this matter for consideration and adoption by the Conference of the Parties at its twenty-second session;

78. *Invites* Parties to submit their views on the membership of the Paris Committee on Capacity-building by 9 March 2016;[2]

79. *Requests* the secretariat to compile the submissions referred to in paragraph 78 above into a miscellaneous document for consideration by the Subsidiary Body for Implementation at its forty-fourth session;

80. *Decides* that the inputs to the Paris Committee on Capacity-building will include, inter alia, submissions, the outcome of the third comprehensive review of the implementation of the capacity-building framework, the secretariat’s annual synthesis report on the implementation of the framework for capacity-building in developing countries, the secretariat’s compilation and synthesis report on capacity-building work of bodies established under the Convention and its Kyoto Protocol, and reports on the Durban Forum and the capacity-building portal;

81. *Requests* the Paris Committee on Capacity-building to prepare annual technical progress reports on its work, and to make these reports available at the sessions of the Subsidiary Body for Implementation coinciding with the sessions of the Conference of the Parties;

82. *Also requests* the Conference of the Parties at its twenty-fifth session (November 2019), to review the progress, need for extension, the effectiveness and enhancement of the Paris Committee on Capacity-building and to take any action it considers appropriate, with a view to making recommendations to the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement at its first session on enhancing institutional arrangements for capacity-building consistent with Article 11, paragraph 5, of the Agreement;

83. *Calls upon* all Parties to ensure that education, training and public awareness, as reflected in Article 6 of the Convention and in Article 12 of the Agreement are adequately considered in their contribution to capacity-building;

84. *Invites* the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement at its first session to explore ways of enhancing the implementation of

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[2] Parties should submit their views via the submissions portal at <http://www.unfccc.int/5900>.

training, public awareness, public participation and public access to information so as to enhance actions under the Agreement;

TRANSPARENCY OF ACTION AND SUPPORT

85. *Decides* to establish a Capacity-building Initiative for Transparency in order to build institutional and technical capacity, both pre- and post-2020. This initiative will support developing country Parties, upon request, in meeting enhanced transparency requirements as defined in Article 13 of the Agreement in a timely manner;

86. *Also decides* that the Capacity-building Initiative for Transparency will aim:

(a) To strengthen national institutions for transparency-related activities in line with national priorities;

(b) To provide relevant tools, training and assistance for meeting the provisions stipulated in Article 13 of the Agreement;

(c) To assist in the improvement of transparency over time;

87. *Urges and requests* the Global Environment Facility to make arrangements to support the establishment and operation of the Capacity-building Initiative for Transparency as a priority reporting-related need, including through voluntary contributions to support developing countries in the sixth replenishment of the Global Environment Facility and future replenishment cycles, to complement existing support under the Global Environment Facility;

88. *Decides* to assess the implementation of the Capacity-building Initiative for Transparency in the context of the seventh review of the financial mechanism;

89. *Requests* that the Global Environment Facility, as an operating entity of the financial mechanism include in its annual report to the Conference of the Parties the progress of work in the design, development and implementation of the Capacity-building Initiative for Transparency referred to in paragraph 85 above starting in 2016;

90. *Decides* that, in accordance with Article 13, paragraph 2, of the Agreement, developing countries shall be provided flexibility in the implementation of the provisions of that Article, including in the scope, frequency and level of detail of reporting, and in the scope of review, and that the scope of review could provide for in-country reviews to be optional, while such flexibilities shall be reflected in the development of modalities, procedures and guidelines referred to in paragraph 92 below;

91. *Also decides* that all Parties, except for the least developed country Parties and small island developing States, shall submit the information referred to in Article 13, paragraphs 7, 8, 9 and 10, as appropriate, no less frequently than on a biennial basis, and that the least developed country Parties and small island developing States may submit this information at their discretion;

92. *Requests* the Ad Hoc Working Group on the Paris Agreement to develop recommendations for modalities, procedures and guidelines in accordance with Article 13, paragraph 13, of the Agreement, and to define the year of their first and subsequent review and update, as appropriate, at regular intervals, for consideration by the Conference of the Parties, at its twenty-fourth session, with a view to forwarding them to the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement for adoption at its first session;

93. *Also requests* the Ad Hoc Working Group on the Paris Agreement in developing the recommendations for the modalities, procedures and guidelines referred to in paragraph 92 above to take into account, inter alia:

(a) The importance of facilitating improved reporting and transparency over time;

(b) The need to provide flexibility to those developing country Parties that need it in the light of their capacities;

(c) The need to promote transparency, accuracy, completeness, consistency, and comparability;

(d) The need to avoid duplication as well as undue burden on Parties and the secretariat;

(e) The need to ensure that Parties maintain at least the frequency and quality of reporting in accordance with their respective obligations under the Convention;

(f) The need to ensure that double counting is avoided;

(g) The need to ensure environmental integrity;

94. *Further requests* the Ad Hoc Working Group on the Paris Agreement, when developing the modalities, procedures and guidelines referred to in paragraph 92 above, to draw on the experiences from and take into account other on-going relevant processes under the Convention;

95. *Requests* the Ad Hoc Working Group on the Paris Agreement, when developing modalities, procedures and guidelines referred to in paragraph 92 above, to consider, inter alia:

(a) The types of flexibility available to those developing countries that need it on the basis of their capacities;

(b) The consistency between the methodology communicated in the nationally determined contribution and the methodology for reporting on progress made towards achieving individual Parties' respective nationally determined contribution;

(c) That Parties report information on adaptation action and planning including, if appropriate**,** their national adaptation plans, with a view to collectively exchanging information and sharing lessons learned;

(d) Support provided, enhancing delivery of support for both adaptation and mitigation through, inter alia, the common tabular formats for reporting support, and taking into account issues considered by the Subsidiary Body for Scientific and Technological Advice on methodologies for reporting on financial information, and enhancing the reporting by developing countries on support received, including the use, impact and estimated results thereof;

(e) Information in the biennial assessments and other reports of the Standing Committee on Finance and other relevant bodies under the Convention;

(f) Information on the social and economic impact of response measures;

96. *Also requests* the Ad Hoc Working Group on the Paris Agreement, when developing recommendations for modalities, procedures and guidelines referred to in paragraph 92 above, to enhance the transparency of support provided in accordance with Article 9 of the Agreement;

97. *Further requests* the Ad Hoc Working Group on the Paris Agreement to report on the progress of work on the modalities, procedures and guidelines referred to in paragraph

92 above to future sessions of the Conference of the Parties, and that this work be concluded no later than 2018;

98. *Decides* that the modalities, procedures and guidelines developed under paragraph 92 above, shall be applied upon the entry into force of the Paris Agreement;

99. *Also decides* that the modalities, procedures and guidelines of this transparency framework shall build upon and eventually supersede the measurement, reporting and verification system established by decision 1/CP.16, paragraphs 40 to 47 and 60 to 64, and decision 2/CP.17, paragraphs 12 to 62, immediately following the submission of the final biennial reports and biennial update reports;

GLOBAL STOCKTAKE

100. *Requests* the Ad Hoc Working Group on the Paris Agreement to identify the sources of input for the global stocktake referred to in Article 14 of the Agreement and to report to the Conference of the Parties, with a view to the Conference of the Parties making a recommendation to the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement for consideration and adoption at its first session, including, but not limited to:

(a) Information on:

(i) The overall effect of the nationally determined contributions communicated by Parties;

(ii) The state of adaptation efforts, support, experiences and priorities from the communications referred to in Article 7, paragraphs 10 and 11, of the Agreement, and reports referred to in Article 13, paragraph 7, of the Agreement;

(iii) The mobilization and provision of support;

(b) The latest reports of the Intergovernmental Panel on Climate Change;

(c) Reports of the subsidiary bodies;

101. *Also requests* the Subsidiary Body for Scientific and Technological Advice to provide advice on how the assessments of the Intergovernmental Panel on Climate Change can inform the global stocktake of the implementation of the Agreement pursuant to its Article 14 of the Agreement and to report on this matter to the Ad Hoc Working Group on the Paris Agreement at its second session;

102. *Further requests* the Ad Hoc Working Group on the Paris Agreement to develop modalities for the global stocktake referred to in Article 14 of the Agreement and to report to the Conference of the Parties, with a view to making a recommendation to the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement for consideration and adoption at its first session;

FACILITATING IMPLEMENTATION AND COMPLIANCE

103. *Decides* that the committee referred to in Article 15, paragraph 2, of the Agreement shall consist of 12 members with recognized competence in relevant scientific, technical, socio-economic or legal fields, to be elected by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement on the basis of equitable geographical representation, with two members each from the five regional groups of the United Nations and one member each from the small island developing States and the least developed countries, while taking into account the goal of gender balance;

104. *Requests* the Ad Hoc Working Group on the Paris Agreement to develop the modalities and procedures for the effective operation of the committee referred to in Article 15, paragraph 2, of the Agreement, with a view to the Ad Hoc Working Group on the Paris

Agreement completing its work on such modalities and procedures for consideration and adoption by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement at its first session;

FINAL CLAUSES

105. *Also requests* the secretariat, solely for the purposes of Article 21 of the Agreement, to make available on its website on the date of adoption of the Agreement as well as in the report of the Conference of the Parties at its twenty-first session, information on the most up-to-date total and per cent of greenhouse gas emissions communicated by Parties to the Convention in their national communications, greenhouse gas inventory reports, biennial reports or biennial update reports;

IV. ENHANCED ACTION PRIOR TO 2020

106. *Resolves* to ensure the highest possible mitigation efforts in the pre-2020 period, including by:

(a) Urging all Parties to the Kyoto Protocol that have not already done so to ratify and implement the Doha Amendment to the Kyoto Protocol;

(b) Urging all Parties that have not already done so to make and implement a mitigation pledge under the Cancun Agreements;

(c) Reiterating its resolve, as set out in decision 1/CP.19, paragraphs 3 and 4, to accelerate the full implementation of the decisions constituting the agreed outcome pursuant to decision 1/CP.13 and enhance ambition in the pre-2020 period in order to ensure the highest possible mitigation efforts under the Convention by all Parties;

(d) Inviting developing country Parties that have not submitted their first biennial update reports to do so as soon as possible;

(e) Urging all Parties to participate in the existing measurement, reporting and verification processes under the Cancun Agreements, in a timely manner, with a view to demonstrating progress made in the implementation of their mitigation pledges;

107. *Encourages* Parties to promote the voluntary cancellation by Party and non-Party stakeholders, without double counting of units issued under the Kyoto Protocol, including certified emission reductions that are valid for the second commitment period;

108. *Urges* host and purchasing Parties to report transparently on internationally transferred mitigation outcomes, including outcomes used to meet international pledges, and emission units issued under the Kyoto Protocol with a view to promoting environmental integrity and avoiding double counting;

109. *Recognizes* the social, economic and environmental value of voluntary mitigation actions and their co-benefits for adaptation, health and sustainable development;

110. *Resolves* to strengthen, in the period 2016–2020, the existing technical examination process on mitigation as defined in decision 1/CP.19, paragraph 5(a), and decision 1/CP.20, paragraph 19, taking into account the latest scientific knowledge, including by:

(a) Encouraging Parties, Convention bodies and international organizations to engage in this process, including, as appropriate, in cooperation with relevant non-Party stakeholders, to share their experiences and suggestions, including from regional events, and to cooperate in facilitating the implementation of policies, practices and actions identified during this process in accordance with national sustainable development priorities;

(b) Striving to improve, in consultation with Parties, access to and participation in this process by developing country Party and non-Party experts;

(c) Requesting the Technology Executive Committee and the Climate Technology Centre and Network in accordance with their respective mandates:

(i) To engage in the technical expert meetings and enhance their efforts to facilitate and support Parties in scaling up the implementation of policies, practices and actions identified during this process;

(ii) To provide regular updates during the technical expert meetings on the progress made in facilitating the implementation of policies, practices and actions previously identified during this process;

(iii) To include information on their activities under this process in their joint annual report to the Conference of the Parties;

(d) Encouraging Parties to make effective use of the Climate Technology Centre and Network to obtain assistance to develop economically, environmentally and socially viable project proposals in the high mitigation potential areas identified in this process;

111. *Encourages* the operating entities of the Financial Mechanism of the Convention to engage in the technical expert meetings and to inform participants of their contribution to facilitating progress in the implementation of policies, practices and actions identified during the technical examination process;

112. *Requests* the secretariat to organize the process referred to in paragraph 110 above and disseminate its results, including by:

(a) Organizing, in consultation with the Technology Executive Committee and relevant expert organizations, regular technical expert meetings focusing on specific policies, practices and actions representing best practices and with the potential to be scalable and replicable;

(b) Updating, on an annual basis, following the meetings referred to in paragraph 112(a) above and in time to serve as input to the summary for policymakers referred to in paragraph 112(c) below, a technical paper on the mitigation benefits and co-benefits of policies, practices and actions for enhancing mitigation ambition, as well as on options for supporting their implementation, information on which should be made available in a user-friendly online format;

(c) Preparing, in consultation with the champions referred to in paragraph 122 below, a summary for policymakers, with information on specific policies, practices and actions representing best practices and with the potential to be scalable and replicable, and on options to support their implementation, as well as on relevant collaborative initiatives, and publishing the summary at least two months in advance of each session of the Conference of the Parties as input for the high-level event referred to in paragraph 121 below;

113. *Decides* that the process referred to in paragraph 110 above should be organized jointly by the Subsidiary Body for Implementation and the Subsidiary Body for Scientific and Technological Advice and should take place on an ongoing basis until 2020;

114. *Also decides* to conduct in 2017 an assessment of the process referred to in paragraph 110 above so as to improve its effectiveness;

115. *Resolves* to enhance the provision of urgent and adequate finance, technology and capacity-building support by developed country Parties in order to enhance the level of ambition of pre-2020 action by Parties, and in this regard *strongly urges* developed country Parties to scale up their level of financial support, with a concrete roadmap to achieve the

goal of jointly providing USD 100 billion annually by 2020 for mitigation and adaptation while significantly increasing adaptation finance from current levels and to further provide appropriate technology and capacity-building support;

116. *Decides* to conduct a facilitative dialogue in conjunction with the twenty-second session of the Conference of the Parties to assess the progress in implementing decision 1/CP.19, paragraphs 3 and 4, and identify relevant opportunities to enhance the provision of financial resources, including for technology development and transfer and capacity-building support, with a view to identifying ways to enhance the ambition of mitigation efforts by all Parties, including identifying relevant opportunities to enhance the provision and mobilization of support and enabling environments;

117. *Acknowledges* with appreciation the results of the Lima-Paris Action Agenda, which build on the climate summit convened on 23 September 2014 by the Secretary-General of the United Nations;

118. *Welcomes* the efforts of non-Party stakeholders to scale up their climate actions, and *encourages* the registration of those actions in the Non-State Actor Zone for Climate Action platform;[3]

119. *Encourages* Parties to work closely with non-Party stakeholders to catalyse efforts to strengthen mitigation and adaptation action;

120. *Also encourages* non-Party stakeholders to increase their engagement in the processes referred to in paragraph 110 above and paragraph 125 below;

121. *Agrees* to convene, pursuant to decision 1/CP.20, paragraph 21, building on the Lima-Paris Action Agenda and in conjunction with each session of the Conference of the Parties during the period 2016–2020, a high-level event that:

(a) Further strengthens high-level engagement on the implementation of policy options and actions arising from the processes referred to in paragraph 110 above and paragraph 125 below, drawing on the summary for policymakers referred to in paragraph 112(c) above;

(b) Provides an opportunity for announcing new or strengthened voluntary efforts, initiatives and coalitions, including the implementation of policies, practices and actions arising from the processes referred to in paragraph 110 above and paragraph 125 below and presented in the summary for policymakers referred to in paragraph 112(c) above;

(c) Takes stock of related progress and recognizes new or strengthened voluntary efforts, initiatives and coalitions;

(d) Provides meaningful and regular opportunities for the effective high-level engagement of dignitaries of Parties, international organizations, international cooperative initiatives and non-Party stakeholders;

122. *Decides* that two high-level champions shall be appointed to act on behalf of the President of the Conference of the Parties to facilitate through strengthened high-level engagement in the period 2016–2020 the successful execution of existing efforts and the scaling-up and introduction of new or strengthened voluntary efforts, initiatives and coalitions, including by:

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[3] <http://climateaction.unfccc.int/>.

(a) Working with the Executive Secretary and the current and incoming Presidents of the Conference of the Parties to coordinate the annual high-level event referred to in paragraph 121 above;

(b) Engaging with interested Parties and non-Party stakeholders, including to further the voluntary initiatives of the Lima-Paris Action Agenda;

(c) Providing guidance to the secretariat on the organization of technical expert meetings referred to in paragraph 112(a) above and paragraph 130(a) below;

123. *Also decides* that the high-level champions referred to in paragraph 122 above should normally serve for a term of two years, with their terms overlapping for a full year to ensure continuity, such that:

(a) The President of the Conference of the Parties of the twenty-first session should appoint one champion, who should serve for one year from the date of the appointment until the last day of the Conference of the Parties at its twenty-second session;

(b) The President of the Conference of the Parties of the twenty-second session should appoint one champion who should serve for two years from the date of the appointment until the last day of the Conference of the Parties at its twenty-third session (November 2017);

(c) Thereafter, each subsequent President of the Conference of the Parties should appoint one champion who should serve for two years and succeed the previously appointed champion whose term has ended;

124. *Invites* all interested Parties and relevant organizations to provide support for the work of the champions referred to in paragraph 122 above;

125. *Decides* to launch, in the period 2016–2020, a technical examination process on adaptation;

126. *Also decides* that the technical examination process on adaptation referred to in paragraph 125 above will endeavour to identify concrete opportunities for strengthening resilience, reducing vulnerabilities and increasing the understanding and implementation of adaptation actions;

127. *Further decides* that the technical examination process referred to in paragraph 125 above should be organized jointly by the Subsidiary Body for Implementation and the Subsidiary Body for Scientific and Technological Advice, and conducted by the Adaptation Committee;

128. *Decides* that the process referred to in paragraph 125 above will be pursued by:

(a) Facilitating the sharing of good practices, experiences and lessons learned;

(b) Identifying actions that could significantly enhance the implementation of adaptation actions, including actions that could enhance economic diversification and have mitigation co-benefits;

(c) Promoting cooperative action on adaptation;

(d) Identifying opportunities to strengthen enabling environments and enhance the provision of support for adaptation in the context of specific policies, practices and actions;

129. *Also decides* that the technical examination process on adaptation referred to in paragraph 125 above will take into account the process, modalities, outputs, outcomes and lessons learned from the technical examination process on mitigation referred to in paragraph 110 above;

130. *Requests* the secretariat to support the technical examination process referred to in paragraph 125 above by:

(a) Organizing regular technical expert meetings focusing on specific policies, strategies and actions;

(b) Preparing annually, on the basis of the meetings referred to in paragraph 130(a) above and in time to serve as an input to the summary for policymakers referred to in paragraph 112(c) above, a technical paper on opportunities to enhance adaptation action, as well as options to support their implementation, information on which should be made available in a user-friendly online format;

131. *Decides* that in conducting the process referred to in paragraph 125 above, the Adaptation Committee will engage with and explore ways to take into account, synergize with and build on the existing arrangements for adaptation-related work programmes, bodies and institutions under the Convention so as to ensure coherence and maximum value;

132. *Also decides* to conduct, in conjunction with the assessment referred to in paragraph 120 above, an assessment of the process referred to in paragraph 125 above, so as to improve its effectiveness;

133. *Invites* Parties and observer organizations to submit information on the opportunities referred to in paragraph 126 above by 3 February 2016;

V. NON-PARTY STAKEHOLDERS

134. *Welcomes* the efforts of all non-Party stakeholders to address and respond to climate change, including those of civil society, the private sector, financial institutions, cities and other subnational authorities;

135. *Invites* the non-Party stakeholders referred to in paragraph 134 above to scale up their efforts and support actions to reduce emissions and/or to build resilience and decrease vulnerability to the adverse effects of climate change and demonstrate these efforts via the Non-State Actor Zone for Climate Action platform[4] referred to in paragraph 118 above;

136. *Recognizes* the need to strengthen knowledge, technologies, practices and efforts of local communities and indigenous peoples related to addressing and responding to climate change, and *establishes* a platform for the exchange of experiences and sharing of best practices on mitigation and adaptation in a holistic and integrated manner;

137. *Also recognizes* the important role of providing incentives for emission reduction activities, including tools such as domestic policies and carbon pricing;

VI. ADMINISTRATIVE AND BUDGETARY MATTERS

138. *Takes note* of the estimated budgetary implications of the activities to be undertaken by the secretariat referred to in this decision and requests that the actions of the secretariat called for in this decision be undertaken subject to the availability of financial resources;

139. *Emphasizes* the urgency of making additional resources available for the implementation of the relevant actions, including actions referred to in this decision, and the implementation of the work programme referred to in paragraph 9 above;

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[4] <http://climateaction.unfccc.int/>.

140. *Urges* Parties to make voluntary contributions for the timely implementation of this decision.

Annex

PARIS AGREEMENT

The Parties to this Agreement,

Being Parties to the United Nations Framework Convention on Climate Change, hereinafter referred to as “the Convention”,

Pursuant to the Durban Platform for Enhanced Action established by decision 1/CP.17 of the Conference of the Parties to the Convention at its seventeenth session,

In pursuit of the objective of the Convention, and being guided by its principles, including the principle of equity and common but differentiated responsibilities and respective capabilities, in the light of different national circumstances,

Recognizing the need for an effective and progressive response to the urgent threat of climate change on the basis of the best available scientific knowledge,

Also recognizing the specific needs and special circumstances of developing country Parties, especially those that are particularly vulnerable to the adverse effects of climate change, as provided for in the Convention,

Taking full account of the specific needs and special situations of the least developed countries with regard to funding and transfer of technology,

Recognizing that Parties may be affected not only by climate change, but also by the impacts of the measures taken in response to it,

Emphasizing the intrinsic relationship that climate change actions, responses and impacts have with equitable access to sustainable development and eradication of poverty,

Recognizing the fundamental priority of safeguarding food security and ending hunger, and the particular vulnerabilities of food production systems to the adverse impacts of climate change,

Taking into account the imperatives of a just transition of the workforce and the creation of decent work and quality jobs in accordance with nationally defined development priorities,

Acknowledging that climate change is a common concern of humankind, Parties should, when taking action to address climate change, respect, promote and consider their respective obligations on human rights, the right to health, the rights of indigenous peoples, local communities, migrants, children, persons with disabilities and people in vulnerable situations and the right to development, as well as gender equality, empowerment of women and intergenerational equity,

Recognizing the importance of the conservation and enhancement, as appropriate, of sinks and reservoirs of the greenhouse gases referred to in the Convention,

Noting the importance of ensuring the integrity of all ecosystems, including oceans, and the protection of biodiversity, recognized by some cultures as Mother Earth, and noting the importance for some of the concept of “climate justice”, when taking action to address climate change,

Affirming the importance of education, training, public awareness, public participation, public access to information and cooperation at all levels on the matters addressed in this Agreement,

Recognizing the importance of the engagements of all levels of government and various actors, in accordance with respective national legislations of Parties, in addressing climate change,

Also recognizing that sustainable lifestyles and sustainable patterns of consumption and production, with developed country Parties taking the lead, play an important role in addressing climate change,

Have agreed as follows:

Article 1

For the purpose of this Agreement, the definitions contained in Article 1 of the Convention shall apply. In addition:

1. “Convention” means the United Nations Framework Convention on Climate Change, adopted in New York on 9 May 1992.
2. “Conference of the Parties” means the Conference of the Parties to the Convention.
3. “Party” means a Party to this Agreement.

Article 2

1. This Agreement, in enhancing the implementation of the Convention, including its objective, aims to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty, including by:
    (a) Holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change;
    (b) Increasing the ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development, in a manner that does not threaten food production;
    (c) Making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development.
2. This Agreement will be implemented to reflect equity and the principle of common but differentiated responsibilities and respective capabilities, in the light of different national circumstances.

Article 3

As nationally determined contributions to the global response to climate change, all Parties are to undertake and communicate ambitious efforts as defined in Articles 4, 7, 9, 10, 11 and 13 with the view to achieving the purpose of this Agreement as set out in Article 2. The efforts of all Parties will represent a progression over time, while recognizing the need to support developing country Parties for the effective implementation of this Agreement.

Article 4

1. In order to achieve the long-term temperature goal set out in Article 2, Parties aim to reach global peaking of greenhouse gas emissions as soon as possible, recognizing that peaking will take longer for developing country Parties, and to undertake rapid reductions thereafter in accordance with best available science, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century, on the basis of equity, and in the context of sustainable development and efforts to eradicate poverty.
2. Each Party shall prepare, communicate and maintain successive nationally determined contributions that it intends to achieve. Parties shall pursue domestic mitigation measures, with the aim of achieving the objectives of such contributions.
3. Each Party’s successive nationally determined contribution will represent a progression beyond the Party’s then current nationally determined contribution and reflect its highest possible ambition, reflecting its common but differentiated responsibilities and respective capabilities, in the light of different national circumstances.
4. Developed country Parties should continue taking the lead by undertaking economy-wide absolute emission reduction targets. Developing country Parties should continue enhancing their mitigation efforts, and are encouraged to move over time towards economy-wide emission reduction or limitation targets in the light of different national circumstances.
5. Support shall be provided to developing country Parties for the implementation of this Article, in accordance with Articles 9, 10 and 11, recognizing that enhanced support for developing country Parties will allow for higher ambition in their actions.

6. The least developed countries and small island developing States may prepare and communicate strategies, plans and actions for low greenhouse gas emissions development reflecting their special circumstances.

7. Mitigation co-benefits resulting from Parties' adaptation actions and/or economic diversification plans can contribute to mitigation outcomes under this Article.

8. In communicating their nationally determined contributions, all Parties shall provide the information necessary for clarity, transparency and understanding in accordance with decision 1/CP.21 and any relevant decisions of the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement.

9. Each Party shall communicate a nationally determined contribution every five years in accordance with decision 1/CP.21 and any relevant decisions of the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement and be informed by the outcomes of the global stocktake referred to in Article 14.

10. The Conference of the Parties serving as the meeting of the Parties to the Paris Agreement shall consider common time frames for nationally determined contributions at its first session.

11. A Party may at any time adjust its existing nationally determined contribution with a view to enhancing its level of ambition, in accordance with guidance adopted by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement.

12. Nationally determined contributions communicated by Parties shall be recorded in a public registry maintained by the secretariat.

13. Parties shall account for their nationally determined contributions. In accounting for anthropogenic emissions and removals corresponding to their nationally determined contributions, Parties shall promote environmental integrity, transparency, accuracy, completeness, comparability and consistency, and ensure the avoidance of double counting, in accordance with guidance adopted by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement.

14. In the context of their nationally determined contributions, when recognizing and implementing mitigation actions with respect to anthropogenic emissions and removals, Parties should take into account, as appropriate, existing methods and guidance under the Convention, in the light of the provisions of paragraph 13 of this Article.

15. Parties shall take into consideration in the implementation of this Agreement the concerns of Parties with economies most affected by the impacts of response measures, particularly developing country Parties.

16. Parties, including regional economic integration organizations and their member States, that have reached an agreement to act jointly under paragraph 2 of this Article shall notify the secretariat of the terms of that agreement, including the emission level allocated to each Party within the relevant time period, when they communicate their nationally determined contributions. The secretariat shall in turn inform the Parties and signatories to the Convention of the terms of that agreement.

17. Each party to such an agreement shall be responsible for its emission level as set out in the agreement referred to in paragraph 16 above in accordance with paragraphs 13 and 14 of this Article and Articles 13 and 15.

18. If Parties acting jointly do so in the framework of, and together with, a regional economic integration organization which is itself a Party to this Agreement, each member State of that regional economic integration organization individually, and together with the regional economic integration organization, shall be responsible for its emission level as set out in the agreement communicated under paragraph 16 of this Article in accordance with paragraphs 13 and 14 of this Article and Articles 13 and 15.

19. All Parties should strive to formulate and communicate long-term low greenhouse gas emission development strategies, mindful of Article 2 taking into account their common but differentiated responsibilities and respective capabilities, in the light of different national circumstances.

Article 5

1. Parties should take action to conserve and enhance, as appropriate, sinks and reservoirs of greenhouse gases as referred to in Article 4, paragraph 1(d), of the Convention, including forests.

2. Parties are encouraged to take action to implement and support, including through results-based payments, the existing framework as set out in related guidance and decisions already agreed under the Convention for: policy approaches and positive incentives for activities relating to reducing emissions from deforestation and forest degradation, and the role of conservation, sustainable management of forests and enhancement of forest carbon

stocks in developing countries; and alternative policy approaches, such as joint mitigation and adaptation approaches for the integral and sustainable management of forests, while reaffirming the importance of incentivizing, as appropriate, non-carbon benefits associated with such approaches.

Article 6

1. Parties recognize that some Parties choose to pursue voluntary cooperation in the implementation of their nationally determined contributions to allow for higher ambition in their mitigation and adaptation actions and to promote sustainable development and environmental integrity.

2. Parties shall, where engaging on a voluntary basis in cooperative approaches that involve the use of internationally transferred mitigation outcomes towards nationally determined contributions, promote sustainable development and ensure environmental integrity and transparency, including in governance, and shall apply robust accounting to ensure, inter alia, the avoidance of double counting, consistent with guidance adopted by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement.

3. The use of internationally transferred mitigation outcomes to achieve nationally determined contributions under this Agreement shall be voluntary and authorized by participating Parties.

4. A mechanism to contribute to the mitigation of greenhouse gas emissions and support sustainable development is hereby established under the authority and guidance of the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement for use by Parties on a voluntary basis. It shall be supervised by a body designated by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement, and shall aim:

   (a) To promote the mitigation of greenhouse gas emissions while fostering sustainable development;

   (b) To incentivize and facilitate participation in the mitigation of greenhouse gas emissions by public and private entities authorized by a Party;

   (c) To contribute to the reduction of emission levels in the host Party, which will benefit from mitigation activities resulting in emission reductions that can also be used by another Party to fulfil its nationally determined contribution; and

   (d) To deliver an overall mitigation in global emissions.

5. Emission reductions resulting from the mechanism referred to in paragraph 4 of this Article shall not be used to demonstrate achievement of the host Party’s nationally determined contribution if used by another Party to demonstrate achievement of its nationally determined contribution.

6. The Conference of the Parties serving as the meeting of the Parties to the Paris Agreement shall ensure that a share of the proceeds from activities under the mechanism referred to in paragraph 4 of this Article is used to cover administrative expenses as well as to assist developing country Parties that are particularly vulnerable to the adverse effects of climate change to meet the costs of adaptation.

7. The Conference of the Parties serving as the meeting of the Parties to the Paris Agreement shall adopt rules, modalities and procedures for the mechanism referred to in paragraph 4 of this Article at its first session.

8. Parties recognize the importance of integrated, holistic and balanced non-market approaches being available to Parties to assist in the implementation of their nationally determined contributions, in the context of sustainable development and poverty eradication, in a coordinated and effective manner, including through, inter alia, mitigation, adaptation, finance, technology transfer and capacity-building, as appropriate. These approaches shall aim to:

   (a) Promote mitigation and adaptation ambition;

   (b) Enhance public and private sector participation in the implementation of nationally determined contributions; and

   (c) Enable opportunities for coordination across instruments and relevant institutional arrangements.

9. A framework for non-market approaches to sustainable development is hereby defined to promote the non-market approaches referred to in paragraph 8 of this Article.

Article 7

1. Parties hereby establish the global goal on adaptation of enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change, with a view to contributing to sustainable development and ensuring an adequate adaptation response in the context of the temperature goal referred to in Article 2.

2. Parties recognize that adaptation is a global challenge faced by all with local, subnational, national, regional and international dimensions, and that it is a key component of and makes a contribution to the long-term global response to climate change to protect people, livelihoods and ecosystems, taking into account the urgent and immediate needs of those developing country Parties that are particularly vulnerable to the adverse effects of climate change.

3. The adaptation efforts of developing country Parties shall be recognized, in accordance with the modalities to be adopted by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement at its first session.

4. Parties recognize that the current need for adaptation is significant and that greater levels of mitigation can reduce the need for additional adaptation efforts, and that greater adaptation needs can involve greater adaptation costs.

5. Parties acknowledge that adaptation action should follow a country-driven, gender-responsive, participatory and fully transparent approach, taking into consideration vulnerable groups, communities and ecosystems, and should be based on and guided by the best available science and, as appropriate, traditional knowledge, knowledge of indigenous peoples and local knowledge systems, with a view to integrating adaptation into relevant socioeconomic and environmental policies and actions, where appropriate.

6. Parties recognize the importance of support for and international cooperation on adaptation efforts and the importance of taking into account the needs of developing country Parties, especially those that are particularly vulnerable to the adverse effects of climate change.

7. Parties should strengthen their cooperation on enhancing action on adaptation, taking into account the Cancun Adaptation Framework, including with regard to:

    (a) Sharing information, good practices, experiences and lessons learned, including, as appropriate, as these relate to science, planning, policies and implementation in relation to adaptation actions;

    (b) Strengthening institutional arrangements, including those under the Convention that serve this Agreement, to support the synthesis of relevant information and knowledge, and the provision of technical support and guidance to Parties;

    (c) Strengthening scientific knowledge on climate, including research, systematic observation of the climate system and early warning systems, in a manner that informs climate services and supports decision-making;

    (d) Assisting developing country Parties in identifying effective adaptation practices, adaptation needs, priorities, support provided and received for adaptation actions and efforts, and challenges and gaps, in a manner consistent with encouraging good practices;

    (e) Improving the effectiveness and durability of adaptation actions.

8. United Nations specialized organizations and agencies are encouraged to support the efforts of Parties to implement the actions referred to in paragraph 7 of this Article, taking into account the provisions of paragraph 5 of this Article.

9. Each Party shall, as appropriate, engage in adaptation planning processes and the implementation of actions, including the development or enhancement of relevant plans, policies and/or contributions, which may include:

    (a) The implementation of adaptation actions, undertakings and/or efforts;

    (b) The process to formulate and implement national adaptation plans;

    (c) The assessment of climate change impacts and vulnerability, with a view to formulating nationally determined prioritized actions, taking into account vulnerable people, places and ecosystems;

    (d) Monitoring and evaluating and learning from adaptation plans, policies, programmes and actions; and

    (e) Building the resilience of socioeconomic and ecological systems, including through economic diversification and sustainable management of natural resources.

10. Each Party should, as appropriate, submit and update periodically an adaptation communication, which may include its priorities, implementation and support needs, plans and actions, without creating any additional burden for developing country Parties.

11. The adaptation communication referred to in paragraph 10 of this Article shall be, as appropriate, submitted and updated periodically, as a component of or in conjunction with other communications or documents, including a national adaptation plan, a nationally determined contribution as referred to in Article 4, paragraph 2, and/or a national communication.

12. The adaptation communications referred to in paragraph 10 of this Article shall be recorded in a public registry maintained by the secretariat.

13. Continuous and enhanced international support shall be provided to developing country Parties for the implementation of paragraphs 7, 9, 10 and 11 of this Article, in accordance with the provisions of Articles 9, 10 and 11.

14. The global stocktake referred to in Article 14 shall, inter alia:

    (a) Recognize adaptation efforts of developing country Parties;

    (b) Enhance the implementation of adaptation action taking into account the adaptation communication referred to in paragraph 10 of this Article;

    (c) Review the adequacy and effectiveness of adaptation and support provided for adaptation; and

    (d) Review the overall progress made in achieving the global goal on adaptation referred to in paragraph 1 of this Article.

Article 8

1. Parties recognize the importance of averting, minimizing and addressing loss and damage associated with the adverse effects of climate change, including extreme weather events and slow onset events, and the role of sustainable development in reducing the risk of loss and damage.

2. The Warsaw International Mechanism for Loss and Damage associated with Climate Change Impacts shall be subject to the authority and guidance of the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement and may be enhanced and strengthened, as determined by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement.

3. Parties should enhance understanding, action and support, including through the Warsaw International Mechanism, as appropriate, on a cooperative and facilitative basis with respect to loss and damage associated with the adverse effects of climate change.

4. Accordingly, areas of cooperation and facilitation to enhance understanding, action and support may include:

    (a) Early warning systems;

    (b) Emergency preparedness;

    (c) Slow onset events;

    (d) Events that may involve irreversible and permanent loss and damage;

    (e) Comprehensive risk assessment and management;

    (f) Risk insurance facilities, climate risk pooling and other insurance solutions;

    (g) Non-economic losses;

    (h) Resilience of communities, livelihoods and ecosystems.

5. The Warsaw International Mechanism shall collaborate with existing bodies and expert groups under the Agreement, as well as relevant organizations and expert bodies outside the Agreement.

Article 9

1. Developed country Parties shall provide financial resources to assist developing country Parties with respect to both mitigation and adaptation in continuation of their existing obligations under the Convention.

2. Other Parties are encouraged to provide or continue to provide such support voluntarily.

3. As part of a global effort, developed country Parties should continue to take the lead in mobilizing climate finance from a wide variety of sources, instruments and channels, noting the significant role of public funds,

through a variety of actions, including supporting country-driven strategies, and taking into account the needs and priorities of developing country Parties. Such mobilization of climate finance should represent a progression beyond previous efforts.

4. The provision of scaled-up financial resources should aim to achieve a balance between adaptation and mitigation, taking into account country-driven strategies, and the priorities and needs of developing country Parties, especially those that are particularly vulnerable to the adverse effects of climate change and have significant capacity constraints, such as the least developed countries and small island developing States, considering the need for public and grant-based resources for adaptation.

5. Developed country Parties shall biennially communicate indicative quantitative and qualitative information related to paragraphs 1 and 3 of this Article, as applicable, including, as available, projected levels of public financial resources to be provided to developing country Parties. Other Parties providing resources are encouraged to communicate biennially such information on a voluntary basis.

6. The global stocktake referred to in Article 14 shall take into account the relevant information provided by developed country Parties and/or Agreement bodies on efforts related to climate finance.

7. Developed country Parties shall provide transparent and consistent information on support for developing country Parties provided and mobilized through public interventions biennially in accordance with the modalities, procedures and guidelines to be adopted by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement, at its first session, as stipulated in Article 13, paragraph 13. Other Parties are encouraged to do so.

8. The Financial Mechanism of the Convention, including its operating entities, shall serve as the financial mechanism of this Agreement.

9. The institutions serving this Agreement, including the operating entities of the Financial Mechanism of the Convention, shall aim to ensure efficient access to financial resources through simplified approval procedures and enhanced readiness support for developing country Parties, in particular for the least developed countries and small island developing States, in the context of their national climate strategies and plans.

Article 10

1. Parties share a long-term vision on the importance of fully realizing technology development and transfer in order to improve resilience to climate change and to reduce greenhouse gas emissions.

2. Parties, noting the importance of technology for the implementation of mitigation and adaptation actions under this Agreement and recognizing existing technology deployment and dissemination efforts, shall strengthen cooperative action on technology development and transfer.

3. The Technology Mechanism established under the Convention shall serve this Agreement.

4. A technology framework is hereby established to provide overarching guidance to the work of the Technology Mechanism in promoting and facilitating enhanced action on technology development and transfer in order to support the implementation of this Agreement, in pursuit of the long-term vision referred to in paragraph 1 of this Article.

5. Accelerating, encouraging and enabling innovation is critical for an effective, long-term global response to climate change and promoting economic growth and sustainable development. Such effort shall be, as appropriate, supported, including by the Technology Mechanism and, through financial means, by the Financial Mechanism of the Convention, for collaborative approaches to research and development, and facilitating access to technology, in particular for early stages of the technology cycle, to developing country Parties.

6. Support, including financial support, shall be provided to developing country Parties for the implementation of this Article, including for strengthening cooperative action on technology development and transfer at different stages of the technology cycle, with a view to achieving a balance between support for mitigation and adaptation. The global stocktake referred to in Article 14 shall take into account available information on efforts related to support on technology development and transfer for developing country Parties.

Article 11

1. Capacity-building under this Agreement should enhance the capacity and ability of developing country Parties, in particular countries with the least capacity, such as the least developed countries, and those that are particularly vulnerable to the adverse effects of climate change, such as small island developing States, to take

effective climate change action, including, inter alia, to implement adaptation and mitigation actions, and should facilitate technology development, dissemination and deployment, access to climate finance, relevant aspects of education, training and public awareness, and the transparent, timely and accurate communication of information.

2. Capacity-building should be country-driven, based on and responsive to national needs, and foster country ownership of Parties, in particular, for developing country Parties, including at the national, subnational and local levels. Capacity-building should be guided by lessons learned, including those from capacity-building activities under the Convention, and should be an effective, iterative process that is participatory, cross-cutting and gender-responsive.

3. All Parties should cooperate to enhance the capacity of developing country Parties to implement this Agreement. Developed country Parties should enhance support for capacity-building actions in developing country Parties.

4. All Parties enhancing the capacity of developing country Parties to implement this Agreement, including through regional, bilateral and multilateral approaches, shall regularly communicate on these actions or measures on capacity-building. Developing country Parties should regularly communicate progress made on implementing capacity-building plans, policies, actions or measures to implement this Agreement.

5. Capacity-building activities shall be enhanced through appropriate institutional arrangements to support the implementation of this Agreement, including the appropriate institutional arrangements established under the Convention that serve this Agreement. The Conference of the Parties serving as the meeting of the Parties to the Paris Agreement shall, at its first session, consider and adopt a decision on the initial institutional arrangements for capacity-building.

Article 12

Parties shall cooperate in taking measures, as appropriate, to enhance climate change education, training, public awareness, public participation and public access to information, recognizing the importance of these steps with respect to enhancing actions under this Agreement.

Article 13

1. In order to build mutual trust and confidence and to promote effective implementation, an enhanced transparency framework for action and support, with built-in flexibility which takes into account Parties’ different capacities and builds upon collective experience is hereby established.

2. The transparency framework shall provide flexibility in the implementation of the provisions of this Article to those developing country Parties that need it in the light of their capacities. The modalities, procedures and guidelines referred to in paragraph 13 of this Article shall reflect such flexibility.

3. The transparency framework shall build on and enhance the transparency arrangements under the Convention, recognizing the special circumstances of the least developed countries and small island developing States, and be implemented in a facilitative, non-intrusive, non-punitive manner, respectful of national sovereignty, and avoid placing undue burden on Parties.

4. The transparency arrangements under the Convention, including national communications, biennial reports and biennial update reports, international assessment and review and international consultation and analysis, shall form part of the experience drawn upon for the development of the modalities, procedures and guidelines under paragraph 13 of this Article.

5. The purpose of the framework for transparency of action is to provide a clear understanding of climate change action in the light of the objective of the Convention as set out in its Article 2, including clarity and tracking of progress towards achieving Parties’ individual nationally determined contributions under Article 4, and Parties’ adaptation actions under Article 7, including good practices, priorities, needs and gaps, to inform the global stocktake under Article 14.

6. The purpose of the framework for transparency of support is to provide clarity on support provided and received by relevant individual Parties in the context of climate change actions under Articles 4, 7, 9, 10 and 11, and, to the extent possible, to provide a full overview of aggregate financial support provided, to inform the global stocktake under Article 14.

7. Each Party shall regularly provide the following information:

(a) A national inventory report of anthropogenic emissions by sources and removals by sinks of greenhouse gases, prepared using good practice methodologies accepted by the Intergovernmental Panel on Climate Change and agreed upon by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement;

(b) Information necessary to track progress made in implementing and achieving its nationally determined contribution under Article 4.

8. Each Party should also provide information related to climate change impacts and adaptation under Article 7, as appropriate.

9. Developed country Parties shall, and other Parties that provide support should, provide information on financial, technology transfer and capacity-building support provided to developing country Parties under Article 9, 10 and 11.

10. Developing country Parties should provide information on financial, technology transfer and capacity-building support needed and received under Articles 9, 10 and 11.

11. Information submitted by each Party under paragraphs 7 and 9 of this Article shall undergo a technical expert review, in accordance with decision 1/CP.21. For those developing country Parties that need it in the light of their capacities, the review process shall include assistance in identifying capacity-building needs. In addition, each Party shall participate in a facilitative, multilateral consideration of progress with respect to efforts under Article 9, and its respective implementation and achievement of its nationally determined contribution.

12. The technical expert review under this paragraph shall consist of a consideration of the Party’s support provided, as relevant, and its implementation and achievement of its nationally determined contribution. The review shall also identify areas of improvement for the Party, and include a review of the consistency of the information with the modalities, procedures and guidelines referred to in paragraph 13 of this Article, taking into account the flexibility accorded to the Party under paragraph 2 of this Article. The review shall pay particular attention to the respective national capabilities and circumstances of developing country Parties.

13. The Conference of the Parties serving as the meeting of the Parties to the Paris Agreement shall, at its first session, building on experience from the arrangements related to transparency under the Convention, and elaborating on the provisions in this Article, adopt common modalities, procedures and guidelines, as appropriate, for the transparency of action and support.

14. Support shall be provided to developing countries for the implementation of this Article.

15. Support shall also be provided for the building of transparency-related capacity of developing country Parties on a continuous basis.

Article 14

1. The Conference of the Parties serving as the meeting of the Parties to the Paris Agreement shall periodically take stock of the implementation of this Agreement to assess the collective progress towards achieving the purpose of this Agreement and its long-term goals (referred to as the “global stocktake”). It shall do so in a comprehensive and facilitative manner, considering mitigation, adaptation and the means of implementation and support, and in the light of equity and the best available science.

2. The Conference of the Parties serving as the meeting of the Parties to the Paris Agreement shall undertake its first global stocktake in 2023 and every five years thereafter unless otherwise decided by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement.

3. The outcome of the global stocktake shall inform Parties in updating and enhancing, in a nationally determined manner, their actions and support in accordance with the relevant provisions of this Agreement, as well as in enhancing international cooperation for climate action.

Article 15

1. A mechanism to facilitate implementation of and promote compliance with the provisions of this Agreement is hereby established.

2. The mechanism referred to in paragraph 1 of this Article shall consist of a committee that shall be expert-based and facilitative in nature and function in a manner that is transparent, non-adversarial and non-punitive. The committee shall pay particular attention to the respective national capabilities and circumstances of Parties.

3. The committee shall operate under the modalities and procedures adopted by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement at its first session and report annually to the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement.

Article 16

1. The Conference of the Parties, the supreme body of the Convention, shall serve as the meeting of the Parties to this Agreement.
2. Parties to the Convention that are not Parties to this Agreement may participate as observers in the proceedings of any session of the Conference of the Parties serving as the meeting of the Parties to this Agreement. When the Conference of the Parties serves as the meeting of the Parties to this Agreement, decisions under this Agreement shall be taken only by those that are Parties to this Agreement.
3. When the Conference of the Parties serves as the meeting of the Parties to this Agreement, any member of the Bureau of the Conference of the Parties representing a Party to the Convention but, at that time, not a Party to this Agreement, shall be replaced by an additional member to be elected by and from amongst the Parties to this Agreement.
4. The Conference of the Parties serving as the meeting of the Parties to the Paris Agreement shall keep under regular review the implementation of this Agreement and shall make, within its mandate, the decisions necessary to promote its effective implementation. It shall perform the functions assigned to it by this Agreement and shall:
    (a) Establish such subsidiary bodies as deemed necessary for the implementation of this Agreement; and
    (b) Exercise such other functions as may be required for the implementation of this Agreement.
5. The rules of procedure of the Conference of the Parties and the financial procedures applied under the Convention shall be applied mutatis mutandis under this Agreement, except as may be otherwise decided by consensus by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement.
6. The first session of the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement shall be convened by the secretariat in conjunction with the first session of the Conference of the Parties that is scheduled after the date of entry into force of this Agreement. Subsequent ordinary sessions of the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement shall be held in conjunction with ordinary sessions of the Conference of the Parties, unless otherwise decided by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement.
7. Extraordinary sessions of the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement shall be held at such other times as may be deemed necessary by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement or at the written request of any Party, provided that, within six months of the request being communicated to the Parties by the secretariat, it is supported by at least one third of the Parties.
8. The United Nations and its specialized agencies and the International Atomic Energy Agency, as well as any State member thereof or observers thereto not party to the Convention, may be represented at sessions of the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement as observers. Any body or agency, whether national or international, governmental or non-governmental, which is qualified in matters covered by this Agreement and which has informed the secretariat of its wish to be represented at a session of the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement as an observer, may be so admitted unless at least one third of the Parties present object. The admission and participation of observers shall be subject to the rules of procedure referred to in paragraph 5 of this Article.

Article 17

1. The secretariat established by Article 8 of the Convention shall serve as the secretariat of this Agreement.
2. Article 8, paragraph 2, of the Convention on the functions of the secretariat, and Article 8, paragraph 3, of the Convention, on the arrangements made for the functioning of the secretariat, shall apply mutatis mutandis to this Agreement. The secretariat shall, in addition, exercise the functions assigned to it under this Agreement and by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement.

Article 18

1. The Subsidiary Body for Scientific and Technological Advice and the Subsidiary Body for Implementation established by Articles 9 and 10 of the Convention shall serve, respectively, as the Subsidiary Body for Scientific and Technological Advice and the Subsidiary Body for Implementation of this Agreement. The provisions of the Convention relating to the functioning of these two bodies shall apply mutatis mutandis to this Agreement. Sessions of the meetings of the Subsidiary Body for Scientific and Technological Advice and the Subsidiary Body for Implementation of this Agreement shall be held in conjunction with the meetings of, respectively, the Subsidiary Body for Scientific and Technological Advice and the Subsidiary Body for Implementation of the Convention.
2. Parties to the Convention that are not Parties to this Agreement may participate as observers in the proceedings of any session of the subsidiary bodies. When the subsidiary bodies serve as the subsidiary bodies of this Agreement, decisions under this Agreement shall be taken only by those that are Parties to this Agreement.
3. When the subsidiary bodies established by Articles 9 and 10 of the Convention exercise their functions with regard to matters concerning this Agreement, any member of the bureaux of those subsidiary bodies representing a Party to the Convention but, at that time, not a Party to this Agreement, shall be replaced by an additional member to be elected by and from amongst the Parties to this Agreement.

Article 19

1. Subsidiary bodies or other institutional arrangements established by or under the Convention, other than those referred to in this Agreement, shall serve this Agreement upon a decision of the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement. The Conference of the Parties serving as the meeting of the Parties to the Paris Agreement shall specify the functions to be exercised by such subsidiary bodies or arrangements.
2. The Conference of the Parties serving as the meeting of the Parties to the Paris Agreement may provide further guidance to such subsidiary bodies and institutional arrangements.

Article 20

1. This Agreement shall be open for signature and subject to ratification, acceptance or approval by States and regional economic integration organizations that are Parties to the Convention. It shall be open for signature at the United Nations Headquarters in New York from 22 April 2016 to 21 April 2017. Thereafter, this Agreement shall be open for accession from the day following the date on which it is closed for signature. Instruments of ratification, acceptance, approval or accession shall be deposited with the Depositary.
2. Any regional economic integration organization that becomes a Party to this Agreement without any of its member States being a Party shall be bound by all the obligations under this Agreement. In the case of regional economic integration organizations with one or more member States that are Parties to this Agreement, the organization and its member States shall decide on their respective responsibilities for the performance of their obligations under this Agreement. In such cases, the organization and the member States shall not be entitled to exercise rights under this Agreement concurrently.
3. In their instruments of ratification, acceptance, approval or accession, regional economic integration organizations shall declare the extent of their competence with respect to the matters governed by this Agreement. These organizations shall also inform the Depositary, who shall in turn inform the Parties, of any substantial modification in the extent of their competence.

Article 21

1. This Agreement shall enter into force on the thirtieth day after the date on which at least 55 Parties to the Convention accounting in total for at least an estimated 55 percent of the total global greenhouse gas emissions have deposited their instruments of ratification, acceptance, approval or accession.
2. Solely for the limited purpose of paragraph 1 of this Article, "total global greenhouse gas emissions" means the most up-to-date amount communicated on or before the date of adoption of this Agreement by the Parties to the Convention.
3. For each State or regional economic integration organization that ratifies, accepts or approves this Agreement or accedes thereto after the conditions set out in paragraph 1 of this Article for entry into force have been fulfilled,

this Agreement shall enter into force on the thirtieth day after the date of deposit by such State or regional economic integration organization of its instrument of ratification, acceptance, approval or accession.

4. For the purposes of paragraph 1 of this Article, any instrument deposited by a regional economic integration organization shall not be counted as additional to those deposited by its member States.

Article 22

The provisions of Article 15 of the Convention on the adoption of amendments to the Convention shall apply mutatis mutandis to this Agreement.

Article 23

1. The provisions of Article 16 of the Convention on the adoption and amendment of annexes to the Convention shall apply mutatis mutandis to this Agreement.
2. Annexes to this Agreement shall form an integral part thereof and, unless otherwise expressly provided for, a reference to this Agreement constitutes at the same time a reference to any annexes thereto. Such annexes shall be restricted to lists, forms and any other material of a descriptive nature that is of a scientific, technical, procedural or administrative character.

Article 24

The provisions of Article 14 of the Convention on settlement of disputes shall apply mutatis mutandis to this Agreement.

Article 25

1. Each Party shall have one vote, except as provided for paragraph 2 of this Article.
2. Regional economic integration organizations, in matters within their competence, shall exercise their right to vote with a number of votes equal to the number of their member States that are Parties to this Agreement. Such an organization shall not exercise its right to vote if any of its member States exercises its right, and vice versa.

Article 26

The Secretary-General of the United Nations shall be the Depositary of this Agreement.

Article 27

No reservations may be made to this Agreement.

Article 28

1. At any time after three years from the date on which this Agreement has entered into force for a Party, that Party may withdraw from this Agreement by giving written notification to the Depositary.
2. Any such withdrawal shall take effect upon expiry of one year from the date of receipt by the Depositary of the notification of withdrawal, or on such later date as may be specified in the notification of withdrawal.
3. Any Party that withdraws from the Convention shall be considered as also having withdrawn from this Agreement.

Article 29

The original of this Agreement, of which the Arabic, Chinese, English, French, Russian and Spanish texts are equally authentic, shall be deposited with the Secretary-General of the United Nations.

DONE at Paris this twelfth day of December two thousand and fifteen.

IN WITNESS WHEREOF, the undersigned, being duly authorized to that effect, have signed this Agreement.

נספח 7

העתק מהדיווח האחרון שהעבירה ישראל

עמ' 229

נספח 7

2019

1000 tons

21.00 CH4 GWP
310 N2O GWP

2019	CO2 emissions (Gg)	CO2 removals (Gg)	CH4 (Gg)	N2O (Gg	CO (Gg)	NOx (Gg)	NMVOCs (Gg)	SOx (Gg)	SF$_6$ (CO2eq Gg)	HFC'S (CO2eq Gg)	PFC'S (CO2eq Gg)	Total CO2eq (Gg)
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO2	CO2	CH4	N2O	CO	NOx	NMVOCs	SOx	SF$_6$	HFC'S	PFC'S	
Total national emissions and removals	**65,876.00**	**-363.00**	**347.48**	**6.32**	**139.24**	**88.20**		**45.95**	**117.40**	**3,973.62**	**185.31**	79,044.64
1. Energy	**63,845.51**		**4.53**	**0.56**	**139.24**	**87.75**		**43.29**				64,114
A. Fuel combustion (sectoral approach)	63,845.51		4.53	0.56	139.24	87.75		43.29				64,114
1. Energy industries	37,995.98		0.58	0.33	9.55	44.05		34.06				38,111
2. Manufacturing industries and construction	6,379.37		0.47	0.04	6.22	10.48		7.04				6,403
3. Transport	18,588.54		3.34	0.17	123.19	31.85		1.49				18,712
4. Other sectors												-
Commercial, institutional	376.47		0.06	0.00	0.12	0.58		0.45				379
residential sectors	427.19		0.07	0.00	0.14	0.68		0.05				430
Agriculture, forestry and fishing	77.97		0.01	0.00	0.02	0.11		0.20				78
5. Other (please specify)												-
B. Fugitive emissions from fuels												-
1. Solid fuels												-
2. Oil and natural gas												-
2. Industrial processes	**1,923.86**		**0.21**	**1.31**		**0.45**	**82.48**	**2.66**	**117.40**	**3,973.62**	**185.31**	6,611
A. Mineral products												-
CEMENT PRODUCTION	1,806.29							0.05				1,806
PRODUCTION OF LIME	105.99											106
SODA ASH USE	11.57											12
ROAD PAVING WITH ASPHALT							76.17					-
Container Glass							0.82					-
B. Chemical industry												-
NITRIC ACID PRODUCTION				1.31		0.45						406
Ethylene			0.21									4
PRODUCTION OF OTHER CHEMICALS							5.49					-
Sulphuric Acid								2.61				-
C. Metal production												-
D. Other production												-
E. Production of halocarbons and sulphur hexafluoride												-
F. Consumption of halocarbons and sulphur hexafluoride									117.40	3,973.62	185.31	4,276
G. Other (please specify)												-
3. Solvent and other product use												-
4. Agriculture			**41.86**	**4.12**								2,156
A. Enteric fermentation			38.75									814
B. Manure management			3.11	0.65								267
C. Rice cultivation			-	-								-
D. Agricultural soils			-	3.47								1,076
E. Prescribed burning of savannahs			-	-								-
F. Field burning of agricultural residues			-	-								-
G. Other (please specify)			-	-								-
5. Land-use change and forestry	**106.63**	**-363.00**										-256
A. Changes in forest and other woody biomass stocks	-	-363.00										-363
B. Forest and grassland conversion	-	-										-
C. Abandonment of managed lands	-	-										-
D. CO2 emissions and removals from soil	106.63	-										107
E. Other (please specify)	-	-										-
6. Waste			**300.88**	**0.33**								6,420
A. Solid waste disposal on land			265.77									5,581
B. Biological Treatment of Solid Waste			4.73	0.21								675
C. Waste incineration												-
D.Waste-water handling			30.37	0.12								
E. Other (please specify)												-
7. Other (please specify)												-
Memo items												-
International bunkers	**4,650**		**0.10**	**0.11**	**19.61**	**36.91**	**5.42**	**12.77**				4,686
Aviation	3,541		0.03	0.10	5.00	15.01	2.50	6.73				3,572
Marine	1,110		0.07	0.01	14.60	21.91	2.92	6.04				1,114
CO2 emissions from biomass												

<u>נספח 8</u>

העתק מהחלטת הממשלה 171

עמ' 231

נספח 8

החלטות ממשלה

מעבר לכלכלה דלת פחמן

מספר החלטה: 171

יחידה: מזכירות הממשלה
ממשלה: הממשלה ה- 36, נפתלי בנט
תאריך פרסום: 25.07.2021
תאריך תחולה: 25.07.2021

החלטה מספר 171 של הממשלה מיום 25.07.2021

נושא ההחלטה:
מעבר לכלכלה דלת פחמן

מחליטים:

1. בהמשך להחלטת הממשלה מס' 542 מיום 20.9.2015 בעניין הפחתת פליטות גזי חממה וייעול צריכת האנרגיה במשק (להלן – החלטת ממשלה 542) ועל-מנת לעמוד במחויבותה של ישראל לפי החלטת הממשלה מס' 2041 בעניין אשרור הסכם פריז בדבר התמודדות בין-לאומית עם שינויי האקלים מיום 14.11.2016, להגיש למזכירות אמנת האקלים יעד לאומי מעודכן להפחתת פליטות גזי חממה לשנת 2030, וכן לפעול למעבר ישראל לכלכלה דלת פחמן עד לשנת 2050 -

א. מדינת ישראל מכירה בחשיבות ההגעה ליעד של אפס פליטת גזי חממה עד 2050 בהתאם להסכם פריז ומחויבותה הבין-לאומית ולמען מניעת חציית רף ההתחממות הגלובלית של מעלה וחצי צלזיוס. מכאן, שהממשלה תבחן מעת לעת את יעדי ההפחתה שהציבה לעצמה בהחלטה זו.

ב. לעדכן את היעד הלאומי להפחתת פליטת גזי חממה לשנת 2030 שנקבע בהחלטת ממשלה 542, כך שהכמות השנתית של פליטות גזי חממה בשנת 2030 תפחת ב-27% לכל הפחות מהכמות השנתית שנמדדה בשנת 2015, אשר עמדה על 79 מיליון טונה. בהתאם לאמור, תעמוד הכמות השנתית של פליטות גזי חממה בשנת 2030 על כ-58 מיליון טונה.

ג. לקבוע יעד לאומי להפחתת פליטות גזי חממה לשנת 2050, והוא – שהכמות השנתית של פליטות גזי חממה בשנת 2050 תפחת ב-85% לכל הפחות מהכמות השנתית שנמדדה בשנת 2015. בהתאם לאמור, תעמוד הכמות השנתית של פליטות גזי חממה בשנת 2050 על כ-12 מיליון טונה.

2. לשם השגת היעדים הלאומיים בסעיף 1 כאמור, לקבוע יעדים מגזריים להפחתת פליטות גזי חממה ולייעול צריכת האנרגיה במשק כמפורט להלן:

א. החל משנת 2026, כל האוטובוסים העירוניים החדשים אשר יירכשו, יהיו רכבים נקיים, כהגדרתם בסעיף 77א לפקודת התעבורה [נוסח חדש].

ב. הפחתת פליטות גזי חממה שמקורן בתחום הפסולת המוצקה עד לשנת 2030 בהיקף של 47% לכל הפחות ביחס לפליטות שנמדדו בשנת 2015, אשר עמדו על 5.5 מיליון טונה.

ג. הפחתה בשיעור של 71% בכמות הפסולת העירונית המוטמנת עד לשנת 2030 ביחס לכמות הפסולת העירונית שהוטמנה בשנת 2018, אשר עמדה על כ-4.5 מיליון טונה.

ד. הפחתת פליטות גזי חממה שמקורן בייצור החשמל עד לשנת 2030 בהיקף של כ-30% ביחס לפליטות שנמדדו בשנת 2015, אשר עמדו על 37.6 מיליון טונה, בהתחשב ביעדי אנרגיות מתחדשות שנקבעו בהחלטת הממשלה מס' 465.

ה. בלימת הגידול בפליטות גזי חממה שמקורן בתחבורה עד לשנת 2030, כך שסך הגידול בפליטות יעמוד על 3.3% בלבד ביחס לכמות הפליטות שנמדדו בשנת 2015, אשר עמדו על 17.6 מיליון טונה.

ו. הגבלת כמות פליטות גזי החממה מרכב חדש, שמשקלו הכולל עד 3.5 טונה, הנרשם החל משנת 2030, לכמות השווה לעד 5% מכמות פליטות גזי החממה הממוצעת לרכב חדש, שמשקלו הכולל עד 3.5 טונה, הנרשם בשנת 2020, בהתאם לעקרונות המפורטים בחקיקה האירופית ובשים לב למאפיינים הייחודיים של ישראל. יעד זה ייבחן בשנת 2025 ויעודכן ככל שיהיה צורך, בשים לב להתפתחות הטכנולוגית, היקף חדירת הרכב החשמלי בישראל ובעולם, בתשתיות החשמל ופריסת עמדות הטעינה בישראל.

ז. שינוי היעד שנקבע בסעיף 1(ב)(1) להחלטת הממשלה 542, כך שבמקומו ייקָבע יעד שלפיו עד לשנת 2030 תעמוד העצימות האנרגטית המושקעת בהפקה של תוצר לאומי גולמי בסך 1 מלש"ח על 122 מגוואט שעה.

ח. הפחתת פליטות גזי חממה מסקטור התעשייה עד לשנת 2030 בהיקף של 30% לכל הפחות ביחס לפליטות בשנת 2015, אשר עמדו על 12 מיליון טונה.

ט. להטיל על משרד הפנים ומינהל התכנון, בשיתוף משרד האנרגיה, המשרד להגנת הסביבה, משרד הבינוי והשיכון ומשרד האוצר לפעול לקביעת יעדים לבנייה מאופסת אנרגיה למבנים בתוך שנה מיום קבלת החלטה זו.

י. הפחתת פליטות גזי חממה שמקורן בתחום הפסולת העירונית עד לשנת 2050 בהיקף של 92% לכל הפחות ביחס לפליטות שנמדדו בשנת 2015, אשר עמדו על 5.5 מיליון טונה.

יא. הפחתת פליטות גזי חממה שמקורן בייצור חשמל עד לשנת 2050 בהיקף של 85% לכל הפחות ביחס לפליטות שנמדדו בשנת 2015, אשר עמדו על 37.4 מיליון טונה. על מנת לעמוד ביעדים להפחתת פליטות גזי חממה ממשק החשמל, להטיל על שרת האנרגיה, בהתאם לסמכותה לפי כל דין, לפעול לבחינת תמהיל ייצור אנרגיה ובכלל זה לפעול לקביעת יעדים לאנרגיה מתחדשת לשנת 2050, תוך הבטחת משק אנרגיה אמין, בר השגה ובר קיימא בתוך 12 חודשים מאישור החלטה זו, ולהקים צוות בין-משרדי בראשות משרד האנרגיה ובהשתתפות המשרד להגנת הסביבה, משרד הפנים, מינהל התכנון, רשות החשמל ומשרד האוצר לבחינת התנאים והמשמעויות הנגזרות מיעדי האנרגיה המתחדשת האמורים, וזאת ובשים לב לעבודות שנעשו, לרבות במשרד האנרגיה.

יב. הפחתת פליטות גזי חממה מסקטור התעשייה עד לשנת 2050 בהיקף של 56% לכל הפחות ביחס לפליטות בשנת 2015, אשר עמדו על 12 מיליון טונה.

יג. הפחתת פליטות גזי חממה שמקורן בתחבורה עד לשנת 2050 בהיקף של 96% לכל הפחות ביחס לפליטות שנמדדו בשנת 2015, אשר עמדו על 17.6 מיליון טונה.

3. להטיל על הוועדה הבין-משרדית להיערכות ומוכנות לשינוי אקלים והפחתת פליטות גזי חממה בראשות מנכ"לית המשרד להגנת הסביבה, אשר הוקמה מתוקף החלטת הממשלה מס' 474 מיום 18.9.2017 (להלן - "הוועדה הבין-משרדית"), לרכז תוכנית לאומית ליישום היעדים בסעיפים 1 ו-2 לעיל. התוכנית הלאומית תורכב מתוכניות יישום בכל סקטור אשר יוכנו בהובלת המשרד האחראי על הסקטור הרלוונטי. לעניין יישומה של החלטה זו ייווספו לוועדה הבין-משרדית מנכ"ל משרד הפנים ומנכ"לית מנהל התכנון. השרות יגישו את התכנית כאמור לאישור הממשלה בתוך 6 חודשים.

4. להטיל על הוועדה הבין-משרדית לגבש עד יום 1.7.2022 מתודולוגיה לבחינה של ההשפעות האפשריות על עמידה ביעדים הלאומיים להפחתת פליטות גזי חממה הקבועים בהצעת החלטה זו, אשר נובעת ממדיניות הממשלה והחלטותיה.

5. לקבוע כי שרי הממשלה של המשרדים להגנת הסביבה, האנרגיה, התחבורה והבטיחות בדרכים, הכלכלה והתעשייה והפנים לדווח לממשלה, בכל שנה, לא יאוחר מ-31 במרס, על הפעולות שננקטו על-ידי משרדיהם בהתאם לתוכנית בשנה שקדמה למועד הדיווח.

6. להטיל על השרה להגנת הסביבה, בהתייעצות עם שרת הכלכלה והתעשייה, לגבש מנגנון וולונטרי לדיווח ולפרסום מידע בנושא השפעה על האקלים ופליטות גזי חממה של מוצרים ושירותים המיוצרים בישראל ומיובאים אליה.

הנוסח המחייב של החלטות הממשלה הינו הנוסח השמור במזכירות הממשלה.
הנוסח המחייב של הצעות חוק ודברי חקיקה הנזכרים בהחלטות הינו הנוסח המתפרסם ברשומות.

החלטות תקציביות כפופות לחוק התקציב השנתי.

דף זה עודכן לאחרונה בתאריך 25.07.2021

שירותים ומידע

אזרחות, תעודות ודרכונים
אכיפה, חוק וממשל
אנשים עם מוגבלות
בנייה, דיור ומקרקעין
בריאות ורווחה
תעשייה, מסחר ותקשורת
אנרגיה, סביבה וחקלאות
משפחה ומצב אישי
חינוך והשכלה
ביטחון וחירום
מסים ותשלומים
עבודה ותעסוקה
עלייה וקליטה
תחבורה
תרבות, ספורט ותיירות

מידע שימושי

העתק אישור תשלום
RSS
צרו קשר עם משרדי הממשלה

תמיכה

מוקד מענה ממשלתי מרכזי
התקשרו למוקד 1299
למענה אנושי בצ'אט - מוקד 1299
תמיכה טכנית בשירותים מקוונים
פנייה לאבטחת מידע

עקבו אחרינו

אודות האתר **תנאי שימוש** **הצהרת נגישות** **תמיכה טכנית** **מפת האתר** **שימוש בקבצי "cookies"** **חופש המידע**

נספח 9

העתק מיעדי ההפחתה שהעבירה ישראל לאו״ם

עמ׳ 234

נספח 9

UPDATE OF ISRAEL'S NATIONALLY DETERMINED CONTRIBUTION UNDER THE PARIS AGREEMENT

Submitted July 2021

This submission is in response to paragraphs 24 and 25 of decision 1/CP.21 and in particular Israel's commitment to communicate or update its nationally determined contribution (NDC). Israel has included in this document accompanying information to facilitate clarity, transparency and understanding (ICTU) of its NDC in compliance with Decision 4/CMA.1.

Israel formally communicated its INDC under the Paris Agreement on 29 September 2015 which became its NDC upon ratification of the Paris Agreement on 22 November 2016.

Since then, Israel has undertaken steps to increase its ambition. Most noteworthy is Government Decision 171 passed on the 25th of July 2021 entitled "Transition to a Low Carbon Economy."

Unlike Israel's original NDC, this new Decision includes an unconditional absolute greenhouse gas (GHG) emissions reduction goal for 2030 of 27% relative to 2015 and an unconditional absolute GHG emissions reduction goal for 2050 of 85% relative to 2015.

Whereas our INDC submitted in 2015 projected 2030 emissions would be 81.65 MtCO2e, under this update they are projected to be 58 MtCO2e by 2030.

This updated goal significantly improves upon Israel's first NDC which was presented as a per capita economy-wide unconditional GHG reduction. The previous target was 7.7 tCO2e by 2030 which corresponded to a total of 81.6 MtCO2e. The updated target presented in this NDC is 58 MtCO2e, which corresponds to a reduction of 23 MtCO2e or 29% in Israel' s total emissions.

We believe that this updated NDC is a marked improvement both in the process by which the 2030 and 2050 national and sectoral goals were determined; in the more ambitious mitigation goal and in the work carried out to increase preparedness and adaptation to Climate Change.

A multi stakeholder process, entitled **"Israel 2050: A Flourishing Economy in a Sustainable Environment",** took place over two years to determine 2050 low carbon goals from which 2030 goals and targets were derived, including recommendations for implementation. Some of these policies already exist and others will be the subject of future government decisions, ministerial policies or other tools as required.

The main provisions of the recently adopted Decision 171 which set out updated national GHG reduction goals are as follows:

- ✓ Revision of the existing national greenhouse gas emission reduction target for 2030 set by Government Decision 542 so that the annual amount of greenhouse gas emissions by 2030 will be reduced by at least 27% from the annual amount measured in 2015 (79 MtCO2e). The annual amount of greenhouse gas emissions in 2030 will be about 58 MtCO2e.
- ✓ Approval of a national reduction target for greenhouse gas emissions by 2050, of at least 85% of the annual amount measured in 2015. Accordingly, the annual amount of greenhouse gas emissions in 2050 will be about 12 MtCO2e.
- ✓ Recognition of the desirability of a net-zero emissions goal by 2050 and a global target to limit temperature increase to 1.5 degrees Celsius. Therefore the 2050 target of 85% GHG emissions reduction will be periodically revisited.

The following sectoral targets were set:

- ✓ **Transport**
  - As of 2026, all new municipal buses purchased will be clean vehicles as defined in section 77A of the Transport Ordinance [New Version].
  - Limit the increase in greenhouse gas emissions from transportation by 2030, so that the total increase in emissions will be only 3.3% compared to emissions measured in 2015, which were 17.6 MtCO2e.
  - Limit the amount of greenhouse gas emissions from new vehicles, weighing up to 3.5 tonnes, registered from 2030, to an amount equal to 5% of the average greenhouse gas emissions for a new vehicle, weighing up to 3.5 tonnes, registered in 2020. This target will be reexamined in 2025, and will be updated as necessary, having regard to technological developments, the extent of the penetration of electric vehicles in Israel and globally, electricity infrastructure and the deployment of charging stations in Israel.
  - Reduction of greenhouse gas emissions from transport by 2050 by at least 96% compared to emissions measured in 2015.
- ✓ **Waste**
  - Reduction of greenhouse gas emissions from solid waste by 2030 by at least 47% compared to emissions measured in 2015, which were 5.5MtCO2e.
  - A 71% reduction in the amount of municipal waste landfilled by 2030 compared to the amount of municipal waste landfilled in 2018, which was about 4.5 million tonnes.
  - Reduction of GHG emissions from municipal waste by 2050 by at least 92% compared to emissions measured in 2015.

- ✓ **Electricity Generation**
  - Reduction of greenhouse gas emissions from electricity generation by 2030 by 30% compared to emissions measured in 2015, which were 37.6 MtCO2e, taking into account the renewable energy targets set in Government Decision No. 465 (see below).
  - Reduction of greenhouse gas emissions from electricity generation by 2050 by at least 85% compared to emissions measured in 2015.
- ✓ **Energy Intensity**
  - To set a new energy intensity target so that by 2030 the energy intensity of GDP will be 122 MWh per NIS 1 million.
- ✓ **Industry**
  - Reduction of greenhouse gas emissions from industry by 2030 by at least 30% relative to emissions in 2015, which were 12 MtCO2e.
  - Reduction of industrial greenhouse gas emissions by 2050 by at least 56% relative to emissions in 2015.
- ✓ **Climate Impacts of Goods and Services**
  - To establish a voluntary mechanism for reporting and publicizing information on the GHG emissions associated with products and services manufactured in and imported to Israel.

Mid-century, long-term low greenhouse gas emission development strategies

Government Decision 171 detailed above also includes targets for 2050 in furtherance of Article 4, paragraph 19, of the Paris Agreement, and paragraph 35 of decision 1/CP.21 and constitutes Israel's current low greenhouse gas emission development strategy. GHG reductions will be reduced from 79.4 MtCO2e emissions in 2019 to 58 MtCO2e in 2030 and 12 MtCO2e in 2050.

Fair and ambitious

Taking into consideration its national circumstances, Israel believes its target to be fair and ambitious reflecting genuine efforts to move forward in a sustainable manner to facilitate the transition to a low-carbon and climate-resilient economy. Further information can be found in section 6(a) of the ICTU table below.

Key sectoral approved decisions and strategies contributing to the NDC's achievement:

Government Decision N° 465 (approved on October 25, 2020) which formalized the decision undertaken by the Minister of Energy to phase-out coal-fired power generation no later than 2026 and determined targets for a renewable power generation share of 20% in 2025 and 30% in 2030.

Implementation of the Kigali Amendment to the Montreal Protocol. In November 2020, the Internal Affairs and Environment Committee of the Knesset amended the Hazardous Materials Regulations to set quotas on the import of HFC refrigerant gases, in line with Israel's targets under the Kigali Amendment, to take effect in July 2022.

National Waste Strategy: In February 2021, the Ministry of Environmental Protection published a new National Strategy for a Circular Economy in 2050 and a Sustainable Waste Sector in 2030. The strategy addresses treatment of Municipal Solid Waste (MSW) in a comprehensive manner and includes the following key abatement measures in relation to sources of GHG emissions.

- Transition from 80% of waste landfilling in 2020, to only 20% by 2030;
- Zero landfilling of untreated organic waste and paper and cardboard by 2030;
- All active landfills will be sealed, and methane collection and destruction/utilization systems will be installed, so that methane collection will amount to no less than 50% of total methane production in the landfill.

Implementation

The government intends to review the national GHG reduction goals and strategy every five years which will also include an independent review process.

More detailed information on implementation is included in Israel's Third National Communication and in Israel's Second Biennial Update Report to be submitted in the near future.

Monitoring Reporting and Verification

In April 2016, the Israeli government set out in its National Greenhouse Gas Emissions Reduction Plan (Resolution 1403) the establishment of a national system for monitoring, reporting and verification, relating to the implementation of the program and national targets for reducing greenhouse gas emissions. Further information can be found in the table below.

Research and Development

Israel continues to be one of the largest investors in Research and Development per capita among OECD countries. A portion of that investment goes to Clean Tech and to climate technologies specifically in areas in which Israel has a relative advantage such as water use, agritech, and adaptation to arid and semi-arid conditions.

Adaptation to Climate Change

Israel has also been focusing on formulating adaptation policies, based on the increasingly severe climate predictions and trends for Israel and the region. The government adopted a government decision in 2018 for Adaptation to Climate Change and established the National Adaptation to Climate Change Committee (NACCC). The role of the NACCC is to mainstream adaptation efforts in all government bodies and relevant organizations, to coordinate cross sector adaptation activities and projects, to mainstream adaptation and to develop and distribute climate knowledge.

In 2019, The Israel Meteorological Service published the "Climate change in Israel – historical trends and future predictions of temperature and precipitation Report". This report presents the first comprehensive analysis of temperature and precipitation trends for Israel, based on data for various areas in Israel, and an analysis of projected climate models for the coming decades.

The Adaptation Committee submitted its first National Adaptation Report in May 2021 including recommendations to recognize Climate Change as a national security threat; outlining steps to be taken at the national and particularly at the local level for which a budget of 2.5 billion NIS over 5 years is proposed. It is intended that this Report will form the basis of a future government decision.

In the interim, the Water Authority, for example, is already incorporating data on the trends and projection into its master plans, thus maintaining Israel's ability to develop new desalination plants and to provide water supply both in Israel and for neighboring countries as well as continuing to develop innovation wastewater treatment and water recycling technologies. Enhancing the resilience of the public health system will be another area of focus

Tel Aviv – Yafo was the first city to publish its Adaptation to Climate Change Plan in 2020, in line with the C-40 covenant. 15 local authorities are currently developing their adaptation plans and In the next few years, it is expected that many more local authorities will follow suit. In recognition of the importance of the local government's role in adaptation efforts and in order to mainstream adaptation efforts, the NACCC developed Adaptation Guidelines for local government to be adopted by all local authorities.

Information to facilitate clarity, transparency and understanding

In line with Article 4, paragraph 8 of the Paris Agreement and Decision 4/CMA.1 Israel submits the following ICTU.

<table>
<tr><th colspan="3">Information to facilitate clarity, transparency and understanding of nationally determined contributions, referred to in decision 1/CP.21, paragraph 28</th></tr>
<tr><td>1.</td><td>Quantifiable information on the reference point (including, as appropriate, a base year):</td><td></td></tr>
<tr><td>(a)</td><td>Reference year(s), base year(s), reference period(s) or other starting point(s);</td><td>The reference year for all GHG emissions is 2015.</td></tr>
<tr><td>(b)</td><td>Quantifiable information on the reference indicators, their values in the reference year(s), base year(s), reference period(s) or other starting point(s), and, as applicable, in the target year;</td><td>Reference indicator: Net greenhouse gas (GHG) emissions in MtCO2e.
In 2015, Israel’s net GHG emissions were 79 MtCO2e. Achieving the targets will reduce emissions to approximately 58 MtCO2e by 2030 and approximately 12 MtCO2e by 2050.
Values in the reference year for the sectorial emission reduction targets are as follows:
<table>
<tr><td>Sector</td><td>GHG emissions (MtCO2e) in 2015</td><td>GHG emissions (MtCO2e) in 2030</td><td>GHG emissions (MtCO2e) in 2050</td></tr>
<tr><td>Electricity generation</td><td>37.6</td><td>26.3</td><td>5.6</td></tr>
<tr><td>Transport</td><td>17.6</td><td>17</td><td>0.7</td></tr>
<tr><td>Industry</td><td>12</td><td>8.4</td><td>5.3</td></tr>
<tr><td>Waste</td><td>5.5</td><td>2.9</td><td>0.4</td></tr>
</table></td></tr>
</table>

		Other | 6.3 | N\A | N\A
(c)	For strategies, plans and actions referred to in Article 4, paragraph 6, of the Paris Agreement, or polices and measures as components of nationally determined contributions where paragraph 1(b) above is not applicable, Parties to provide other relevant information;	Not applicable.
(d)	Target relative to the reference indicator, expressed numerically, for example in percentage or amount of reduction;	Israel will achieve an economy-wide net reduction in GHG emissions of 27% by 2030 relative to 2015 emission levels. Israel will achieve an economy-wide net reduction in GHG emissions of 85% by 2050 relative to 2015 emission levels. In addition, sectorial emissions reduction targets – relative to the annual amount measured in 2015 in each corresponding sector – have been approved: Sector | **2030** | **2050** **Electricity generation** | 30% | 85% **Transport** | 3.3% increase | 96% **Industry** | 30% | 56% **Waste** | 47% | 92% Israel has further committed to a complete phase out of coal-fired power generation by 2026, and to increase the share of renewable power generation to 20% in 2025 and 30% in 2030.

(e)	Information on sources of data used in quantifying the reference point(s);	Data used in quantifying the reference points will be based on the 2008-2030 Israeli GHG Inventory submitted to the UNFCCC in 2032.
(f)	Information on the circumstances under which the Party may update the values of the reference indicators.	Where necessary, the Israeli GHG inventory may be revised to incorporate methodological improvements, changes to international reporting guidelines and new data.
2.	**Time frames and/or periods for implementation:**	
(a)	Time frame and/or period for implementation, including start and end date, consistent with any further relevant decision adopted by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement (CMA);	NDC time frame: January 2021 - 31 December 2030 Long-term low-emission development strategy timeframe: January 2021 – 31 December 2050
(b)	Whether it is a single-year or multi-year target, as applicable.	Single-year target in 2030 and in 2050.
3.	**Scope and coverage:**	
(a)	General description of the target;	Israel's target is economy-wide to achieve a 27% reduction in net GHG emissions by 2030 relative to 2015, to a level of no more than 58 MtCO2e. In addition, Israel aims to achieve an 85% reduction in net GHG emissions by 2050, relative to 2015, to a level of no more than 12 MtCO2e. In order to achieve its economy-wide target, Israel has also approved sectorial targets for 2030 and 2050 (see above clause 1.d)

(b)	Sectors, gases, categories and pools covered by the nationally determined contribution, including, as applicable, consistent with Intergovernmental Panel on Climate Change (IPCC) guidelines;	**Sectors covered:** • Energy (Fuel combustion) in: energy industries (electricity generation), manufacturing industries, construction, transport, other sectors (residential, commercial, institutional, agriculture) • Industrial Processes • Agriculture • Waste and Wastewater • Land-use Change and Forestry **Greenhouse gases covered:** Carbon Dioxide (CO2), Methane (CH4), Nitrous Oxide (N2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), Sulphur Hexafluoride (SF6). **Categories covered:** Category 1.B. “Fugitive emissions from fuels” is currently not covered by Israel’s NDC. However, this category is to be included in Israel’s National GHG Inventory in the future (see below, section 3(c). Initial estimates are that fugitive emissions constitute between 0.1% to 0.8% of Israel’s total GHG emissions . LULUCF pools are negligible in Israel. The sectors, gases, categories and pools covered by Israel's NDC are based on the revised 1996 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories, the 2006 IPCC Guidelines for National GHG Inventories and the Global Warming Potential (GWP) values from the IPCC Second Assessment Report (1995).

(c)	How the Party has taken into consideration paragraph 31(c) and (d) of decision 1/CP.21;	Category 1.B. "Fugitive emissions from fuels" have not been included in past Israel's Inventories but will be included in future inventories, starting with the report for the 2020 inventory year. Previous figures will be revised to include this category as well. Otherwise, all relevant categories of anthropogenic emissions or removals are included and will continue to be included.
(d)	Mitigation co-benefits resulting from Parties' adaptation actions and/or economic diversification plans, including description of specific projects, measures and initiatives of Parties' adaptation actions and/or economic diversification plans	Not applicable.
4.	**Planning process**	
(a)	Information on the planning processes that the Party undertook to prepare its nationally determined contribution and, if available, on the Party's implementation plans, including, as appropriate:	**NDC update and Long-Term Low-Emission Development Strategy** In early 2019, in cooperation with the Israel Democracy Institute and the OECD, the Israeli government initiated a broad and collaborative multi-sector process for formulating Israel's Long-Term Low-GHG Emission Development Strategy to transition to a prosperous and low-carbon economy by 2050. Five sectoral working groups (power generation, transport, industry, waste, and cities and buildings) were established, as well as a macroeconomic team and a social impacts team, consisting of a broad range of relevant stakeholders.
i.	Domestic institutional arrangements, public participation and engagement with local communities and indigenous peoples, in a gender-responsive manner;	A public consultation process was launched once the sectorial teams were established in the beginning of 2019. This consultation process enabled a wide participation of the public in the on-going work of the sectorial teams. It resulted in the integration of insights and comments by the public within the

		work of the sectorial teams, and ultimately it facilitated a more holistic and inclusive strategy for a low-carbon transition. **Inter-ministerial Steering Committee for GHG Emissions Reductions** The decision-making process going forward is supported by an Inter-ministerial Steering Committee for GHG Emissions Reductions, which consists of representatives from all relevant government ministries and other relevant stakeholders. The Steering Committee submits an annual report to the government evaluating the effectiveness of government measures to reduce emissions, the progress towards meeting national GHG emission reduction targets and supporting targets and recommends additional measures as needed. **Monitoring, Reporting and Verification of GHG emission reductions** In April 2016, the Israeli government set out in its National Greenhouse Gas Emissions Reduction Plan (Resolution 1403) the establishment of a national system for monitoring, reporting and verification, relating to the implementation of the program and national targets for reducing greenhouse gas emissions. To date, Israel monitors emission reduction on both a national and a policy level in accordance with the national Monitoring, Reporting and Verification (MRV) system. The MRV system was implemented in 2016 by the Ministry of Environmental Protection in cooperation with other government ministries and relevant statutory bodies. It operates on the basis of guiding principles of the UN Climate Convention and on the basis of methodologies developed in accordance with the characteristics of the Israeli economy. It is managed by the Ministry of Environmental Protection, on behalf of the Steering Committee.
ii.	Contextual matters, including, inter alia, as appropriate:	
a.	National circumstances, such as geography, climate, economy, sustainable development and poverty eradication;	National circumstances are described in detail in Israel's National Communication submitted in 2018 and additional information is detailed in the Biennial Update Report that will be submitted shortly.

		Sustainable development and poverty eradication: Israel is committed to the implementation of Agenda 2030 and the Sustainable Development Goals as detailed in its Voluntary National Review submitted to the UN in July 2019.
b.	Best practices and experience related to the preparation of the nationally determined contribution;	The establishment of sectorial working groups consisting of representatives of relevant ministries, local authorities, public representatives, NGOs, academia and others as described in section 4(a) above ensured broad public involvement and commitment, while the involvement of public policy think tanks and the OECD further contributed to the acceptability of the results. Within this context, establishing Israel’s Long-Term Low-Emission Development Strategy further informed the process to revise Israel’s 2030 NDC targets. (See above clause 4.a.)
c.	Other contextual aspirations and priorities acknowledged when joining the Paris Agreement;	Not applicable
(b)	Specific information applicable to Parties, including regional economic integration organizations and their member States, that have reached an agreement to act jointly under Article 4, paragraph 2, of the Paris Agreement, including the Parties that agreed to act jointly and the terms of the agreement, in accordance with Article 4, paragraphs 16–18, of the Paris Agreement;	Not applicable
(c)	How the Party’s preparation of its nationally determined contribution has been informed by the outcomes of the global stocktake, in accordance with	Israel participated actively in the Talanoa Dialogues and looks forward to participating in the Global Stocktake in 2023.

	Article 4, paragraph 9, of the Paris Agreement;	
(d)	Each Party with a nationally determined contribution under Article 4 of the Paris Agreement that consists of adaptation action and/or economic diversification plans resulting in mitigation co-benefits consistent with Article 4, paragraph 7, of the Paris Agreement to submit information on:	
i.	How the economic and social consequences of response measures have been considered in developing the nationally determined contribution;	Not applicable
ii.	Specific projects, measures and activities to be implemented to contribute to mitigation co-benefits, including information on adaptation plans that also yield mitigation co-benefits, which may cover, but are not limited to, key sectors, such as energy, resources, water resources, coastal resources, human settlements and urban planning, agriculture and forestry; and economic diversification actions, which may cover, but are not limited to, sectors such as manufacturing and industry, energy and mining, transport and communication, construction, tourism, real estate, agriculture and fisheries	Not applicable
5	**Assumptions and methodological approaches, including those for estimating and accounting for anthropogenic greenhouse gas emissions and, as appropriate, removals:**	
(a)	Assumptions and methodological approaches used for accounting for anthropogenic greenhouse gas emissions and removals corresponding to the Party's nationally determined contribution, consistent with decision 1/CP.21,	In accordance with the modalities, procedures and guidelines outlined in Decisions 4/CMA.1 and 18/CMA.1 of the Paris Rulebook, Israel will publish and submit to the UNFCCC, an annual National Inventory Report and Biennial Transparency Report by 31 December 2024 at the latest, and biennially thereafter.

	paragraph 31, and accounting guidance adopted by the CMA;	The National Inventory Report will account for Israel anthropogenic GHG emissions and removals and the Biennial Transparency Report will report on progress towards the Israel's NDC. Israel will compare achieved net GHG emission reductions with its NDC target for 2030. Israel will comply with future UNFCCC reporting guidelines on tracking, and reporting on progress. For current IPCC methodologies and metrics used, see section 5(d). Final accounting towards the target will take place in 2032. It will be based on the 2008-2030 Israel GHG Inventory, by comparing 2030 net GHG emissions to the 2015 reference year.
(b)	Assumptions and methodological approaches used for accounting for the implementation of policies and measures or strategies in the nationally determined contribution;	For domestic MRV and UNFCCC reporting see section 4(a)(i) above. Israel has established a market-wide and sector specific GHG emissions modelling framework which enables to forecast emissions throughout to 2050 given different scenarios, abatement measures and assumptions. In addition, Israel has an MRV system which produces the following annual information and results: → Policy Measure Impacts: Within the MRV system framework, both achieved (ex-post) and expected (ex-ante) emission reductions are monitored for key policy measures. The expected reductions are calculated for each of the target years (2020, 2025 and 2030), for two levels of implementation: • Implementation of the policy measure to the extent that it has already approved (but not necessarily fully implemented) • Implementation in accordance with approved sectorial targets.

		→ Abatement Scenario Emissions: Abatement scenario emissions are forecasted for each of the target years and each of the abovementioned three levels of implementation. The MRV system facilitates the following: • Measurement of national progress towards achieving mitigation goals. • Measurement of the effectiveness of specific government GHG reduction policies and actions. • Revision and expansion of the policy actions to maximize the achieved economic and environmental benefits. • Fulfillment of reporting obligations to the UN on mitigation actions by Israel and their effects. • Transparency of information on Israel's progress towards its reduction goals The monitoring is conducted on the basis of approved government methodologies, which define the calculation methodology, the parameters to be monitored, and the requisite QA/ QC procedures. The methodologies also define the manner in which overlapping effects between different government measures are accounted for in order to avoid double counting. The current methodologies under approval within the MRV system framework are: o Monitoring fuel consumption and emission reductions in power generation o Monitoring energy efficiency and electricity consumption o Monitoring energy efficiency in buildings o Monitoring grant programs and support for energy efficiency and reduction of greenhouse gas emissions projects o Monitoring fuel consumption and emission reductions in the transport sector o Monitoring fuel consumption and emission reductions in industry and buildings sectors o Monitoring emissions reduction from the prevention of solid waste landfilling and emissions from the waste sector o Monitoring national targets for reduction of GHG emissions from fluorinated gases o Updating emission forecasts from agriculture, land use, wastewater and industrial process emissions

(c)	If applicable, information on how the Party will take into account existing methods and guidance under the Convention to account for anthropogenic emissions and removals, in accordance with Article 4, paragraph 14, of the Paris Agreement, as appropriate;	See section 5(d) below
(d)	IPCC methodologies and metrics used for estimating anthropogenic greenhouse gas emissions and removals;	**IPCC methodologies:** The revised 1996 IPCC Guidelines for National GHG Inventories were applied for the calculation of GHGs in all sectors, except agriculture and waste. Agriculture (category 4) is calculated according to the 2006 IPCC Guidelines for National GHG Inventories as of the 2011 Inventory year. Waste (category 6) was recalculated in 2012, for all inventory years according to the 2006 IPCC Guidelines. Additional Guidance: In addition to the IPCC Guidelines for National GHG Inventories, the 'Good Practice Guidance and Uncertainty Management in National GHG Inventories' guidelines were used for preparation of the inventories. Tier Levels : The tier level applied in the national GHG inventory varies from sector to sector due to the varying availability of data and information: • Module 1-Energy: In principle, Tier 1 was applied, with notable exceptions being the application of Tier 2 using information that is unique to Israel such as calorific values of primary energy sources (coal, natural gas, shale oil). Tier 3 was applied for emissions of SOx, NOx, and CO from vehicles, as well as emissions of SOx and NOx from electricity generation.

		• Module 2-Industrial Processes: In principle, Tier 1 was applied. For some sources emission factors specific to Israeli industry were used and therefore Tier 3 was applied. Regarding emissions of fluorinated gases, a methodology was adapted specifically to Israel and therefore Tier 3 was applied. • Module 3-Solvent and Other Product Use: There is no calculation of emissions from sources as such and therefore no tier level was applied yet. • Module 4- Agriculture: In principle, Tier 1 was applied, taking into account the specific processes in Israel’s agriculture sector and appropriate emission factors.For some sub sectors Tier 2 was applied. • Module 5- Land Use Change and Forestry: Israel uses the Tier 1 approach for estimating removals in forest land areas. There is no forest inventory in place as the forest land in Israel is negligible. However, data on forest land and on the mass of trees harvested do exist and are periodically updated. • Module 6- Waste: Tier 2 is applied to waste and Tier 1 to wastewater. **Metrics:** Global Warming Potential (GWP) values for a 100-year time horizon from the IPCC Second Assessment Report (1995).
(e)	Sector-, category- or activity-specific assumptions, methodologies and approaches consistent with IPCC guidance, as appropriate, including, as applicable:	
i.	Approach to addressing emissions and subsequent removals from natural disturbances on managed lands;	Not applicable
ii.	Approach used to account for emissions and removals from harvested wood products;	Not applicable
iii.	Approach used to address the effects of age-class structure in forests;	The effects of age-class structure are not currently taken into account in Israel's GHG Inventory.
(f)	Other assumptions and methodological approaches used for understanding the nationally determined contribution and, if applicable, estimating corresponding emissions and removals, including:	

i.	How the reference indicators, baseline(s) and/or reference level(s), including, where applicable, sector-, category- or activity-specific reference levels, are constructed, including, for example, key parameters, assumptions, definitions, methodologies, data sources and models used	Final reference year and target year emissions will be based on the 2015-2030 GHG Inventory to be submitted to the UNFCCC in 2032 for the 2030 target year. Emissions estimates in Israel's GHG Inventory are made using methodologies outlined in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories and subsequent IPCC guidelines (see section 5(d)). The Inventory is revised annually and undergoes extensive review processes.
ii.	For Parties with nationally determined contributions that contain non-greenhouse-gas components, information on assumptions and methodological approaches used in relation to those components, as applicable;	Not applicable
iii.	For climate forcers included in nationally determined contributions not covered by IPCC guidelines, information on how the climate forcers are estimated;	Not applicable
iv.	Further technical information, as necessary;	Not applicable
(g)	The intention to use voluntary cooperation under Article 6 of the Paris Agreement, if applicable.	Israel is planning to achieve its NDC mitigation objectives through domestic means but is following Article 6 negotiations so that this option remains open should it be relevant in the future.
6	**How the Party considers that its nationally determined contribution is fair and ambitious in the light of its national circumstances:**	
(a)	How the Party considers that its nationally determined contribution is fair and ambitious in the light of its national circumstances;	Taking into consideration its national circumstances, Israel believes its target to be fair and ambitious reflecting genuine efforts to move forward in a sustainable manner to facilitate the transition to a low-carbon and climate-resilient economy.

		Israel is a small and densely populated country characterized by an expanding population and economic growth, facing land and water scarcity. Arid zones comprise over 45% of the area of the country while there is an exceptionally high degree of biological diversity that must be protected. Electricity generation has been largely based on domestic and imported fossil fuels as Israel has no access to a number of widely used low-carbon sources of energy such as nuclear, hydro-electric and geothermal power. The country is an energy island, without grid interconnectivity. There is limited surface area available for large-scale energy installations. The few available areas are subject to competing uses such as industrial development and housing, bio-diversity preservation, habitat conservation, agriculture and defense. Electricity generation from renewable energy (mostly solar PV) amounted to 6.1% of the total electricity generation in 2020. For many years, there has been significant use of solar heaters for water heating and greenhouse gas emissions associated with water heating are substantially lower than the global average. An additional factor limiting Israel's abatement potential is its small share of heavy industry sector with relatively low emissions reduction potential. Israel attains extremely high levels of water reuse (85%). However, to meet increasing water demand several desalination plants have been constructed. These installations are comparatively energy efficient and currently account for 5% of energy consumption. Water scarcity may necessitate the construction of additional plants in the future.
(b)	Fairness considerations, including reflecting on equity;	See above, section 6(a)
(c)	How the Party has addressed Article 4, paragraph 3, of the Paris Agreement;	Israel’s first NDC formulated a per capita GHG emissions target that did not entail a reduction in absolute emissions .

		Considering the previous target set in 2015 and revised population growth forecasts, the expected annual GHG emissions in 2030 would have been around more than 85 MtCO2e. The current target of 58 MtCO2e is significantly more ambitious.
(d)	How the Party has addressed Article 4, paragraph 4, of the Paris Agreement;	Israel's NDC is an economy-wide absolute emissions reduction target in compliance with Article 4.4 of the Paris Agreement. Sectorial targets were defined as well in order to facilitate successful implementation of the economy-wide target. See above, section 1(d).
(e)	How the Party has addressed Article 4, paragraph 6, of the Paris Agreement.	Not applicable
7	**How the nationally determined contribution contributes towards achieving the objective of the Convention as set out in its Article 2:**	
(a)	How the nationally determined contribution contributes towards achieving the objective of the Convention as set out in its Article 2;	This NDC represents Israel's contribution to achieving the objective of Article 2 of the Convention and reflects Israel's highest ambition at this time to stabilize GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.
(b)	How the nationally determined contribution contributes towards Article 2, paragraph 1(a), and Article 4, paragraph 1, of the Paris Agreement.	Israel has outlined its specific circumstances (a growing population, limited land use area, and limitations on the forms of suitable renewable energies, among others). Through its multisectoral consultation process, Israel has determined a mid-century long-term low carbon strategy which was formalized and approved by the government. Thus, Israel aims to support the collective effort to reach global peaking of GHG emissions as soon as possible (which is expected to occur in Israel by mid-decade), as set out in Article 4.1 of the Paris Agreement.

נספח 10

העתק מעיקרי האסטרטגיה הלאומית לישראל דלת פחמן ומשגשגת

עמ׳ 255

נספח 10

המשרד להגנת הסביבה

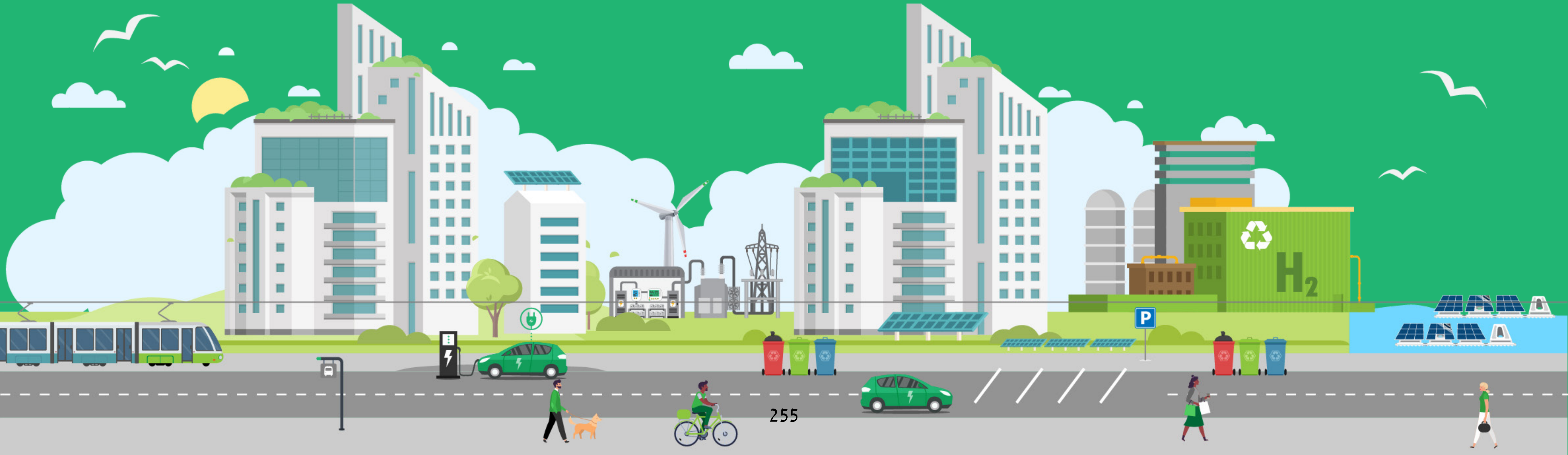
الوزارة لحماية البيئة

Israel Ministry of Environmental Protection

תקציר מנהלים

עיקרי האסטרטגיה הלאומית לישראל דלת פחמן ומשגשגת

אוקטובר 2021



ראשי פרקים

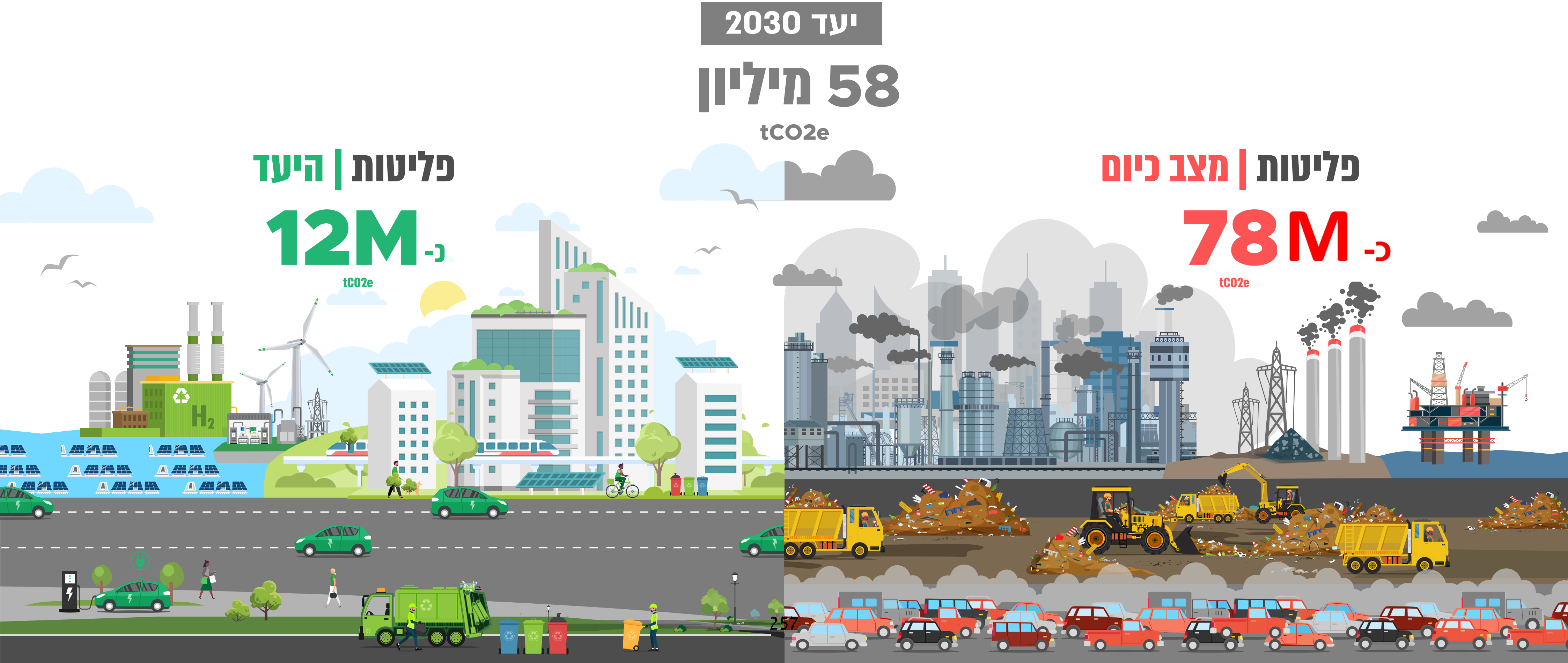
מעבר לכלכלה דלת פחמן

המצב כיום

משבר אקלים מאיים לפגוע בכדור הארץ בכלל, ובחברה האנושית בפרט. לאור כך, יש צורך בהרחבת והעמקת הצעדים להפחתת פליטות גזי חממה. **כיום, ישראל אחראית לפליטה של כ-78 מיליון טונות CO2e** (שווה ערך פד"ח). במסגרתם, 44% מהפליטות מיוצרות משימוש בחשמל, 21% משימוש בתחבורה ו-19% מהליכי הייצור בתעשיות. לצד זאת, ניכרות פליטות משמעותיות הנובעות מדרכי הטיפול בפסולת ותכנון הערים והמבנים במדינה. מדו"ח כלכלה משגשגת בסביבה מקיימת (להלן: הדו"ח), עולה כי במידה שישראל תמשיך במסלול 'עסקים כרגיל' היא צפויה להגיע ל-86 מיליון טונות CO2e בשנת 2050.

מעבר לכלכלה דלת פחמן 2050

לשם מניעת הסלמת המשבר והגדלת הפליטות שהוצגה במסגרת 'עסקים כרגיל', על ישראל מוטלת החובה לבצע שינויים מרחיקי לכת ולעבור לכלכלה דלת פחמן. תקציר מנהלים זה מרכז את היעדים והצעדים המרכזיים הנדרשים על מנת לאפשר לישראל לצמצם את כמות הפליטות **ולהגיע עד ל-12 מיליון טונות CO2e עד לשנת 2050.** שני האמצעים הרוחביים המשמעותיים ביותר שיסייעו לישראל לעמוד ביעדים אלו הם תמחור פחמן וחקיקת חוק אקלים (להלן פרק 7).



חשמל | פליטות, מדדים, יעדים וצעדי מדיניות

משק החשמל הוא האחראי המרכזי לפליטות גזי חממה. הוא מייצר 44% מסך הפליטות הנפלטות מידי שנה **(נכון לשנת 2020) המהוות כ-35 מיליון טון CO2e.** במידה שמדינת ישראל תמשיך לנוע במסלול 'עסקים כרגיל', הפליטות יעלו ל-49 מיליון טון CO2e בשנת 2050. זאת, לעומת החזון המוצג בדו"ח השואף לצמצם את הפליטות בשנת 2030 ל-25 מיליון CO2e כיעד ביניים במטרה **להגיע ל-5.5 מיליון טון CO2e עד לשנת 2050.**

כדי לממש את החזון נקבעו מספר מדדים (להרחבה בדו"ח). אחד המדדים המרכזיים הצפוי להוביל לשינוי הרצוי הוא מעבר ישראל לאנרגיות מתחדשות - **כיום כמות צריכת האנרגיות המתחדשות עומדת על 4.2 TWh בלבד.** במסגרת החלטת הממשלה נקבע להגיע ליעד של 30% מהייצור בשנת 2030 (כ-28 TWh). **ועד להפקת 86-54% מהייצור בשנת 2050 (כ-96-154 Twh).** זאת לעומת כ-31 Twh שעה אם ישראל תמשיך לנוע במסלול עסקים כרגיל.

כ- **35 מיליון**
tCO2e

יעד 2030
25 מיליון
tCO2e

כ- **5.5 מיליון**
tCO2e

6%
4
TWh

אנרגיות מתחדשות

86%-54%
154-96
TWh

צעדי המדיניות המוצעים

סגירת תחנות הכוח הפחמיות

קידום תכנית דו-שימוש בקרקע ותוכנית לקידום אגריה

תמיכות להתייעלות באנרגיה בתעשייה ובשלטון המקומי

אנרגיות מתחדשות יעדים בעולם

🇬🇷	**64%** **עד 2030**
🇮🇹	**55%** **עד 2030**
🇲🇽	**38%** **עד 2030**

תחבורה | פליטות, מדדים, יעדים וצעדי מדיניות

תחום התחבורה הינו השני בייצור פליטות גזי חממה בישראלי, מיוצרים בו 21% מסך הפליטות (16 מיליון טונות CO2e). במידה שמדינת ישראל תמשיך לנוע במסלול 'עסקים כרגיל', חרף ביצוע תהליכי חשמול רכבים רחבי היקף, אנו צפויים לעלות לכ-18 מיליון טונות CO2e פליטות. החזון המוצג בדו"ח שואף למנוע גידול בפליטות בשנת 2030 ולהתייצב סביב ה-18 מיליון טונות CO2e כיעד ביניים, במטרה **להגיע ל-1 מיליון טונות CO2e עד לשנת 2050.**

כדי לממש את החזון נקבעו כמה מדדים (להרחבה בדו"ח). מתוכם, שני מדדים מרכזיים צפויים להוביל לשינוי הרצוי: (1) שיעור הרכבים מאופסי פליטות מסך מצבת הרכבים; (2) שיעור נסיעות ארצי באמצעים מקיימים.

1. **יעד רכבים מאופסי פליטות 2050: כיום, שיעור הרכבים מאופסי פליטה עומד על 0.04%.** ההחזון הוא להגיע ליעד ביניים של 25% מהרכבים הקלים בשנת 2030 ועד **ל-100% בשנת 2050.** בנוסף 100% מהאוטובוסים העירוניים החדשים משנת 2026 יהיו מאופסי פליטה. זאת לעומת כמות של 63% בהינתן שישראל תמשיך בתרחיש 'עסקים כרגיל'.
2. **שיעור נסיעות באמצעים מקיימים:** נכון ל-2018, שיעור הנסיעות באמצעים מקיימים עמד על כ-37%. החזון מתווה יעד ביניים של כ-50% בשנת 2030, לעומת כ-42% בתרחיש עסקים כרגיל. ולכ-70% בשנת 2050, זאת לעומת ל-43% אם ישראל תמשיך בתרחיש עסקים כרגיל.

כ- 16 מיליון* tCO2e	**עד 2030** 18 מיליון tCO2e	כ- 1 מיליון tCO2e
0.04%	לרכבים מאופסי פליטה	100%
37% (2018)	% הנסיעות באמצעים מקיימים	70%

* חלה ירידה של כ-10% בפליטות מתחבורה ביחס לשנת 2019, בעקבות משבר הקורונה

צעדי המדיניות המוצעים

פיתוח תשתיות הסעת המונים

....

מענקים לרכישת אוטובוסים מאופסי פליטה

שיעור רכבים מאופסי פליטה מסך מצבת הרכבים יעדים בעולם

🇩🇪	**100%** **עד 2050**
🇬🇧	**100%** **עד 2050**
🇫🇷	**100%** **ב-2040**
🇳🇱	**100%** **עד 2050**

תעשייה | פליטות, מדדים, יעדים וצעדי מדיניות

(פסקת הפליטות) סקטור התעשייה מהווה הסקטור השני בתרומתו לפליטות גזי חממה במשק הישראלי. במסגרת כך, מיוצרות בו 19% מסך הפליטות הנפלטות מדי שנה. במידה שמדינת ישראל תמשיך לנוע במסלול 'עסקים כרגיל' הפליטות יעמדו על 8 מיליון טונות CO2e בשנת 2050. זאת לעומת החזון המוצג בדו"ח השואף לצמצם את הפליטות בשנת 2030 ל-8 מיליון טונות CO2e (ביחס ל-9 מיליון טונות CO2e בתרחיש עסקים כרגיל), במטרה להגיע **ל-5 מיליון טון CO2e עד לשנת 2050.**

מדדים: הפליטות בסקטור התעשייה מתחלקות לשלוש קטגוריות מרכזיות: (1) פליטות מצריכת דלקים; (2) פליטות תהליך; (3) פליטות עקב שימוש בגזים תעשייתיים (גזי קירור).

1. **פליטות מצריכת דלקים:** **כיום, נפלטים כ-7 מיליון טונות CO2e בעקבות צריכת דלקים.** החזון שואף להגיע ליעד ביניים של 4.6 מיליון טונות CO2e בשנת 2030 ועד לכ-3 מיליון טונות CO2e בשנת 2050. זאת לעומת כמות של כ-5 מיליון טונות CO2e, בהינתן שישראל תמשיך בתרחיש 'עסקים כרגיל'.

2. **פליטות כתוצאה משימוש בגזי קירור:** **נכון להיום, נפלטו כ-5 מיליון טונות CO2e** בעקבות שימוש בגזי קירור. החזון שואף להגיע ליעד ביניים של 1.6 מיליון טונות CO2e בשנת 2030 ועד **לכ-0.4 מיליון טונות CO2e בשנת 2050.** זאת לעומת כמות של 1.05 מיליון טונות CO2e, בהינתן שישראל תמשיך בתרחיש 'עסקים כרגיל'.

כ-**14 מיליון**
tCO2e

יעד 2030
8 מיליון
tCO2e

כ-**5 מיליון**
tCO2e

7 tCO2e	**פליטות מצריכת דלקים**	**3** tCO2e
5 tCO2e	**פליטות עקב שימוש בגזי קירור**	**0.4** tCO2e

צעדי המדיניות המוצעים

תמיכה בייעול השימוש באנרגיה ומעבר למקורות אנרגיה נקיים

תמיכה בתכנית סימביוזה תעשייתית המאפשרת להחזיר פסולת של תהליך יצור כחומר גלם

חקיקה להסדרת מקצוע מתקיני ונותני שירות למערכות מיזוג וקירור

פליטות מתעשייה יעדים בעולם

🇫🇷 **81%** הפחתה עד שנת 2050, ביחס ל-2015

🇩🇪 **49-51%** הפחתה עד שנת 2030, ביחס ל-1990

פסולת | פליטות, מדדים, יעדים וצעדי מדיניות

סקטור הפסולת מהווה אף הוא גורם משמעותי בתרומתו לפליטות גזי חממה במשק הישראלי. במסגרת כך, הטמנת פסולת הייתה אחראית **לכ-7% מפליטות גזי החממה,** כאשר עיקר פליטות גזי החממה נובעות ממתאן הנפלט ממטמנות מפסולת פריקה ביולוגית. במידה שמדינת ישראל תמשיך לנוע במסלול 'עסקים כרגיל' הפליטות יעמדו על 7 מיליון טונות CO2e מפליטות גזי החממה בשנת 2050. זאת, לעומת החזון המוצג בדו"ח השואף לצמצם את הפליטות בשנת 2030 ל-3 מיליון טונות CO2e כיעד ביניים, **במטרה להגיע ל-0.4 מיליון טונות CO2e פליטות עד לשנת 2050.**

כדי לממש את החזון נקבעו כמה מדדים (להרחבה בדו"ח). מתוכם, המדד המרכזי הצפוי להוביל לשינוי הרצוי הוא **צמצום הטמנת הפסולת: נכון להיום, במדינת ישראל כ-80% מהפסולת מוטמנת,** כאשר כמות הפסולת תגדל לאור הגידול בילודה. החזון שואף להגיע ליעד ביניים של 20% הטמנה בשנת 2030 ועד **ל-0% הטמנה בשנת 2050.** זאת, **לעומת כ-80%** בהינתן שישראל תמשיך בתרחיש 'עסקים כרגיל'.

כ- **5 מיליון**
tCO2e

יעד 2030
3 מיליון
tCO2e

כ- **0.4 מיליון**
tCO2e

כ-80% .... **הטמנת פסולת** **0%**

צעדי המדיניות המוצעים

קביעת חובת טיפול בפסולת אורגנית וקביעת תקנים מחייבים לשימוש בחומר המטופל

קביעת איסור הטמנת פסולת לא ממוינת ופסולת אורגנית לא מטופלת

תמיכה בפיילוטים להפחתת כמות הפסולת העירונית המיוצרת במשק הבתים (חסוך ומחזר)

פליטות מפסולת יעדים בעולם

🇩🇪	**87%** **הפחתה עד שנת 2050, ביחס ל-1990**
🇳🇱	**66%** **הפחתה עד שנת 2050, ביחס ל-2015**
🇩🇰	**100%** **מאופס פליטות עד שנת 2030**

ערים ומבנים | פליטות, מדדים, יעדים וצעדי מדיניות

הערים והמבנים אחראיים ל-26% מפליטות גזי החממה בישראל (כולל פליטות מצריכת חשמל בערים ומבנים). במידה שישראל תמשיך לנוע במסלול 'עסקים כרגיל', פליטות גזי החממה עקב מפליטות ישירות ועקיפות, קרי בתוספת הפליטות בעקבות מייצור חשמל עבור סקטור המבנים, יגדלו ל-33 מיליון טונות CO2e בשנת 2050. זאת, לעומת החזון המוצג בדו"ח ושואף לצמצם את הפליטות בשנת 2030 ל-17 מיליון טונות CO2e כיעד ביניים, במטרה **להגיע ל-4 מיליון טונות CO2e בלבד עד לשנת 2050.**

כדי לממש את החזון נקבעו כמה מדדים (הרחבה בדו"ח). מתוכם, שני מדדים מרכזיים צפויים להוביל לשינוי הרצוי: (1) בנייה ירוקה; (2) בנייה מאופסת אנרגיה. **בשנת 2020, שיעור הבנייה הירוקה מסך התחלות הבנייה עומד על כ-25%.** במסלול עסקים כרגיל, שיעור הבנייה הירוקה מסך התחלות הבנייה יעמוד רק על 55%. החזון שואף **להגיע ליעד ביניים של 100% מהתחלות הבנייה כבר ב-2030.** יתרה מכך, בתרחיש 'עסקים כרגיל' שיעור הבנייה מאופסת אנרגיה מהתחלות הבנייה יעמוד על 0% לעומת 100% במבני מגורים ומבנים ציבוריים ו-50% במבנים המסחריים - בהינתן נקיטת צעדי הפחתה אפקטיביים.

כ- **21 מיליון** tCO2e

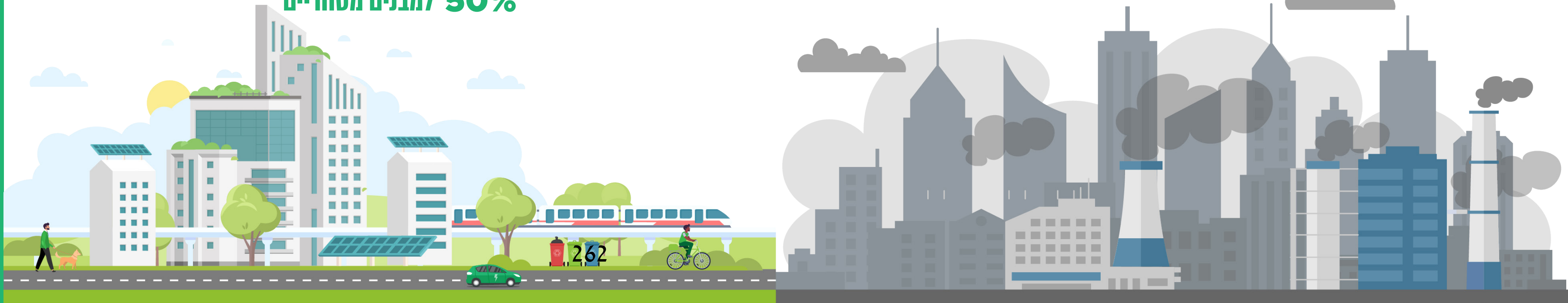
*כולל פליטות עקיפות
(מצריכת חשמל)

יעד 2030
17 מיליון tCO2e

כ- **4 מיליון** tCO2e

25% ………… **בנייה ירוקה במבנים חדשים** ………… **100%**

0% ………… **בנייה מאופסת אנרגיה במבנים חדשים** ………… **100%** **במבנים למגורים וציבוריים**
50% למבנים מסחריים



צעדי המדיניות המוצעים

החלת תקן בנייה ירוקה (ת"י 5281) כמחייב על כלל המבנים החדשים בישראל

……………………

יצירת מסמך הגדרות ברור להגדרת מבנה מאופס אנרגיה

……………………

עדכון והחמרת דרישות הצפיפות בתמ"א 35

……………………

קידום תוכניות מפורטות ומתאריות ומסמכי מדיניות להתחדשות עירונית

מבנים כמעט מאופסי אנרגיה יעדים בעולם

🇩🇪	**100%** **עד 2050**
🇫🇷	**100%** **עד 2050**
🇳🇱	**100%** **ב-2030**

צעדים רוחביים | פליטות, מדדים, יעדים וצעדי מדיניות

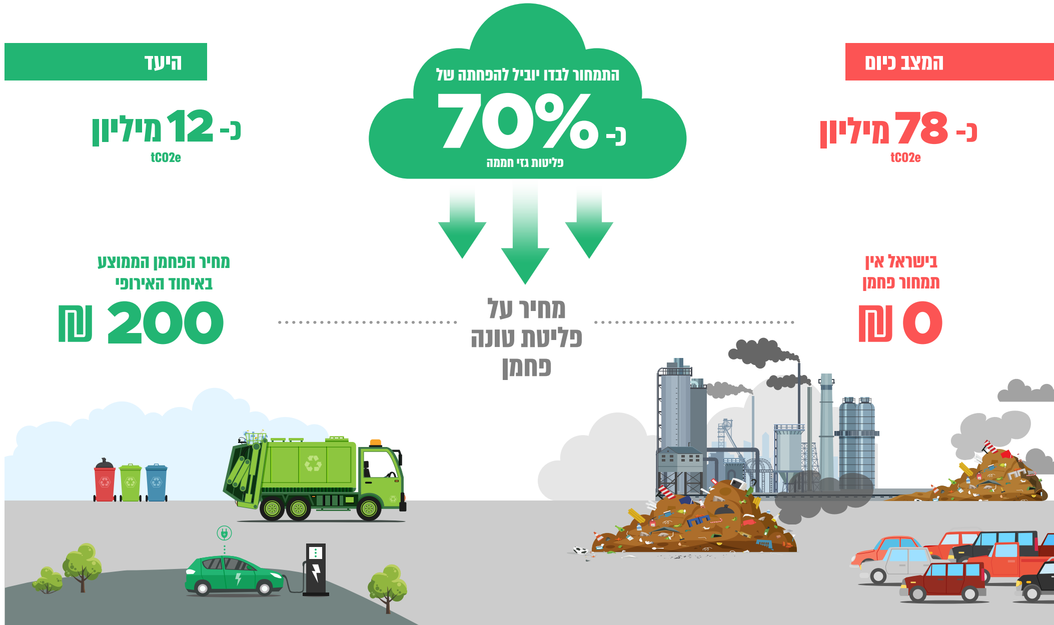
תמחור פחמן

קיים קונצנזוס בקרב המומחים בתחום ולפיו תמחור הפחמן הוא הפעולה היעילה והאפקטיבית ביותר לעידוד הפחתת פליטות גזי חממה בחלקים נרחבים מהמשק בטווח הארוך וליצירת וודאות בשווקים. לצד זאת, תמחור פחמן מאפשר השגה של יעדי אקלים תוך שמירה על המטרות הפיסקאליות של גביית מיסים, כך שלא תיווצר חריגה משמעותית מיעדי הגידול בתמ״ג.

מגוון פעולות אנושיות יומיומיות כגון ייצור חשמל ושימוש בתחבורה מבוססת דלקים פוסיליים מובילות לפליטות מזהמים לאוויר. לפליטות אלו השפעות חיצוניות שליליות על הסביבה אשר תיאורטית היו אמורות להיות מגולמות במחיר העסקה. אולם, העלויות הללו הן חיצוניות לשוק ולרוב אינן מיוחסות באופן ישיר לפעולה שגרמה לפליטת המזהמים ומשכך אינן מתומחרות. הלכה למעשה, תמחור הפחמן מאפשר הפנמה של עלויות חיצוניות מפליטות אלו ותשלום עליהן ישירות על ידי המזהם.

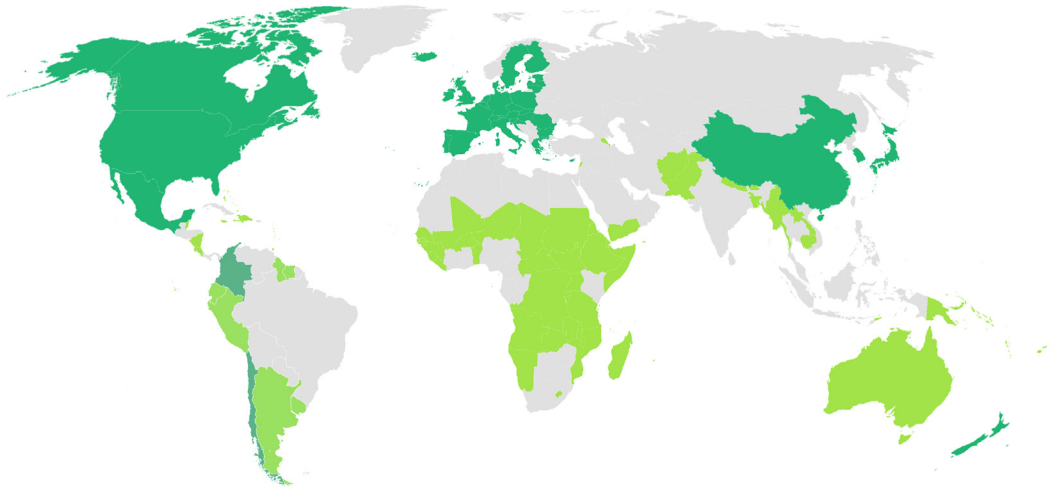
חוק אקלים

טיפול מקצועי ויעיל במשבר האקלים מחייב חלוקת אחריות וקביעת נהלים ברורים; לכן מדיניות האקלים זקוקה למסגרת חקיקתית-לאומית ייעודית ומתפקדת. בשל רמת המורכבות הגבוהה של המתווים שהוכחו כיעילים להתמודדות עם משבר האקלים, ממשלות המעוניינות לקדם מדיניות אקלים אפקטיבית זקוקות למסגרת פעולה יציבה שתאפשר להן לרתום את כלל השחקנים הרלוונטיים במשק באופן מסודר, לתאם ביניהם, ולספק להם הנחיות ברורות לתכנון מבוסס סקטורים ארוך-טווח. מדיניות רבות בעולם כבר התחילו לעבור לכלכלה דלת פחמן: **כ-120 מדינות** בעולם החלו תהליך מעבר לכלכלה מאופסת פליטות גזי חממה הכולל קביעת יעדים, גיבוש תוכניות אסטרטגיות ועיגונם בחקיקה. נכון לשנת 2019 **כ-67% ממדינות ה-OECD** גיבשו או השיקו תהליכי ניסוח חוקי אקלים, הכוללים יעדי הפחתה מפורשים ולעתים גם יעדים מגזריים. במידה שאנחנו רוצים לשמור על כלכלה תחרותית אנחנו חייבים לעבור יחד עם העולם לכלכלה דלת פחמן.



🟩 **מדינות שהצהירו על כוונתן לעבור לכלכלה מאופסת פליטה**

🟩 **מדינות שהתחייבו פורמלית לאיפוס פליטות**



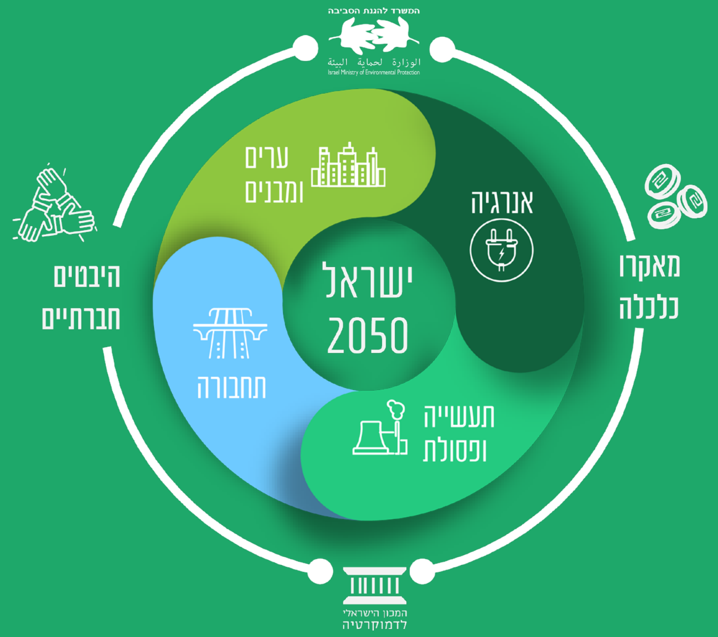
תהליך גיבוש המדיניות

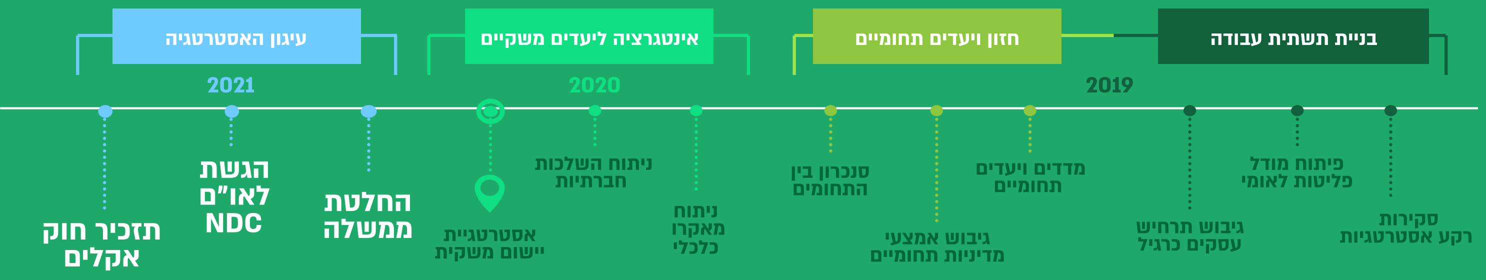
המשרד להגנת הסביבה בשיתוף המכון הישראלי לדמוקרטיה הובילו מהלך לאומי רב מגזרי בהשתתפות ארבעה משרדי ממשלה (אנרגיה, תחבורה, מינהל תכנון וכלכלה) לגיבוש אסטרטגיה למעבר כלכלת ישראל לכלכלה דלת פחמן. זאת, על מנת להבטיח איכות חיים טובה יותר בישראל בשנת 2050 ולעמוד בהתחייבויות וביעדים שישראל קיבלה עליה מכוח הסכם פריז לשנת 2030. תהליך גיבוש המדיניות החל עוד בשנת 2019 אך המשבר הכלכלי-בריאותי בעקבות נגיף הקורונה חידד את המשמעויות ואת החשיבות של היערכות מדינת ישראל למשבר האקלים.

השותפים תהליך גיבוש המדיניות התקדם בשישה צירים בו זמנית אשר אחת לתקופה נפגשו על מנת להסתנכרן ולהתקדם. הוקמו 4 צוותים תחומיים ו 2 צוותים רוחביים: ערים ומבנים - בהובלת מינהל התכנון | אנרגיה - בהובלת משרד האנרגיה | תעשייה ופסולת - בהובלת משרד הכלכלה | תחבורה - בהובלת משרד התחבורה | מאקרו כלכלי - בהובלת פרופ׳ נתן זוסמן והמשרד להגנת הסביבה | עין חברתית - המכון הישראלי לדמוקרטיה.

תהליך גיבוש המדיניות

לנוכח מורכבות הנושא וריבוי השותפים, תהליך גיבוש המדיניות התקדם יד ביד עם תהליך השיתוף. בתהליך התכנון בנינו תשתית נתונים וביצענו סקירות מעמיקות על מנת לבנות מודלים ותרחישים אפשריים. בתהליך השיתוף נתנו תמיכה מלאה לצוותי העבודה. קיימנו פגישות אישיות עם מובילי הצוותים, ערכנו מפגשי צוותים לקידום העבודה, הפקנו כנס מרכזי להצגת התקדמות ופתחנו תהליכי התייעצות לחשיבה משותפת. לאורך התהליך קיימנו כ-**30** מפגשי עבודה של הצוותים, השתתפו בהם למעלה מ-**200** ארגונים שונים ולמעלה מ-**3,000** משתתפים.





סיכום והמלצות

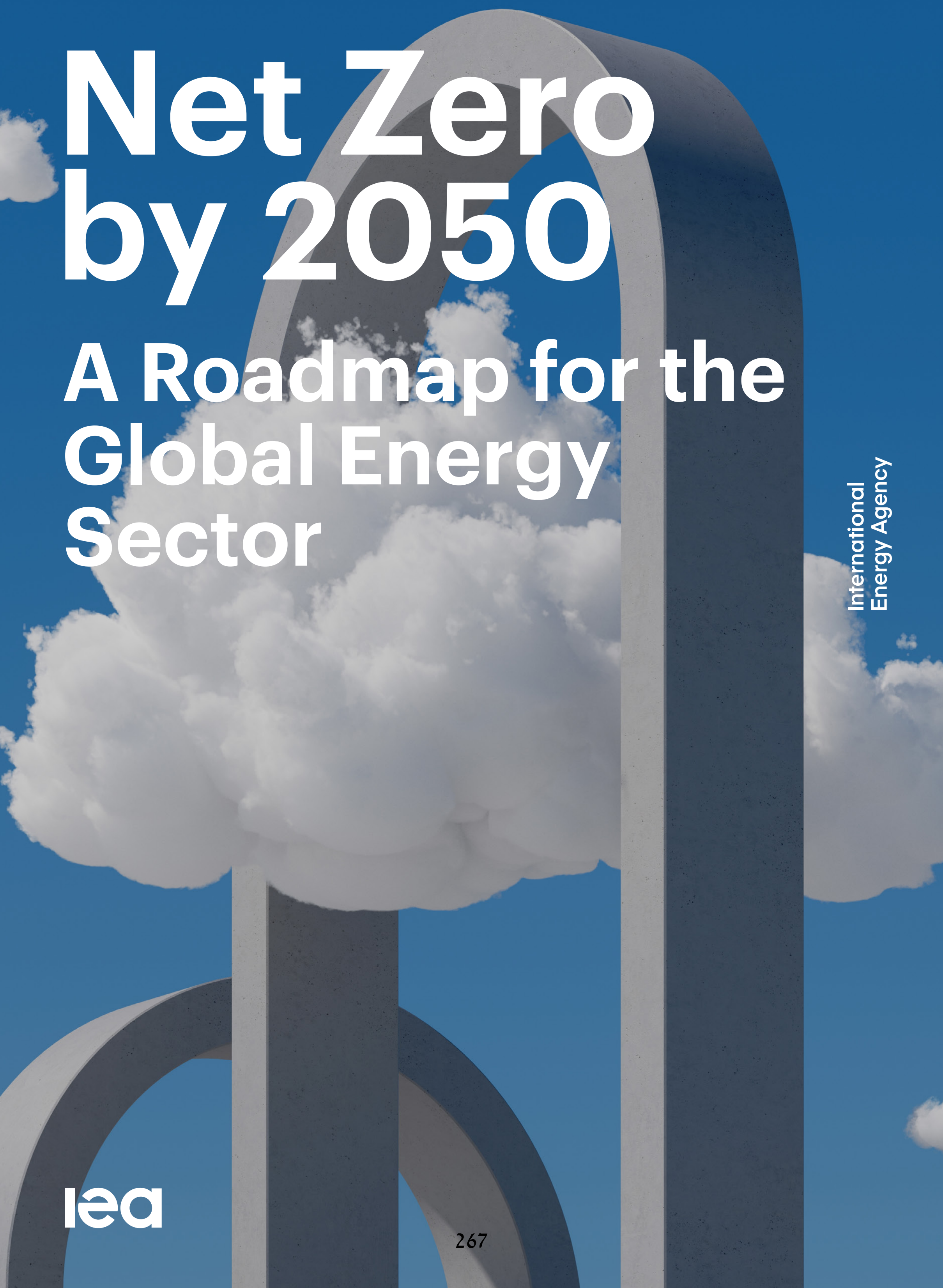
		פליטות			מדדים ויעדים			צעדי המדיניות המוצעים
		2020 MtCO2e	יעד 2030 MtCO2e	יעד 2050 MtCO2e	מצב כיום	מדד מרכזי	יעד 2050	
44%	**חשמל**	35	25	5.5	6%	% אנרגיות מתחדשות	86%-54%	• סגירת תחנות הכוח הפחמיות • קידום תוכנית דו-שימוש בקרקע ותוכנית לקידום אגירה • תמיכות להתייעלות באנרגיה בתעשייה ובשלטון המקומי
21%	**תחבורה**	16	18	1	0.04%	% רכבים קלים מאופסי פליטה	100%	• פיתוח תשתיות הסעת המונים • מענקים לרכישת אוטובוסים מאופסי פליטה
19%	**תעשייה**	14	8	5	7	פליטות מצריכת דלקים	3	• תמיכה בייעול השימוש באנרגיה ומעבר למקורות אנרגיה נקיים • תמיכה בתוכנית סימביוזה תעשייתית המאפשרת להחזיר פסולת של תהליך ייצור כחומר גלם • חקיקה להסדרת מקצוע מתקיני ונותני שירות למערכות מיזוג וקירור
7%	**פסולת**	5	3	0.4	80%	% שיעור הטמנת פסולת	0%	• קביעת חובת טיפול בפסולת אורגנית וקביעת תקנים מחייבים לשימוש בחומר המטופל • קביעת איסור הטמנת פסולת לא ממוינת ופסולת אורגנית לא מטופלת • תמיכה בפיילוטים להפחתת כמות הפסולת העירונית המיוצרת במשקי הבתים (חסוך ומחזר)
26%	**ערים ומבנים** כולל חשמל	21	17	4	25%	% שיעור בנייה ירוקה מהתחלות הבנייה	100%	• החלת תקן בנייה ירוקה (ת"י 5281) כמחייב על כלל המבנים החדשים בישראל • יצירת מסמך הגדרות ברור להגדרת מבנה מאופס אנרגיה • עדכון והחמרת דרישות הצפיפות בתמ"א 35 • קידום תוכניות מפורטות ומתאריות ומסמכי מדיניות להתחדשות עירונית
100%	**מאקרו**	78	58	12				• **תמחור פחמן** • **חוק אקלים**

נספח 11

העתק מדו״ח ה IEA ו- דו״ח ה IPPC

עמ׳ 267

נספח 11



Net Zero by 2050

A Roadmap for the Global Energy Sector

International Energy Agency

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Net Zero by 2050

A Roadmap for the Global Energy Sector

Net Zero by 2050 Interactive
iea.li/nzeroadmap

Net Zero by 2050 Data
iea.li/nzedata

INTERNATIONAL ENERGY AGENCY

The IEA examines the full spectrum of energy issues including oil, gas and coal supply and demand, renewable energy technologies, electricity markets, energy efficiency, access to energy, demand side management and much more. Through its work, the IEA advocates policies that will enhance the reliability, affordability and sustainability of energy in its 30 member countries, 8 association countries and beyond.

Revised version, October 2021 (4th revision)
Information notice found at: www.iea.org/corrections

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We are approaching a decisive moment for international efforts to tackle the climate crisis – a great challenge of our times. The number of countries that have pledged to reach net-zero emissions by mid-century or soon after continues to grow, but so do global greenhouse gas emissions. This gap between rhetoric and action needs to close if we are to have a fighting chance of reaching net zero by 2050 and limiting the rise in global temperatures to 1.5 °C.

Doing so requires nothing short of a total transformation of the energy systems that underpin our economies. We are in a critical year at the start of a critical decade for these efforts. The 26th Conference of the Parties (COP26) of the United Nations Framework Convention on Climate Change in November is the focal point for strengthening global ambitions and action on climate by building on the foundations of the 2015 Paris Agreement. The International Energy Agency (IEA) has been working hard to support the UK government's COP26 Presidency to help make it the success the world needs. I was delighted to co-host the IEA-COP26 Net Zero Summit with COP26 President Alok Sharma in March, where top energy and climate leaders from more than 40 countries highlighted the global momentum behind clean energy transitions.

The discussions at that event fed into this special report, notably through the Seven Key Principles for Implementing Net Zero that the IEA presented at the Summit, which have been backed by 22 of our member governments to date. This report maps out how the global energy sector can reach net zero by 2050. I believe the report – *Net Zero by 2050: A roadmap for the global energy system* – is one of the most important and challenging undertakings in the IEA's history. The Roadmap is the culmination of the IEA's pioneering work on energy data modelling, combining for the first time the complex models of our two flagship series, the *World Energy Outlook* and *Energy Technology Perspectives*. It will guide the IEA's work and will be an integral part of both those series going forward.

Despite the current gap between rhetoric and reality on emissions, our Roadmap shows that there are still pathways to reach net zero by 2050. The one on which we focus is – in our analysis – the most technically feasible, cost-effective and socially acceptable. Even so, that pathway remains narrow and extremely challenging, requiring all stakeholders – governments, businesses, investors and citizens – to take action this year and every year after so that the goal does not slip out of reach.

This report sets out clear milestones – more than 400 in total, spanning all sectors and technologies – for what needs to happen, and when, to transform the global economy from one dominated by fossil fuels into one powered predominantly by renewable energy like solar and wind. Our pathway requires vast amounts of investment, innovation, skilful policy design and implementation, technology deployment, infrastructure building, international co-operation and efforts across many other areas.

Since the IEA's founding in 1974, one of its core missions has been to promote secure and affordable energy supplies to foster economic growth. This has remained a key concern of our Roadmap, drawing on special analysis carried out with the International Monetary Fund and the International Institute for Applied Systems Analysis. It shows that the enormous challenge of transforming our energy systems is also a huge opportunity for our economies, with the potential to create millions of new jobs and boost economic growth.

Another guiding principle of the Roadmap is that clean energy transitions must be fair and inclusive, leaving nobody behind. We have to ensure that developing economies receive the financing and technological know-how they need to continue building their energy systems to meet the needs of their expanding populations and economies in a sustainable way. It is a moral imperative to bring electricity to the hundreds of millions of people who currently are deprived of access to it, the majority in of them in Africa.

The transition to net zero is for and about people. It is paramount to remain aware that not every worker in the fossil fuel industry can ease into a clean energy job, so governments need to promote training and devote resources to facilitating new opportunities. Citizens must be active participants in the entire process, making them feel part of the transition and not simply subject to it. These themes are among those being explored by the Global Commission on People-Centred Clean Energy Transitions, which I convened at the start of 2021 to examine how to enable citizens to benefit from the opportunities and navigate the disruptions of the shift to a clean energy economy. Headed by Prime Minister Mette Frederiksen of Denmark and composed of government leaders, ministers and prominent thinkers, the Global Commission will make public its key recommendations ahead of COP26 in November.

The pathway laid out in our Roadmap is global in scope, but each country will need to design its own strategy, taking into account its specific circumstances. There is no one-size-fits-all approach to clean energy transitions. Plans need to reflect countries' differing stages of economic development: in our pathway, advanced economies reach net zero before developing economies do. As the world's leading energy authority, the IEA stands ready to provide governments with support and advice as they design and implement their own roadmaps, and to encourage the international co-operation across sectors that is so essential to reaching net zero by 2050.

This landmark report would not have been possible without the extraordinary dedication of the IEA colleagues who have worked so tirelessly and rigorously on it. I would like to thank the entire team under the outstanding leadership of my colleagues Laura Cozzi and Timur Gül.

The world has a huge challenge ahead of it to move net zero by 2050 from a narrow possibility to a practical reality. Global carbon dioxide emissions are already rebounding sharply as economies recover from last year's pandemic-induced shock. It is past time for governments to act, and act decisively to accelerate the clean energy transformation.

As this report shows, we at the IEA are fully committed to leading those efforts.

Dr Fatih Birol
Executive Director
International Energy Agency

This study, a cross-agency effort, was prepared by the World Energy Outlook team and the Energy Technology Perspectives team. The study was designed and directed by **Laura Cozzi**, Chief Energy Modeller and Head of Division for Energy Demand Outlook, and **Timur Gül**, Head of Division for Energy Technology Policy.

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The individuals and organisations that contributed to this study are not responsible for any opinions or judgments it contains. All errors and omissions are solely the responsibility of the IEA.

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The energy sector is the source of around three-quarters of greenhouse gas emissions today and holds the key to averting the worst effects of climate change, perhaps the greatest challenge humankind has faced. Reducing global carbon dioxide (CO_2) emissions to net zero by 2050 is consistent with efforts to limit the long-term increase in average global temperatures to 1.5 °C. This calls for nothing less than a complete transformation of how we produce, transport and consume energy. The growing political consensus on reaching net zero is cause for considerable optimism about the progress the world can make, but the changes required to reach net-zero emissions globally by 2050 are poorly understood. A huge amount of work is needed to turn today's impressive ambitions into reality, especially given the range of different situations among countries and their differing capacities to make the necessary changes. This special IEA report sets out a pathway for achieving this goal, resulting in a clean and resilient energy system that would bring major benefits for human prosperity and well-being.

The global pathway to net-zero emissions by 2050 detailed in this report requires all governments to significantly strengthen and then successfully implement their energy and climate policies. Commitments made to date fall far short of what is required by that pathway. The number of countries that have pledged to achieve net-zero emissions has grown rapidly over the last year and now covers around 70% of global emissions of CO_2. This is a huge step forward. However, most pledges are not yet underpinned by near-term policies and measures. Moreover, even if successfully fulfilled, the pledges to date would still leave around 22 billion tonnes of CO_2 emissions worldwide in 2050. The continuation of that trend would be consistent with a temperature rise in 2100 of around 2.1 °C. Global emissions fell in 2020 because of the Covid-19 crisis but are already rebounding strongly as economies recover. Further delay in acting to reverse that trend will put net zero by 2050 out of reach.

In this Summary for Policy Makers, we outline the essential conditions for the global energy sector to reach net-zero CO_2 emissions by 2050. The pathway described in depth in this report achieves this objective with no offsets from outside the energy sector, and with low reliance on negative emissions technologies. It is designed to maximise technical feasibility, cost-effectiveness and social acceptance while ensuring continued economic growth and secure energy supplies. We highlight the priority actions that are needed today to ensure the opportunity of net zero by 2050 – narrow but still achievable – is not lost. The report provides a global view, but countries do not start in the same place or finish at the same time: advanced economies have to reach net zero before emerging markets and developing economies, and assist others in getting there. We also recognise that the route mapped out here is a path, not necessarily the path, and so we examine some key uncertainties, notably concerning the roles played by bioenergy, carbon capture and behavioural changes. Getting to net zero will involve countless decisions by people across the world, but our primary aim is to inform the decisions made by policy makers, who have the greatest scope to move the world closer to its climate goals.

Net zero by 2050 hinges on an unprecedented clean technology push to 2030

The path to net-zero emissions is narrow: staying on it requires immediate and massive deployment of all available clean and efficient energy technologies. In the net-zero emissions pathway presented in this report, the world economy in 2030 is some 40% larger than today but uses 7% less energy. A major worldwide push to increase energy efficiency is an essential part of these efforts, resulting in the annual rate of energy intensity improvements averaging 4% to 2030 – about three-times the average rate achieved over the last two decades. Emissions reductions from the energy sector are not limited to CO_2: in our pathway, methane emissions from fossil fuel supply fall by 75% over the next ten years as a result of a global, concerted effort to deploy all available abatement measures and technologies.

Ever-cheaper renewable energy technologies give electricity the edge in the race to zero. Our pathway calls for scaling up solar and wind rapidly this decade, reaching annual additions of 630 gigawatts (GW) of solar photovoltaics (PV) and 390 GW of wind by 2030, four-times the record levels set in 2020. For solar PV, this is equivalent to installing the world's current largest solar park roughly every day. Hydropower and nuclear, the two largest sources of low-carbon electricity today, provide an essential foundation for transitions. As the electricity sector becomes cleaner, electrification emerges as a crucial economy-wide tool for reducing emissions. Electric vehicles (EVs) go from around 5% of global car sales to more than 60% by 2030.

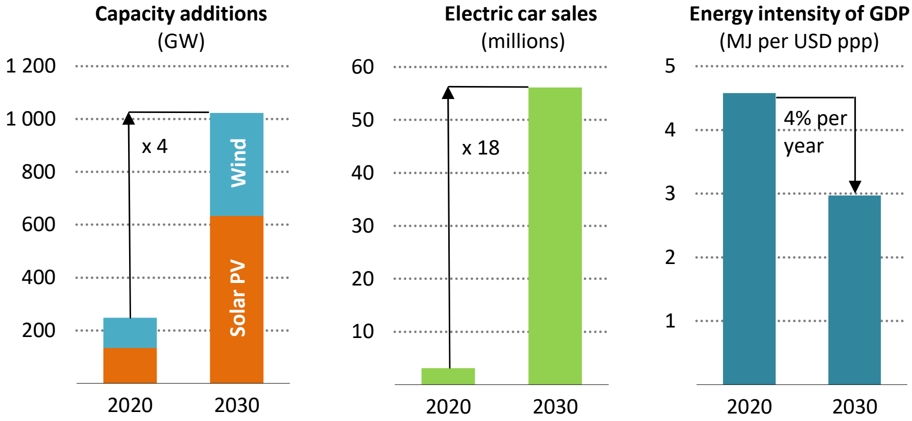
PRIORITY ACTION

Make the 2020s the decade of massive clean energy expansion

All the technologies needed to achieve the necessary deep cuts in global emissions by 2030 already exist, and the policies that can drive their deployment are already proven.

As the world continues to grapple with the impacts of the Covid-19 pandemic, it is essential that the resulting wave of investment and spending to support economic recovery is aligned with the net zero pathway. Policies should be strengthened to speed the deployment of clean and efficient energy technologies. Mandates and standards are vital to drive consumer spending and industry investment into the most efficient technologies. Targets and competitive auctions can enable wind and solar to accelerate the electricity sector transition. Fossil fuel subsidy phase-outs, carbon pricing and other market reforms can ensure appropriate price signals. Policies should limit or provide disincentives for the use of certain fuels and technologies, such as unabated coal-fired power stations, gas boilers and conventional internal combustion engine vehicles. Governments must lead the planning and incentivising of the massive infrastructure investment, including in smart transmission and distribution grids.

Key clean technologies ramp up by 2030 in the net zero pathway



Note: MJ = megajoules; GDP = gross domestic product in purchasing power parity.

Net zero by 2050 requires huge leaps in clean energy innovation

Reaching net zero by 2050 requires further rapid deployment of available technologies as well as widespread use of technologies that are not on the market yet. Major innovation efforts must occur over this decade in order to bring these new technologies to market in time. Most of the global reductions in CO_2 emissions through 2030 in our pathway come from technologies readily available today. But in 2050, almost half the reductions come from technologies that are currently at the demonstration or prototype phase. In heavy industry and long-distance transport, the share of emissions reductions from technologies that are still under development today is even higher.

The biggest innovation opportunities concern advanced batteries, hydrogen electrolysers, and direct air capture and storage. Together, these three technology areas make vital contributions the reductions in CO_2 emissions between 2030 and 2050 in our pathway. Innovation over the next ten years – not only through research and development (R&D) and demonstration but also through deployment – needs to be accompanied by the large-scale construction of the infrastructure the technologies will need. This includes new pipelines to transport captured CO_2 emissions and systems to move hydrogen around and between ports and industrial zones.

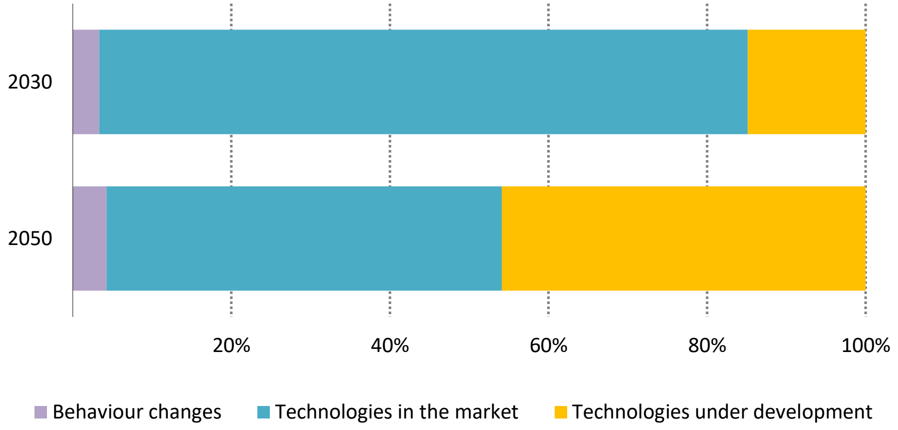
PRIORITY ACTION

Prepare for the next phase of the transition by boosting innovation

Clean energy innovation must accelerate rapidly, with governments putting R&D, demonstration and deployment at the core of energy and climate policy.

Government R&D spending needs to be increased and reprioritised. Critical areas such as electrification, hydrogen, bioenergy and carbon capture, utilisation and storage (CCUS) today receive only around one-third of the level of public R&D funding of the more established low-carbon electricity generation and energy efficiency technologies. Support is also needed to accelerate the roll-out of demonstration projects, to leverage private investment in R&D, and to boost overall deployment levels to help reduce costs. Around USD 90 billion of public money needs to be mobilised globally as soon as possible to complete a portfolio of demonstration projects before 2030. Currently, only roughly USD 25 billion is budgeted for that period. Developing and deploying these technologies would create major new industries, as well as commercial and employment opportunities.

Annual CO_2 emissions savings in the net zero pathway, relative to 2020



The transition to net zero is for and about people

A transition of the scale and speed described by the net zero pathway cannot be achieved without sustained support and participation from citizens. The changes will affect multiple aspects of people's lives – from transport, heating and cooking to urban planning and jobs. We estimate that around 55% of the cumulative emissions reductions in the pathway are linked to consumer choices such as purchasing an EV, retrofitting a house with energy-efficient technologies or installing a heat pump. Behavioural changes, particularly in advanced economies – such as replacing car trips with walking, cycling or public transport, or foregoing a long-haul flight – also provide around 4% of the cumulative emissions reductions.

Providing electricity to around 785 million people that have no access and clean cooking solutions to 2.6 billion people that lack those options is an integral part of our pathway. Emissions reductions have to go hand-in-hand with efforts to ensure energy access for all by 2030. This costs around USD 40 billion a year, equal to around 1% of average annual energy sector investment, while also bringing major co-benefits from reduced indoor air pollution.

Some of the changes brought by the clean energy transformation may be challenging to implement, so decisions must be transparent, just and cost-effective. Governments need to ensure that clean energy transitions are people-centred and inclusive. Household energy expenditure as a share of disposable income – including purchases of efficient appliances and fuel bills – rises modestly in emerging market and developing economies in our net zero pathway as more people gain access to energy and demand for modern energy services increases rapidly. Ensuring the affordability of energy for households demands close attention: policy tools that can direct support to the poorest include tax credits, loans and targeted subsidies.

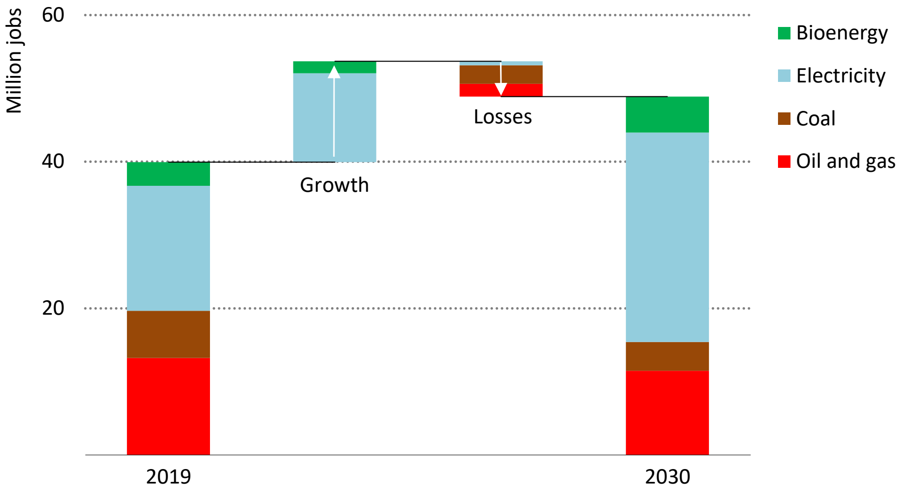
PRIORITY ACTION

Clean energy jobs will grow strongly but must be spread widely

Energy transitions have to take account of the social and economic impacts on individuals and communities, and treat people as active participants.

The transition to net zero brings substantial new opportunities for employment, with 14 million jobs created by 2030 in our pathway thanks to new activities and investment in clean energy. Spending on more efficient appliances, electric and fuel cell vehicles, and building retrofits and energy-efficient construction would require a further 16 million workers. But these opportunities are often in different locations, skill sets and sectors than the jobs that will be lost as fossil fuels decline. In our pathway, around 5 million jobs are lost. Most of those jobs are located close to fossil fuel resources, and many are well paid, meaning structural changes can cause shocks for communities with impacts that persist over time. This requires careful policy attention to address the employment losses. It will be vital to minimise hardships associated with these disruptions, such as by retraining workers, locating new clean energy facilities in heavily affected areas wherever possible, and providing regional aid.

Global employment in energy supply in the net zero pathway, 2019-2030



An energy sector dominated by renewables

In the net zero pathway, global energy demand in 2050 is around 8% smaller than today, but it serves an economy more than twice as big and a population with 2 billion more people. More efficient use of energy, resource efficiency and behavioural changes combine to offset increases in demand for energy services as the world economy grows and access to energy is extended to all.

Instead of fossil fuels, the energy sector is based largely on renewable energy. Two-thirds of total energy supply in 2050 is from wind, solar, bioenergy, geothermal and hydro energy. Solar becomes the largest source, accounting for one-fifth of energy supplies. Solar PV capacity increases 20-fold between now and 2050, and wind power 11-fold.

Net zero means a huge decline in the use of fossil fuels. They fall from almost four-fifths of total energy supply today to slightly over one-fifth by 2050. Fossil fuels that remain in 2050 are used in goods where the carbon is embodied in the product such as plastics, in facilities fitted with CCUS, and in sectors where low-emissions technology options are scarce.

Electricity accounts for almost 50% of total energy consumption in 2050. It plays a key role across all sectors – from transport and buildings to industry – and is essential to produce low-emissions fuels such as hydrogen. To achieve this, total electricity generation increases over two-and-a-half-times between today and 2050. At the same time, no additional new final investment decisions should be taken for new unabated coal plants, the least efficient coal plants are phased out by 2030, and the remaining coal plants still in use by 2040 are retrofitted. By 2050, almost 90% of electricity generation comes from renewable sources, with wind and solar PV together accounting for nearly 70%. Most of the remainder comes from nuclear.

Emissions from industry, transport and buildings take longer to reduce. Cutting industry emissions by 95% by 2050 involves major efforts to build new infrastructure. After rapid innovation progress through R&D, demonstration and initial deployment between now and 2030 to bring new clean technologies to market, the world then has to put them into action. Every month from 2030 onwards, ten heavy industrial plants are equipped with CCUS, three new hydrogen-based industrial plants are built, and 2 GW of electrolyser capacity are added at industrial sites. Policies that end sales of new internal combustion engine cars by 2035 and boost electrification underpin the massive reduction in transport emissions. In 2050, cars on the road worldwide run on electricity or fuel cells. Low-emissions fuels are essential where energy needs cannot easily or economically be met by electricity. For example, aviation relies largely on biofuels and synthetic fuels, and ammonia is vital for shipping. In buildings, bans on new fossil fuel boilers need to start being introduced globally in 2025, driving up sales of electric heat pumps. Most old buildings and all new ones comply with zero-carbon-ready building energy codes.[1]

PRIORITY ACTION

Set near-term milestones to get on track for long-term targets

Governments need to provide credible step-by-step plans to reach their net zero goals, building confidence among investors, industry, citizens and other countries.

Governments must put in place long-term policy frameworks to allow all branches of government and stakeholders to plan for change and facilitate an orderly transition. Long-term national low-emissions strategies, called for by the Paris Agreement, can set out a vision for national transitions, as this report has done on a global level. These long-term objectives need to be linked to measurable short-term targets and policies. Our pathway details more than 400 sectoral and technology milestones to guide the global journey to net zero by 2050.

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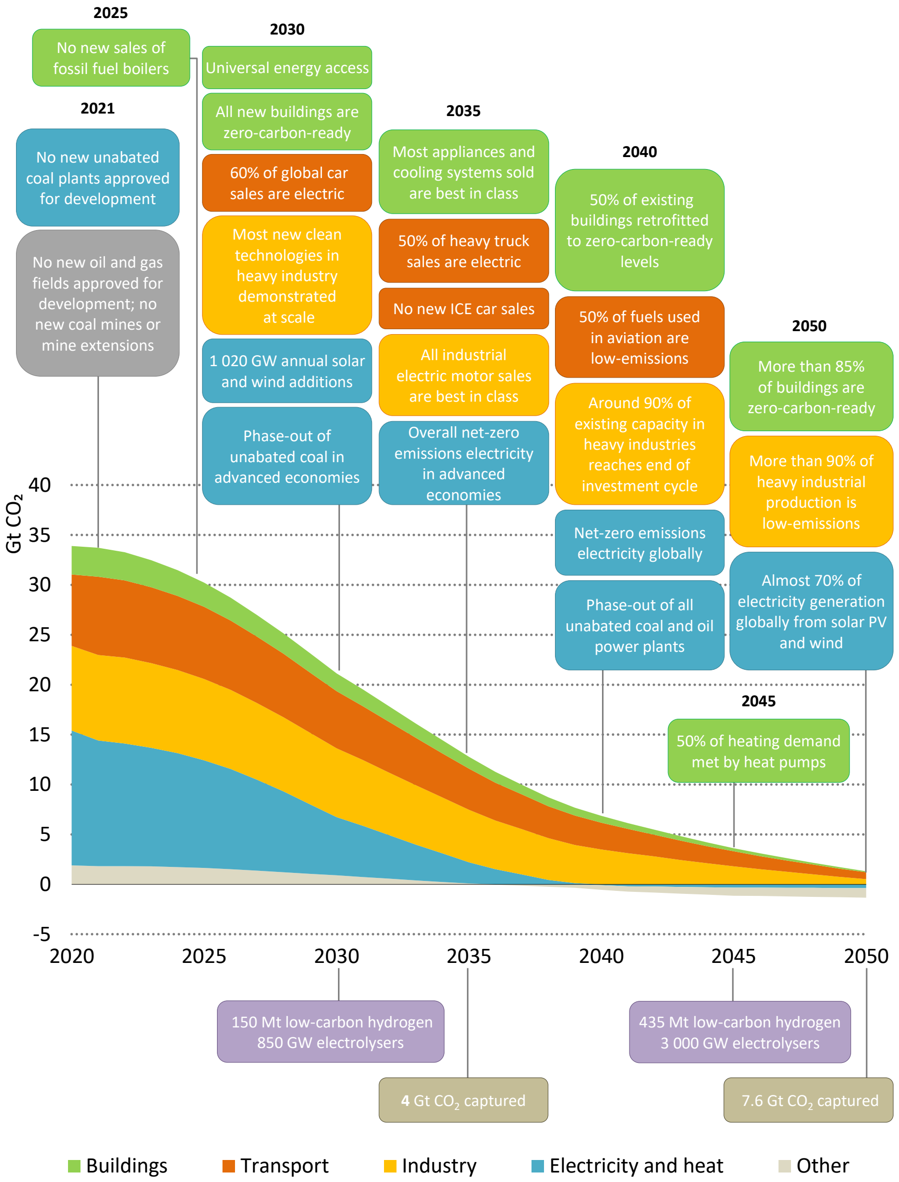
[1] A zero-carbon-ready building is highly energy efficient and either uses renewable energy directly or uses an energy supply that will be fully decarbonised by 2050, such as electricity or district heat.

Key milestones in the pathway to net zero



2021

No new unabated coal plants approved for development

No new oil and gas fields approved for development; no new coal mines or mine extensions

2025

No new sales of fossil fuel boilers

2030

Universal energy access

All new buildings are zero-carbon-ready

60% of global car sales are electric

Most new clean technologies in heavy industry demonstrated at scale

1 020 GW annual solar and wind additions

Phase-out of unabated coal in advanced economies

150 Mt low-carbon hydrogen
850 GW electrolysers

2035

Most appliances and cooling systems sold are best in class

50% of heavy truck sales are electric

No new ICE car sales

All industrial electric motor sales are best in class

Overall net-zero emissions electricity in advanced economies

4 Gt CO_2 captured

2040

50% of existing buildings retrofitted to zero-carbon-ready levels

50% of fuels used in aviation are low-emissions

Around 90% of existing capacity in heavy industries reaches end of investment cycle

Net-zero emissions electricity globally

Phase-out of all unabated coal and oil power plants

2045

50% of heating demand met by heat pumps

435 Mt low-carbon hydrogen
3 000 GW electrolysers

2050

More than 85% of buildings are zero-carbon-ready

More than 90% of heavy industrial production is low-emissions

Almost 70% of electricity generation globally from solar PV and wind

7.6 Gt CO_2 captured

There is no need for investment in new fossil fuel supply in our net zero pathway

Beyond projects already committed as of 2021, there are no new oil and gas fields approved for development in our pathway, and no new coal mines or mine extensions are required. The unwavering policy focus on climate change in the net zero pathway results in a sharp decline in fossil fuel demand, meaning that the focus for oil and gas producers switches entirely to output – and emissions reductions – from the operation of existing assets. Unabated coal demand declines by 98% to just less than 1% of total energy use in 2050. Gas demand declines by 55% to 1 750 billion cubic metres and oil declines by 75% to 24 million barrels per day (mb/d), from around 90 mb/d in 2020.

Clean electricity generation, network infrastructure and end-use sectors are key areas for increased investment. Enabling infrastructure and technologies are vital for transforming the energy system. Annual investment in transmission and distribution grids expands from USD 260 billion today to USD 820 billion in 2030. The number of public charging points for EVs rises from around 1 million today to 40 million in 2030, requiring annual investment of almost USD 90 billion in 2030. Annual battery production for EVs leaps from 160 gigawatt-hours (GWh) today to 6 600 GWh in 2030 – the equivalent of adding almost 20 gigafactories[2] each year for the next ten years. And the required roll-out of hydrogen and CCUS after 2030 means laying the groundwork now: annual investment in CO_2 pipelines and hydrogen-enabling infrastructure increases from USD 1 billion today to around USD 40 billion in 2030.

PRIORITY ACTION

Drive a historic surge in clean energy investment

Policies need to be designed to send market signals that unlock new business models and mobilise private spending, especially in emerging economies.

Accelerated delivery of international public finance will be critical to energy transitions, especially in developing economies, but ultimately the private sector will need to finance most of the extra investment required. Mobilising the capital for large-scale infrastructure calls for closer co-operation between developers, investors, public financial institutions and governments. Reducing risks for investors will be essential to ensure successful and affordable clean energy transitions. Many emerging market and developing economies, which rely mainly on public funding for new energy projects and industrial facilities, will need to reform their policy and regulatory frameworks to attract more private finance. International flows of long-term capital to these economies will be needed to support the development of both existing and emerging clean energy technologies.

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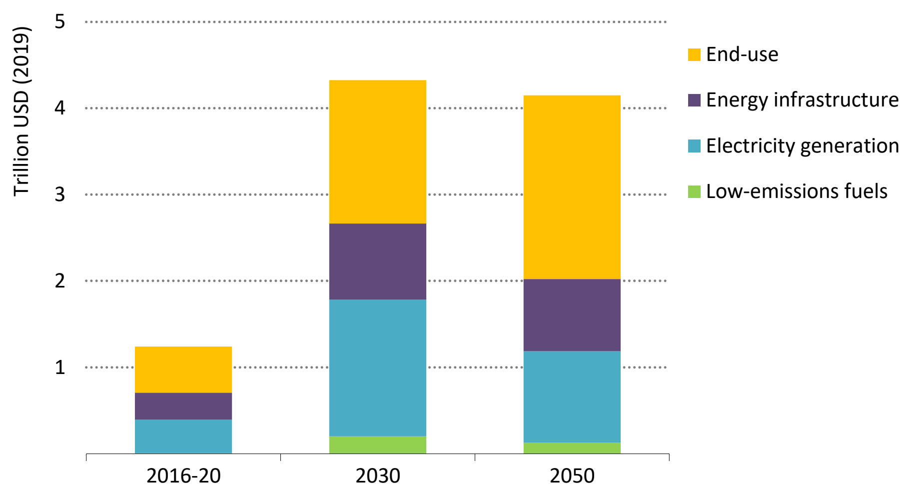
[2] Battery gigafactory capacity assumption = 35 gigawatt-hours per year.

Clean energy investment in the net zero pathway



An unparalleled clean energy investment boom lifts global economic growth

Total annual energy investment surges to USD 5 trillion by 2030, adding an extra 0.4 percentage point a year to annual global GDP growth, based on our joint analysis with the International Monetary Fund. This unparalleled increase – with investment in clean energy and energy infrastructure more than tripling already by 2030 – brings significant economic benefits as the world emerges from the Covid-19 crisis. The jump in private and government spending creates millions of jobs in clean energy, including energy efficiency, as well as in the engineering, manufacturing and construction industries. All of this puts global GDP 4% higher in 2030 than it would be based on current trends.

Governments have a key role in enabling investment-led growth and ensuring that the benefits are shared by all. There are large differences in macroeconomic impacts between regions. But government investment and public policies are essential to attract large amounts of private capital and to help offset the declines in fossil fuel income that many countries will experience. The major innovation efforts needed to bring new clean energy technologies to market could boost productivity and create entirely new industries, providing opportunities to locate them in areas that see job losses in incumbent industries. Improvements in air quality provide major health benefits, with 2 million fewer premature deaths globally from air pollution in 2030 than today in our net zero pathway. Achieving universal energy access by 2030 would provide a major boost to well-being and productivity in developing economies.

New energy security concerns emerge, and old ones remain

The contraction of oil and natural gas production will have far-reaching implications for all the countries and companies that produce these fuels. No new oil and natural gas fields are needed in our pathway, and oil and natural gas supplies become increasingly concentrated in a small number of low-cost producers. For oil, the OPEC share of a much-reduced global oil supply increases from around 37% in recent years to 52% in 2050, a level higher than at any point in the history of oil markets. Yet annual per capita income from oil and natural gas in producer economies falls by about 75%, from USD 1 800 in recent years to USD 450 by the 2030s, which could have knock-on societal effects. Structural reforms and new sources of revenue are needed, even though these are unlikely to compensate fully for the drop in oil and gas income. While traditional supply activities decline, the expertise of the oil and natural gas industry fits well with technologies such as hydrogen, CCUS and offshore wind that are needed to tackle emissions in sectors where reductions are likely to be most challenging.

The energy transition requires substantial quantities of critical minerals, and their supply emerges as a significant growth area. The total market size of critical minerals like copper, cobalt, manganese and various rare earth metals grows almost sevenfold between 2020 and 2030 in the net zero pathway. Revenues from those minerals are larger than revenues from coal well before 2030. This creates substantial new opportunities for mining companies. It also creates new energy security concerns, including price volatility and additional costs for transitions, if supply cannot keep up with burgeoning demand.

The rapid electrification of all sectors makes electricity even more central to energy security around the world than it is today. Electricity system flexibility – needed to balance wind and solar with evolving demand patterns – quadruples by 2050 even as retirements of fossil fuel capacity reduce conventional sources of flexibility. The transition calls for major increases in all sources of flexibility: batteries, demand response and low-carbon flexible power plants, supported by smarter and more digital electricity networks. The resilience of electricity systems to cyberattacks and other emerging threats needs to be enhanced.

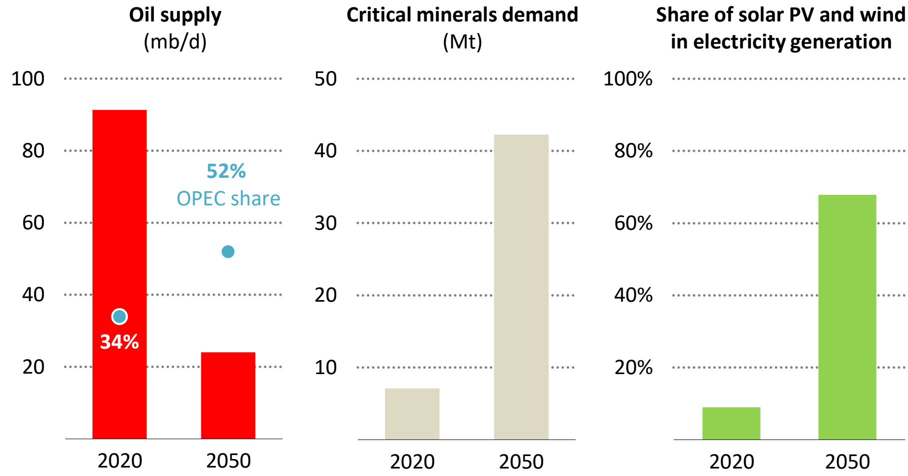
PRIORITY ACTION

Address emerging energy security risks now

Ensuring uninterrupted and reliable supplies of energy and critical energy-related commodities at affordable prices will only rise in importance on the way to net zero.

The focus of energy security will evolve as reliance on renewable electricity grows and the role of oil and gas diminishes. Potential vulnerabilities from the increasing importance of electricity include the variability of supply and cybersecurity risks. Governments need to create markets for investment in batteries, digital solutions and electricity grids that reward flexibility and enable adequate and reliable supplies of electricity. The growing dependence on critical minerals required for key clean energy technologies calls for new international mechanisms to ensure both the timely availability of supplies and sustainable production. At the same time, traditional energy security concerns will not disappear, as oil production will become more concentrated.

Global energy security indicators in the net zero pathway



Note: mb/d = million barrels per day; Mt = million tonnes.

International co-operation is pivotal for achieving net-zero emissions by 2050

Making net-zero emissions a reality hinges on a singular, unwavering focus from all governments – working together with one another, and with businesses, investors and citizens. All stakeholders need to play their part. The wide-ranging measures adopted by governments at all levels in the net zero pathway help to frame, influence and incentivise the purchase by consumers and investment by businesses. This includes how energy companies invest in new ways of producing and supplying energy services, how businesses invest in equipment, and how consumers cool and heat their homes, power their devices and travel.

Underpinning all these changes are policy decisions made by governments. Devising cost-effective national and regional net zero roadmaps demands co-operation among all parts of government that breaks down silos and integrates energy into every country's policy making on finance, labour, taxation, transport and industry. Energy or environment ministries alone cannot carry out the policy actions needed to reach net zero by 2050.

Changes in energy consumption result in a significant decline in fossil fuel tax revenues. In many countries today, taxes on diesel, gasoline and other fossil fuel consumption are an important source of public revenues, providing as much as 10% in some cases. In the net zero pathway, tax revenue from oil and gas retail sales falls by about 40% between 2020 and 2030. Managing this decline will require long-term fiscal planning and budget reforms.

The net zero pathway relies on unprecedented international co-operation among governments, especially on innovation and investment. The IEA stands ready to support governments in preparing national and regional net zero roadmaps, to provide guidance and assistance in implementing them, and to promote international co-operation to accelerate the energy transition worldwide.

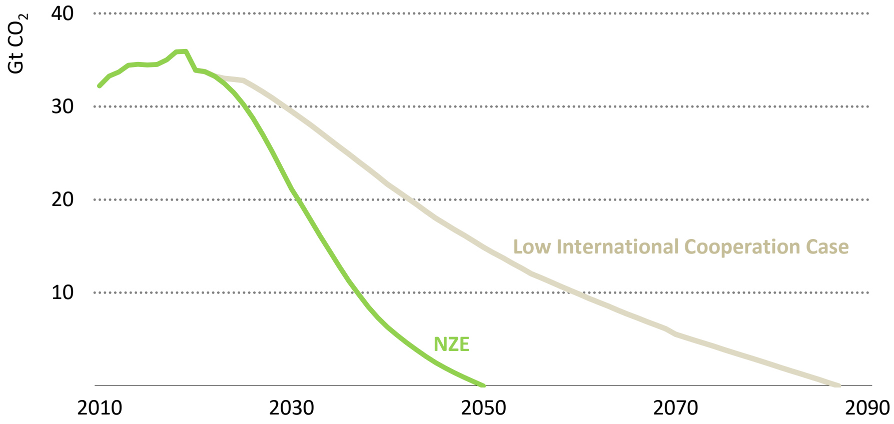
PRIORITY ACTION

Take international co-operation to new heights

This is not simply a matter of all governments seeking to bring their national emissions to net zero – it means tackling global challenges through co-ordinated actions.

Governments must work together in an effective and mutually beneficial manner to implement coherent measures that cross borders. This includes carefully managing domestic job creation and local commercial advantages with the collective global need for clean energy technology deployment. Accelerating innovation, developing international standards and co-ordinating to scale up clean technologies needs to be done in a way that links national markets. Co-operation must recognise differences in the stages of development of different countries and the varying situations of different parts of society. For many rich countries, achieving net-zero emissions will be more difficult and costly without international co-operation. For many developing countries, the pathway to net zero without international assistance is not clear. Technical and financial support is needed to ensure deployment of key technologies and infrastructure. Without greater international co-operation, global CO_2 emissions will not fall to net zero by 2050.

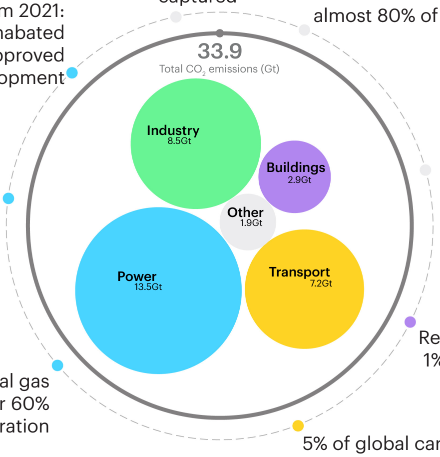
Global energy-related CO_2 emissions in the net zero pathway and Low International Co-operation Case



Note: Gt = gigatonnes.

Net Zero Emissions by 2050 Interactive iea.li/nzeroadmap

2020



40 Mt CO_2 captured

Fossil fuels account for almost 80% of TES

From 2021: No new oil and gas fields approved for development; no new coal mines or mine extensions

Retrofit rates below 1% globally

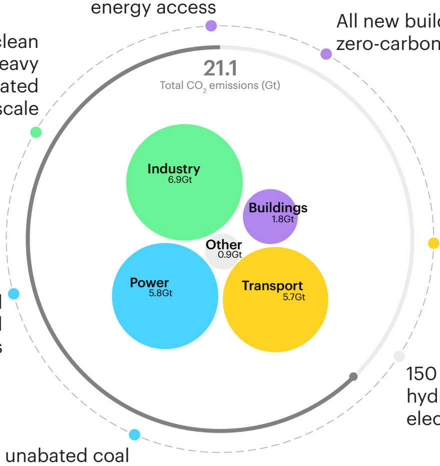
5% of global car sales are electric

Unabated coal, natural gas and oil account for over 60% of total electricity generation

Solar PV and wind accounts for almost 10% of total electricity generation

From 2021: No new unabated coal plants approved for development

2030



Universal energy access

All new buildings are zero-carbon-ready

60% of global car sales are electric

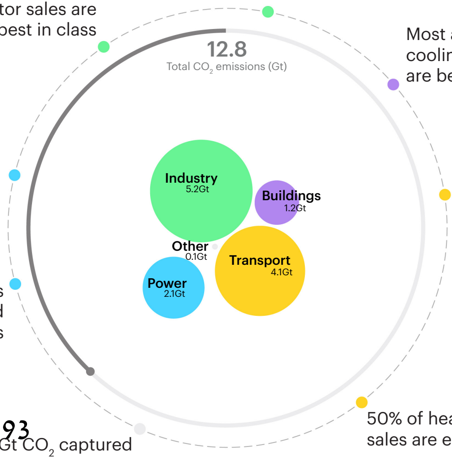
150 Mt low-carbon hydrogen; 850 GW electrolysers

Phase-out of unabated coal in advanced economies

1 020 GW annual solar and wind additions

Most new clean technologies in heavy industry demonstrated at scale

2035



Virtually all heavy industry capacity additions are innovative low-emissions routes

Most appliances and cooling systems sold are best in class

No new internal combustion engine car sales

50% of heavy truck sales are electric

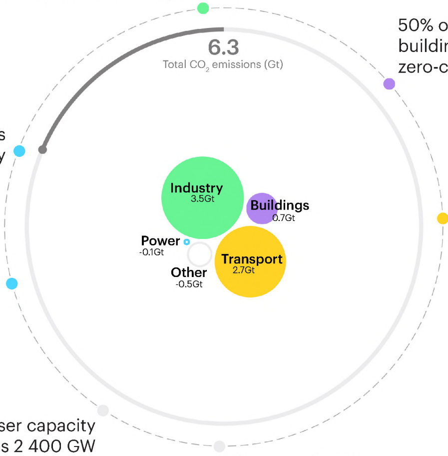
4 Gt CO_2 captured

Overall net-zero emissions electricity in advanced economies

Capacity fitted with CCUS or co-firing hydrogen-based fuels reaches 6% of total generation

All industrial electric motor sales are best in class

2040



Around 90% of existing capacity in heavy industries reaches end of investment cycle

50% of existing buildings retrofitted to zero-carbon-ready levels

Net-zero emissions electricity globally

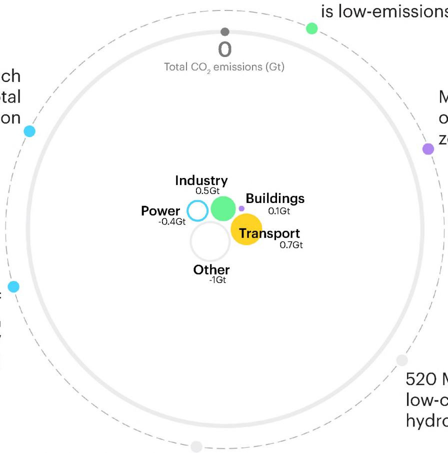
50% of fuels used in aviation are low-emissions

Phase-out of all unabated coal and oil power plants

Electrolyser capacity reaches 2 400 GW

Oil demand is 50% of 2020 level

2050



More than 90% of heavy industrial production is low-emissions

Renewables reach almost 90% of total electricity generation

More than 85% of buildings are zero-carbon-ready

Almost 70% of electricity generation globally from solar PV and wind

520 Mt low-carbon hydrogen

7.6 Gt CO_2 captured

Announced net zero pledges and the energy sector

SUMMARY

- There has been a rapid increase over the last year in the number of governments pledging to reduce greenhouse gas emissions to net zero. Net zero pledges to date cover around 70% of global GDP and CO_2 emissions. However, fewer than a quarter of announced net zero pledges are fixed in domestic legislation and few are yet underpinned by specific measures or policies to deliver them in full and on time.
- The Stated Policies Scenario (STEPS) takes account only of specific policies that are in place or have been announced by governments. Annual energy-related and industrial process CO_2 emissions rise from 34 Gt in 2020 to 36 Gt in 2030 and remain around this level until 2050. If emissions continue on this trajectory, with similar changes in non-energy-related GHG emissions, this would lead to a temperature rise of around 2.7 °C by 2100 (with a 50% probability). Renewables provide almost 55% of global electricity generation in 2050 (up from 29% in 2020), but clean energy transitions lag in other sectors. Global coal use falls by 15% between 2020 and 2050; oil use in 2050 is 15% higher than in 2020; and natural gas use is almost 50% higher.
- The Announced Pledges Case (APC) assumes that all announced national net zero pledges are achieved in full and on time, whether or not they are currently underpinned by specific policies. Global energy-related and industrial process CO_2 emissions fall to 30 Gt in 2030 and 22 Gt in 2050. Extending this trajectory, with similar action on non-energy-related GHG emissions, would lead to a temperature rise in 2100 of around 2.1 °C (with a 50% probability). Global electricity generation nearly doubles to exceed 50 000 TWh in 2050. The share of renewables in electricity generation rises to nearly 70% in 2050. Oil demand does not return to its 2019 peak and falls about 10% from 2020 to 80 mb/d in 2050. Coal use drops by 50% to 2 600 Mtce in 2050, while natural gas use expands by 10% to 4 350 bcm in 2025 and remains about that level to 2050.
- Efficiency, electrification and the replacement of coal by low-emissions sources in electricity generation play a central role in achieving net zero goals in the APC, especially over the period to 2030. The relative contributions of nuclear, hydrogen, bioenergy and CCUS vary across countries, depending on their circumstances.
- The divergence in trends between the APC and the STEPS shows the difference that current net zero pledges could make, while underlining at the same time the need for concrete policies and short-term plans that are consistent with long-term net zero pledges. However, the APC also starkly highlights that existing net zero pledges, even if delivered in full, fall well short of what is necessary to reach global net-zero emissions by 2050.

1.1 Introduction

November 2021 will see the most important UN Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP 26) since the Paris Agreement was signed in 2015. As COP 26 approaches, an increasing number of countries have announced long-term goals to achieve net-zero greenhouse gas (GHG) emissions over the coming decades. On 31 March 2021, the International Energy Agency (IEA) hosted a Net Zero Summit to take stock of the growing list of commitments from countries and companies to reach the goals of the Paris Agreement, and to focus on the actions necessary to start turning those net zero goals into reality.

Achieving those goals will be demanding. The Covid-19 pandemic delivered a major shock to the world economy, resulting in an unprecedented 5.8% decline in CO_2 emissions in 2020. However, our monthly data show that global energy-related CO_2 emissions started to climb again in December 2020, and we estimate that they will rebound to around 33 gigatonnes of carbon dioxide (Gt CO_2) in 2021, only 1.2% below the level in 2019 (IEA, 2021). Sustainable economic recovery packages offered a unique opportunity to make 2019 the definitive peak in global emissions, but the evidence so far points to a rebound in emissions in parallel with renewed economic growth, at least in the near term (IEA, 2020a).

Recent IEA analyses examined the technologies and policies needed for countries and regions to achieve net-zero emissions energy systems. The *World Energy Outlook 2020* examined what would be needed over the period to 2030 to put the world on a path towards net-zero emissions by 2050 in the context of the pandemic-related economic recovery (IEA, 2020b). The Faster Innovation Case in *Energy Technology Perspectives 2020* explored whether net-zero emissions could be achieved globally by 2050 through accelerated energy technology development and deployment alone: it showed that, relative to baseline trends, almost half of the emissions savings needed in 2050 to reach net-zero emissions rely on technologies that are not yet commercially available (IEA, 2020c).

This special report, prepared at the request of the UK President of the COP 26, incorporates the insights and lessons learned from both reports to create a comprehensive and detailed pathway, or roadmap, to achieve net-zero energy-related and industrial process CO_2 emissions globally by 2050. It assesses the costs of achieving this goal, the likely impacts on employment and the economy, and the wider implications for the world. It also highlights the key milestones for technologies, infrastructure, investment and policy that are needed along the road to 2050.

This report is set out in four chapters:

- **Chapter 1** explores the outlook for global CO_2 emissions and energy supply and use based on existing policies and pledges. It sets out projections of global energy use and emissions based on the **Stated Policies Scenario (STEPS)**, which includes only the firm policies that are in place or have been announced by countries, including Nationally

Determined Contributions. It also examines the **Announced Pledges Case (APC)**, a variant of the STEPS that assumes that all of the net zero targets announced by countries around the world to date are met in full.

- **Chapter 2** presents the **Net-Zero Emissions by 2050 Scenario (NZE)**, which describes how energy demand and the energy mix will need to evolve if the world is to achieve net-zero emissions by 2050. It also assesses the corresponding investment needs and explores key uncertainties surrounding technology and consumer behaviour.
- **Chapter 3** examines the implications of the NZE for various sectors, covering fossil fuel supply, the supply of low-emissions fuels (such as hydrogen, ammonia, biofuels, synthetic fuels and biomethane) and the electricity, transport, industry and buildings sectors. It highlights the key changes required to achieve net-zero emissions in the NZE and the major milestones that are needed along the way.
- **Chapter 4** explores the implications of the NZE for the economy, the energy industry, citizens and governments.

1.2 Emissions reduction targets and net zero pledges

1.2.1 Nationally Determined Contributions

Under the Paris Agreement, Parties[1] are required to submit Nationally Determined Contributions (NDCs) to the UNFCCC and to implement policies with the aim of achieving their stated objectives. The process is dynamic; it requires Parties to update their NDCs every five years in a progressive manner to reflect the highest possible ambition. The first round of NDCs, submitted by 191 countries, covers more than 90% of global energy-related and industrial process CO_2 emissions.[2] The first NDCs included some targets that were unconditional and others that were conditional on international support for finance, technology and other means of implementation.

As of 23 April 2021, 80 countries have submitted new or updated NDCs to the UNFCCC, covering just over 40% of global CO_2 emissions (Figure 1.1).[3] Many of the updated NDCs include more stringent targets than in the initial round of NDCs, or targets for a larger number of sectors or for a broader coverage of GHGs. In addition, 27 countries and the European Union have communicated long-term low GHG emissions development strategies to the UNFCCC, as requested by the Paris Agreement. Some of these strategies incorporate a net zero pledge.

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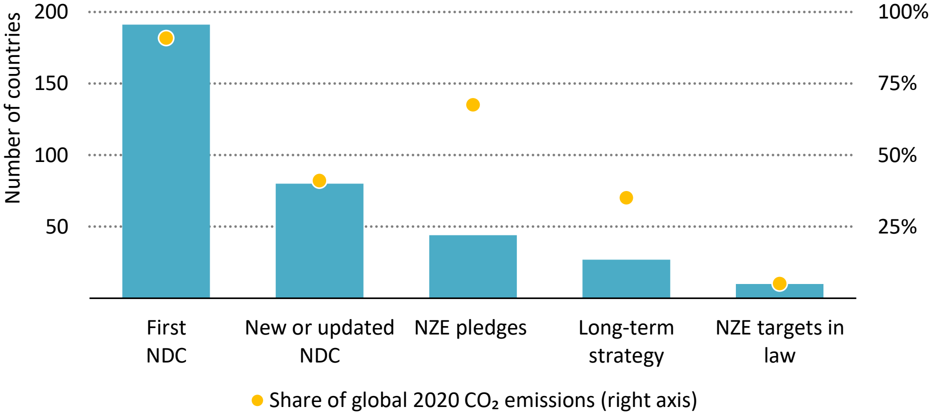
[1] Parties refers to the 197 members of the UNFCCC which includes all United Nations member states, United Nations General Assembly Observer State of Palestine, UN non-member states Niue and the Cook Islands and the European Union.

[2] Unless otherwise stated, CO_2 emissions in this report refer to energy-related and industrial process CO_2 emissions.

[3] Several countries have indicated that they intend to submit new or updated NDCs later in 2021 or in 2022.

Figure 1.1 ▷ **Number of countries with NDCs, long-term strategies and net zero pledges, and their shares of 2020 global CO_2 emissions**



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Around 40% of countries that have ratified the Paris Agreement have updated their NDCs, but net zero pledges cover around 70% of global CO_2 emissions

1.2.2 Net-zero emissions pledges

There has been a rapid increase in the number of governments making pledges to reduce GHG emissions to net zero (Figure 1.2). In the Paris Agreement, countries agreed to "achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second-half of the century". The Intergovernmental Panel on Climate Change (IPCC) *Special Report on Global Warming of 1.5 °C* highlighted the importance of reaching net-zero CO_2 emissions globally by mid-century or sooner to avoid the worst impacts of climate change (IPCC, 2018).

Net-zero emissions pledges have been announced by national governments, subnational jurisdictions, coalitions[4] and a large number of corporate entities (see Spotlight). As of 23 April 2021, 44 countries and the European Union have pledged to meet a net-zero emissions target: in total they account for around 70% of global CO_2 emissions and GDP (Figure 1.3). Of these, ten countries have made meeting their net zero target a legal obligation, eight are proposing to make it a legal obligation, and the remainder have made their pledges in official policy documents.

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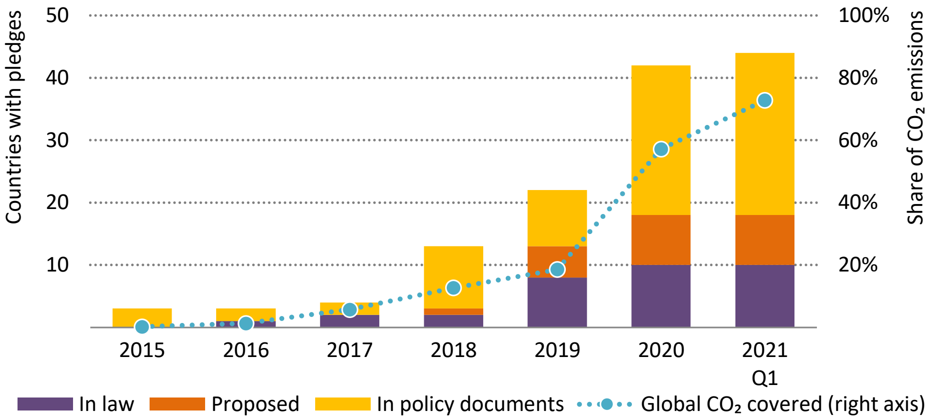
[4] Examples include: the UN-led Climate Ambition Alliance in which signatories signal they are working towards achieving net-zero emissions by 2050; and the Carbon Neutrality Coalition launched at the UN Climate Summit in 2017, in which signatories commit to develop long-term low GHG emissions strategies in line with limiting temperature rises to 1.5 °C.

Figure 1.2 ▹ Number of national net zero pledges and share of global CO_2 emissions covered



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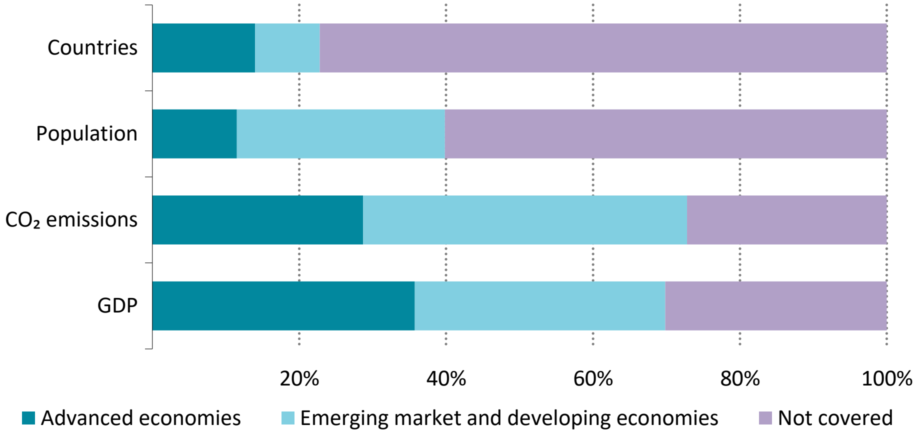
There has been a significant acceleration in net-zero emissions pledges announced by governments, with an increasing number enshrined in law

Notes: In law = a net zero pledge has been approved by parliament and is legally binding. Proposed = a net zero pledge has been proposed to parliament to be voted into law. In policy document = a net zero pledge has been proposed but does not have legally binding status.

Figure 1.3 ▹ Coverage of announced national net zero pledges



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Countries accounting for around 70% of global CO_2 emissions and GDP have set net zero pledges in law, or proposed legislation or in an official policy document

Note: GDP = gross domestic product at purchasing power parity.

In contrast to some of the shorter term commitments contained within NDCs, few net zero pledges are supported by detailed policies and firm routes to implementation. Net-zero emissions pledges also vary considerably in their timescale and scope. Some key differences include:

- **GHG coverage.** Most pledges cover all GHG emissions, but some include exemptions or different rules for certain types of emissions. For example, New Zealand's net zero pledge covers all GHGs except biogenic methane, which has a separate reduction target.
- **Sectoral boundaries**. Some pledges exclude emissions from specific sectors or activities. For example, the Netherlands aims to achieve net-zero GHG emissions only in its electricity sector (as part of an overall aim to reduce total GHG emissions by 95%), and some countries, including France, Portugal and Sweden, exclude international aviation and shipping.
- **Use of carbon dioxide removal (CDR)**. Pledges take varying approaches to account for CDR within a country's sovereign territory. CDR options include natural CO_2 sinks, such as forests and soils, as well as technological solutions, such as direct air capture or bioenergy with carbon capture and storage. For example, Uruguay has stated that natural CO_2 sinks will be used to help it reach net-zero emissions, while Switzerland plans to use CDR technologies to balance a part of its residual emissions in 2050.
- **Use of international mitigation transfers**. Some pledges allow GHG mitigation that occurs outside a country's borders to be counted towards the net zero target, such as through the transfer of carbon credits, while others do not. For example, Norway allows the potential use of international transfers, while France explicitly rules them out. Some countries, such as Sweden, allow such transfers but specify an upper limit to their use.
- **Timeframe**. The majority of pledges, covering 35% of global CO_2 emissions in 2020, target net-zero emissions by 2050, but Finland aims to reach that goal by 2035, Austria and Iceland by 2040 and Sweden by 2045. Among others, the People's Republic of China (hereafter China) and Ukraine have set a target date after 2050.

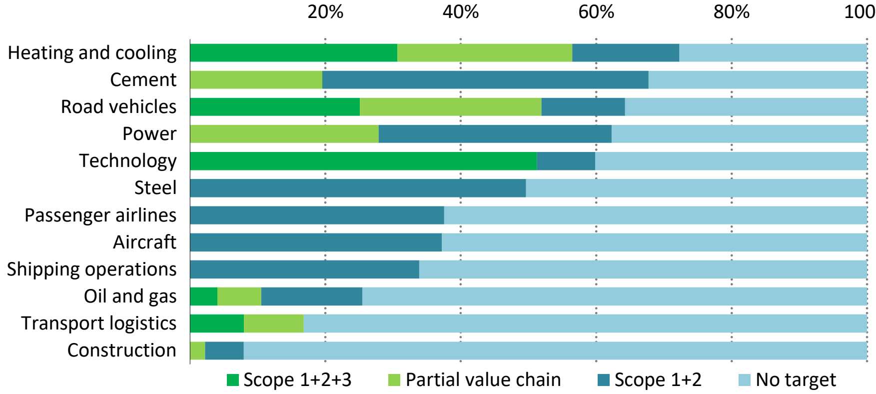
SPOTLIGHT

How are businesses responding to the need to reach net-zero emissions?

There has been a rapid rise in net-zero emissions announcements from companies in recent years: as of February 2021, around 110 companies that consume large amounts of energy directly or produce energy-consuming goods have announced net-zero emissions goals or targets.

Around 60-70% of global production of heating and cooling equipment, road vehicles, electricity and cement is from companies that have announced net-zero emissions targets (Figure 1.4). Nearly 60% of gross revenue in the technology sector is also generated by companies with net-zero emission targets. In other sectors, net zero pledges cover 30-40% of air and shipping operations, 15% of transport logistics and 10% of construction. All these shares are likely to keep growing as more companies make pledges.

Figure 1.4 ▷ **Sectoral activity of large energy-related companies with announced pledges to reach net-zero emissions by 2050**



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Some sectors are more advanced in terms of the extent of net zero targets by companies active in the sector

Notes: Scope 1 = direct emissions from energy and other sources owned or controlled. Scope 2 = indirect emissions from the production of electricity and heat, and fuels purchased and used. Scope 3 = indirect emissions from sources not owned or directly controlled but related to their activities (such as employee travel, extraction, transport and production of purchased materials and fuels, and end-use of fuels, products and services). Partial value chain includes Scope 1 and 2 emissions and Scope 3 emissions in specific geographic locations or sections of a company's value chain.

Source: IEA analysis based on company reports from the largest 10-25 companies within each sector.

Company pledges may not be readily comparable. Most companies account for emissions and set net zero pledges based on the GHG Protocol (WRI, WBCSD, 2004), but the coverage and timeframe of these pledges varies widely. Some cover only their own emissions, for example by shifting to the use of zero-emissions electricity in offices and production facilities, and by eliminating the use of oil in transport or industrial operations, e.g. FedEx, ArcelorMittal and Maersk. Others also cover wider emissions from certain parts of their values chains, e.g. Renault in Europe, or all indirect emissions related to their activities, e.g. Daikin, Toyota, Shell, Eni and Heidelberg. Around 60% of pledges aim to achieve net-zero emissions by 2050, but several companies have set an earlier deadline of 2030 or 2040.

Around 40% of companies that have announced net zero pledges have yet to set out how they aim to achieve them. For those with detailed plans, the main options include direct emissions reductions, use of CO_2 removal technologies, such as afforestation, bioenergy with carbon capture, utilisation and storage (CCUS), or direct air capture with CO_2 storage, and purchasing emissions (credits generated through emissions reductions that occur elsewhere). The use of offsets could be a cost-effective mechanism to eliminate emissions from parts of value chains where emissions reductions are most challenging, provided that schemes to generate emissions credits result in permanent, additional and verified emissions reductions. However, there is likely to be a limited supply of emissions credits consistent with net-zero emissions globally and the use of such credits could divert investment from options that enable direct emissions reductions.

1.3 Outlook for emissions and energy in the STEPS

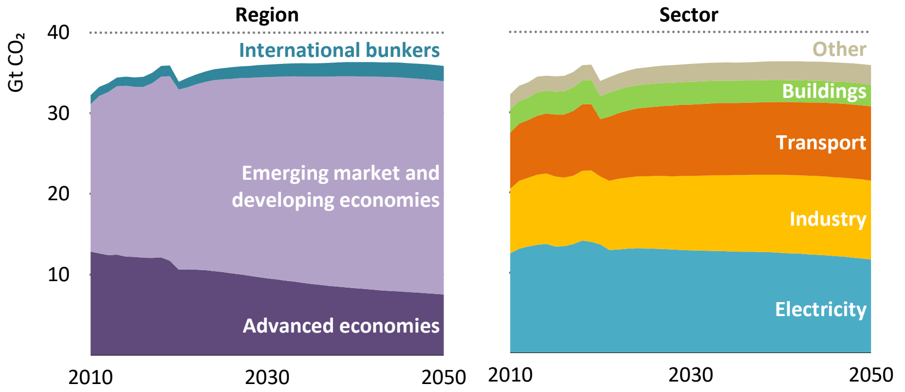
The IEA Stated Policies Scenario (STEPS) illustrates the consequences of existing and stated policies for the energy sector. It draws on the latest information regarding national energy and climate plans and the policies that underpin them. It takes account of all policies that are backed by robust implementing legislation or regulatory measures, including the NDCs that countries have put forward under the Paris Agreement up to September 2020 and the energy components of announced economic stimulus and recovery packages. So far, few net-zero emissions pledges have been backed up by detailed policies, implementation plans or interim targets: most net zero pledges therefore are not included in the STEPS.

1.3.1 CO_2 emissions

Global CO_2 emissions in the STEPS bring about only a marginal overall improvement in recent trends. Switching to renewables leads to an early peak in emissions in the electricity sector, but reductions across all sectors fall far short of what is required for net-zero emissions in 2050. Annual CO_2 emissions rebound quickly from the dip caused by the Covid-19 pandemic in 2020: they increase from 34 Gt in 2020 to 36 Gt in 2030 and then remain around this level until 2050 (Figure 1.5). If emissions trends were to continue along the same trajectory after 2050, and with commensurate changes in other sources of GHG emissions, the global average surface temperature rise would be around 2.7 °C in 2100 (with a 50% probability).

There is strong divergence between the outlook for emissions in advanced economies on one hand and the emerging market and developing economies on the other. In advanced economies, despite a small rebound in the early 2020s, CO_2 emissions decline by about a third between 2020 and 2050, thanks to the impact of policies and technological progress in reducing energy demand and switching to cleaner fuels. In emerging market and developing economies, energy demand continues to grow strongly because of increased population, brisk economic growth, urbanisation and the expansion of infrastructure: these effects outweigh improvements in energy efficiency and the deployment of clean technologies, causing CO_2 emissions to grow by almost 20% by the mid-2040s, before declining marginally to 2050.

Figure 1.5 ⊳ **Energy-related and industrial process CO_2 emissions by region and sector in the STEPS**



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Global CO_2 emissions rebound quickly after 2020 and then plateau, with declines in advanced economies offset by increases elsewhere

Note: Other = agriculture and own use in the energy sector.

1.3.2 Total energy supply, total final consumption and electricity generation

The projected trends in CO_2 emissions in the STEPS result from changes in the amount of energy used and the mix of fuels and technologies. Total energy supply (TES)[5] worldwide rises by just over 30% between 2020 and 2050 in the STEPS (Figure 1.6). Without a projected annual average reduction of 2.2% in energy intensity, i.e. energy use per unit of GDP, TES in 2050 would be around 85% higher. In advanced economies, energy use falls by around 5% to 2050, despite a 75% increase in economic activity over the period. In emerging market and developing economies, energy use increases by 50% to 2050, reflecting a tripling of economic output between 2020 and 2050. Despite the increase in GDP and energy use in emerging market and developing economies, 750 million people still have no access to electricity in 2050, more than 95% of them in sub-Saharan Africa, and 1.5 billion people continue to rely on the traditional use of bioenergy for cooking.

The global fuel mix changes significantly between 2020 and 2050. Coal use, which peaked in 2014, falls by around 15%. Having fallen sharply in 2020 due to the pandemic, oil demand rebounds quickly, returning to the 2019 level of 98 million barrels per day (mb/d) by 2023 and reaching a plateau of around 104 mb/d shortly after 2030. Natural gas demand increases from 3 900 billion cubic metres (bcm) in 2020 to 4 600 bcm in 2030 and 5 700 bcm in 2050. Nuclear energy grows by 15% between 2020 and 2030, mainly reflecting expansions in China.

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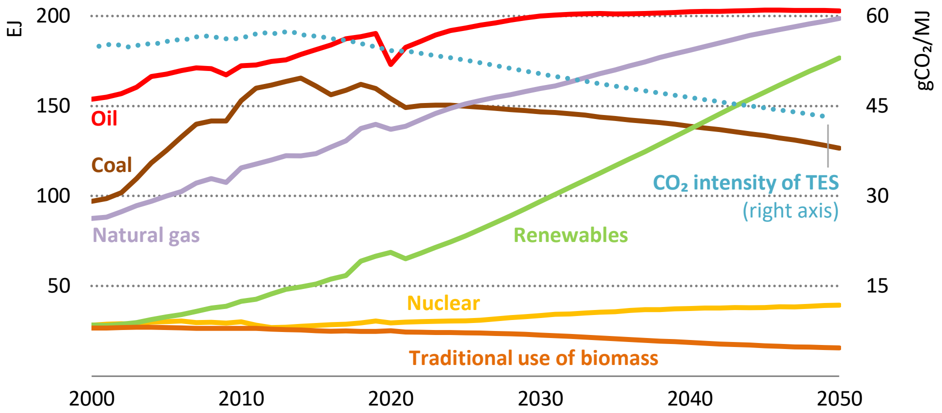
[5] Total primary energy supply (or total primary energy demand) has been renamed total energy supply in accordance with the International Recommendations for Energy Statistics (IEA, 2020d).

Figure 1.6 ⊳ **Total energy supply and CO_2 emissions intensity in the STEPS**



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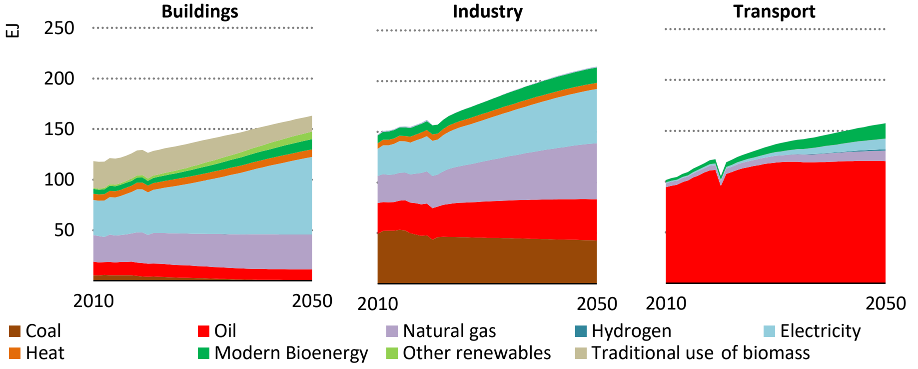
Coal use declines, oil plateaus and renewables and natural gas grow substantially to 2050

Note: EJ = exajoule; MJ = megajoule; TES = total energy supply.

Total final consumption increases in all sectors in the STEPS, led by electricity and natural gas (Figure 1.7). All the growth is in emerging market and developing economies. The biggest change in energy use is in the electricity sector (Figure 1.8). Global electricity demand increases by 80% between 2020 and 2050, around double the overall rate of growth in final energy consumption. More than 85% of the growth in global electricity demand comes from emerging market and developing economies. Coal continues to play an important role in electricity generation in those economies to 2050, despite strong growth in renewables: in advanced economies, the use of coal for electricity generation drops sharply.

Figure 1.7 ⊳ **Total final consumption by sector and fuel in the STEPS**



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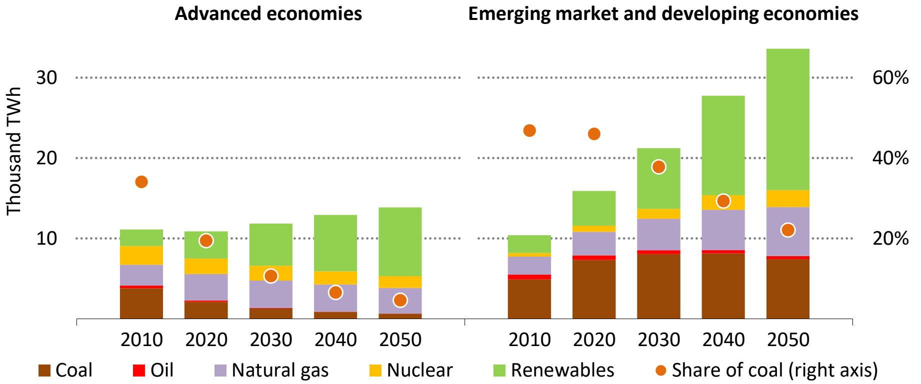
Final energy consumption grows on average by 1% per year between 2020 and 2050, with electricity and natural gas meeting most of the increase

Figure 1.8 ▷ Electricity generation by fuel and share of coal in the STEPS



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Emerging market and developing economies drive most of the increase in global electricity demand, met mainly by renewables and gas, though coal remains important

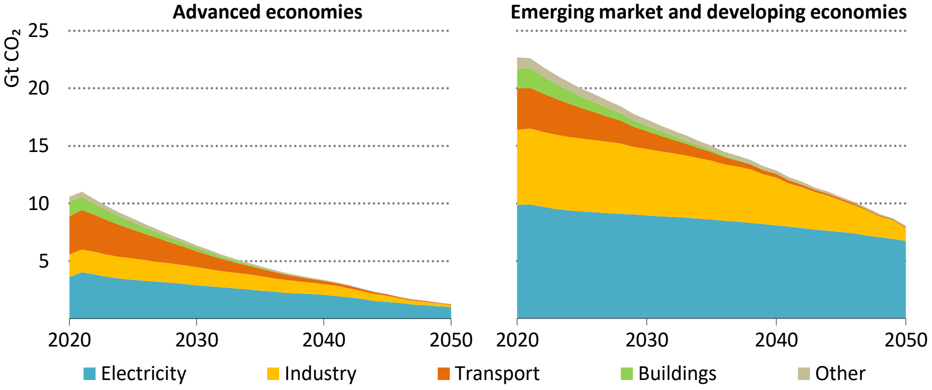
1.3.3 Emissions from existing assets

The energy sector contains a large number of long-lived and capital-intensive assets. Urban infrastructure, pipelines, refineries, coal-fired power plants, heavy industrial facilities, buildings and large hydro power plants can have technical and economic lifetimes of well over 50 years. If today's energy infrastructure was to be operated until the end of the typical lifetime in a manner similar to the past, we estimate that this would lead to cumulative energy-related and industrial process CO_2 emissions between 2020 and 2050 of just under 650 Gt CO_2. This is around 30% more than the remaining total CO_2 budget consistent with limiting global warming to 1.5 °C with a 50% probability (see Chapter 2).

The electricity sector accounts for more than 50% of the total emissions that would come from existing assets; 40% of total emissions would come from coal-fired power plants alone. Industry is the next largest sector, with steel, cement, chemicals and other industry accounting for around 30% total emissions from existing assets. The long lifetime of production facilities in these sub-sectors (typically 30-40 years for a blast furnace or cement kiln) and the relatively young age of the global capital stock explain their large contribution. Transport accounts for just over 10% of emissions from existing assets and the buildings sector accounts for just under 5%. The lifetime of vehicles and equipment in the transport and buildings sectors is generally much shorter than is the case in electricity and industry – passenger cars, for example, are generally assumed to have a lifetime of around 17 years – but associated infrastructure networks such as roads, electricity networks and gas grids have very long lifetimes.

There are some large regional differences in emissions levels from existing assets (Figure 1.9). Advanced economies tend to have much older capital stocks than emerging market and developing economies, particularly in the electricity sector, and existing assets will reach the end of their lifetimes earlier. For example, the average age of coal-fired power plants in China is 13 years and 16 years in the rest of Asia, compared to around 35 years in Europe and 40 years in the United States (IEA, 2020e).

Figure 1.9 ▻ **Emissions from existing infrastructure by sector and region**



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Emerging market and developing economies account for three-quarters of cumulative emissions from existing infrastructure through to 2050

1.4 Announced Pledges Case

The Announced Pledges Case (APC) assumes that all national net-zero emissions pledges are realised in full and on time. It therefore goes beyond the policy commitments incorporated in the STEPS. The aim of the APC is to see how far full implementation of the national net-zero emissions pledges would take the world towards reaching net-zero emissions, and to examine the scale of the transformation of the energy sector that such a path would require.

The way these pledges are assumed to be implemented in the APC has important implications for the energy system. A net zero pledge for all GHG emissions does not necessarily mean that CO_2 emissions from the energy sector need to reach net zero. For example, a country's net zero plans may envisage some remaining energy-related emissions are offset by the absorption of emissions from forestry or land use, or by negative emissions arising from the use of bioenergy or direct capture of CO_2 from the air (DAC) with CCUS.[6] It is not possible to know exactly how net zero pledges will be implemented, but the design of the APC, particularly with respect to the details of the energy system pathway, has been informed by the pathways that a number of national bodies have developed to support net zero pledges (Box 1.1). Policies in countries that have not yet made a net zero pledge are assumed to be the same as in the STEPS. Non policy assumptions, including population and economic growth, are the same as in the STEPS.

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[6] For example, in recent economy-wide net zero mitigation pathways for the European Union, around 140-210 million tonnes CO_2 of emissions from the energy sector remain in 2050, which are offset by CDR from managed land-use sinks, and bioenergy and DAC with CCUS (European Commission, 2018).

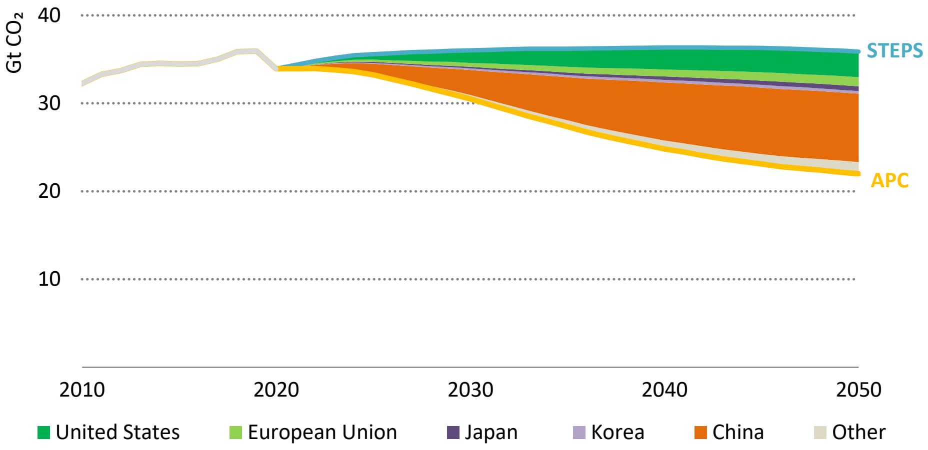
Box 1.1 ▷ **Consultations with national bodies on achieving national net-zero emissions goals**

To help inform its work on net zero pathways, the IEA engaged in extensive consultations with experts in academia and national bodies that have developed pathways to support net zero pledges made by governments. This includes groups that have developed net-zero emissions pathways for several countries including China, European Union, Japan, United Kingdom and United States, as well as the IPCC. These pathways were not used directly as input for the APC, but the discussions informed our modelling of national preferences and constraints within each jurisdiction and to benchmark the overall level of energy-related CO_2 emissions reductions that are commensurate with economy-wide net zero goals.

1.4.1 CO_2 emissions

In the APC, there is a small rebound in emissions to 2023, although this is much smaller than the increase that immediately followed the financial crisis in 2008-09. Emissions never reach the previous peak of 36 Gt CO_2. Global CO_2 emissions fall around 10% to 30 Gt in 2030 and to 22 Gt in 2050. This is around 35% below the level in 2020 and 14 Gt CO_2 lower than in the STEPS (Figure 1.10). If emissions continue this trend after 2050, and with a similar level of changes in non-energy-related GHG emissions, the global average surface temperature rise in 2100 would be around 2.1 °C (with a 50% probability).

Figure 1.10 ▷ **Global energy-related and industrial process CO_2 emissions by scenario and reductions by region, 2010-2050**



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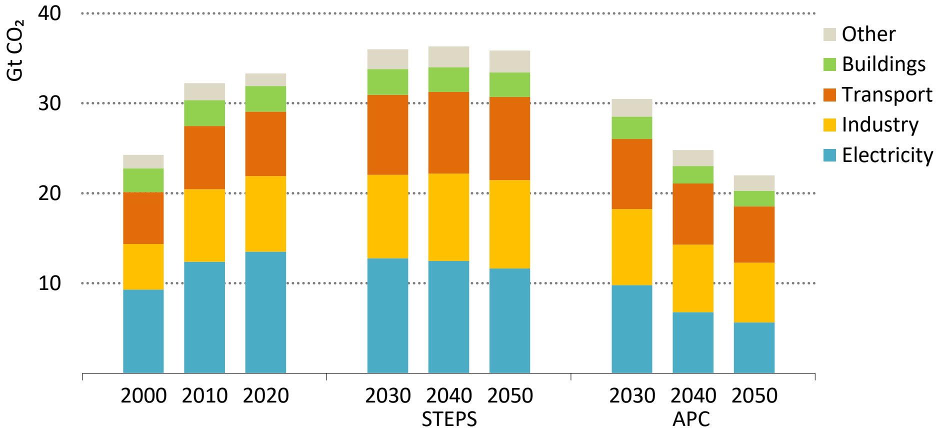
Achieving existing net zero pledges would reduce emissions globally to 22 Gt CO_2 in 2050, a major reduction compared with current policies but still far from net-zero emissions

The net zero pledges that have been made to date therefore make a major difference to the current trajectory for CO_2 emissions. Equally, however, existing net zero pledges fall well short of what is necessary to reach net-zero emissions globally by 2050. This highlights the importance of concrete policies and plans to deliver in full long-term net zero pledges. It also underlines the value of other countries making (and delivering on) net zero pledges: the more countries that do so, and the more ambitious those pledges are, the more the gap will narrow with what is needed to reach net-zero emissions by 2050.

The largest drop in CO_2 emissions is in the APC is in the electricity sector with global emissions falling by nearly 60% between 2020 and 2050. This occurs despite a near-doubling of electricity demand as energy end-uses are increasingly electrified, notably in transport and buildings (Figure 1.11). This compares with a fall in emissions of less than 15% in the STEPS.

Figure 1.11 ▷ Global CO_2 emissions by sector in the STEPS and APC



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Announced net zero pledges would cut emissions in 2050 by 60% in the electricity sector, 40% in buildings, 25% in industry and just over 10% in transport

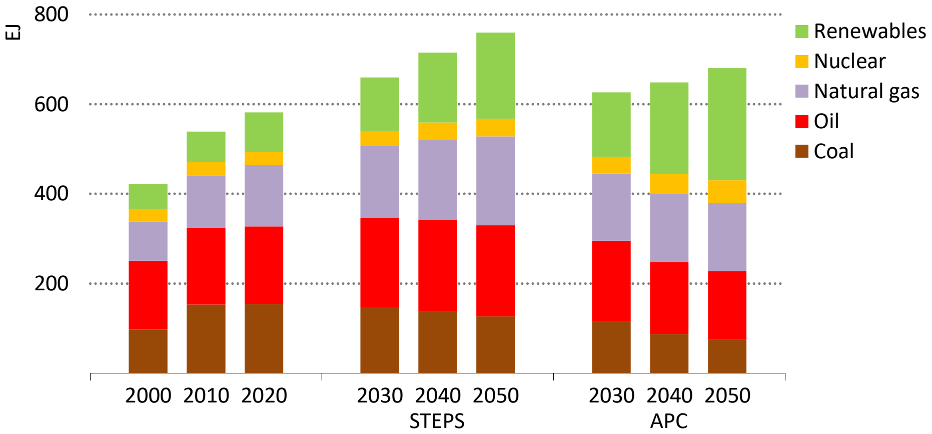
The transport and industry sectors see a less marked fall in CO_2 emissions to 2050 in the APC, with increases in energy demand in regions without net zero pledges partially offsetting emissions reduction efforts in other regions. Emissions from the buildings sector decline by around 40% between 2020 and 2050, compared with around 5% in the STEPS: fossil fuel use in buildings is mostly to provide heating, and countries that have made pledges account for a relatively high proportion of global heating demand.

Even in regions with net zero pledges, there are some residual emissions in 2050, mainly in industry and transport. This reflects the scarcity of commercially available options to eliminate all emissions from heavy-duty trucks, aviation, shipping and heavy industry.

1.4.2 Total energy supply

Global total energy supply increases by more than 15% between 2020 and 2050 in the APC, compared with a third in the STEPS (Figure 1.12). Energy intensity falls on average by around 2.6% per year to 2050 compared with 2.2% in the STEPS. There is a substantial increase in energy demand in emerging market and developing economies, where economic and population growth is fastest and where there are fewer net zero pledges, which outweighs the reductions in energy demand in the countries with net zero pledges.

Figure 1.12 ▷ Total energy supply by source in STEPS and APC



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Announced net zero pledges lift renewables in the APC from 12% of total energy supply in 2020 to 35% in 2050, mainly at the expense of coal and oil

The global increase in energy supply in the APC is led by renewables, which increase their share in the energy mix from 12% in 2020 to 35% by 2050 (compared with 25% in 2050 in the STEPS). Solar photovoltaics (PV) and wind in the electricity sector together contribute about 50% of the growth in renewables supply, and bioenergy contributes around 30%. Bioenergy use doubles in industry, triples in electricity generation and grows by a factor of four in transport: it plays an important role in reducing emissions from heat supply and removing CO_2 from the atmosphere when it is combined with CCUS. Nuclear maintains its share of the energy mix, its output rising by a quarter to 2030 (compared with a 15% increase in the STEPS), driven by lifetime extensions at existing plants and new reactors in some countries.

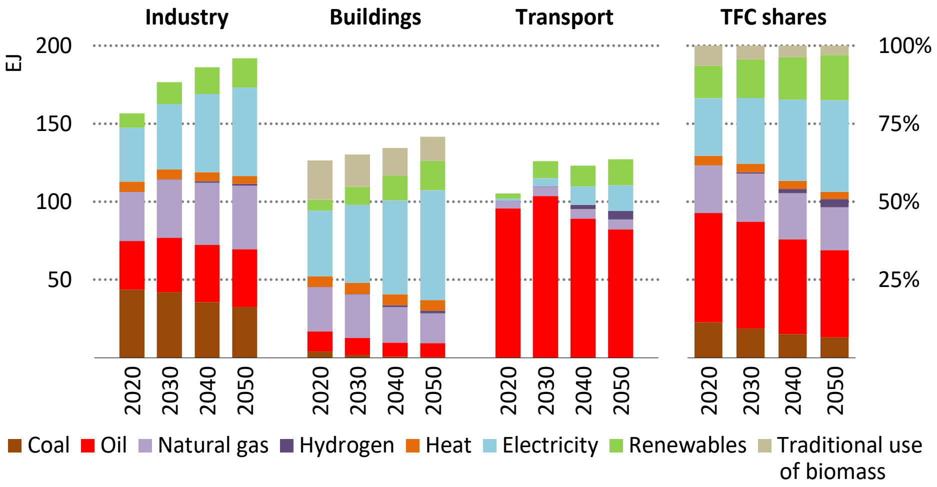
Global coal use falls significantly more rapidly in the APC than in the STEPS. It drops from 5 250 million tonnes of coal equivalent (Mtce) in 2020 to 4 000 Mtce in 2030 and 2 600 Mtce in 2050 (compared with 4 300 Mtce in the STEPS in 2050). Most of this decline is due to reduced coal-fired electricity generation in countries with net zero pledges as plants are repurposed, retrofitted or retired. In advanced economies, unabated coal-fired power plants are generally phased out over the next 10-15 years. China's coal consumption for electricity declines by 85% between 2020 and 2050 on its path towards carbon neutrality in 2060. These declines more than offset continued growth for coal in countries without net zero pledges. Globally, coal use in industry falls by 25% between 2020 and 2050, compared with a 5% decline in the STEPS.

Oil demand recovers slightly in the early 2020s but never again reaches its historic peak in 2019. It declines to 90 mb/d in the early 2030s and to 80 mb/d in 2050, around 25 mb/d lower than in the STEPS, thanks to a strong push to electrify transport and shifts to biofuels and hydrogen, especially in regions with pledges. Natural gas demand increases from about 3 900 bcm in 2020 to around 4 350 bcm in 2025, but is then broadly flat to 2050 (it continues to grow to around 5 700 bcm in the STEPS).

1.4.3 Total final consumption

Global energy use continues to grow in all major end-use sectors in the APC, albeit substantially more slowly than in the STEPS (Figure 1.13). Total final consumption (TFC) increases by around 20% in 2020-50, compared with a 35% increase globally in the STEPS. Measures to improve energy efficiency play a major role in the APC in reducing demand growth in countries with net zero pledges. Without those efficiency gains, electricity demand growth would make it much harder for renewables to displace fossil fuels in electricity generation. The biggest reduction in energy demand relative to the STEPS is in transport, thanks to an accelerated shift to electric vehicles (EVs), which are around three-times as energy efficient as conventional internal combustion engine vehicles.

Figure 1.13 ▷ Total final consumption in the APC



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Announced net zero pledges lead to a shift away from fossil fuels globally to electricity, renewables and hydrogen. Electricity's share rises from 20% to 30% in 2050

The fuel mix in final energy use shifts substantially in the APC. By 2050, electricity is the largest single fuel used in all sectors except transport, where oil remains dominant. The persistence of oil in transport stems partly from the extent of its continued use in countries without net zero pledges, and partly from the difficulty of electrifying substantial parts of the transport sector, notably trucking and aviation. Electricity does make inroads into transport, however, and rapid growth in the uptake of EVs puts oil use into decline after 2030, with EVs accounting for around 35% of global passenger car sales by 2030 and nearly 50% in 2050 in the APC (versus around 25% in the STEPS in 2050). Electrification in the buildings sector is also much faster in the APC than in the STEPS.

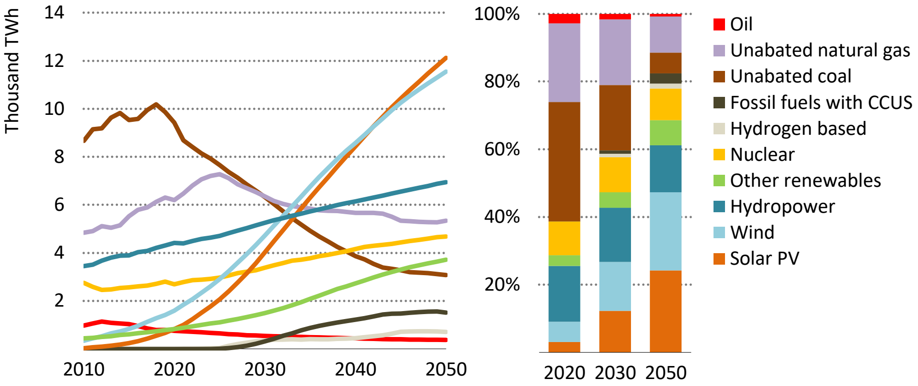
The direct use of renewables expands in all end-use sectors globally through to 2050. Modern bioenergy accounts for the bulk of this growth, predominantly through the blending of biomethane into natural gas networks and liquid biofuels in transport. This occurs mainly in regions with net zero pledges. Hydrogen and hydrogen-based fuels play a larger role in the APC than in the STEPS, reaching almost 15 exajoules (EJ) in 2050, though they still account for only 3% of total final consumption worldwide in 2050. Transport accounts for more than two-thirds of all hydrogen consumption in 2050. In parallel, on-site hydrogen production in the industry and refining sectors gradually shifts towards low-carbon technologies.

1.4.4 Electricity generation

Global electricity generation nearly doubles during the next three decades in the APC, rising from about 26 800 terawatt-hours (TWh) in 2020 to over 50 000 TWh in 2050, some 4 000 TWh higher than in the STEPS. Low-emissions energy sources provide all the increase. The share of renewables in electricity generation rises from 29% in 2020 to nearly 70% in 2050, compared with about 55% in the STEPS, as solar PV and wind race ahead of all other sources of generation (Figure 1.14). By 2050, solar PV and wind together account for almost half of electricity supply. Hydropower also continues to expand, emerging as the third-largest energy source in the electricity mix by 2050. Nuclear power increases steadily too, maintaining its global market share of about 10%, led by increases in China. Natural gas use in electricity increases slightly to the mid-2020s before starting to fall back, while coal's share of electricity generation falls from around 35% in 2020 to below 10% in 2050. At that point, 20% of the remaining coal-fired output comes from plants equipped with CCUS.

Hydrogen and ammonia start to emerge as fuel inputs to electricity generation by around 2030, used largely in combination with natural gas in gas turbines and with coal in coal-fired power plants. This extends the life of existing assets, contributes to electricity system adequacy and reduces the overall costs of transforming the electricity sectors in many countries. Total battery capacity also rises substantially, reaching 1 600 gigawatts (GW) in 2050, 70% more than in the STEPS.

Figure 1.14 ▷ Global electricity generation by source in the APC



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Renewables reach new heights in the APC, rising from just under 30% of electricity supply in 2020 to nearly 70% in 2050, while coal-fired generation steadily declines

Note: Other renewables = geothermal, solar thermal and marine.

A global pathway to net-zero CO_2 emissions in 2050

SUMMARY

- The Net-Zero Emissions by 2050 Scenario (NZE) shows what is needed for the global energy sector to achieve net-zero CO_2 emissions by 2050. Alongside corresponding reductions in GHG emissions from outside the energy sector, this is consistent with limiting the global temperature rise to 1.5 °C without a temperature overshoot (with a 50% probability). Achieving this would require all governments to increase ambitions from current Nationally Determined Contributions and net zero pledges.
- In the NZE, global energy-related and industrial process CO_2 emissions fall by nearly 40% between 2020 and 2030 and to net zero in 2050. Universal access to sustainable energy is achieved by 2030. There is a 75% reduction in methane emissions from fossil fuel use by 2030. These changes take place while the global economy more than doubles through to 2050 and the global population increases by 2 billion.
- Total energy supply falls by 7% between 2020 and 2030 in the NZE and remains at around this level to 2050. Solar PV and wind become the leading sources of electricity globally before 2030 and together they provide nearly 70% of global generation in 2050. The traditional use of bioenergy is phased out by 2030.
- Coal demand declines by 90% to less than 600 Mtce in 2050, oil declines by 75% to 24 mb/d, and natural gas declines by 55% to 1 750 bcm. The fossil fuels that remain in 2050 are used in the production of non-energy goods where the carbon is embodied in the product (like plastics), in plants with carbon capture, utilisation and storage (CCUS), and in sectors where low-emissions technology options are scarce.
- Energy efficiency, wind and solar provide around half of emissions savings to 2030 in the NZE. They continue to deliver emissions reductions beyond 2030, but the period to 2050 sees increasing electrification, hydrogen use and CCUS deployment, for which not all technologies are available on the market today, and these provide more than half of emissions savings between 2030 and 2050. In 2050, there is 1.9 Gt of CO_2 removal in the NZE and 520 million tonnes of low-carbon hydrogen demand. Behavioural changes by citizens and businesses avoid 1.7 Gt CO_2 emissions in 2030, curb energy demand growth, and facilitate clean energy transitions.
- Annual energy sector investment, which averaged USD 2.3 trillion globally in recent years, jumps to USD 5 trillion by 2030 in the NZE. As a share of global GDP, average annual energy investment to 2050 in the NZE is around 1% higher than in recent years.
- The NZE taps into all opportunities to decarbonise the energy sector, across all fuels and all technologies. But the path to 2050 has many uncertainties. If behavioural changes were to be more limited than envisaged in the NZE, or sustainable bioenergy less available, then the energy transition would be more expensive. A failure to develop CCUS for fossil fuels could delay or prevent the development of CCUS for process emissions from cement production and carbon removal technologies, making it much harder to achieve net-zero emissions by 2050.

2.1 Introduction

Achieving a global energy transition that is compatible with the world's climate goals is unquestionably a formidable task. As highlighted in Chapter 1, current pledges by governments to reduce emissions to net zero collectively cover around 70% of today's global economic activity and global CO_2 emissions. The Announced Pledges Case shows that, if all those pledges were met in full, it would narrow the gap between where we are heading and where we need to be to achieve net-zero emissions by 2050 worldwide. But it also shows that the gap would remain large. Meeting all existing net zero pledges in full would still leave 22 gigatonnes (Gt) of energy-related and industrial process CO_2 emissions globally in 2050, consistent with a temperature rise in 2100 of around 2.1 °C (with a 50% probability).

In this chapter, we examine the energy sector transformation which is embodied in our Net-Zero Emissions by 2050 Scenario. First, it provides an overview of the key assumptions and market dynamics underlying the projections, including projected fossil fuel and CO_2 prices. It discusses trends in global CO_2 emissions, energy use and investment, including the key roles played by efficiency measures, behavioural change, electrification, renewables, hydrogen and hydrogen-based fuels, bioenergy, and carbon capture, utilisation and storage (CCUS). Further, it discusses some of the key uncertainties surrounding the global pathway towards net-zero emissions related to behavioural change, the availability of sustainable bioenergy, and the deployment of CCUS for fossil fuels. The transformation of specific energy sectors is assessed and discussed in detail in Chapter 3.

2.2 Scenario design

The Net-Zero Emissions by 2050 Scenario (NZE) is designed to show what is needed across the main sectors by various actors, and by when, for the world to achieve net-zero energy-related and industrial process CO_2 emissions by 2050.[1] It also aims to minimise methane emissions from the energy sector. In recent years, the energy sector was responsible for around three-quarters of global greenhouse gas (GHG) emissions. Achieving net-zero energy-related and industrial process CO_2 emissions by 2050 in the NZE does not rely on action in areas other than the energy sector, but limiting climate change does require such action. We therefore additionally examine the reductions in CO_2 emissions from land use that would be commensurate with the transformation of the energy sector in the NZE, working in co-operation with the International Institute for Applied Systems Analysis (IIASA). In parallel with action on reducing all other sources of GHG emissions, achieving net-zero CO_2 emissions from the energy sector by 2050 is consistent with around a 50% chance of limiting the long-term average global temperature rise to 1.5 °C without a temperature overshoot (IPCC, 2018).

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[1] Unless otherwise stated, carbon dioxide (CO_2) emissions in this chapter refer to energy-related and industrial process CO_2 emissions. Net-zero CO_2 emissions refers to zero CO_2 emissions to the atmosphere, or with any residual CO_2 emissions offset by CO_2 removal from direct air capture or bioenergy with carbon capture and storage.

The NZE aims to ensure that energy-related and industrial process CO_2 emissions to 2030 are in line with reductions in 1.5 °C scenarios with no or low or limited temperature overshoot assessed in the IPCC in its Special Report on Global Warming of 1.5 °C.[2] In addition, the NZE incorporates concrete action on the energy-related United Nations Sustainable Development Goals related to achieving universal energy access by 2030 and delivering a major reduction in air pollution. The projections in the NZE were generated by a hybrid model that combines components of the IEA's World Energy Model (WEM), which is used to produce the projections in the annual *World Energy Outlook,* and the Energy Technology Perspectives (ETP) model.

Box 2.1 ▷ International Energy Agency modelling approach for the NZE

A new, hybrid modelling approach was adopted to develop the NZE and combines the relative strengths of the WEM and the ETP model. The WEM is a large-scale simulation model designed to replicate how competitive energy markets function and to examine the implications of policies on a detailed sector-by-sector and region-by-region basis. The ETP model is a large-scale partial-optimisation model with detailed technology descriptions of more than 800 individual technologies across the energy conversion, industry, transport and buildings sectors.

This is the first time this modelling approach has been implemented. The combination of the two models allows for a unique set of insights on energy markets, investment, technologies, and the level and detail of policies that would be needed to bring about the energy sector transformation in the NZE.

Results from the WEM and ETP model have been coupled with the Greenhouse Gas - Air Pollution Interactions and Synergies (GAINS) model developed by IIASA (Amann et al., 2011). The GAINS model is used to evaluate air pollutant emissions and resultant health impacts linked to air pollution. For the first time, IEA model results have also been coupled with the IIASA's Global Biosphere Management Model (GLOBIOM) to provide data on land use and net emissions impacts of bioenergy demand.

The impacts of changes in investment and spending on global GDP in the NZE have been estimated by the International Monetary Fund (IMF) using the Global Integrated Monetary and Fiscal (GIMF) model. GIMF is a multi-country dynamic stochastic general equilibrium model used by the IMF for policy and risk analysis (Laxton et al., 2010; Anderson et al., 2013). It has been used to produce the IMF's World Economic Outlook scenario analyses since 2008.

There are many possible paths to achieve net-zero CO_2 emissions globally by 2050 and many uncertainties that could affect any of them; the NZE is therefore *a* path, not *the* path to net-zero emissions. Much depends, for example, on the pace of innovation in new and emerging

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[2] The IPCC classifies scenarios as "no or limited temperature overshoot", if temperatures exceed 1.5 °C by less than 0.1 °C but return to less than 1.5 °C in 2100, and as "higher overshoot", if temperatures exceed 1.5 °C by 0.1-0.4 °C but return to less than 1.5 °C in 2100.

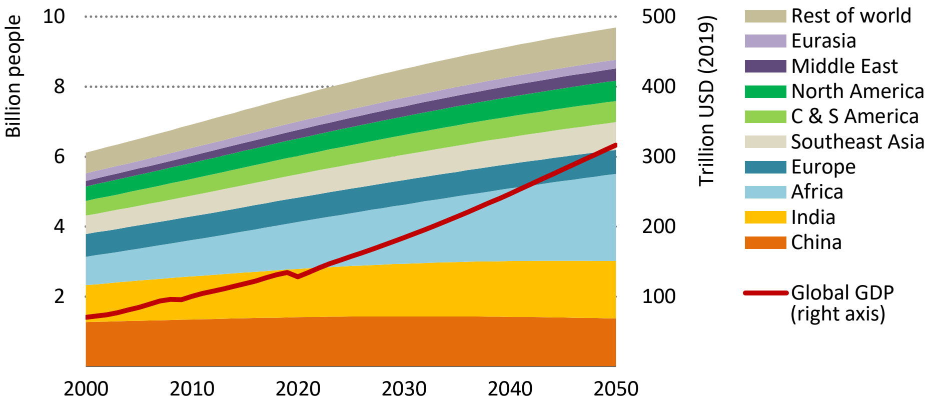
technologies, the extent to which citizens are able or willing to change behaviour, the availability of sustainable bioenergy and the extent and effectiveness of international collaboration. We investigate some of the key alternatives and uncertainties here and in Chapter 3. The Net-Zero Emissions by 2050 Scenario is built on the following principles.

- The uptake of all the available technologies and emissions reduction options is dictated by costs, technology maturity, policy preferences, and market and country conditions.
- All countries co-operate towards achieving net-zero emissions worldwide. This involves all countries participating in efforts to meet the net zero goal, working together in an effective and mutually beneficial way, and recognising the different stages of economic development of countries and regions, and the importance of ensuring a just transition.
- An orderly transition across the energy sector. This includes ensuring the security of fuel and electricity supplies at all times, minimising stranded assets where possible and aiming to avoid volatility in energy markets.

2.2.1 Population and GDP

The energy sector transformation in the NZE occurs against the backdrop of large increases in the world's population and economy (Figure 2.1). In 2020, there were around 7.8 billion people in the world; this is projected to increase by around 750 million by 2030 and by nearly 2 billion people by 2050 in line with the median variant of the United Nations projections (UNDESA, 2019). Nearly all of the population increase is in emerging market and developing economies: the population of Africa alone increases by more than 1.1 billion between 2020 and 2050.

Figure 2.1 ▷ World population by region and global GDP in the NZE



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By 2050, the world's population expands to 9.7 billion people and the global economy is more than twice as large as in 2020

Notes: GDP = gross domestic product in purchasing power parity; C & S America = Central and South America.
Sources: IEA analysis based on UNDESA (2019); Oxford Economics (2020); IMF (2020a, 2020b).

The world's economy is assumed to recover rapidly from the impact of the Covid-19 pandemic. Its size returns to pre-crisis levels in 2021. From 2022, the GDP growth trend is close to the pre-pandemic rate of around 3% per year on average, in line with assessments from the IMF. The response to the pandemic leads to a large increase in government debt, but resumed growth, along with low interest rates in many countries, make this manageable in the long term. By 2030, the world's economy is around 45% larger than in 2020, and by 2050 it is more than twice as large.

2.2.2 Energy and CO_2 prices

Projections of future energy prices are inevitably subject to a high degree of uncertainty. In IEA scenarios, they are designed to maintain an equilibrium between supply and demand. The rapid drop in oil and natural gas demand in the NZE means that no fossil fuel exploration is required and no new oil and natural gas fields are required beyond those that have already been approved for development. No new coal mines or mine extensions are required either. Prices are increasingly set by the operating costs of the marginal project required to meet demand, and this results in significantly lower fossil fuel prices than in recent years. The oil price drops to around USD 35/barrel by 2030 and then drifts down slowly towards USD 25/barrel in 2050.

Table 2.1 ▷ Fossil fuel prices in the NZE

Real terms (USD 2019)	2010	2020	2030	2040	2050
IEA crude oil (USD/barrel)	91	37	35	28	24
Natural gas (USD/MBtu)					
United States	5.1	2.1	1.9	2.0	2.0
European Union	8.7	2.0	3.8	3.8	3.5
China	7.8	5.7	5.2	4.8	4.6
Japan	12.9	5.7	4.4	4.2	4.1
Steam coal (USD/tonne)					
United States	60	45	24	24	22
European Union	108	56	51	48	43
Japan	125	75	57	53	49
Coastal China	135	81	60	54	50

Notes: MBtu = million British thermal units. The IEA crude oil prices are a weighted average import price among IEA member countries. Natural gas prices are weighted averages expressed on a gross calorific-value basis. US natural gas prices reflect the wholesale price prevailing on the domestic market. The European Union and China gas prices reflect a balance of pipeline and liquefied natural gas (LNG) imports, while Japan gas prices solely reflect LNG imports. LNG prices used are those at the customs border, prior to regasification. Steam coal prices are weighted averages adjusted to 6 000 kilocalories per kilogramme. US steam coal prices reflect mine-mouth price plus transport and handling cost. Coastal China steam coal price reflects a balance of imports and domestic sales, while the European Union and Japanese steam coal prices are solely for imports.

In line with the principle of orderly transitions governing the NZE, the trajectory for oil markets and prices avoids excessive volatility. What happens depends to a large degree on the strategies adopted by resource-rich governments and their national oil companies. In the NZE it is assumed that, despite having lower cost resources at their disposal, they restrict investment in new fields. This limits the need for the shutting in and closure of higher cost production. The market share of major resource-rich countries nevertheless still rises in the NZE due to the large size and slow decline rates of their existing fields.

Producer economies could pursue alternative approaches. Faced with rapidly falling oil and gas demand, they could, for example, opt to increase production so as to capture an even larger share of the market. In this event, the combination of falling demand and increased availability of low cost oil would undoubtedly lead to even lower – and probably much more volatile – prices. In practice, the options open to particular producer countries would depend on their resilience to lower oil prices and on the extent to which export markets have developed for low-emissions fuels that could be produced from their natural resources.

Anticipating and mitigating feedbacks from the supply side is a central element of the discussion about orderly energy transitions. A drop in prices usually results in some rebound in demand, and policies and regulations would be essential to avoid this leading to any increase in the unabated use of fossil fuels, which would undermine wider emissions reduction efforts.

As the energy sector transforms, more fuels are traded globally, such as hydrogen-based fuels and biofuels. The prices of these commodities are assumed to be set by the marginal cost of domestic production or imports within each region.

A broad range of energy policies and accompanying measures are introduced across all regions to reduce emissions in the NZE. This includes: renewable fuel mandates; efficiency standards; market reforms; research, development and deployment; and the elimination of inefficient fossil fuel subsidies. Direct emissions reduction regulations are also needed in some cases. In the transport sector, for example, regulations are implemented to reduce sales of internal combustion engine vehicles and increase the use of liquid biofuels and synthetic fuels in aviation and shipping, as well as measures to ensure that low oil prices do not lead to an increase in consumption.

CO_2 prices are introduced across all regions in the NZE (Table 2.2). They are assumed to be introduced in the immediate future across all advanced economies for the electricity generation, industry and energy production sectors, and to rise on average to USD 130 per tonne (tCO_2) by 2030 and to USD 250/tCO_2 by 2050. In a number of other major economies – including China, Brazil, Russia and South Africa – CO_2 prices in these sectors are assumed to rise to around USD 200/tCO_2 in 2050. CO_2 prices are introduced in all other emerging market and developing economies, although it is assumed that they pursue more direct policies to adapt and transform their energy systems and so the level of CO_2 prices is lower than elsewhere.

Table 2.2 ▷ **CO_2 prices for electricity, industry and energy production in the NZE**

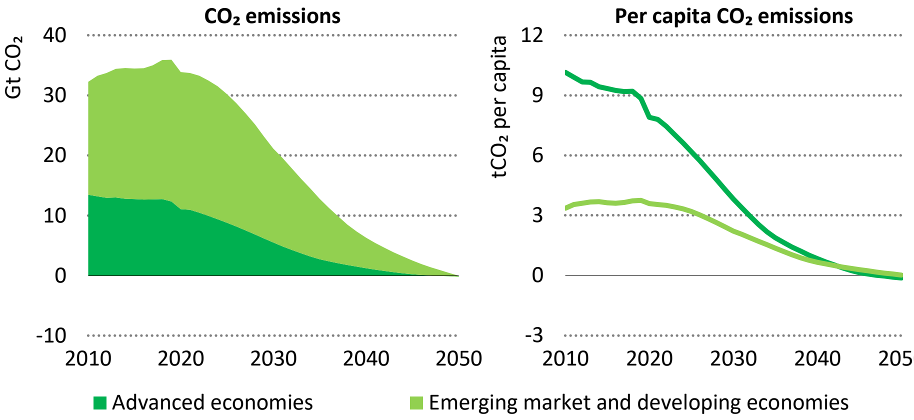
USD (2019) per tonne of CO_2	2025	2030	2040	2050
Advanced economies	75	130	205	250
Selected emerging market and developing economies*	45	90	160	200
Other emerging market and developing economies	3	15	35	55

* Includes China, Russia, Brazil and South Africa.

2.3 CO_2 emissions

Global energy-related and industrial process CO_2 emissions in the NZE fall to around 21 Gt CO_2 in 2030 and to net-zero in 2050 (Figure 2.2).[3] CO_2 emissions in advanced economies as a whole fall to net zero by around 2045 and these countries collectively remove around 0.2 Gt CO_2 from the atmosphere in 2050. Emissions in several individual emerging market and developing economies also fall to net zero well before 2050, but in aggregate there are around 0.2 Gt CO_2 of remaining emissions in this group of countries in 2050. These are offset by CO_2 removal in advanced economies to provide net-zero CO_2 emissions at the global level.

Figure 2.2 ▷ **Global net CO_2 emissions in the NZE**



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CO_2 emissions fall to net zero in advanced economies around 2045 and globally by 2050. Per capita emissions globally are similar by the early-2040s.

Note: Includes CO_2 emissions from international aviation and shipping.

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[3] In the period to 2030, CO_2 emissions in the NZE fall at a broadly similar rate to the P2 illustrative pathway in the IPCC SR 1.5 (IPCC, 2018). The P2 scenario is described as "a scenario with … shifts towards sustainable and healthy consumption patterns, low-carbon technology innovation, and well-managed land systems with limited societal acceptability for BECCS [bioenergy with carbon capture and storage]". After 2030, emissions in the NZE fall at a much faster pace than in the P2 scenario, which has 5.6 Gt CO_2 of residual energy sector and industrial process CO_2 emissions remaining in 2050.

Several emerging market and developing economies with a very large potential for producing renewables-based electricity and bioenergy are also a key source of carbon dioxide removal (CDR). This includes making use of renewable electricity sources to produce large quantities of biofuels with CCUS, some of which is exported, and to carry out direct air capture with carbon capture and storage (DACCS).

Per capita CO_2 emissions in advanced economies drop from around 8 tCO_2 per person in 2020 to around 3.5 tCO_2 in 2030, a level close to the average in emerging market and developing economies in 2020. Per capita emissions also fall in emerging market and developing economies, but from a much lower starting point. By the early 2040s, per capita emissions in both regions are broadly similar at around 0.5 tCO_2 per person.

Cumulative global energy-related and industrial process CO_2 emissions between 2020 and 2050 amount to just over 460 Gt in the NZE. Assuming parallel action to address CO_2 emissions from agriculture, forestry and other land use (AFOLU) over the period to 2050 would result in around 40 Gt CO_2 from AFOLU (see section 2.7.2). This means that total CO_2 emissions from all sources – some 500 Gt CO_2 – are in line with the CO_2 budgets included in the IPCC SR1.5, which indicated that the total CO_2 budget from 2020 consistent with providing a 50% chance of limiting warming to 1.5 °C is 500 Gt CO_2 (IPCC, 2018).[4] As well as reducing CO_2 emissions to net-zero, the NZE seeks to reduce non-CO_2 emissions from the energy sector. Methane emissions from fossil fuel production and use, for example, fall from 115 million tonnes (Mt) methane in 2020 (3.5 Gt CO_2-equivalent [CO_2-eq])[5] to 30 Mt in 2030 and 10 Mt in 2050.

The fastest and largest reductions in global emissions in the NZE are initially seen in the electricity sector (Figure 2.3). Electricity generation was the largest source of emissions in 2020, but emissions drop by nearly 60% in the period to 2030, mainly due to major reductions from coal-fired power plants, and the electricity sector becomes a small net negative source of emissions around 2040. Emissions from the buildings sector fall by 40% between 2020 and 2030 thanks to a shift away from the use of fossil fuel boilers, and retrofitting the existing building stock to improve its energy performance. Emissions from industry and transport both fall by around 20% over this period, and their pace of emissions reductions accelerates during the 2030s as the roll-out of low-emissions fuels and other emissions reduction options is scaled up. Nonetheless, there are a number of areas in transport and industry in which it is difficult to eliminate emissions entirely – such as aviation and heavy industry – and both sectors have a small level of residual emissions in 2050. These residual emissions are offset with applications of BECCS and DACCS.

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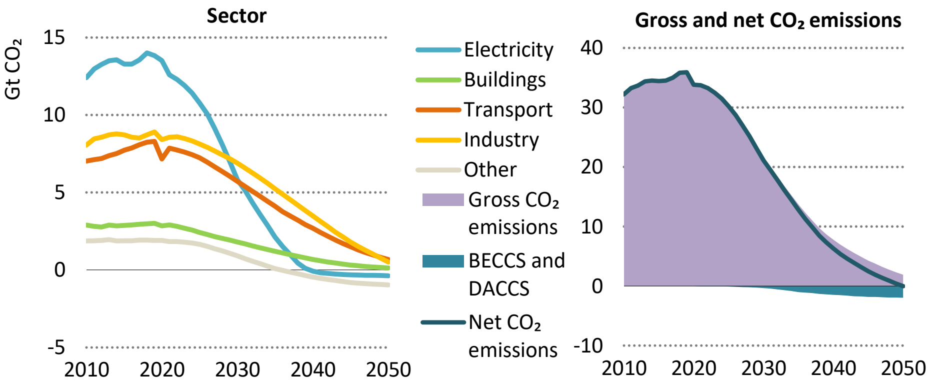
[4] This budget is based on Table 2.2 of the IPCC SR1.5 (IPCC, 2018). It assumes 0.53 °C additional warming from the 2006-2015 period to give a remaining CO_2 budget from 2018 of 580 Gt CO_2. There were around 80 Gt CO_2 emissions emitted from 2018 to 2020.

[5] Non-CO_2 gases are converted to CO_2-equivalents based on the 100-year global warming potentials reported by the IPCC 5th Assessment Report (IPCC, 2014). One tonne of methane is equivalent to 30 tonnes of CO_2.

Figure 2.3 ▷ **Global net-CO_2 emissions by sector, and gross and net CO_2 emissions in the NZE**



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Emissions from electricity fall fastest, with declines in industry and transport accelerating in the 2030s. Around 1.9 Gt CO_2 are removed in 2050 via BECCS and DACCS.

Notes: Other = agriculture, fuel production, transformation and related process emissions, and direct air capture. BECCS = bioenergy with carbon capture and storage; DACCS = direct air capture with carbon capture and storage. BECCS and DACCS includes CO_2 emissions captured and permanently stored.

The NZE includes a systematic preference for all new assets and infrastructure to be as sustainable and efficient as possible, and this accounts for 50% of total emissions reductions in 2050. Tackling emissions from existing infrastructure accounts for another 35% of reductions in 2050, while behavioural changes and avoided demand, including materials efficiency[6] gains and modal shifts in the transport sector, provide the remaining 15% of emissions reductions (see section 2.5.2). A wide range of technologies and measures are deployed in the NZE to reduce emissions from existing infrastructure such as power plants, industrial facilities, buildings, networks, equipment and appliances. The NZE is designed to minimise stranded capital where possible, i.e. cases where the initial investment is not recouped, but in many cases early retirements or lower utilisation lead to stranded value, i.e. a reduction in revenue.

The rapid deployment of more energy-efficient technologies, electrification of end-uses and swift growth of renewables all play a central part in reducing emissions across all sectors in the NZE (Figure 2.4). By 2050, nearly 90% of all electricity generation is from renewables, as is around 25% of non-electric energy use in industry and buildings. There is also a major role for emerging fuels and technologies, notably hydrogen and hydrogen-based fuels, bioenergy and CCUS, especially in sectors where emissions are often most challenging to reduce.

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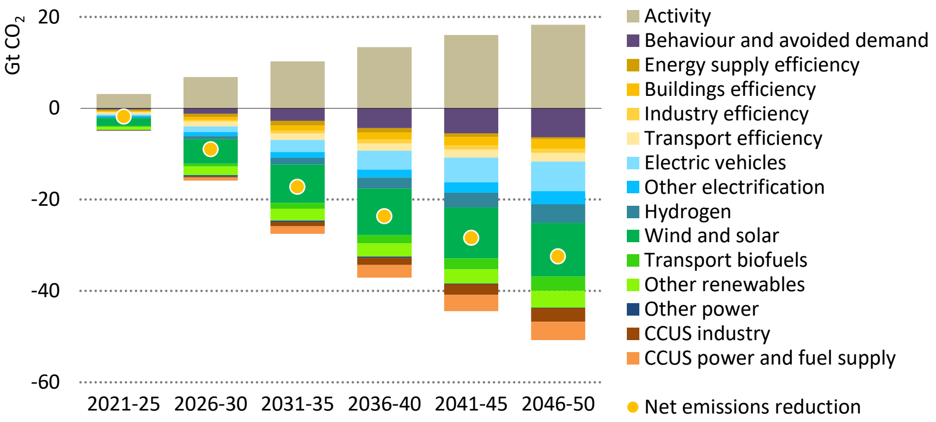
[6] Materials efficiency includes strategies that reduce material demand, or shift to the use of lower emissions materials or lower emissions production routes. Examples include lightweighting and recycling.

Figure 2.4 ▻ Average annual CO_2 reductions from 2020 in the NZE



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Renewables and electrification make the largest contribution to emissions reductions, but a wide range of measures and technologies are needed to achieve net-zero emissions

Notes: Activity = changes in energy service demand from economic and population growth. Behaviour = change in energy service demand from user decisions, e.g. changing heating temperatures. Avoided demand = change in energy service demand from technology developments, e.g. digitalisation.

2.4 Total energy supply and final energy consumption

2.4.1 Total energy supply[7]

Total energy supply falls to 550 exajoules (EJ) in 2030, 7% lower than in 2020 (Figure 2.5). This occurs despite significant increases in the global population and economy because of a fall in energy intensity (the amount of energy used to generate a unit of GDP). Energy intensity falls by 4% on average each year between 2020 and 2030. This is achieved through a combination of electrification, a push to pursue all energy and materials efficiency opportunities, behavioural changes that reduce demand for energy services, and a major shift away from the traditional use of bioenergy.[8] This level of improvement in energy intensity is much greater than has been achieved in recent years: between 2010 and 2020, average annual energy intensity fell by less then 2% each year.

After 2030, continuing electrification of end-use sectors helps to reduce energy intensity further, but the emphasis on maximising energy efficiency improvements in the years up to

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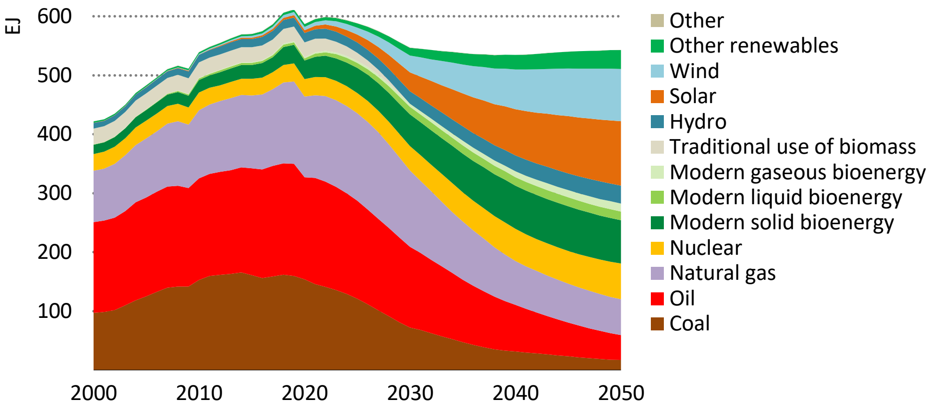
[7] The terms total primary energy supply (TPES) or total primary energy demand (TPED) have been renamed as total energy supply (TES) in accordance with the International Recommendations for Energy Statistics (IEA, 2020a).

[8] Modern forms of cooking require much less energy than the traditional use of biomass in inefficient stoves. For example, cooking with a liquefied petroleum gas stove uses around five-times less energy than the traditional use of biomass.

2030 limits the available opportunities in later years. At the same time, increasing production of new fuels, such as advanced biofuels, hydrogen and synthetic fuels, tends to push up energy use. As a result, the rate of decline in energy intensity between 2030 and 2050 slows to 2.7% per year. With continued economic and population growth, this means that total energy supply falls slightly between 2030 and 2040 but then remains broadly flat to 2050. Total energy supply in 2050 in the NZE is close to the level in 2010, despite a global population that is nearly 3 billion people higher and a global economy that is over three-times larger.

Figure 2.5 ▹ Total energy supply in the NZE



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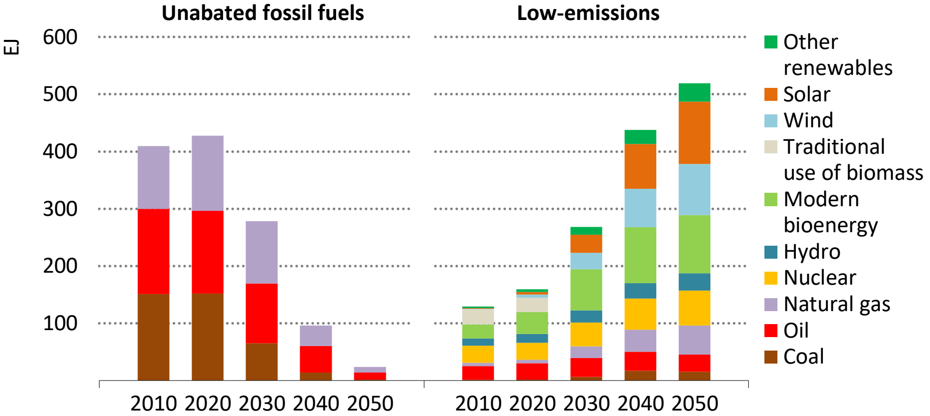
Renewables and nuclear power displace most fossil fuel use in the NZE, and the share of fossil fuels falls from 80% in 2020 to just over 20% in 2050

The energy mix in 2050 in the NZE is much more diverse than today. In 2020, oil provided 30% of total energy supply, while coal supplied 26% and natural gas 23%. In 2050, renewables provide two-thirds of energy use, split between bioenergy, wind, solar, hydroelectricity and geothermal (Figure 2.6). There is also a large increase in energy supply from nuclear power, which nearly doubles between 2020 and 2050.

There are large reductions in the use of fossil fuels in the NZE. As a share of total energy supply, they fall from 80% in 2020 to just over 20% in 2050. However, their use does not fall to zero in 2050: significant amounts are still used in producing non-energy goods, in plants with CCUS, and in sectors where emissions are especially hard to abate such as heavy industry and long-distance transport. All remaining emissions in 2050 are offset by negative emissions elsewhere (Box 2.2). Coal use falls from 5 250 million tonnes of coal equivalent (Mtce) in 2020 to 2 500 Mtce in 2030 and to less than 600 Mtce in 2050 – an average annual decline of 7% each year from 2020 to 2050. Oil demand dropped below 90 million barrels per day (mb/d) in 2020 and demand does not return to its 2019 peak: it falls to 72 mb/d in 2030 and 24 mb/d in 2050 – an annual average decline of more than 4% from 2020 to 2050. Natural gas use dropped to 3 900 billion cubic metres (bcm) in 2020, but exceeds its previous

2019 peak in the mid-2020s before starting to decline as it is phased out in the electricity sector. Natural gas use declines to 3 700 bcm in 2030 and 1 750 bcm in 2050 – an annual average decline of just under 3% from 2020 to 2050.

Figure 2.6 ▻ Total energy supply of unabated fossil fuels and low-emissions energy sources in the NZE



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Some fossil fuels are still used in 2050 in the production of non-energy goods, in plants equipped with CCUS, and in sectors where emissions are hard to abate

Note: Low-emissions includes the use of fossil fuels with CCUS and in non-energy uses.

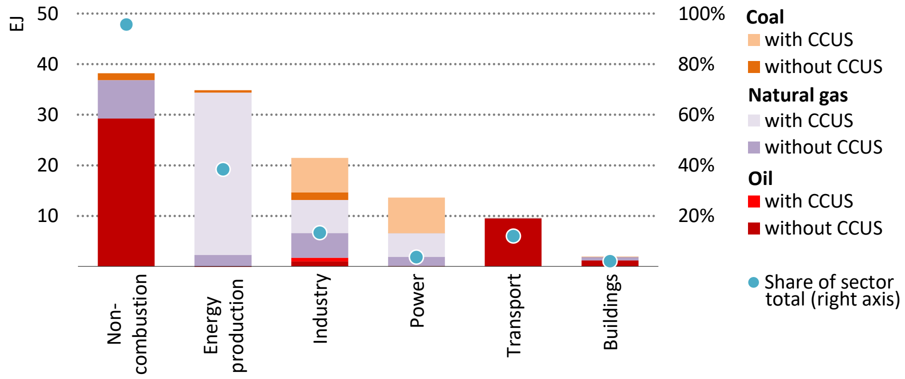
Box 2.2 ▻ Why does fossil fuel use not fall to zero in 2050 in the NZE?

In total, around 120 EJ of fossil fuels is consumed in 2050 in the NZE relative to 460 EJ in 2020. Three main reasons underlie why fossil fuel use does not fall to zero in 2050, even though the energy sector emits no CO_2 on a net basis:

- **Use for non-energy purposes**. More than 30% of total fossil fuel use in 2050 in the NZE – including 70% of oil use – is in applications where the fuels are not combusted and so do not result in any direct CO_2 emissions (Figure 2.7). Examples include use as chemical feedstocks and in lubricants, paraffin waxes and asphalt. There are major efforts to limit fossil fuel use in these applications in the NZE, for instance global plastic collection rates for recycling rising from 15% in 2020 to 55% in 2050, but fossil fuel use in non-energy applications still rises slightly to 2050.
- **Use with CCUS.** Around half of fossil fuel use in 2050 is in plants equipped with CCUS (around 3.5 Gt CO_2 emissions are captured from fossil fuels in 2050). Around 925 bcm of natural gas is converted to hydrogen with CCUS. In addition, around 470 Mtce of coal and 225 bcm of natural gas are used with CCUS in the electricity and industrial sectors, mainly to extend the operations of young facilities and reduce stranded assets.

- **Use in sectors where technology options are scarce.** The remaining 20% of fossil fuel use in 2050 in the NZE is in sectors where the complete elimination of emissions is particularly challenging. Mostly this is oil, as it continues to fuel aviation in particular. A small amount of unabated coal and natural gas are used in industry and in the production of energy. The unabated use of fossil fuel results in around 1.7 Gt CO_2 emissions in 2050, which are fully offset by BECCS and DACCS.

Figure 2.7 ▷ **Fossil fuel use and share by sector in 2050 in the NZE**



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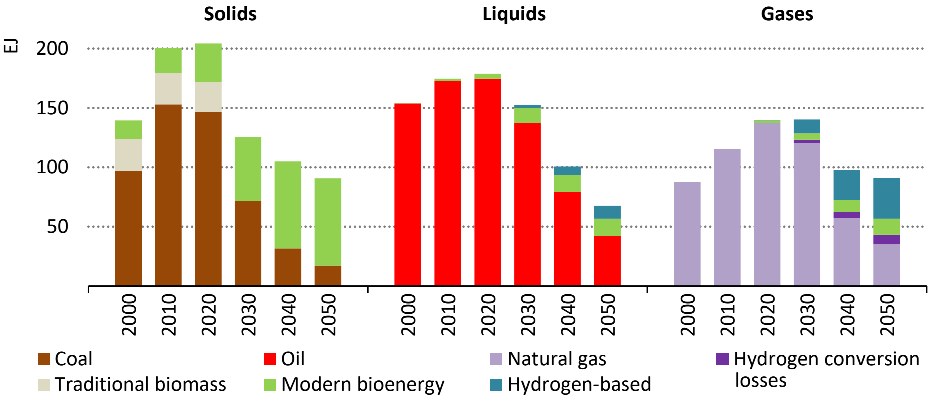
More than 30% of fossil fuel use in 2050 is not combusted and so does not result in direct CO_2 emissions, around 50% is paired with CCUS

Notes: Non-combustion includes use for non-emitting, non-energy purposes such as petrochemical feedstocks, lubricants and asphalt. Energy production includes fuel use for direct air capture.

Solid, liquid and gaseous fuels continue to play an important role in the NZE, which sees large increases in bioenergy and hydrogen (Figure 2.8). Around 40% of bioenergy used today is for the traditional use of biomass in cooking: this is rapidly phased out in the NZE. Modern forms of solid biomass, which can be used to reduce emissions in both the electricity and industry sectors, rise from 32 EJ in 2020 to 55 EJ in 2030 and 75 EJ in 2050, offsetting a large portion of a drop in coal demand. The use of low-emissions liquid fuels, such as ammonia, synthetic fuels and liquid biofuels, increases from 3.5 EJ (1.6 million barrels of oil equivalent per day [mboe/d]) in 2020 to just above 25 EJ (12.5 mboe/d) in 2050. The supply of low-emissions gases, such as hydrogen, synthetic methane, biogas and biomethane rises from 2 EJ in 2020 to 17 EJ in 2030 and 50 EJ in 2050. The increase in gaseous hydrogen production between 2020 and 2030 in the NZE is twice as fast as the fastest ten-year increase in shale gas production in the United States.

Figure 2.8 ▷ **Solid, liquid and gaseous fuels in the NZE**



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Increases in low-emissions solids, liquids and gases from bioenergy, hydrogen and hydrogen-based fuels offset some of the declines in coal, oil and natural gas

Notes: Hydrogen conversion losses = consumption of natural gas when producing low-carbon merchant hydrogen using steam methane reforming. Hydrogen-based includes hydrogen, ammonia and synthetic fuels.

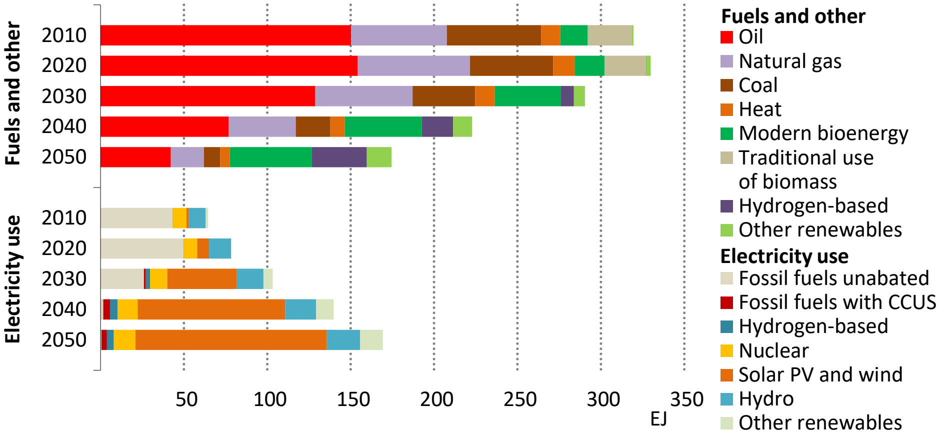
2.4.2 Total final consumption

Total final consumption worldwide rebounds marginally following its 5% drop in 2020, but it never returns to 2019 levels in the NZE (435 EJ). It falls by just under 1% each year on average between 2025 and 2050 to 340 EJ. Energy efficiency measures and electrification are the two main contributing factors, with behavioural changes and materials efficiency also playing a role. Without these improvements, final energy consumption in 2050 would be around 640 EJ, around 90% higher than the level in the NZE. Final consumption of electricity increases by 25% from 2020 to 2030, and by 2050 it is more than double the level in 2020. The increase in electricity consumption from end-uses sectors and from hydrogen production means that overall annual electricity demand growth is equivalent to adding an electricity market the size of India every year in the NZE. The share of electricity in global final energy consumption jumps from 20% in 2020 to 26% in 2030 and to around 50% in 2050 (Figure 2.9). The direct use of renewables in buildings and industry together with low-emissions fuels such as bioenergy and hydrogen-based fuels provide a further 28% of final energy consumption in 2050; fossil fuels comprise the remainder, most of which are used in non-emitting processes or in facilities equipped with CCUS.

In industry, most of the global emissions reductions in the NZE during the period to 2030 are delivered through energy and materials efficiency improvements, electrification of heat, and fuel switching to solar thermal, geothermal and bioenergy. Thereafter, CCUS and hydrogen play an increasingly important role in reducing CO_2 emissions, especially in heavy industries such as steel, cement and chemicals. Electricity consumption in industry more than doubles between 2020 and 2050, providing 45% of total industrial energy needs in 2050 (Figure 2.10).

The demand for merchant hydrogen in industry increases from less than 1 Mt today to around 40 Mt in 2050. A further 10% of industrial energy demand in 2050 is met by fossil fuels used in plants equipped with CCUS.

Figure 2.9 ▷ Global total final consumption by fuel in the NZE



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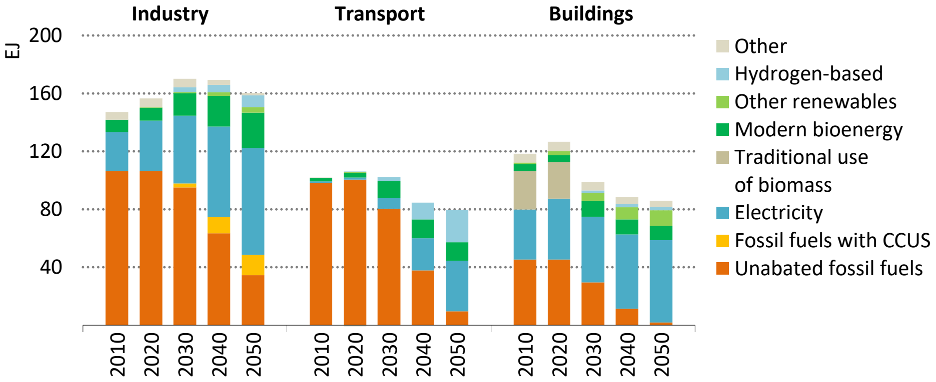
The share of electricity in final energy use jumps from 20% in 2020 to 50% in 2050

Note: Hydrogen-based includes hydrogen, ammonia and synthetic fuels.

In transport, there is a rapid transition away from oil worldwide, which provided more than 90% of fuel use in 2020. In road transport, electricity comes to dominate the sector, providing more than 60% of energy use in 2050, while hydrogen and hydrogen-based fuels play a smaller role, mainly in fuelling long-haul heavy-duty trucks. In shipping, energy efficiency improvements significantly reduce energy needs (especially up to 2030), while advanced biofuels and hydrogen-based fuels, such as ammonia, increasingly displace oil. In aviation, the use of synthetic liquids and advanced biofuels grows rapidly, and their share of total energy demand rises from almost zero today to almost 80% in 2050. Overall, electricity becomes the dominant fuel in the transport sector globally by the early 2040s, and it accounts for around 45% of energy consumption in the sector in 2050 (compared with 1.5% in 2020). Hydrogen and hydrogen-based fuels account for nearly 30% of consumption (almost zero in 2020) and bioenergy for a further 15% (around 4% in 2020).

In buildings, the electrification of end-uses including heating leads to demand for electricity increasing by around 35% between 2020 and 2050: it becomes the dominant fuel, reaching 16 000 terawatt-hours (TWh) in 2050, and accounting for two-thirds of total buildings sector energy consumption. By 2050, two-thirds of residential buildings in advanced economies and around 40% of residential buildings in emerging market and developing economies are fitted with a heat pump. Onsite renewables-based energy systems such as solar water heaters and biomass boilers provide a further quarter of final energy use in the buildings sector in 2050 (up from 6% in 2020). Low-emissions district heating and hydrogen provide only 7% of energy use, but play a significant role in some regions.

Figure 2.10 ▷ Global final energy consumption by sector and fuel in the NZE



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There is a wholesale shift away from unabated fossil fuel use to electricity, renewables, hydrogen and hydrogen-based fuels, modern bioenergy and CCUS in end-use sectors

Note: Hydrogen-based includes hydrogen, ammonia and synthetic fuels.

Buildings energy consumption falls by 25% between 2020 and 2030, largely as a result of a major push to improve efficiency and to phase out the traditional use of solid biomass for cooking: it is replaced by liquefied petroleum gas (LPG), biogas, electric cookers and improved bioenergy stoves. Universal access to electricity is achieved by 2030, and this adds less than 1% to global electricity demand in 2030. Energy consumption in the buildings sector contracts by around 15% between 2030 and 2050 given continued efficiency improvements and electrification. By 2050, energy use in buildings is 35% lower than in 2020. Energy efficiency measures – including improving building envelopes and ensuring that all new appliances brought to market are the most efficient models available – play a key role in limiting the rise in electricity demand in the NZE. Without these measures, electricity demand in buildings would be around 10 000 TWh higher in 2050, or around 70% higher than the level in the NZE.

SPOTLIGHT

How does the NZE compare with similar 1.5 °C scenarios assessed by the IPCC?

The IPCC SR1.5 includes 90 individual scenarios that have at least a 50% chance of limiting warming in 2100 to 1.5 °C (IPCC, 2018).[9] Only 18 of these scenarios have net-zero CO_2 energy sector and industrial process emissions in 2050. In other words, only one-in-five of the 1.5 °C scenarios assessed by the IPCC have the same level of emissions reduction

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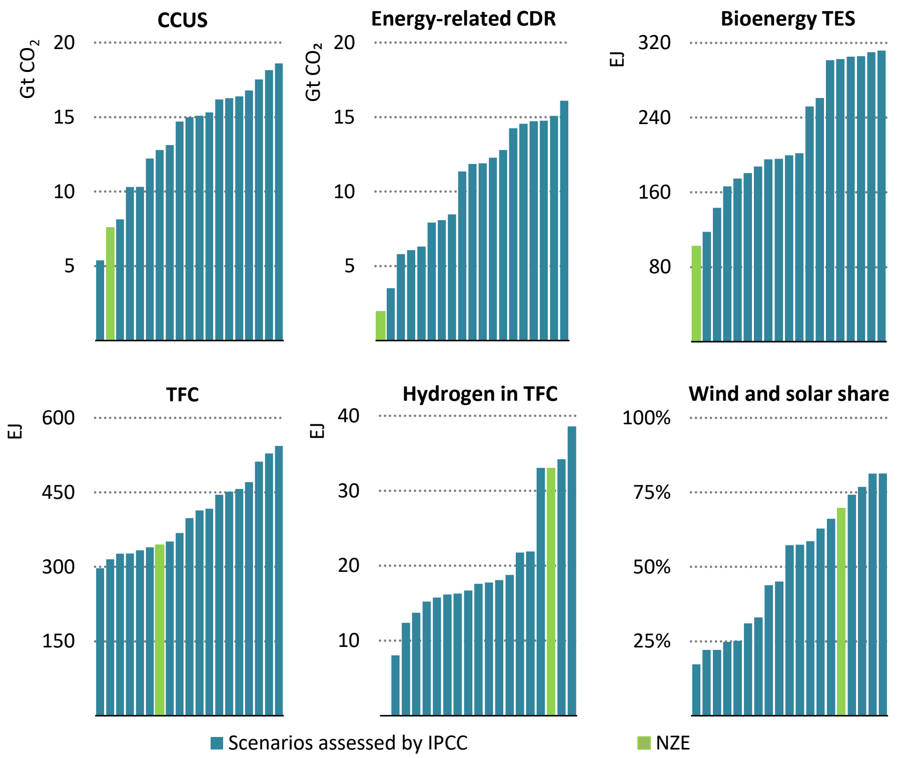
[9] Includes 53 scenarios with no or limited temperature overshoot and 37 scenarios with a higher temperature overshoot.

ambition for the energy and industrial process sectors to 2050 as the NZE.[10] Some comparisons between these 18 scenarios and the NZE in 2050 (Figure 2.11):

Figure 2.11 ⊳ **Comparison of selected indicators of the IPCC scenarios and the NZE in 2050**



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The NZE has the lowest level of energy-related CDR and bioenergy of any scenario that achieves net-zero energy sector and industrial process CO_2 emissions in 2050

Notes: CCUS = carbon capture, utilisation and storage; CDR = carbon direct removal; TES = total energy supply; TFC = total final consumption. Energy-related CDR includes CO_2 captured through bioenergy with CCUS and direct air capture with CCUS and put into permanent storage. Wind and solar share are given as a percentage of total electricity generation. Only 17 of the 18 scenarios assessed by the IPCC report hydrogen use in TFC.

- **Use of CCUS.** The scenarios assessed by the IPCC have a median of around 15 Gt CO_2 captured using CCUS in 2050, more than double the level in the NZE.
- **Use of CDR.** CO_2 emissions captured and stored from BECCS and DACCS in the IPCC scenarios range from 3.5-16 Gt CO_2 in 2050, compared with 1.9 Gt CO_2 in the NZE.

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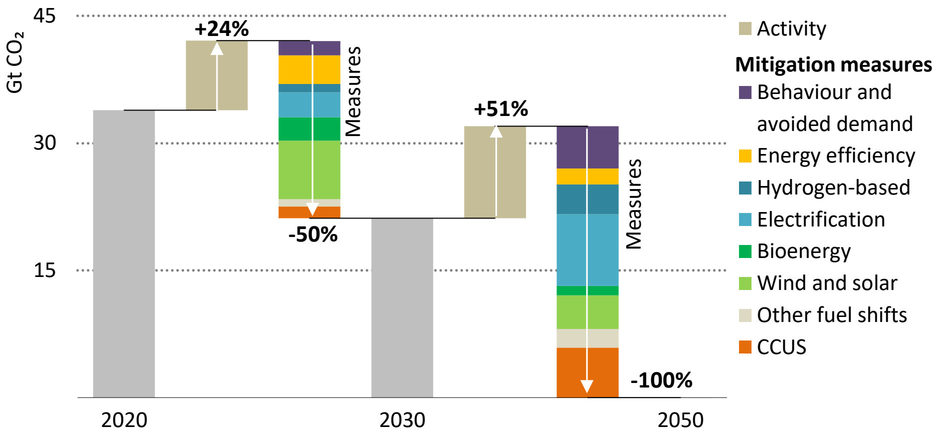
[10] The low-energy demand scenario has around 4.5 Gt CO_2 energy sector and industrial process emissions in 2050 and is not included in this comparison.

- **Bioenergy.** The IPCC scenarios use a median of 200 EJ of primary bioenergy in 2050 (compared with 63 EJ today) and a number use more than 300 EJ. The NZE uses 100 EJ of primary bioenergy in 2050.
- **Energy efficiency.** Total final consumption in the IPCC scenarios range from 300-550 EJ in 2050 (compared with around 410 EJ in 2020). The NZE has final energy consumption of 340 EJ in 2050.
- **Hydrogen.** The IPCC scenarios have a median of 18 EJ hydrogen in total final consumption in 2050, compared with 33 EJ in the NZE.[11]
- **Electricity generation.** The shares of wind and solar in total electricity generation in 2050 in the IPCC scenarios range from around 15-80% with a median value of 50%. In the NZE, wind and solar provide 70% of total generation in 2050.

2.5 Key pillars of decarbonisation

Achieving the rapid reduction in CO_2 emissions over the next 30 years in the NZE requires a broad range of policy approaches and technologies (Figure 2.12). The key pillars of decarbonisation of the global energy system are energy efficiency, behavioural changes, electrification, renewables, hydrogen and hydrogen-based fuels, bioenergy and CCUS.

Figure 2.12 ▷ Emissions reductions by mitigation measure in the NZE, 2020-2050



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Solar, wind and energy efficiency deliver around half of emissions reductions to 2030 in the NZE, while electrification, CCUS and hydrogen ramp up thereafter

Notes: Activity = energy service demand changes from economic and population growth. Behaviour = energy service demand changes from user decisions, e.g. changing heating temperatures. Avoided demand = energy service demand changes from technology developments, e.g. digitalisation. Other fuel shifts = switching from coal and oil to natural gas, nuclear, hydropower, geothermal, concentrating solar power or marine.

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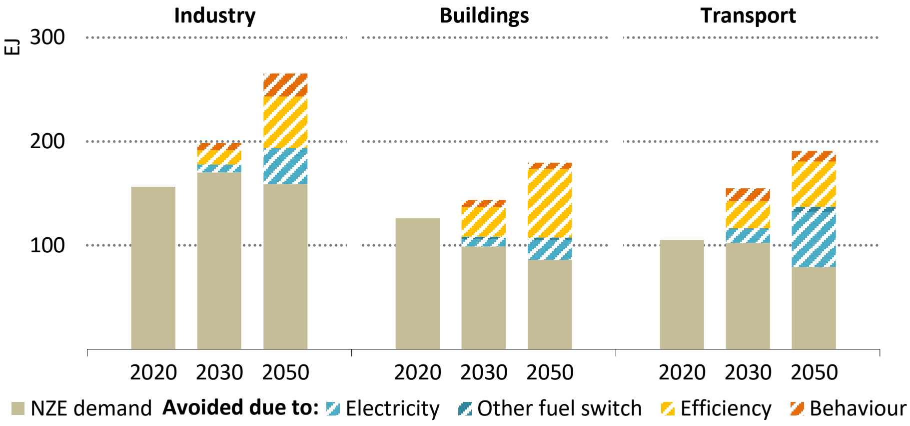
[11] The NZE value for hydrogen includes the total energy content of hydrogen and hydrogen-based fuels consumed in final energy consumption.

2.5.1 Energy efficiency

Minimising energy demand growth through improvements in energy efficiency makes a critical contribution in the NZE. Many efficiency measures in industry, buildings, appliances and transport can be put into effect and scaled up very quickly. As a result, energy efficiency measures are front-loaded in the NZE, and they play their largest role in curbing energy demand and emissions in the period to 2030. Although energy efficiency improves further after 2030, its contribution to overall emissions reductions falls as other mitigation measures play an expanding role. Without the energy efficiency, behavioural changes and electrification measures deployed in the NZE, final energy consumption would be around 300 EJ higher in 2050, almost 90% above the 2050 level in the NZE (Figure 2.13). Efficiency improvements also help reduce the vulnerability of businesses and consumers to potential disruptions to electricity supplies.

Figure 2.13 ▷ Total final consumption and demand avoided by mitigation measure in the NZE



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Energy efficiency plays a key role in reducing energy consumption across end-use sectors

Notes: Other fuel switch includes switching to hydrogen-related fuels, bioenergy, solar thermal, geothermal, or district heat.

In the buildings sector, many efficiency measures yield financial savings as well as reducing energy use and emissions. In the NZE, there are immediate and rapid improvements in energy efficiency in buildings, mainly from large-scale retrofit programmes. Around 2.5% of existing residential buildings in advanced economies are retrofitted each year to 2050 in the NZE to comply with zero-carbon-ready building standards[12] (compared with a current retrofit rate of less than 1%). In emerging market and developing economies, building replacement

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[12] A zero-carbon-ready building is highly energy efficient and uses either renewable energy directly or from an energy supply that will be fully decarbonised by 2050 in the NZE (such as electricity or district heat). A zero-carbon-ready building will become a zero-carbon building by 2050, without further changes to the building or its equipment (see Chapter 3).

rates are higher and the annual rate of retrofits is around 2% through to 2050. By 2050, the vast majority of existing residential buildings are retrofitted to be zero-carbon buildings. Energy-related building codes are introduced in all regions by 2030 to ensure that virtually all new buildings constructed are zero-carbon-ready. Minimum energy performance standards and replacement schemes for low-efficiency appliances are introduced or strengthened in the 2020s in all countries. By the mid-2030s, nearly all household appliances sold worldwide are as efficient as the most efficient models available today.

In the transport sector, stringent fuel-economy standards and ensuring no new passenger cars running on internal combustion engines (ICEs) are sold globally from 2035 result in a rapid shift in vehicle sales toward much more efficient electric vehicles (EVs).[13] The impact on efficiency is seen in the 2030s, as the composition of the vehicle stock changes: electric cars make up 20% of all cars on the road in 2030 and 60% in 2040 (compared with 1% today). Continuous improvements in the fuel economy of heavy road vehicles take place through to 2050 as they switch to electricity or fuel cells, while efficiency in shipping and aviation improves as more efficient planes and ships replace existing stock.

In the industry sector, most manufacturing stock is already quite efficient, but there are still opportunities for energy efficiency improvements. Energy management systems, best-in-class industrial equipment such as electric motors, variable speed drives, heaters and grinders are installed, and process integration options such as waste heat recovery are exploited to their maximum economic potentials in the period to 2030 in the NZE. After 2030, the rate of efficiency improvement slows because many of the technologies needed to reduce emissions in industry in the NZE require more energy than their equivalent conventional technologies. The use of CCUS, for example, increases energy consumption to operate the capture equipment, and producing electrolytic hydrogen on-site requires additional energy than that needed for the main manufacturing process.

Table 2.3 ⊳ Key global milestones for energy efficiency in the NZE

Sector	2020	2030	2050
Total energy supply	*2010-20*	*2020-30*	*2030-50*
Annual energy intensity improvement (MJ per USD GDP)	-1.6%	-4.2%	-2.7%
Industry			
Energy intensity of direct reduced iron from natural gas (GJ per tonne)	12	11	10
Process energy intensity of primary chemicals (GJ per tonne)	17	16	15
Transport			
Average fuel consumption of ICE heavy trucks fleet (index 2020=100)	100	81	63
Buildings			
Share of zero-carbon-ready buildings in total stock	<1%	25%	>85%
New buildings: heating & cooling energy consumption (index 2020=100)	100	50	20
Appliances: unit energy consumption (index 2020=100)	100	75	60

Notes: ICE = internal combustion engine; zero-carbon-ready buildings = see description in section 3.7.

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[13] In 2020, the average battery electric car required around 30% of the energy of the average ICE car to provide the same level of activity.

2.5.2 Behavioural change

The wholescale transformation of the energy sector demonstrated in the NZE cannot be achieved without the active and willing participation of citizens. It is ultimately people who drive demand for energy-related goods and services, and societal norms and personal choices will play a pivotal role in steering the energy system onto a sustainable path. Just under 40% of emissions reductions in the NZE result from the adoption of low-carbon technologies that require massive policy support and investment but little direct engagement from citizens or consumers, e.g. technologies in electricity generation or steel production. A further 55% of emissions reductions require a mixture of the deployment of low-carbon technologies and the active involvement or engagement of citizens and consumers, e.g. installing a solar water heater or buying an EV. A final 8% of emissions reductions stem from behavioural changes and materials efficiency gains that reduce energy demand, e.g. flying less for business purposes (Figure 2.14). Consumer attitudes can also impact investment decisions by businesses concerned about public image.

In the NZE, behavioural change refers to changes in ongoing or repeated behaviour on the part of consumers which impact energy service demand or the energy intensity of an energy-related activity.[14] Reductions in energy service demand in the NZE also come from advances in technology, but these are not counted as behavioural changes. For example, increased digitalisation and a growing market share of smart appliances, such as smart thermostats or space-differentiated thermal controls reduce the necessity for people to play an active role in energy saving in homes over time in the NZE.

There are three main types of behavioural change included in the NZE. A wide range of government interventions could be used to motivate these changes (see section 2.7.1).

- **Reducing excessive or wasteful energy use.** This includes reducing energy use in buildings and on roads, e.g. by reducing indoor temperature settings, adopting energy saving practices in homes and limiting driving speeds on motorways to 100 kilometres per hour.
- **Transport mode switching.** This includes a shift to cycling, walking, ridesharing or taking buses for trips in cities that would otherwise be made by car, as well as replacing regional air travel by high-speed rail in regions where this is feasible. Many of these types of behavioural changes would represent a break in familiar or habitual ways of life and as such would require a degree of public acceptance and even enthusiasm. Many would also require new infrastructure, such as cycle lanes and high-speed rail networks, clear policy support and high quality urban planning.
- **Materials efficiency gains.** This includes reduced demand for materials, e.g. higher rates of recycling, and improved design and construction of buildings and vehicles. The scope for gains to some extent reflects societal preferences. For instance, in some places there

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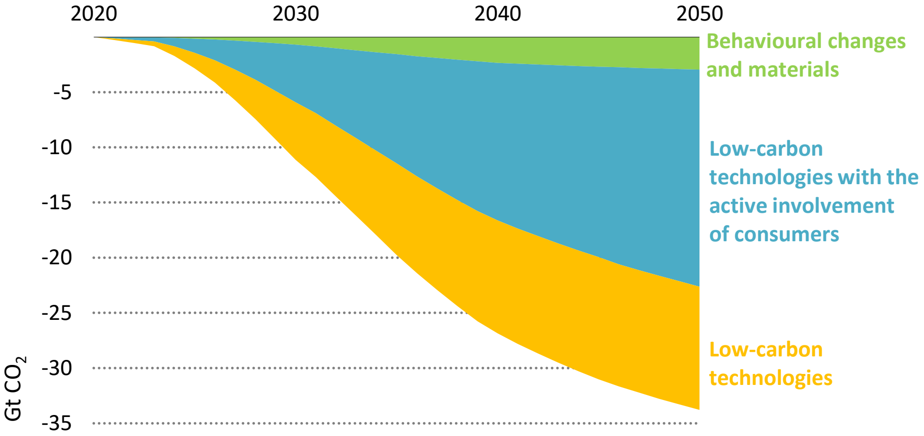
[14] This means, for example, that purchasing an electric heat pump instead of a gas boiler is not considered as a behavioural change, as it is both an infrequent event and does not necessarily impact energy service demand.

has been a shift away from the use of single-use plastics in recent years, a trend that accelerates in the NZE. Gains in materials efficiency depend on a mixture of technical innovation in manufacturing and buildings construction, standards and regulations to support best-practice and ensure universal adoption of these innovations, and increased recycling in society at large.

Figure 2.14 ▷ Role of technology and behavioural change in emissions reductions in the NZE



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Around 8% of emissions reductions stem from behavioural changes and materials efficiency

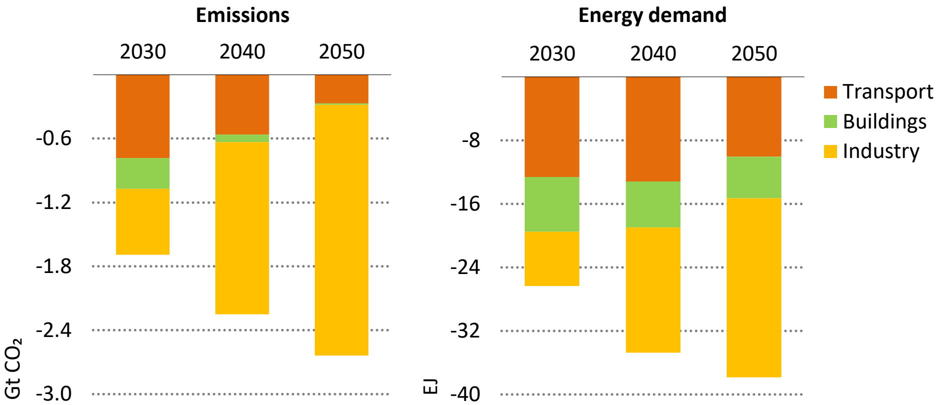
Notes: Low-carbon technologies include low-carbon electricity generation, low-carbon gases in end-uses and biofuels. Low-carbon technologies with the active involvement of citizens includes fuel switching, electrification and efficiency gains in end-uses. Behavioural changes and materials efficiency includes transport mode switching, curbing excessive or wasteful energy use, and materials efficiency measures.

Three-quarters of the emissions reductions from behavioural changes in the NZE are achieved through targeted government policies supported by infrastructure development, e.g. a shift to rail travel supported by high-speed railways. The remainder come from adopting voluntary changes in energy saving habits, mainly in homes. Even in this case, public awareness campaigns can help shape day-to-day choices about how consumers use energy. (Details of what governments can do to help bring about behavioural changes are discussed in Chapter 4).

Behavioural changes reduce energy-related activity by around 10-15% on average over the period to 2050 in the NZE, reducing overall global energy demand by over 37 EJ in 2050 (Figure 2.15). In 2030, around 1.7 Gt CO_2 emissions are avoided, 45% of which come from transport, notably through measures to phase out car use in cities and to improve fuel economy. For example, reducing speed limits on motorways to 100 km/h reduces emissions from road transport by 3% or 140 Mt CO_2 in 2030. A shift away from single occupancy car use towards ridesharing or cycling and walking in large cities saves a further 185 Mt CO_2. Around

40% of emissions savings in 2030 occur in industry because of improvements in materials efficiency and increased recycling, with the biggest impacts coming from reducing waste and improving the design and construction of buildings. The remainder of emissions savings in 2030 are from behavioural changes in buildings, for example adjusting space heating and cooling temperatures.

Figure 2.15 ▷ CO_2 emissions and energy demand reductions from behavioural changes and materials efficiency in the NZE



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By 2030, behaviour changes and materials efficiency gains reduce emissions by 1.7 Gt CO_2, and energy demand by 27 EJ; reductions increase further through to 2050

In 2050, the growing importance of low-emissions electricity and fuels in transport and buildings means that 90% of emissions reductions are in industry, predominantly in those sectors where it is most challenging to tackle emissions directly. Material efficiency alone reduces demand for cement and steel by 20%, saving around 1 700 Mt CO_2. Of the emissions reductions in transport in 2050, nearly 80% come from measures to reduce passenger aviation demand, with the remainder from road transport.

The scope, scale and speed of adoption of the behavioural changes in the NZE varies widely between regions, depending on several factors including the ability of existing infrastructure to support such changes and differences in geography, climate, urbanisation, social norms and cultural values. For example, regions with high levels of private car use today see a more gradual shift than others towards public transport, shared car use, walking and cycling; air travel is assumed to switch to high-speed rail on existing or potential routes only where trains could offer a similar journey time; and the potential for moderating air conditioning in buildings and vehicles takes into account seasonal effects and humidity. Wealthier regions generally have higher levels of per capita energy-related activity, and behavioural changes play an especially important role in these regions in reducing excessive or wasteful energy consumption.

Most of the behavioural changes in the NZE would have some effect on nearly everyone's daily life, but none represents a radical departure from energy-reducing practices already experienced in many parts of the world today. For example, in Japan an awareness campaign has successfully reduced cooling demand in line with the reductions assumed in many regions in the NZE by 2040; legislation to limit urban car use has been introduced in many large cities; and speed limit reductions to around 100 km/h (the level adopted globally in the NZE by 2030) have been tested in the United Kingdom and Spain to reduce air pollution and improve safety.

Table 2.4 ▷ Key global milestones for behavioural change in the NZE

Sector	Year	Milestone
Industry	2020	- Global average plastics collection rate = 17%.
	2030	- Global average plastics collection rate = 27%. - Lightweighting reduces the weight of an average passenger car by 10%.
	2050	- Global average plastics collection rate = 54%. - Efficiency of fertiliser use improved by 10%.
Transport	2030	- Eco-driving and motorway speed limits of 100 km/h introduced. - Use of ICE cars phased out in large cities.
	2050	- Regional flights are shifted to high-speed rail where feasible. - Business and long-haul leisure air travel does not exceed 2019 levels.
Buildings	2030	- Space heating temperatures moderated to 19-20 °C on average. - Space cooling temperatures moderated to 24-25°C on average. - Excessive hot-water temperatures reduced.
	2050	- Use of energy-intensive materials per unit of floor area decreases by 30%. - Building lifetime extended by 20% on average.

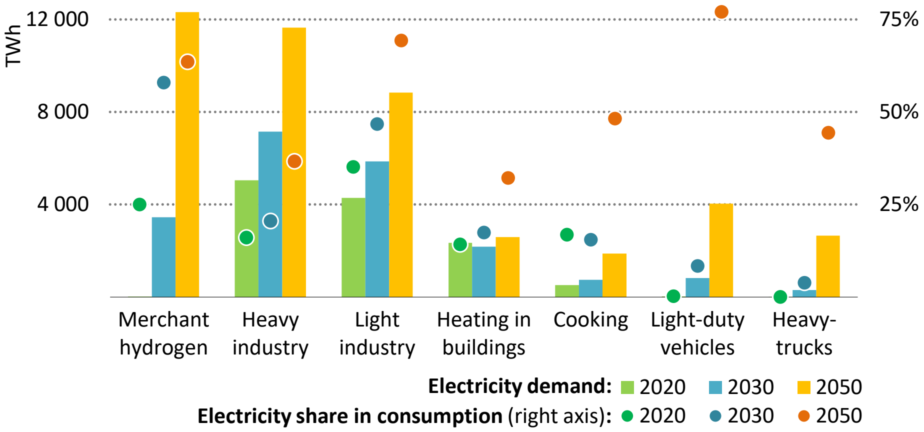
Note: Eco-driving involves pre-emptive stopping and starting; ICE = internal combustion engine.

2.5.3 Electrification

The direct use of low-emissions electricity in place of fossil fuels is one of the most important drivers of emissions reductions in the NZE, accounting for around 20% of the total reduction achieved by 2050. Global electricity demand more than doubles between 2020 and 2050, with the largest absolute rise in electricity use in end-use sectors taking place in industry, which registers an increase of more than 11 000 TWh between 2020 and 2050. Much of this is due to the increasing use of electricity for low- and medium-temperature heat and in secondary scrap-based steel production (Figure 2.16).

In transport, the share of electricity increases from less than 2% in 2020 to around 45% in 2050 in the NZE. More than 60% of total passenger car sales globally are EVs by 2030 (compared with 5% of sales in 2020), and the car fleet is almost fully electrified worldwide by 2050 (the remainder are hydrogen-powered cars). The increase in electric passenger car sales globally over the next ten years is over twenty-times higher than the increase in ICE car sales over the last decade. Electrification is slower for trucks because it depends on higher density batteries than those currently available on the market, especially for long-haul trucking, and on new high-power charging infrastructure: electric trucks nevertheless account for around 25% of total heavy truck sales globally by 2030 and around two-thirds in 2050. The electrification of shipping and aviation is much more limited and only gets under way after large improvements in battery energy density (see section 3.6) (Figure 2.17). In the NZE, demand for batteries for transport reaches around 14 TWh in 2050, 90-times more than in 2020. Growth in battery demand translates into an increasing demand for critical minerals. For example, demand for lithium for use in batteries grows 30-fold to 2030 and is more than 100-times higher in 2050 than in 2020 (IEA, 2021).

Figure 2.16 ⊳ **Global electricity demand and share of electricity in energy consumption in selected applications in the NZE**



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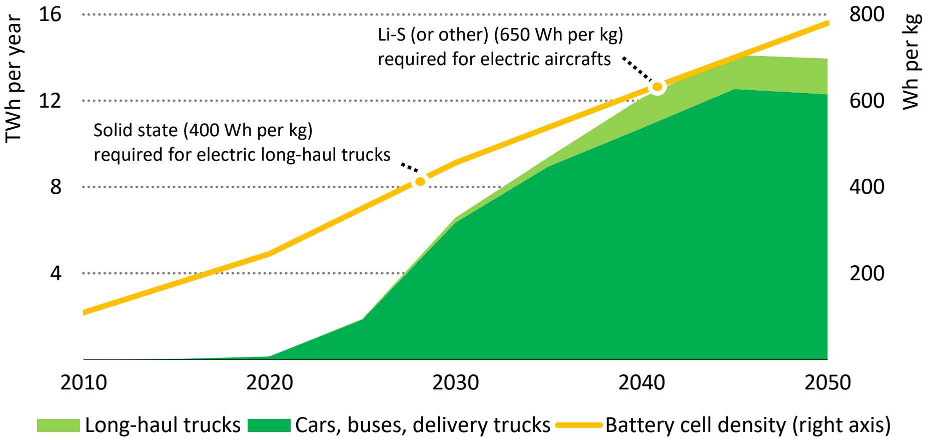
Global electricity demand more than doubles in the period to 2050, with the largest rises to produce hydrogen and in industry

Notes: Merchant hydrogen = hydrogen produced by one company to sell to others. Light-duty vehicles = passenger cars and vans. Heavy trucks = medium-freight trucks and heavy-freight trucks.

In buildings, electricity demand is moderated in the NZE by a huge push to improve the efficiency of appliances, cooling, lighting and building envelopes. But a large increase in activity, along with the widespread electrification of heating through the use of heat pumps, means that electricity demand in buildings still rises steadily over the period reaching 66% of total energy consumption in buildings in 2050.

Alongside the growth in the direct use of electricity in end-use sectors, there is also a huge increase in the use of electricity for hydrogen production. Merchant hydrogen produced using electrolysis requires around 12 000 TWh in 2050 in the NZE, which is greater than current total annual electricity demand of China and the United States combined.

Figure 2.17 ▻ Battery demand growth in transport and battery energy density in the NZE



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Nearly 20 battery giga-factories open every year to 2030 to satisfy battery demand for electric cars in the NZE; higher density batteries are needed to electrify long-haul trucks

Notes: Li-S = lithium-sulphur battery; Wh per kg = Watt hours per kilogramme.

The acceleration of electricity demand growth from 2% per year over the past decade to 3% per year through to 2050, together with a significantly increased share of variable renewable electricity generation, means that annual electricity sector investment in the NZE is three-times higher on average than in recent years. The rise in electricity demand also calls for extensive efforts to ensure the stability and flexibility of electricity supply through demand-side management, the operation of flexible low-emissions sources of generation including hydropower and bioenergy, and battery storage.

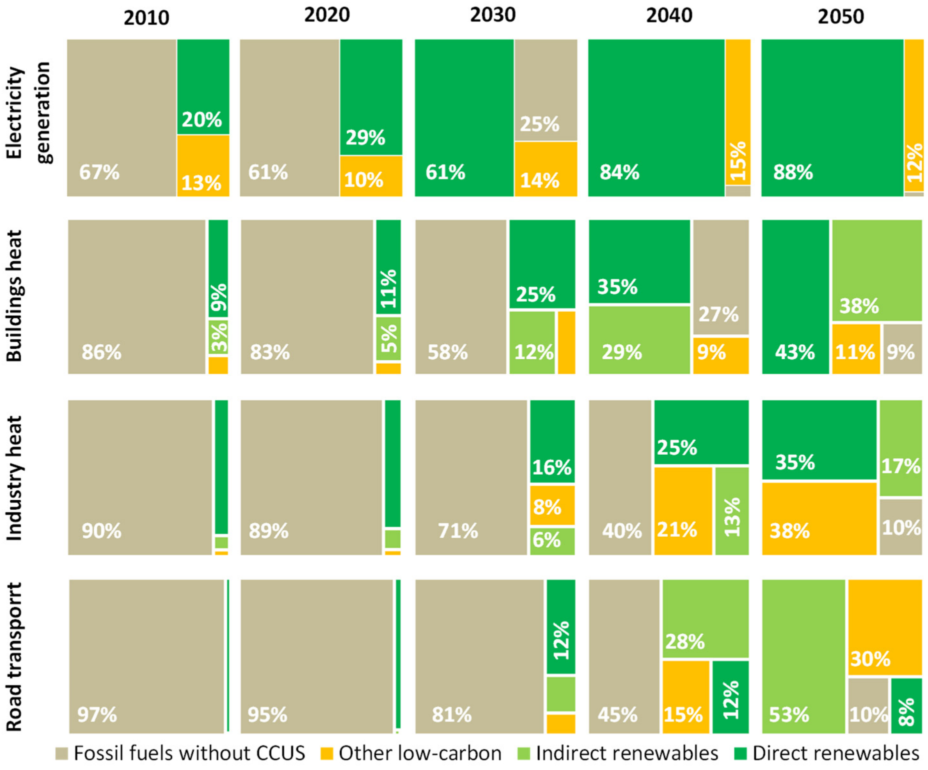
Table 2.5 ▻ Key global milestones for electrification in the NZE

Sector		2020	2030	2050
Share of electricity in total final consumption		20%	26%	49%
Industry				
Share of steel production using electric arc furnace		24%	37%	53%
Electricity share of light industry		43%	53%	76%
Transport				
Share of electric vehicles in stock:	cars	1%	20%	86%
	two/three-wheelers	26%	54%	100%
	bus	2%	23%	79%
	vans	0%	22%	84%
	heavy trucks	0%	8%	59%
Annual battery demand for electric vehicles (TWh)		0.16	6.6	14
Buildings				
Heat pumps installed (millions)		180	600	1 800
Share of heat pumps in energy demand for heating		7%	20%	55%
Million people without access to electricity		786	0	0

2.5.4 Renewables

At a global level, renewable energy technologies are the key to reducing emissions from electricity supply. Hydropower has been a leading low-emission source for many decades, but it is mainly the expansion of wind and solar that triples renewables generation by 2030 and increases it more than eightfold by 2050 in the NZE. The share of renewables in total electricity generation globally increases from 29% in 2020 to over 60% in 2030 and to nearly 90% in 2050 (Figure 2.18). To achieve this, annual capacity additions of wind and solar between 2020 and 2050 are five-times higher than the average over the last three years. Dispatchable renewables are critical to maintain electricity security, together with other low-carbon generation, energy storage and robust electricity networks. In the NZE, the main dispatchable renewables globally in 2050 are hydropower (12% of generation), bioenergy (5%), concentrating solar power (2%) and geothermal (1%).

Figure 2.18 ▷ Fuel shares in total energy use in selected applications in the NZE



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Renewables are central to emissions reductions in electricity, and they make major contributions to cut emissions in buildings, industry and transport both directly and indirectly

Notes: Indirect renewables = use of electricity and district heat produced by renewables. Other low-carbon = nuclear power, facilities equipped with CCUS, and low-carbon hydrogen and hydrogen-based fuels.

Renewables also play an important role in reducing emissions in buildings, industry and transport. Renewables can be used either indirectly, via the consumption of electricity or district heating that was produced by renewables, or directly, mainly to produce heat.

In transport, renewables play an important indirect role in reducing emissions by generating the electricity to power electric vehicles. They also contribute to direct emissions reductions through the use of liquid biofuels and biomethane.

In buildings, renewable energy is mainly used for water and space heating. The direct use of renewable energy rises from about 10% of heating demand globally in 2020 to 40% in 2050, about three-quarters of the increase is in the form of solar thermal and geothermal. Deep retrofits and energy-related building codes are paired with renewables whenever possible: almost all buildings with available roof space and sufficient solar insolation are equipped with solar thermal water heaters by 2050, as they are more productive per square metre than solar PV and as heat storage in water tanks is generally more cost-effective than storage of electricity. Rooftop solar PV, which produces renewable electricity onsite, is currently installed on around 25 million rooftops worldwide; the number increases to 100 million rooftops by 2030 and 240 million by 2050. A further 15% of heating in buildings in 2030 comes indirectly from renewables in the form of electricity, and this rises to almost 40% in 2050.

In industry, bioenergy is the most important direct renewable energy source for low- and medium-temperature needs in the NZE. Solar thermal and geothermal also produce low temperature heat for use in non-energy-intensive industries and ancillary or downstream processes in heavy industries. Bioenergy, solar thermal and geothermal together provide about 15% of industry heat demand in 2030, roughly double their share in 2010, and this increases to 40% in 2050. The indirect use of renewable energy via electricity adds 15% to the contribution that renewables make to total industry energy use in 2050.

Table 2.6 ▻ Key deployment milestones for renewables

Sector		2020	2030	2050
Electricity sector				
Renewables share in generation		29%	61%	88%
Annual capacity additions (GW):	Total solar PV	134	630	630
	Total wind	114	390	350
	– of which: Offshore wind	5	80	70
	Dispatchable renewables	31	120	90
End-uses sectors				
Renewable share in TFC		5%	12%	19%
Households with rooftop solar PV (million)		25	100	240
Share of solar thermal and geothermal in buildings		2%	5%	12%
Share of solar thermal and geothermal in industry final consumption		0%	1%	2%

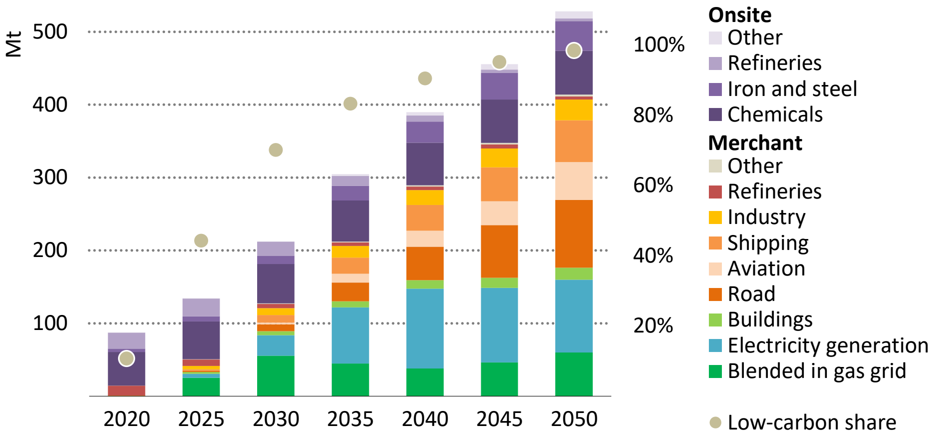
Note: TFC = total final consumption.

2.5.5 Hydrogen and hydrogen-based fuels

The initial focus for hydrogen use in the NZE is the conversion of existing uses of fossil energy to low-carbon hydrogen in ways that do not immediately require new transmission and distribution infrastructure. This includes hydrogen use in industry and in refineries and power plants, and the blending of hydrogen into natural gas for distribution to end-users.

Global hydrogen use expands from less than 90 Mt in 2020 to more than 200 Mt in 2030; the proportion of low-carbon hydrogen rises from 10% in 2020 to 70% in 2030 (Figure 2.19). Around half of low-carbon hydrogen produced globally in 2030 comes from electrolysis and the remainder from coal and natural gas with CCUS, although this ratio varies substantially between regions. Hydrogen is also blended with natural gas in gas networks: the global average blend in 2030 includes 15% of hydrogen in volumetric terms, reducing CO_2 emissions from gas consumption by around 6%.

Figure 2.19 ▷ Global hydrogen and hydrogen-based fuel use in the NZE



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The initial focus for hydrogen is to convert existing uses to low-carbon hydrogen; hydrogen and hydrogen-based fuels then expand across all end-uses

Note: Includes hydrogen and hydrogen contained in ammonia and synthetic fuels.

These developments facilitate a rapid scaling up of electrolyser manufacturing capacity and the parallel development of new hydrogen transport infrastructure. This leads to rapid cost reductions for electrolysers and for hydrogen storage, notably in salt caverns. Stored hydrogen is used to help balance both seasonal fluctuations in electricity demand and imbalances that may arise between the demand for hydrogen and its supply by off-grid renewable systems. During the 2020s, there is also a large increase in the installation of end-use equipment for hydrogen, including more than 15 million hydrogen fuel cell vehicles on the road by 2030.

After 2030, low-carbon hydrogen use expands rapidly in all sectors in the NZE. In the electricity sector, hydrogen and hydrogen-based fuels provide an important low-carbon source of electricity system flexibility, mainly through retrofitting existing gas-fired capacity to co-fire with hydrogen, together with some retrofitting of coal-fired power plants to co-fire with ammonia. Although these fuels provide only around 2% of overall electricity generation in 2050, this translates into very large volumes of hydrogen and makes the electricity sector an important driver of hydrogen demand. In transport, hydrogen provides around one-third of fuel use in trucks in 2050 in the NZE: this is contingent on policy makers taking decisions that enable the development of the necessary infrastructure by 2030. By 2050, hydrogen-based fuels also provide more than 60% of total fuel consumption in shipping.

Of the 530 Mt of hydrogen produced in 2050, around 25% is produced within industrial facilities (including refineries), and the remainder is merchant hydrogen (hydrogen produced by one company to sell to others). Almost 30% of the low-carbon hydrogen used in 2050 takes the form of hydrogen-based fuels, which include ammonia and synthetic liquids and gases. An increasing share of hydrogen production comes from electrolysers, which account for 60% of total production in 2050. Electrolysers are powered by grid electricity, dedicated renewables in regions with excellent renewable resources and other low-carbon sources such as nuclear power. Rolling out electrolysers at the pace required in the NZE is a key challenge given the lack of manufacturing capacity today, as is ensuring the availability of sufficient electricity generation capacity. Global trade in hydrogen develops over time in the NZE, with large volumes exported from gas and renewables-rich areas in the Middle East, Central and South America and Australia to demand centres in Asia and Europe.

Table 2.7 ▷ Key deployment milestones for hydrogen and hydrogen-based fuels

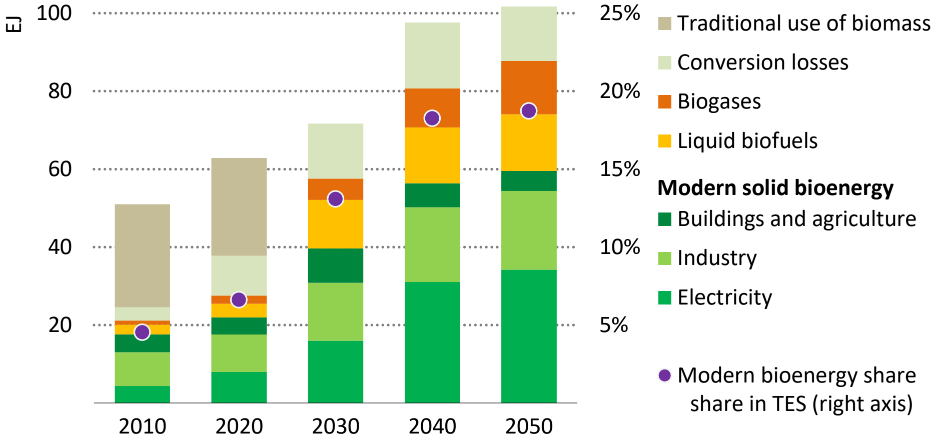
Sector	2020	2030	2050
Total production hydrogen-based fuels (Mt)	**87**	**212**	**528**
Low-carbon hydrogen production	9	150	520
share of fossil-based with CCUS	*95%*	*46%*	*38%*
share of electrolysis-based	*5%*	*54%*	*62%*
Merchant production	15	127	414
Onsite production	73	85	114
Total consumption hydrogen-based fuels (Mt)	**87**	**212**	**528**
Electricity	0	52	102
of which hydrogen	0	43	88
of which ammonia	0	8	13
Refineries	36	25	8
Buildings and agriculture	0	17	23
Transport	0	25	207
of which hydrogen	0	11	106
of which ammonia	0	8	44
of which synthetic fuels	0	5	56
Industry	51	93	187

Note: Hydrogen-based fuels are reported in million tonnes of hydrogen required to produce them.

2.5.6 Bioenergy

Global primary demand for bioenergy was almost 65 EJ in 2020, of which about 90% was solid biomass. Some 40% of the solid biomass was used in traditional cooking methods which is unsustainable, inefficient and polluting, and was linked to 2.5 million premature deaths in 2020. The use of solid biomass in this manner falls to zero by 2030 in the NZE, to achieve the UN Sustainable Development Goal 7. Increases in all forms of modern bioenergy more than offset this, with production rising from less than 40 EJ in 2020 to around 100 EJ in 2050 (Figure 2.20).[15] All bioenergy in 2050 comes from sustainable sources and the figures in the NZE for total bioenergy use are well below estimates of global sustainable bioenergy potential, thus avoiding the risk of negative impacts on biodiversity, fresh water systems, and food prices and availability (see section 2.7.2).

Figure 2.20 ▷ Total bioenergy supply in the NZE



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Modern bioenergy use rises to 100 EJ in 2050, meeting almost 20% of total energy needs. Global demand in 2050 is well below the assessed sustainable potential

Notes: TES = Total energy supply. Conversion losses occur during the production of biofuels and biogases.

Modern solid bioenergy use rises by about 3% each year on average to 2050. In the electricity sector, where demand reaches 35 EJ in 2050, solid bioenergy provides flexible low-emissions generation to complement generation from solar PV and wind, and it removes CO_2 from the atmosphere when equipped with CCUS. In 2050, electricity generation using bioenergy fuels reaches 3 300 TWh, or 5% of total generation. Bioenergy also provides around 50% of district heat production. In industry, where demand reaches 20 EJ in 2050, solid bioenergy provides high temperature heat and can be co-fired with coal to reduce the emissions intensity of

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[15] Modern bioenergy includes biogases, liquid biofuels and modern solid biomass harvested from sustainable sources. It excludes the traditional use of biomass.

existing generation assets. Demand is highest for paper and cement production: in 2050, bioenergy meets 60% of energy demand in the paper sector and 30% of energy demand for cement production. Modern solid bioenergy demand in buildings increases to nearly 10 EJ in 2030, most of it for use in improved cookstoves as unsustainable traditional uses of biomass disappear. Bioenergy is also increasingly used for space and water heating in advanced economies.

Household and village biogas digesters in rural areas provide a source of renewable energy and clean cooking for nearly 500 million households by 2030 in the NZE and total biogas use rises to 5.5 EJ in 2050 (from under 2 EJ in 2020).[16] Biomethane demand grows to 8.5 EJ, thanks to blending mandates for gas networks, with average blending rates increasing to above 80% in many regions by 2050. Half of total biomethane use is in the industry sector, where biomethane replaces natural gas as a source of process heat. The buildings and transport sectors each account for around a further 20% of biomethane consumption in 2050.

One of the key advantages of bioenergy is that it can use existing infrastructure. For example, biomethane can use existing natural gas pipelines and end-user equipment, while many drop-in liquid biofuels can use existing oil distribution networks and be used in vehicles with only minor or limited alterations. BioLPG – LPG derived from renewable feedstocks – is identical to conventional LPG and so can be blended and distributed in the same way. Sustainable bioenergy also provides a valuable source of employment and income for rural communities, reduces undue burdens on women often tasked with fuel collection, brings health benefits from reduced air pollution and proper waste management, and reduces methane emissions from inefficient combustion and the decomposition of waste.

Liquid biofuel consumption rises from 1.6 mboe/d in 2020 to 6 mboe/d in 2030 in the NZE, mainly used in road transport. After 2030, liquid biofuels grow more slowly to around 7 mboe/d in 2050 and their use shifts to shipping and aviation as electricity increasingly dominates road transport. Almost half of liquid biofuel use in 2050 is for aviation, where bio-kerosene accounts for around 45% of total fuel use in aircraft.

Bioenergy with carbon capture and storage (BECCS) plays a critical role in the NZE in offsetting emissions from sectors where the full elimination of emissions is very difficult to achieve. In 2050, around 10% of total bioenergy is used in facilities equipped with CCUS and around 1.3 Gt CO_2 is captured using BECCS. Around 45% of this CO_2 is captured in biofuels production, 40% in the electricity sector and the rest in heavy industry, notably cement production.

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[16] Biogas is a mixture of methane, CO_2 and small quantities of other gases produced by anaerobic digestion of organic matter in an oxygen free environment. Biomethane is a near pure source of methane produced either by removing CO_2 and other contaminants from biogas or through the gasification of solid biomass (IEA, 2020b).

Table 2.8 ▷ Key deployment milestones for bioenergy

	2020	2030	2050
Total energy supply (EJ)	**63**	**72**	**102**
Share of advanced biomass feedstock	27%	85%	97%
Modern gaseous bioenergy (EJ)	**2.1**	**5.4**	**13.7**
Biomethane	0.3	2.3	8.3
Modern liquid bioenergy (mboe/d)	**1.6**	**6.0**	**7.0**
Advanced biofuels	0.1	2.7	6.2
Modern solid bioenergy (EJ)	**32**	**54**	**74**
Traditional use of solid biomass (EJ)	**25**	**0**	**0**
Million people using traditional biomass for cooking	2 340	0	0

Notes: mboe/d = million barrels of oil equivalent per day. Bioenergy from forest plantings is considered advanced when forests are sustainably managed (see section 2.7.2).

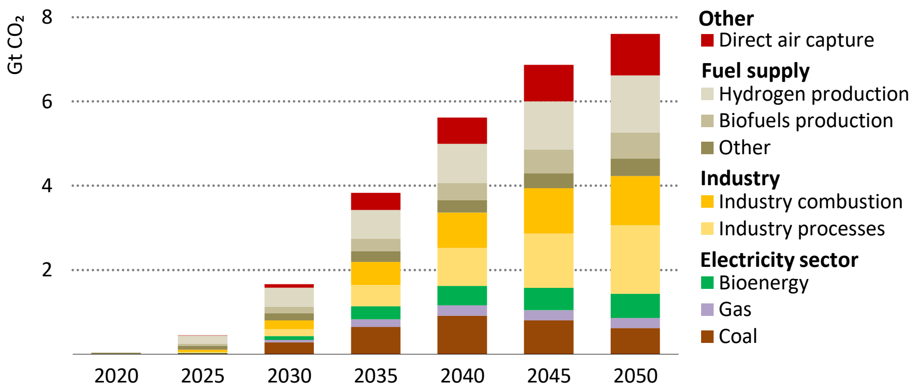
2.5.7 Carbon capture, utilisation and storage

CCUS can facilitate the transition to net-zero CO_2 emissions by: tackling emissions from existing assets; providing a way to address emissions from some of the most challenging sectors; providing a cost-effective pathway to scale up low-carbon hydrogen production rapidly; and allowing for CO_2 removal from the atmosphere through BECCS and DACCS.

In the NZE, policies support a range of measures to establish markets for CCUS investment and to encourage use of shared CO_2 transport and storage infrastructure by those involved in the production of hydrogen and biofuels, the operation of industrial hubs, and retrofitting of existing coal-fired power plants. Capture volumes in the NZE increase marginally over the next five years from the current level of around 40 Mt CO_2 per year, reflecting projects currently under development, but there is a rapid expansion over the following 25 years as policy action bears fruit. By 2030, 1.6 Gt CO_2 per year is captured globally, rising to 7.6 Gt CO_2 in 2050 (Figure 2.21). Around 95% of total CO_2 captured in 2050 is stored in permanent geological storage and 5% is used to provide synthetic fuels. Estimates of global geological storage capacity are considerably above what is necessary to store the cumulative CO_2 captured and stored in the NZE. A total of 2.4 Gt CO_2 is captured in 2050 from the atmosphere through bioenergy with CO_2 capture and direct air capture, of which 1.9 Gt CO_2 is permanently stored and 0.5 Gt CO_2 is used to provide synthetic fuels in particular for aviation.

Energy-related and process CO_2 emissions in industry account for almost 40% of the CO_2 captured in 2050 in the NZE. CCUS is particularly important for cement manufacturing. Although efforts are pursued in the NZE to produce cement more efficiently, CCUS remains central to efforts to limit the process emissions that occur during cement manufacturing. The electricity sector accounts for almost 20% of the CO_2 captured in 2050 (of which around 45% is from coal-fired plants, 40% from bioenergy plants and 15% from gas-fired plants). CCUS-equipped power plants contribute just 3% of total electricity generation in 2050 but the volumes of CO_2 captured are comparatively large. In emerging market and developing economies, where large numbers of coal power plants have been built relatively recently, retrofits play an important role where there are storage opportunities. In advanced economies, gas-fired plants with CCUS play a bigger role, providing dispatchable electricity at relatively low cost in regions with cheap natural gas and existing networks. In 2030, around 50 GW of coal-fired power plants (4% of the total at that time) and 30 GW of natural gas power plants (1% of the total) are equipped with CCUS, and this rises to 220 GW of coal (almost half of the total) and 170 GW of natural gas (7% of the total) capacity in 2050. A further 30% of CO_2 captured in 2050 comes from fuel transformation, including hydrogen and biofuels production as well as oil refining. The remaining 10% is from DAC, which is rapidly scaled up from several of pilot projects today to 90 Mt CO_2 per year in 2030 and just under 1 Gt CO_2 per year by 2050.

Figure 2.21 ▷ Global CO_2 capture by source in the NZE



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By 2050, 7.6 Gt of CO_2 is captured per year from a diverse range of sources. A total of 2.4 Gt CO_2 is captured from bioenergy use and DAC, of which 1.9 Gt CO_2 is permanently stored.

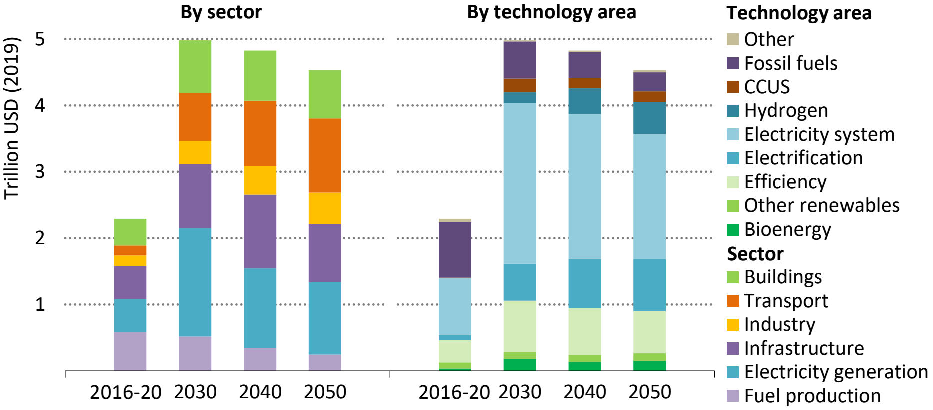
Table 2.9 ▷ Key global milestones for CCUS

	2020	2030	2050
Total CO_2 captured (Mt CO_2)	**40**	**1 670**	**7 600**
CO_2 captured from fossil fuels and processes	39	1 325	5 245
Power	3	340	860
Industry	3	360	2 620
Merchant hydrogen production	3	455	1 355
Non-biofuels production	30	170	410
CO_2 captured from bioenergy	1	255	1 380
Power	0	90	570
Industry	0	15	180
Biofuels production	1	150	625
Direct air capture	0	90	985
Removal	0	70	630

2.6 Investment

The radical transformation of the global energy system required to achieve net-zero CO_2 emissions in 2050 hinges on a big expansion in investment and a big shift in what capital is spent on. The NZE expands annual investment in energy from just over USD 2 trillion globally on average over the last five years to almost USD 5 trillion by 2030 and to USD 4.5 trillion by 2050 (Figure 2.22).[17] Total annual capital investment in energy in the NZE rises from around 2.5% of global GDP in recent years to about 4.5% in 2030 before falling back to 2.5% by 2050.

Figure 2.22 ▷ Annual average capital investment in the NZE



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Capital investment in energy rises from 2.5% of GDP in recent years to 4.5% by 2030; the majority is spent on electricity generation, networks and electric end-user equipment

Notes: Infrastructure includes electricity networks, public EV charging, CO_2 pipelines and storage facilities, direct air capture and storage facilities, hydrogen refuelling stations, and import and export terminals for hydrogen, fossil fuels pipelines and terminals. End-use efficiency investments are the incremental cost of improving the energy performance of equipment relative to a conventional design. Electricity systems include electricity generation, storage and distribution, and public EV charging. Electrification investments include spending in batteries for vehicles, heat pumps and industrial equipment for electricity-based material production routes.

The shift in what capital is spent on leads to annual investment in electricity generation rising from just over USD 500 billion over the last five years to more than USD 1 600 billion in 2030, before falling back as the cost of renewable energy technologies continues to decline. Annual nuclear investment rises too: it more than doubles by 2050 compared with current levels. Annual investment in fuel supply however drops from about USD 575 billion on average over

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[17] Investment levels presented in this report include a broader accounting of efficiency improvements in buildings than reported in the IEA World Energy Investment (IEA, 2020c) and so differ from the numbers presented there.

the last half-decade to USD 315 billion in 2030 and USD 110 billion in 2050. The share of fossil fuel supply in total energy sector investment drops from its 25% level in recent years to just 7% by 2050: this is partly offset by the rise in spending on low-emissions fuel supply, such as hydrogen, hydrogen-based fuels and bioenergy. Annual investment in these fuels increases to nearly USD 140 billion in 2050. Investment in transport increases significantly in the NZE from USD 150 per year in recent years to more than USD 1 100 billion in 2050: this stems mainly from the upfront cost of electric cars compared with conventional vehicles despite the decline in the cost of batteries.

By technology area, electrification is the dominant focus in the NZE. In addition to more investment in electricity generation, there is a huge increase in investment in expansion and modernisation of electricity networks. Annual investment rises from USD 260 billion on average in recent years to around USD 800 billion in 2030 and remains about that level to 2050. Such investment is needed to ensure electricity security in the face of rising electricity demand and the proportion of variable generation in the power mix. There is also a large increase in investment in the electrification of end-use sectors, which includes spending on EV batteries, heat pumps and electricity-based industrial equipment. In addition to investment in electrification, there is a moderate increase in investment in hydrogen to 2030 as production facilities are scaled up, and larger increases after as hydrogen use in transport expands: annual investment in hydrogen, including production facilities, refuelling stations and end-user equipment, reaches USD 165 billion in 2030 and over USD 470 billion in 2050. There is also an increase in global investment in CCUS (annual investment exceeds USD 160 billion by 2050 and in efficiency (around USD 640 billion annual investment by 2050, mostly for deep building retrofits and efficient appliances in the industry and buildings sectors).

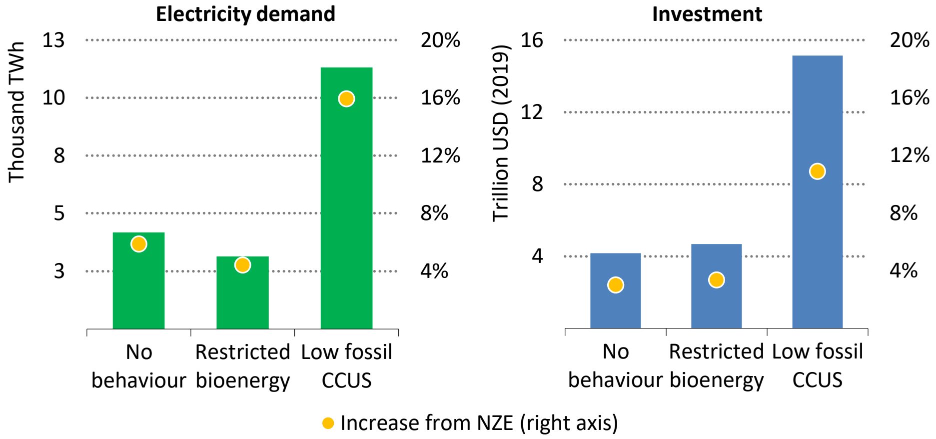
Financing the investment needed in the NZE involves redirecting existing capital towards clean energy technologies and substantially increasing the overall level of investment in energy. Most of this increase in investment comes from private sources, mobilised by public policies that create incentives, set appropriate regulatory frameworks and reform energy taxes. However, direct government financing is also needed to boost the development of new infrastructure projects and to accelerate innovation in technologies that are in the demonstration or prototype phase today. Projects in many emerging market and developing economies are often relatively reliant on public financing, and policies that ensure a predictable flow of bankable projects have an important role in boosting private investment in these economies, as does the scaling up of concessional debt financing and the use of development finance. There are extensive cross-country co-operation efforts in the NZE to facilitate the international flow of capital.

The large increase in capital investment in the NZE is partly compensated for by lower operating expenditure. Operating costs account today for a large share of the total cost of upstream fuel supply projects and fossil fuel generation projects: the clean technologies that play an increasing role in the NZE are characterised by much lower operating costs.

2.7 Key uncertainties

The road to net-zero emissions is uncertain for many reasons: we cannot be sure how underlying economic conditions will change, which policies will be most effective, how people and businesses will respond to market and policy signals, or how technologies and their costs will evolve from within or outside the energy sector. The NZE therefore is just one possible pathway to achieve net-zero emissions by 2050. Against this background, this section looks at what the implications would be if the assumptions in the NZE turn out to be off the mark with respect to behavioural change, bioenergy and CCUS for fossil fuels. These three areas were selected because the assumptions made about them involve a high degree of uncertainty and because of their critical contributions to achieve net-zero emissions by 2050.

Figure 2.23 ▷ Additional electricity demand in 2050 and additional investment between 2021-2050 for selected areas of uncertainty



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The absence of behaviour change, restrictions on bioenergy use and failure to develop fossil fuel CCUS would each raise investment to meet net-zero emissions by USD 4-15 trillion

Notes: No behaviour assumes none of the behavioural changes included in the NZE. Restricted bioenergy assumes no increase in land use for bioenergy production. Low fossil CCUS assumes no increase in fossil fuel-based CCUS apart from projects already approved or under construction.

Our analysis clearly highlights that more pessimistic assumptions would add considerably to both the costs and difficulty of achieving net-zero emissions by 2050 (Figure 2.23).

- Behavioural changes are important in reducing energy demand in transport, buildings and industry. If the changes in behaviour assumed in the NZE were not attainable, emissions would be around 2.6 Gt CO_2 higher in 2050. Avoiding these emissions through the use of additional low-carbon electricity and hydrogen would cost an additional USD 4 trillion.

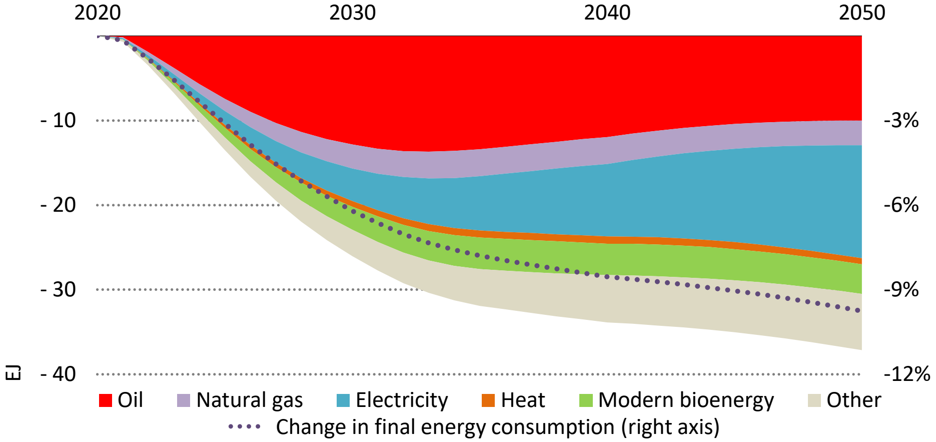
- Bioenergy use grows by 60% between 2020 and 2050 in the NZE and land use for its propagation increases by around 25%. Bioenergy use in 2050 in the NZE is well below current best estimates of global sustainable bioenergy potential, but there is a high degree of uncertainty concerning this level. If land use for bioenergy remains at today's level, bioenergy use in 2050 would be around 10% lower, and achieving net-zero emissions in 2050 would require USD 4.5 trillion extra investment.
- A failure to develop CCUS for fossil fuels would substantially increase the risk of stranded assets and would require around USD 15 trillion of additional investment in wind, solar and electrolyser capacity to achieve the same level of emissions reductions. It could also critically delay progress on BECCS and DACCS: if these cannot be deployed at scale, then achieving net-zero emissions by 2050 would be very much harder.

2.7.1 Behavioural change

Impact of behavioural changes in selected sectors in the NZE

Changes in the behaviour of energy consumers play an important role in cutting CO_2 emissions and energy demand growth in the NZE. Behavioural changes reduce global energy demand by 37 EJ in 2050, a 10% reduction in energy demand at that time, and without them cumulative emissions between 2021 and 2050 would be around 10% higher (Figure 2.24). Behavioural change plays a particularly important role in the transport sector.

Figure 2.24 ▷ Reduction in total final consumption due to behavioural changes by fuel in the NZE



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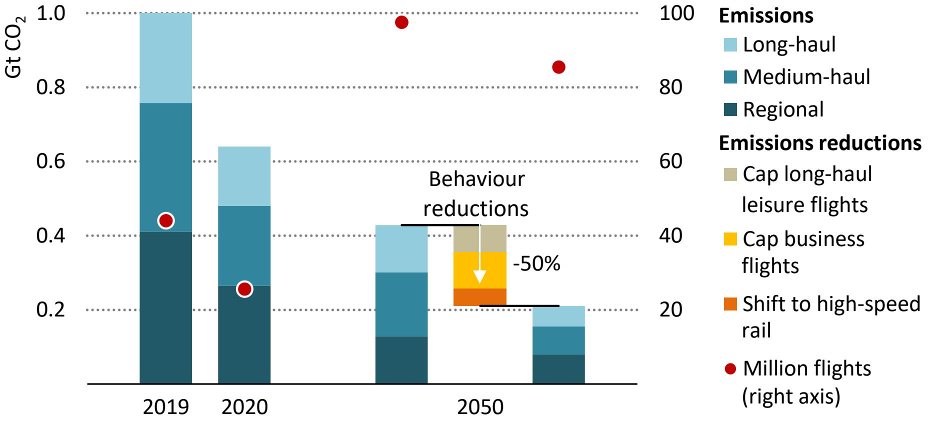
The impact of behaviour changes and materials efficiency on final energy consumption increases over time

Note: Other includes coal, hydrogen, geothermal, solar thermal, synthetic oil and synthetic gas.

Passenger aviation. Demand would grow more than threefold globally between 2020 and 2050 in the absence of the assumed changes in behaviour in the NZE. About 60% of this growth would occur in emerging market and developing economies. In the NZE, three changes lead to a 50% reduction in emissions from aviation in 2050, while reducing the number of flights by only 12% (Figure 2.25).

- Keeping air travel for business purposes at 2019 levels. Although business trips fell to almost zero in 2020, they accounted for just over one-quarter of air travel before the pandemic. This avoids around 110 Mt CO_2 in 2050 in the NZE.
- Keeping long-haul flights (more than six hours) for leisure purposes at 2019 levels. Emissions from an average long-haul flight are 35-times greater than from a regional flight (less than one hour). This affects less than 2% of flights but avoids 70 Mt CO_2 in 2050.
- A shift to high-speed rail. The opportunities for shifting regional flights to high-speed rail vary by region. Globally, we estimate that around 15% of regional flights in 2019 could have been shifted given existing rail infrastructure; future high-speed rail lines ensure that by 2050 around 17% could be shifted (IEA, 2019).[18] This would reduce emissions by around 45 Mt CO_2 in 2050 (high-speed trains generate no emissions in 2050 in the NZE).

Figure 2.25 ▷ Global CO_2 emissions from aviation and impact of behavioural changes in the NZE



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Demand for passenger aviation is set to grow significantly by 2050, but behavioural changes reduce emissions by 50% in 2050 despite reducing flights by only 12%

Notes: Long-haul = more than 6 hour flight; medium-haul = 1-6 hour flight; regional = less than 1 hour. Business flights = trips for work purposes; leisure flights = trips for leisure purposes. Average speeds vary by flight distance and range from 680-750 km/h.

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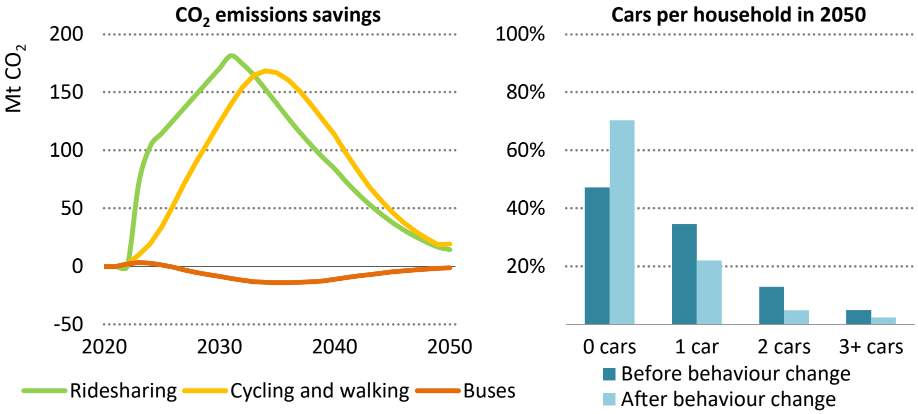
[18] This assumes that: new rail routes avoid water bodies and tunnelling through elevated terrain; travel times are similar to aviation; and centres of demand are sufficiently large to ensure that high-speed rail is economically viable.

Car use. A variety of new measures that aim to reduce the use of cars in cities and overall car ownership levels are assumed in the NZE. They lead to rapid growth in the rideshare market in urban areas, as well as phasing out polluting cars in large cities and replacing them with cycling, walking and public transport. The timing of these changes in the NZE depends on cities having the necessary infrastructure and public support to ensure a shift away from private car use. Between 20-50% of car trips are shifted to buses, depending on the city in question, with the remainder replaced by cycling, walking and public transport. These changes reduce emissions from cars in cities by more than 320 Mt CO_2 in total in the mid-2030s (Figure 2.26). Their impact on emissions fades over time as cars are increasingly electrified, but they still have a significant impact on curbing energy use in 2050.

Figure 2.26 ▷ Global CO_2 emissions savings and car ownership per household due to behavioural change in the NZE



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Policies discouraging car use in cities lead to rapid reductions in CO_2 emissions and lower car ownership levels, though the impact diminishes over time as cars are electrified

The gradual move away from cars in cities also has an impact on car ownership levels. Survey data indicates that car-share schemes and the provision of public transport reduces car ownership by up to 35%, with the biggest changes taking place in multiple car households (Jochem et al., 2020; Martin, Shaheen and Lidiker, 2010). Without behavioural changes, 35% of households would have a car in 2050; with behavioural changes this share falls to around 20% in the NZE, and two-car households fall from 13% of the total to less than 5%.

The changing patterns of mobility in cities in NZE have implications for materials demand. Reduced car ownership leads to a small drop in steel demand in 2050, saving around 40 Mt CO_2 in steel production. Increased cycling would need to be supported by building an estimated 80 000 km of new cycle lanes globally over the period to 2050, generating increased demand for cement and bitumen. This effect is small, however: the extra emissions associated with this would be less than 5% of the emissions avoided by lower car use.

How to bring about the behavioural changes in NZE

Regulations and mandates could enable roughly 70% of the emissions saved by behavioural changes in the NZE. Examples include:

- Upper speed limits, which are reduced over time in the NZE from their current levels to 100 km/h, cutting emissions from road vehicles by 3% in 2050.
- Appliance standards, which maximise energy efficiency in the buildings sector.
- Regulations covering heating temperatures in offices and default cooling temperatures for air conditioning units, which reduce excessive thermal demand.
- Changes initially tackled by market-based mechanisms, e.g. swapping regional flights for high-speed rail,[19] which can be addressed by regulation over time to mirror changes in public sentiment and consumer norms.

Market-based instruments use a mix of financial incentives and disincentives to influence decision making. They could enable around two-thirds of the emissions saved by behavioural changes in the NZE. Examples include:

- Congestion pricing and targeted interventions differentiated by vehicle type,[20] such as charges aimed at the most polluting vehicles, or preferential parking for clean cars.
- Transport demand measures that reduce travel, such as fuel taxes and distance-based vehicle insurance and registration fees (Byars, Wei and Handy, 2017).
- Information measures that help consumers to drive change, such as mandatory labelling of embodied or lifecycle emissions in manufacturing and a requirement for companies to disclose their carbon emissions.

Information and awareness measures could enable around 30% of the emissions saved by behavioural changes in the NZE. Examples include:

- Personalised and real-time travel planning information, which facilitates a switch to walking, cycling and public transport.
- Product labelling and public awareness campaigns in combination, which help make recycling widespread and habitual.
- Comparisons with consumption patterns of similar households, which can reduce wasteful energy use by up to 20% (Aydin, Brounen and Kok, 2018).

Not all the behavioural changes in the NZE would be equally easy to achieve everywhere, and policy interventions would need to draw on insights from behavioural science and take into account existing behavioural norms and cultural preferences. Some behavioural changes may be more socially acceptable than others. Citizen assemblies in the United Kingdom and

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[19] A law banning domestic flights where a rail alternative of under two-and-a-half hours exists has been proposed in France (Assemblee Nationale, 2021).

[20] Congestion charging is currently used in 11 major cities and has been shown to reduce traffic volumes by up to 27%. Low-emissions zones charge vehicles to enter urban zones based vehicle type and currently exist in 15 countries (TFL, 2021; Tools of Change, 2014; European Commission, 2021).

France indicate a large level of support for taxes on frequent and long-distance flyers and for banning polluting vehicles from city centres; conversely, measures that limit car ownership or reduce speed limits have gained less acceptance (Convention Citoyenne pour le Climat, 2021; Climate Assembly UK, 2020). Behavioural changes which reduce energy use in homes may be particularly well supported: a recent survey showed 85% support for line-drying clothes and switching off appliances, and only 20% of people felt that reducing temperature settings in homes was undesirable (Newgate Research and Cambridge Zero, 2021).

Table 2.10 ▻ Key behavioural changes in the NZE

	Policy options	Related policy-goals	Cost-effectiveness	Timeliness	Social acceptability	CO_2 emissions impact
Low-car cities • Phase out ICE cars from large cities. • Rideshare all urban car trips.	• Low-emissions zones. • Access restrictions. • Parking restrictions. • Registration caps. • Parking pricing. • Congestion charges. • Investment in cycling lanes and public transportation.	• Air pollution mitigation. • Public health. • Reduced congestion. • Urban space. • Beautification and liveability.	🟡	🟡	🟡	🟢
Fuel-efficient driving • Reduce motorway speeds to less than 100 km/h. • Eco-driving. • Raise air conditioning temperature in cars by 3 °C.	• Speed limits. • Real-time fuel efficiency displays. • Awareness campaigns.	• Road safety. • Reduced noise pollution.	🟢	🟢	🟡	🟢
Reduce regional flights • Replace all flights <1h where high-speed rail is a feasible alternative.	• High-speed rail investment. • Subsidies for high-speed rail travel. • Price premiums.	• Lower air pollution. • Lower noise pollution.	🔴	🔴	🟡	🟡
Reduce international flights • Keep air travel for business purposes at 2019 levels. • Keep long-haul flights for leisure at 2019 levels.	• Awareness campaigns. • Price premiums. • Corporate targets. • Frequent-flyer levies.	• Lower air pollution. • Lower noise pollution.	🟢	🟢	🟡	🟢
Space heating • Target average set-point temperatures of 19-20 °C.	• Awareness campaigns. • Consumption feedback. • Corporate targets.	• Public health. • Energy affordability.	🟢	🟢	🟢	🟢
Space cooling • Target average set-point temperatures of 24-25 °C.	• Awareness campaigns. • Consumption feedback. • Corporate targets.	• Public health. • Energy affordability.	🟢	🟢	🟢	🔴

🔴 = poor match 🟡 = neutral match 🟢 = good match

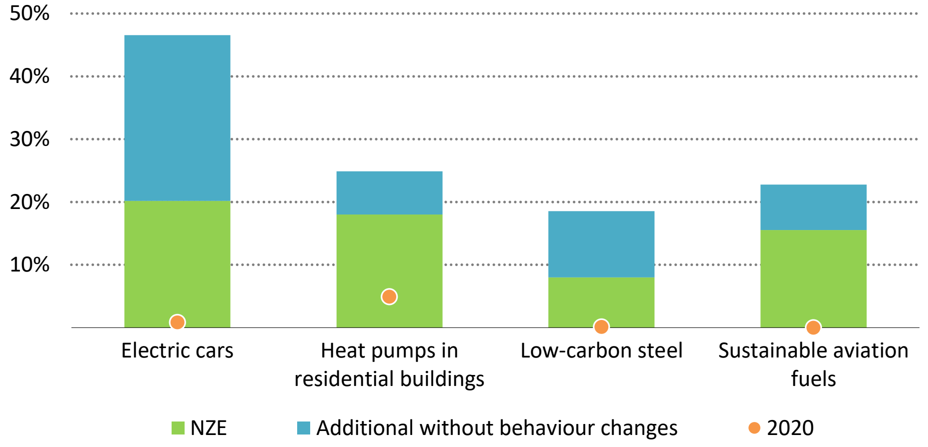
Notes: Large cities = cities over 1 million inhabitants. ICE = internal combustion engine. CO_2 emissions impact = cumulative reductions 2020-2050. Eco-driving = early upshifting as well as avoiding sudden acceleration, stops or idling. The number of jobs that can be done at home varies considerably by region, globally, an average of 20% of jobs can be done at home.

The behavioural changes in the NZE would bring wider benefits in terms of air pollution in cities, road safety, noise pollution, congestion and health. Attitudes to policy interventions can change quickly when co-benefits become apparent. For example, support for congestion charging in Stockholm jumped from less than 40% when the scheme was introduced to around 70% three years later; a similar trend was seen in Singapore, London and other cities, all of which experienced declines in air pollution after the introduction of charging (Tools of Change, 2014; DEFRA, 2012).

Are net-zero emissions by 2050 still possible without behavioural change?

If the behavioural changes described in the NZE were not to materialise, final energy use would be 27 EJ and emissions 1.7 Gt CO_2 higher in 2030, and they would be 37 EJ and 2.6 Gt CO_2 higher in 2050. This would further increase the already unprecedented ramp-up needed in low-carbon technologies. The share of EVs in the global car fleet would need to increase from around 20% in 2030 to 45% to ensure the same level of emissions reductions (Figure 2.27). Achieving the same reduction in emissions in homes would require electric heat pumps sales to reach 680 million in 2030 (compared with 440 million in the NZE). Without gains in materials efficiency, the share of low-carbon primary steel production would need to be more than twice as high in 2030 as in the NZE. In 2050, the use of sustainable aviation fuels would also need to rise to 7 mboe/d (compared with 5 mboe/d in the NZE). Emissions from cement and steel production would be 1.7 Gt CO_2 higher in 2050 than in the NZE, and so require increased deployment of CCUS in industry, deployment of electric arc furnaces and more use of low-carbon hydrogen.

Figure 2.27 ⊳ Share of low-carbon technologies and fuels with and without behavioural change in 2030 in the NZE



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In the absence of behavioural changes, the share of low-emissions technologies in end-uses in 2030 would need to be much larger to achieve the same emissions as in the NZE

Notes: Electric cars = share of electric cars on the road globally. Sustainable aviation fuels = biojet kerosene and synthetic jet kerosene. Low-carbon steel refers to primary steel production.

2.7.2 Bioenergy and land-use change

Modern forms of bioenergy play a key role in achieving net-zero emissions in the NZE. Bioenergy is a versatile renewable energy source that can be used in all sectors, and it can often make use of existing transmission and distribution infrastructure and end-user equipment. But there are constraints on expanding the supply of bioenergy: with finite potential for bioenergy production from waste streams, there are possible trade-offs between expanding bioenergy production, achieving sustainable development goals and avoiding conflicts with other land uses, notably food production.

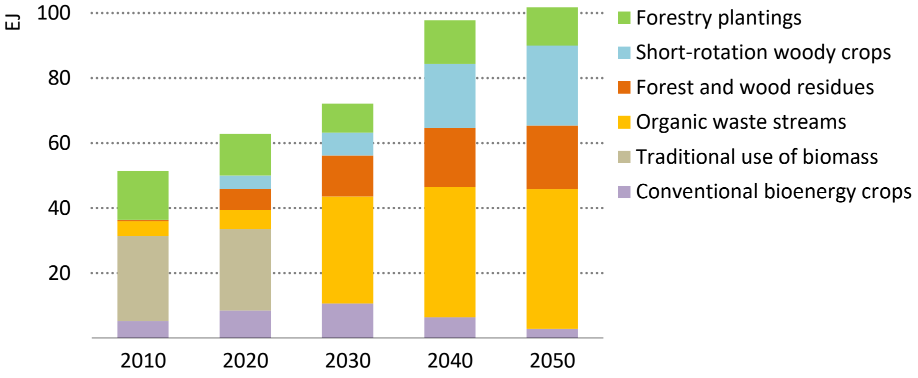
The level of bioenergy use in the NZE takes account of these constraints: bioenergy demand in 2050 is around 100 EJ. The global sustainable bioenergy potential in 2050 has been assessed to be at least 100 EJ (Creutzig, 2015) and recent assessments estimate a potential between 150-170 EJ when integrating relevant UN Sustainable Development Goals (Frank, 2021; IPCC, 2019; IPCC, 2014; Wu, 2019). However, there is a high degree of uncertainty over the precise levels of this potential. Using modelling developed in co-operation with IIASA, here we examine the implications for achieving net-zero CO_2 emissions by 2050 if the available levels of sustainable bioenergy were to be lower. We also examine what would need to be done to achieve large reductions in emissions from agriculture, forestry and other land use (AFOLU).

Ensuring a sustainable supply of bioenergy

Most liquid biofuels produced today come from dedicated bioenergy crops such as sugarcane, corn or oil crops, often known as conventional biofuels. The expanded use of feedstocks and arable land to produce these biofuels can conflict with food production. In the NZE, there is a shift towards the use of sustainable, certified agricultural products and wood. Biofuel production processes in the NZE use advanced conversion technologies coupled with CCUS where possible (see section 3.3.2). The emphasis is also on advanced bioenergy feedstocks, including waste streams from other processes, short-rotation woody crops and feedstocks that do not require the use of arable land. Advanced bioenergy accounts for the vast majority of bioenergy supply in the NZE by 2050. The use of conventional energy crops for biofuel production grows from around 9 EJ in 2020 to around 11 EJ in 2030, but then falls by 70% to 3 EJ in 2050 (including feedstocks consumed in the biofuel production processes).

Advanced bioenergy feedstocks that do not require land include organic waste streams from agriculture and industry, and woody residues from forest harvesting and wood processing. Investment in comprehensive waste collection and sorting in the NZE unlocks around 45 EJ of bioenergy supply from various organic waste streams which is primarily used to produce biogases and advanced biofuels (Figure 2.28). Woody residues from wood processing and forest harvesting provide a further 20 EJ of bioenergy in 2050 in the NZE – less than half of current best estimates of the total sustainable potential. Bioenergy can also be produced from dedicated short-rotation woody crops (25 EJ of bioenergy supply in 2050).[21] Sustainably managed forestry fuelwood or plantations[22] and tree plantings integrated with agricultural production via agroforestry systems that do not conflict with food production or biodiversity provide just over 10 EJ of bioenergy in 2050.

Figure 2.28 ▹ Global bioenergy supply by source in the NZE



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Bioenergy use increases by around 60% between 2020 and 2050, while shifting away from conventional feedstocks and the traditional use of biomass

Note: Organic waste streams include agricultural residues, food processing, industrial and municipal organic waste streams; they do not require land area.

Source: IEA analysis based on IIASA data.

The total land area dedicated to bioenergy production in the NZE increases from 330 million hectares (Mha) in 2020 to 410 Mha in 2050. In 2050, around 270 Mha is forest, representing around one-quarter of the total area of global managed forests, and around 5% of total forest area. There is 130 Mha of land used for short-rotation advanced bioenergy crops in 2050 and 10 Mha for conventional bioenergy crops. There is no overall increase in cropland use for bioenergy production in the NZE from today's level and no bioenergy crops are developed on forested land in the NZE.[23] As well as allowing a much greater level of bioenergy crop production on marginal lands, woody energy crops can produce twice as much bioenergy per hectare as conventional bioenergy crops.

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[21] Woody short-rotation coppice crops grown on crop land, pasture land or marginal lands not suited to food crops.

[22] Sustainable forestry management ensures that the carbon stock and carbon absorption capability of the forest is expanded or remains unchanged.

[23] Of the 140 Mha land used for bioenergy crops in 2050, 70 Mha are marginal lands or land currently used for livestock grazing and 70 Mha are cropland. There is a 60 Mha increase in cropland use for woody crops to 2050 in the NZE but this is offset by a reduction in cropland use for producing conventional biofuel feedstocks.

Total land use for bioenergy in the NZE is well below estimated ranges of potential land availability that take full account of sustainability constraints, including the need to protect biodiversity hotspots and to meet the UN Sustainable Development Goal 15 on biodiversity and land use. The certification of bioenergy products and strict control of what land can be converted to expand forestry plantations and woody energy crops nevertheless is critical to avoid land-use conflict issues. Certification is also critical to ensure the integrity of CO_2 offsets (see Chapter 1), the use of which should be carefully managed and restricted to sectors that lack alternative mitigation options. A related land-use issue is how to tackle emissions that arise from outside the energy sector (Box 2.3).

Box 2.3 ▷ Balancing emissions from land use, agriculture and forestry

To limit the global temperature rise, all sources of GHG emissions need to decline to close to zero or to be offset with CDR. The energy sector accounted for around three quarters of total GHG emissions in recent years. The largest source of GHG emissions other than the energy sector is agriculture, forestry and other land use (AFOLU), which produced between 10-12 Gt CO_2-eq net GHG emissions in recent years.[24] CO_2 emissions from AFOLU were around 5-6 Gt CO_2, and nitrous oxide and methane emissions were around 5-6 Gt CO_2-eq (IPCC, 2019).

Options to reduce emissions from AFOLU and enhance removals include: halting deforestation; improving forest management practices; instituting farming practices that increase soil carbon levels; and afforestation. A number of companies have recently expressed interest in these sorts of nature-based solutions to offset emissions from their operations (see Chapter 1). For afforestation, converting around 170 Mha (roughly half the size of India) to forests would sequester around 1 Gt CO_2 annually by 2050.

Achieving net-zero energy-related and industrial process CO_2 emissions by 2050 in the NZE does not rely on any offsets from outside the energy sector. But commensurate action on AFOLU would help limit climate change. The energy-sector transformation in the NZE would reduce CO_2 emissions from AFLOU in 2050 by around 150 Mt CO_2 given the switch away from conventional crops and the increase in short rotation advanced-bioenergy crop production on marginal lands and pasture land. To reduce emissions from AFOLU further would require reducing deforestation by two-thirds by 2050, instituting improved forest management practices and planting around 250 Mha of new forests. The combined impact of these changes would reduce CO_2 emissions from AFOLU to zero by 2040 and absorb 1.3 Gt CO_2 annually by 2050. In this case, cumulative AFOLU CO_2 emissions between 2020 and 2050 would be around 40 Gt CO_2.

Non-CO_2 emissions from livestock, as well as other agricultural emissions, may be more difficult to mitigate given the link between livestock production and nitrous oxide and methane emissions. Changes to farming practices and technology improvements,

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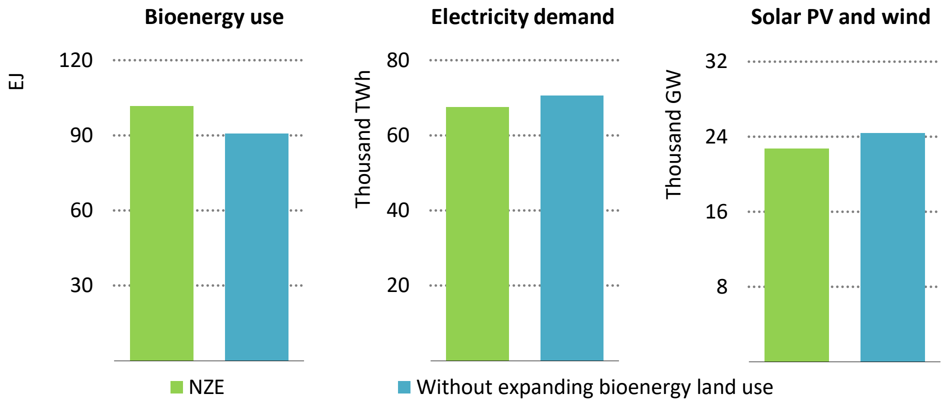
[24] AFOLU emissions are emissions from anthropogenic activities and do not include CO_2 emissions removal from the atmosphere by natural land sinks.

including changes to animal feed, could help to reduce these emissions, but it may be necessary to use afforestation to offset these emissions entirely. An alternative could be to reduce these emissions by reducing the demand for livestock products. For example, we estimate that reducing meat consumption in households with the highest levels of per capita consumption today to the global average level would reduce GHG emissions by more than 1 Gt CO_2-eq in 2050. Lower demand for livestock products would reduce the pasture needed globally for livestock by close to 200 Mha and the cropland that is used to grow feed for livestock by a further 80 Mha.

Are net-zero emissions by 2050 possible without expanding land use for bioenergy?

Estimates of the global sustainable bioenergy potential are subject to a high degree of uncertainty, in particular over the extent to which new land area could sustainably be converted to bioenergy production. As a result, the NZE takes a cautious approach to bioenergy use, with consumption in 2050 (100 EJ) well below the latest estimates that integrate relevant SDGs, which suggest a potential between 150-170 EJ. But it is possible that the land available to provide sustainable bioenergy is even more limited. Here we explore the implications for emissions of restricting land use for dedicated bioenergy crops and forestry plantations to around 330 Mha, which is what is used today.

Figure 2.29 ▷ Impact on electricity demand and ability to achieve net-zero emissions by 2050 without expanded bioenergy land use



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Achieving net-zero emissions without expanding bioenergy land use would require a further 3 200 TWh from solar PV and wind, increasing capacity in the NZE by nearly 10%

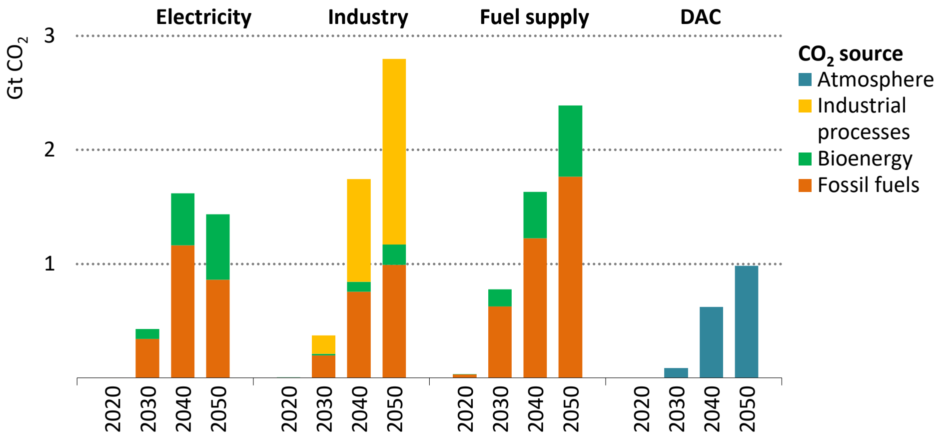
Limiting land use to 330 Mha would reduce available bioenergy supply in 2050 by more than 10 EJ. This would mostly take the form of a reduction in the availability of short-rotation woody energy crops, which are mainly used in the NZE in place of fossil fuels to provide high temperature heat for industrial processes and for electricity generation. Without bioenergy, it is likely that hydrogen and synthetic methane would be used instead, and their production would require around 70 Mt of hydrogen in 2050 (15% more than in the NZE). If this were to be produced through the use of electrolysis it would require around 750 GW of electrolyser capacity and increase electricity demand in 2050 by around 3 200 TWh (Figure 2.29).

The additional electricity that would be needed could be produced using renewables, which would require an additional 1 700 GW of wind and solar PV capacity and almost 350 GW of additional battery capacity in 2050. Annual capacity additions during the 2030s would need to be 160 GW higher than in the NZE. The additional wind, solar, battery and electrolyser capacity, together with the electricity networks and storage needed to support this higher level of deployment would cost more than USD 5 trillion by 2050. This is USD 4.5 trillion more than would be needed if the use of bioenergy were to be expanded as envisaged in the NZE, and would increase the total investment needed in the NZE by 3%. While it might therefore be possible still to achieve net-zero emissions in 2050 without expanding land use for bioenergy, this would make the energy transition significantly more expensive.

2.7.3 CCUS applied to emissions from fossil fuels

A total of 7.6 Gt CO_2 is captured in 2050 in the NZE, almost 50% of which is from fossil fuel combustion, 20% is from industrial processes, and around 30% is from bioenergy use with CO_2 capture and DAC (Figure 2.30). The use of CCUS with fossil fuels provides almost 70% of the total growth in CCUS to 2030 in the NZE. Yet the prospects for the rapid scaling up of CCUS are very uncertain for economic, political and technical reasons. Here we look at the implications for reaching net-zero emissions in 2050 if fossil fuel CCUS does not expand beyond existing and planned projects.

Figure 2.30 ▷ CCUS by sector and emissions source in the NZE



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Fossil fuel emissions account for almost 70% of total CO_2 capture in 2030 and almost 50% in 2050

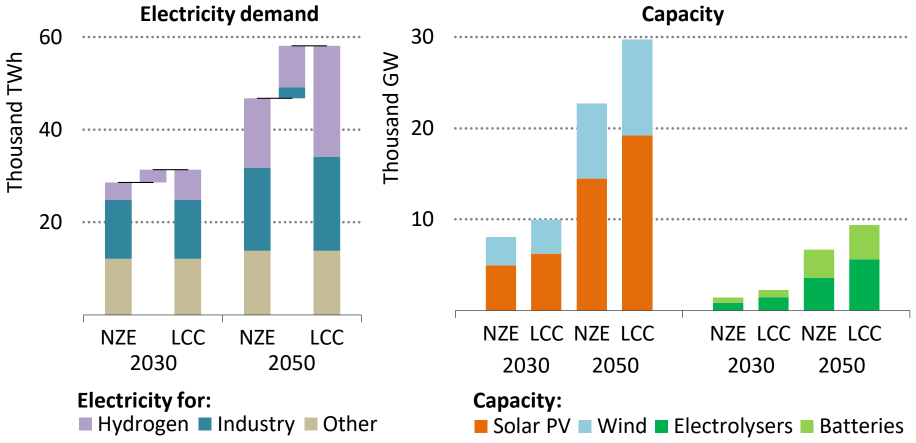
Note: DAC = direct air capture.

Are net-zero emissions by 2050 possible without fossil fuel-based CCUS?

Fossil fuel-based CCUS applications comprise most of the CCUS projects added to 2030 in the NZE. These projects help to reduce risks for other non-fossil fuel CCUS applications that are essential to reach net zero. In view of the challenges that fossil fuel-based CCUS projects face, we have constructed a *Low CCUS Case (LCC)* in which no new fossil fuel CCUS projects are developed beyond those already under construction or approved for development. In the LCC, CO_2 emissions captured from fossil fuels are only around 150 Mt in 2050, compared with 3 600 Mt in 2050 in the NZE.

In industry, the lack of new fossil fuel CCUS projects leads in the LCC to 1.2 Gt of additional CO_2 emissions compared with the NZE in 2050. It would be necessary to use alternative technologies to eliminate these emissions in order to achieve net zero by 2050. A number of technologies that are at the prototype stage of development would be needed, such as electric cement kilns or electric steam crackers for high-value chemicals production (see Box 2.4). Assuming that these technologies could be demonstrated and deployed at scale, this would increase electricity demand by around 2 400 TWh and hydrogen demand in industry by around 45 Mt in 2050. It would also be necessary to replace the 145 Mt of hydrogen that is produced in the NZE from fossil fuels equipped with CCUS. Provision of this 190 Mt of hydrogen through electrolysis would require an additional 2 000 GW capacity of electrolysers in 2050 (almost 60% more than in the NZE) and an additional 9 000 TWh of electricity (Figure 2.31).

Figure 2.31 ▷ Impacts of achieving net-zero emissions by 2050 without expanded fossil fuel-based CCUS



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Failure to deploy fossil fuel-based CCUS would significantly increase electricity demand and require much more solar, wind and electrolyser capacity

Note: LCC = Low CCUS Case where CCUS applied to fossil fuels is restricted to projects under construction or approved for development today.

Box 2.4 ▻ Technology innovation in the NZE

Innovation is key to developing new clean energy technologies and advancing existing ones. The importance of innovation increases as we get closer to 2050 because existing technologies will not be able to get us all the way along the path to net-zero emissions. Almost 50% of the emissions reductions needed in 2050 in the NZE depend on technologies that are at the prototype or demonstration stage, i.e. are not yet available on the market (see Chapter 4).

After a new idea makes its way from the drawing board to the laboratory and out into the world, there are four key stages in the clean energy innovation pipeline (IEA, 2020d). But the pathway to maturity can be long and success is not guaranteed.

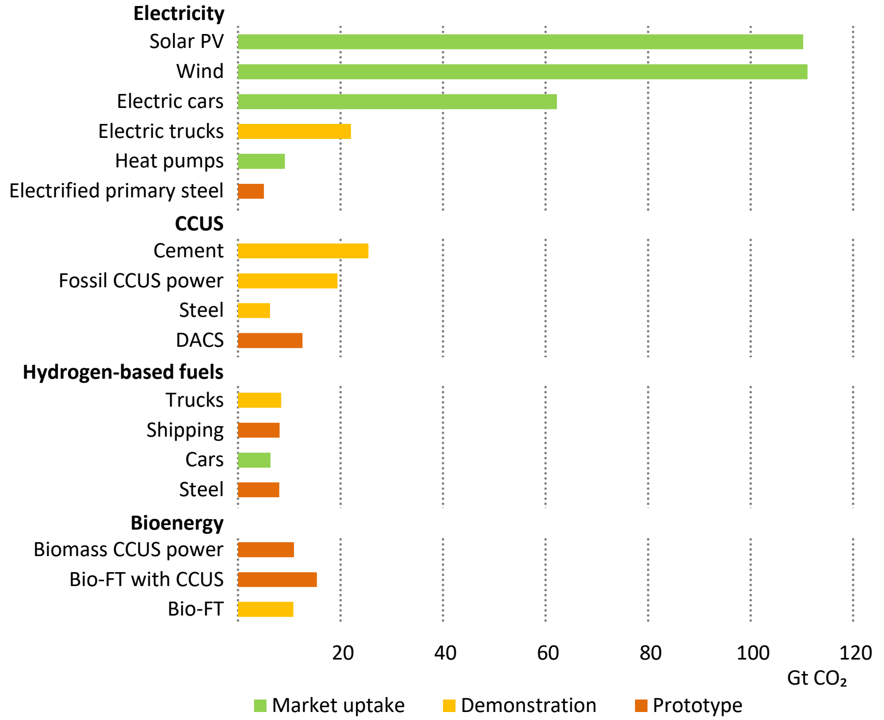
- **Prototype.** A concept is developed into a design and then into a prototype for a new device, e.g. a furnace that produces steel with pure hydrogen instead of coal.
- **Demonstration.** The first examples of a new technology are introduced at the size of a full-scale commercial unit, e.g. a system that captures CO_2 emissions from cement plants.
- **Market uptake.** The technology is being deployed in a number of markets. However, it either has a cost and performance gap with established technologies (e.g. electrolysers for hydrogen production) or it is competitive but there are still barriers, such as integration with existing infrastructure or consumer preferences, to reaching its full market potential (e.g. heat pumps). Policy attention is needed in both cases to stimulate wider diffusion to reduce costs and to overcome existing barriers, with more of the costs and risks being borne gradually by the private sector.
- **Maturity.** The technology has reached market stability, and new purchases or installations are constant or even declining in some environments as newer technologies start to compete with the stock of existing assets, e.g. hydropower turbines.

Innovation is critical in the NZE to bring new technologies to market and to improve emerging technologies, including for electrification, CCUS, hydrogen and sustainable bioenergy. The degree of reliance on innovation in the NZE varies across sectors and along the various steps of the value chains involved (Figure 2.32).

- **Electrification.** Almost 30% of the 170 Gt CO_2 cumulative emissions reductions from the use of low-emissions electricity in the NZE comes from technologies that are currently at prototype or demonstration stage, such as electricity-based primary steel production or electric trucks.
- **Hydrogen.** Not all steps of the low-carbon hydrogen value chain are available on the market today. The majority of demand technologies, such as hydrogen-based steel production, are only at the demonstration or prototype stage. These deliver more than 75% of the cumulative emissions reductions in the NZE related to hydrogen.

- **CCUS.** Around 55% of the cumulative emissions reductions that come from CCUS in the NZE are from technologies that are at the demonstration or prototype stage today. While CO_2 capture has been in use for decades in certain industrial and fuel transformation processes, such as ammonia production and natural gas processing, it is still being demonstrated at a large scale in many of the other possible applications.
- **Bioenergy.** Around 45% of the cumulative emissions reductions in the NZE related to sustainable bioenergy come from technologies that are at the demonstration or prototype stage today, mainly for the production of biofuels.

Figure 2.32 ▹ Cumulative CO_2 emissions reductions for selected technologies by maturity category in the NZE



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CCUS, hydrogen and bioenergy technologies are less mature than electrification. Most technologies for heavy industry and trucks are at early stages of development.

Notes: Bio-FT = Biomass gasification with Fischer-Tropsch synthesis. Maturity levels are the technology design at the most advanced stage.

In the electricity sector, it would be necessary to produce an additional 11 300 TWh of electricity for industry and fuel transformation and to replace virtually all of the electricity generated from fossil fuel powered plants equipped with CCUS in 2050 in the NZE. Using renewables, this would require an additional 7 000 GW of wind and solar PV capacity in 2050. This is around 30% more than in the NZE, and would mean that annual capacity additions of solar PV and wind during the 2030s would need to reach 1 300 GW (300 GW more than in the NZE). To accommodate this additional level of variable renewables and to provide the flexibility that is available from fossil fuel CCUS equipped plants in the NZE, around 660 GW more battery capacity would be needed in 2050 (20% more than in the NZE in in 2050), together with additional 110 GW of other dispatchable capacity.

Reducing the rate of adding CCUS at existing coal- and gas-fired generation plants in the LCC would also raise the risk of stranded assets. We estimate that up to USD 90 billion of existing coal- and gas-fired capacity could be stranded in 2030 and up to USD 400 billion by 2050. Investment in fossil fuel-based CCUS in the NZE to 2050 is around USD 650 billion, which would be avoided in the LCC. But additional investment is required in the LCC for extra wind, solar and electrolyser capacity, for electricity-based routes in heavy industry, and for expanded electricity networks and storage to support this higher level of deployment. As a result, the additional cumulative investment to reach net-zero emissions in 2050 in the LCC is USD 15 trillion higher than in the NZE.

Failure to develop CCUS for fossil fuels would also be likely to delay or prevent the development of other CCUS applications. Without fossil fuel-based CCUS, the number of users and the volumes of the CO_2 transport and storage infrastructure deployed around industrial clusters would be reduced. Fewer actors and more limited pools of capital would be available to incur the high upfront costs of infrastructure, as well as other risks associated with the initial roll-out of CCUS infrastructure clusters. In addition, there would be fewer spill-over learning and cost-reduction benefits from developing fossil fuel-based CCUS, making the successful demonstration and scale up of more nascent CCUS technologies much less likely. A delay in the development of other CCUS technologies would have a major impact on the prospect of getting to net-zero emissions in 2050. For example, CCUS is the only scalable low-emissions option to remove CO_2 from the atmosphere and to almost eliminate emissions from cement production. If progress in these technologies were delayed and could not be deployed at scale, then achieving net-zero emissions by 2050 would be vastly more difficult.

Sectoral pathways to net-zero emissions by 2050

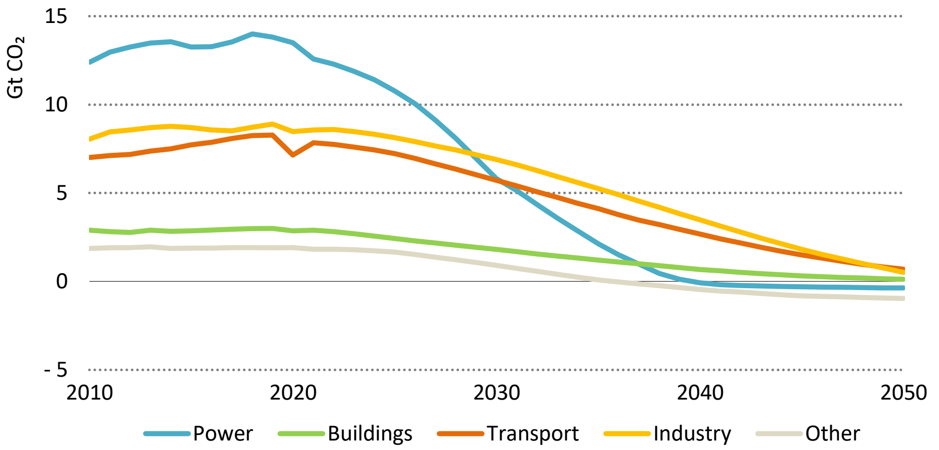
SUMMARY

- Fossil fuel use falls drastically in the Net-Zero Emissions Scenario (NZE) by 2050, and no new oil and natural gas fields are required beyond those that have already been approved for development. No new coal mines or mine extensions are required. Low-emissions fuels – biogases, hydrogen and hydrogen-based fuels – see rapid growth. They account for almost 20% of global final energy in 2050, compared with 1% in 2020. More than 500 Mt of low-carbon hydrogen is produced in 2050, of which about 60% is produced using electrolysis that accounts for 20% of global electricity generation in 2050. Liquid biofuels provide 45% of global aviation fuel in 2050.
- Electricity demand grows rapidly in the NZE, rising 40% from today to 2030 and more than two-and-a-half-times to 2050, while emissions from generation fall to net-zero in aggregate in advanced economies by 2035 and globally by 2040. Renewables drive the transformation, up from 29% of generation in 2020 to 60% in 2030 and nearly 90% in 2050. From 2030 to 2050, 600 GW of solar PV and 340 GW of wind are added each year. The least-efficient coal plants are phased out by 2030 and all unabated coal by 2040. Investment in electricity grids triples to 2030 and remains elevated to 2050.
- In industry**,** emissions drop by 20% to 2030 and 90% to 2050. Around 60% of heavy industry emissions reductions in 2050 in the NZE come from technologies that are not ready for market today: many of these use hydrogen or CCUS. From 2030, all new industry capacity additions are near-zero emissions. Each month from 2030, the world equips 10 new and existing heavy industry plants with CCUS, adds 3 new hydrogen-based industrial plants and adds 2 GW of electrolyser capacity at industrial sites.
- In transport, emissions drop by 20% to 2030 and 90% to 2050. The initial focus is on increasing the operational and technical efficiency of transport systems, modal shifts, and the electrification of road transport. By 2030, electric cars account for over 60% of car sales (4.6% in 2020) and fuel cell or electric vehicles are 30% of heavy truck sales (less than 0.1% in 2020). By 2035, nearly all cars sold globally are electric, and by 2050 nearly all heavy trucks sold are fuel cell or electric. Low-emissions fuels and behavioural changes help to reduce emissions in long-distance transport, but aviation and shipping remain challenging and account for 330 Mt CO_2 emissions in 2050.
- In buildings**,** emissions drop by 40% to 2030 and more than 95% to 2050. By 2030, around 20% of the existing building stock worldwide is retrofitted and all new buildings comply with zero-carbon-ready building standards. Over 80% of the appliances sold are the most efficient models available by 2025 in advanced economies and by the mid-2030s worldwide. There are no new fossil fuel boilers sold from 2025, except where they are compatible with hydrogen, and sales of heat pumps soar. By 2050, electricity provides 66% of energy use in buildings (33% in 2020). Natural gas use for heating drops by 98% in the period to 2050.

3.1 Introduction

The Net-Zero Emissions by 2050 Scenario (NZE) involves a global energy system transformation that is unparalleled in its speed and scope. This chapter looks at how the main sectors are transformed, as well as the specific challenges and opportunities this involves (Figure 3.1). It covers the supply of fossil and low-emissions fuels, electricity generation and the three main end-use sectors – industry, transport and buildings. For each sector, we set out some key technology and infrastructure milestones on which the NZE depends for its successful delivery. Further we discuss what key policy decisions are needed, and by when, to achieve these milestones. Recognising that there is no single pathway to achieve net-zero emissions by 2050 and that there are many uncertainties related to clean energy transitions, in this chapter we also explore the implications of choosing not to rely on certain fuels, technologies or emissions reduction options across the transformation and end-use sectors.

Figure 3.1 ▷ CO_2 emissions by sector in the NZE



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Emissions fall fastest in the power sector, with transport, buildings and industry seeing steady declines to 2050. Reductions are aided by the increased availability of low-emissions fuels

Note: Other = agriculture, fuel production, transformation and related process emissions, and direct air capture.

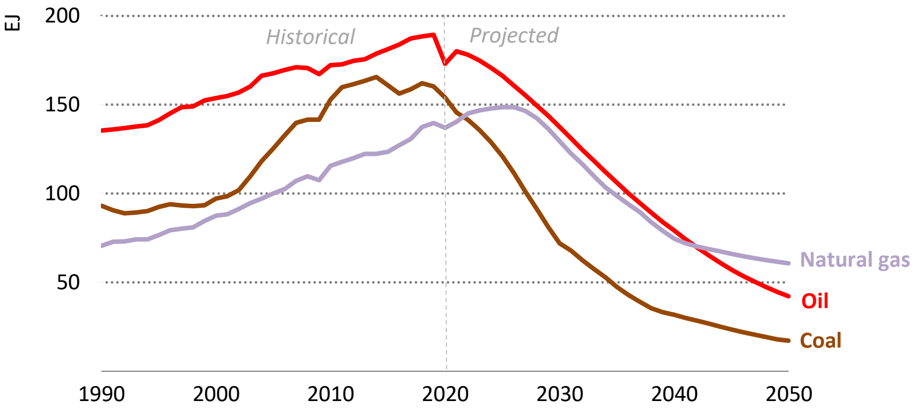
3.2 Fossil fuel supply

3.2.1 Energy trends in the Net-Zero Emissions Scenario

Coal use declines from 5 250 million tonnes of coal equivalent (Mtce) in 2020 to 2 500 Mtce in 2030 and to less than 600 Mtce in 2050. Even with increasing deployment of carbon capture, utilisation and storage (CCUS), coal use in 2050 is 90% lower than in 2020

(Figure 3.2). Oil demand never returns to its 2019 peak and it declines from 88 million barrels per day (mb/d) in 2020 to 72 mb/d in 2030 and to 24 mb/d in 2050, a fall of almost 75% between 2020 and 2050. Natural gas quickly rebounds from the dip in demand in 2020 and rises through to the mid-2020s, reaching a peak of around 4 300 billion cubic metres (bcm), before dropping to 3 700 bcm in 2030 and to 1 750 bcm in 2050. By 2050, natural gas use is 55% lower than in 2020.

Figure 3.2 ▻ **Coal, oil and natural gas production in the NZE**



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Between 2020 and 2050, demand for coal falls by 90%, oil by 75%, and natural gas by 55%

Oil

The trajectory of oil demand in the NZE means that no exploration for new resources is required and, other than fields already approved for development, no new oil fields are necessary. However, continued investment in existing sources of oil production are needed. On average oil demand in the NZE falls by more than 4% per year between 2020 and 2050. If all capital investment in producing oil fields were to cease immediately, this would lead to a loss of over 8% of supply each year. If investment were to continue in producing fields but no new fields were developed, then the average annual loss of supply would be around 4.5% (Figure 3.3). The difference is made up by fields that are already approved for development.

These dynamics are reflected in the oil price in the NZE, which drops to around USD 35/barrel in 2030 and USD 25/barrel in 2050. This price trajectory is largely determined by the operating costs for fields currently in operation, and only a very small volume of existing production would need to be shut in. However, income from oil production in all countries is much lower in the NZE than in recent years,[1] and the NZE projects significant stranded

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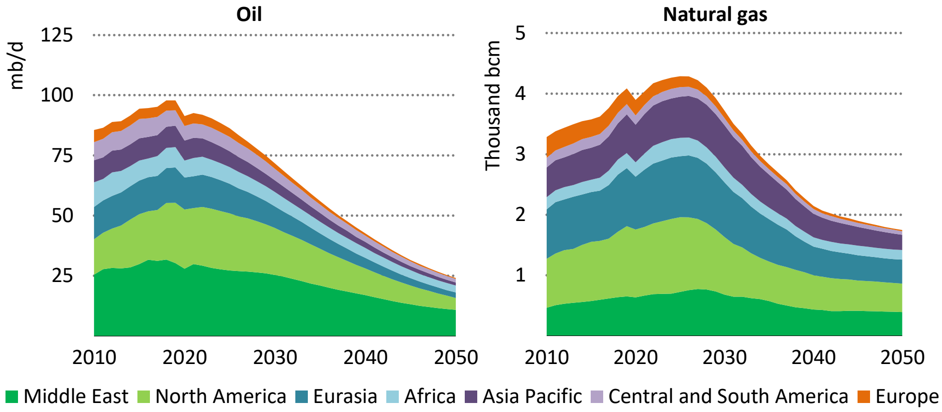
[1] Governments may also reduce or eliminate upstream taxes to ensure that production costs are below the oil price to maintain domestic production.

capital and stranded value.[2] The oil price in the NZE would be sufficient in principle to cover the cost of developing new fields for the lowest cost producers, including those in the Middle East, but it is assumed that major resource holders do not proceed with investment in new fields because doing so would create significant additional downward pressure on prices.

The refining sector also faces major challenges in the NZE. Refinery throughput drops considerably and there are significant changes in product demand. With rapid electrification of the vehicle fleet, there is a major drop in demand for traditional refined products such as gasoline and diesel, while demand for non-combusted products such as petrochemicals increases. In recent years, around 55% of oil demand was for gasoline and diesel, but this drops to less than 15% in 2050, while the share of ethane, naphtha and liquefied petroleum gas (LPG) rises from 20% in recent years to almost 60% in 2050. This shift accentuates the drop in oil demand for refiners, and refinery runs fall by 85% between 2020 and 2050. Refiners are used to coping with changing demand patterns, but the scale of the changes in the NZE would inevitably lead to refinery closures, especially for refineries not able to concentrate primarily on petrochemical operations or the production of biofuels.

Figure 3.3 ▻ **Oil and natural gas production in the NZE**



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No new oil and natural gas fields are required beyond those already approved for development. Supply is increasingly concentrated in a few major producing countries

Natural gas

No new natural gas fields are needed in the NZE beyond those already under development. Also not needed are many of the liquefied natural gas (LNG) liquefaction facilities currently under construction or at the planning stage. Between 2020 and 2050, natural gas traded as

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[2] Stranded capital is capital investment in fossil fuel infrastructure that is not recovered over the operating lifetime of the asset because of reduced demand or reduced prices resulting from climate policies. Stranded value is a reduction in the future revenue generated by an asset or asset owner assessed at a given point in time because of reduced demand or reduced prices resulting from climate policies (IEA, 2020a).

LNG falls by 60% and trade by pipeline falls by 65%. During the 2030s, global natural gas demand declines by more than 5% per year on average, meaning that some fields may be closed prematurely or shut in temporarily. Declines in natural gas demand slow after 2040, and more than half of natural gas use globally in 2050 is to produce hydrogen in facilities with CCUS. The large level of hydrogen, also produced using electrolysis, and biomethane in the NZE, means that the decline in total gaseous fuels is more muted than the decline in natural gas. This has important implications for the future of the gas industry (see Chapter 4).

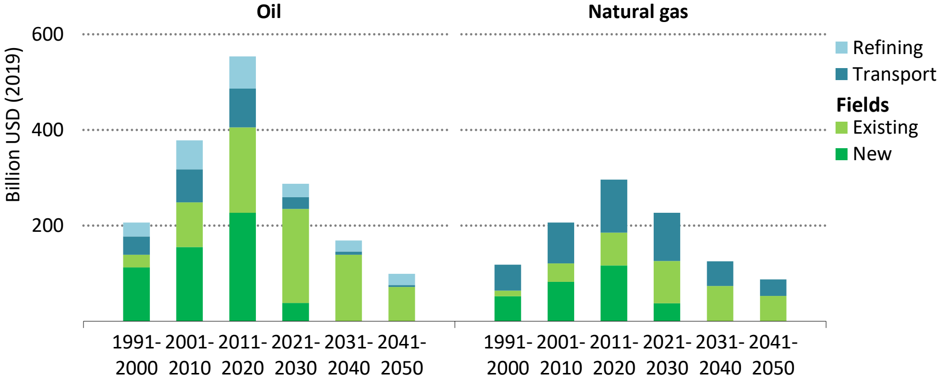
Coal

No new coal mines or extensions of existing ones are needed in the NZE as coal demand declines precipitously. Demand for coking coal falls at a slightly slower rate than for steam coal, but existing sources of production are sufficient to cover demand through to 2050. Such a decline in coal demand would have major consequences for employment in coal mining regions (see Chapter 4). There is a slowdown in the rate of decline in the 2040s as coal production facilities are increasingly equipped with CCUS: in the NZE, around 80% of coal produced in 2050 applies CCUS.

3.2.2 Investment in oil and gas

Upstream oil and gas investment averages about USD 350 billion each year from 2021 to 2030 in the NZE (Figure 3.4). This is similar to the level in 2020, but around 30% lower than average levels during the previous five years. Once fields under development start production, all of the upstream investment in the NZE is to support operations in existing fields; after 2030, total annual upstream investment is around USD 170 billion each year.

Figure 3.4 ▷ Investment in oil and natural gas supply in the NZE



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Once fields under development start production, all upstream oil and gas investment is spent on maintaining production at existing fields

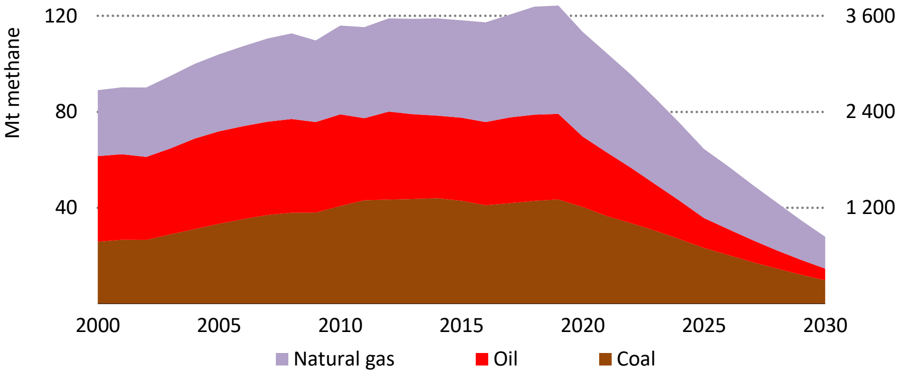
Note: Investment in new fields in the 2021-2030 period is for projects that are already under construction or have been approved.

3.2.3 Emissions from fossil fuel production

Emissions from the supply chains of coal, oil and natural gas fall dramatically in the NZE. The global average greenhouse gas (GHG) emissions intensity of oil production today is just under 100 kilogrammes of carbon-dioxide equivalent (kg CO_2-eq) per barrel. Without changes, a large proportion of global production would become uneconomic, as CO_2 prices are applied to the full value chains of fossil fuels. For example, by 2030 the CO_2 price in advanced economies in the NZE is USD 100 per tonne of CO_2 (tCO_2), which would add USD 10 to the cost of producing each barrel at today's average level of emissions intensity.

Methane constitutes about 60% of emissions from the coal and natural gas supply chains and about 35% of emissions from the oil supply chain. In the NZE, total methane emissions from fossil fuels fall by around 75% between 2020 and 2030, equivalent to a 2.5 gigatonne of carbon-dioxide equivalent (Gt CO_2-eq) reduction in GHG emissions (Figure 3.5). Around one-third of this decline is a result of an overall reduction in fossil fuel consumption, but the larger share comes from a huge increase in the deployment of emissions reduction measures and technologies, which leads to the elimination of all technically avoidable methane emissions by 2030 (IEA, 2020a).

Figure 3.5 ▷ Methane emissions from coal, oil and natural gas in the NZE



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Methane emissions from fossil fuels fall by 75% between 2020 and 2030 as result of a concerted global effort to deploy all available reduction measures and technologies

Note: Mt = million tonnes.

Actions to reduce the emissions intensity of existing oil and gas operations in the NZE leads to: the end of all flaring; the use of CCUS with centralised sources of emissions (including to capture natural sources of CO_2 that are often extracted with natural gas); and significant electrification of upstream operations (often making use of off-grid renewable energy sources).

The NZE inevitably brings significant challenges for fossil fuel industries and those who work in them, but it also brings opportunities. Coal mining declines dramatically in the NZE, but the mining of minerals needed for clean energy transitions increases very rapidly, and mining expertise is likely to be highly valued in this context. The oil and gas industry could play a key role in helping to develop at scale a number of clean energy technologies such as CCUS, low-carbon hydrogen, biofuels and offshore wind. Scaling up these technologies and bringing down their costs will rely on large-scale engineering and project management capabilities, qualities that are a good match to those of large oil and gas companies. These issues, including the question of how to help those affected by the major changes implied by the NZE, are discussed in more detail in Chapter 4.

3.3 Low-emissions fuel supply

3.3.1 Energy trends in the Net-Zero Emissions Scenario

Reaching net-zero emissions will require low-emissions fuels[3] where energy needs cannot easily or economically be met by electricity (Figure 3.6). This is likely to be the case for some modes of long-distance transport (trucks, aviation and shipping) and of heat and feedstock supply in heavy industry. Some low-emissions fuels are effectively drop-in, i.e. they are compatible with the existing fossil fuel distribution infrastructure and end-use technologies, and require few if any modifications to equipment or vehicles.

Low-emissions fuels today account for just 1% of global final energy demand, a share that increases to 20% in 2050 in the NZE. Liquid biofuels meet 14% of global transport energy demand in 2050, up from 4% in 2020; hydrogen-based fuels meet a further 28% of transport energy needs by 2050. Low-carbon gases (biomethane, synthetic methane and hydrogen) meet 35% of global demand for gas supplied through networks in 2050, up from almost zero today. The combined share of low-carbon hydrogen and hydrogen-based fuels in total final energy use worldwide reaches 13% in 2050. Hydrogen and ammonia also provide important low-emissions sources of power system flexibility and contribute 2% of overall electricity generation in 2050, which is enough to make the electricity sector an important driver of hydrogen demand.

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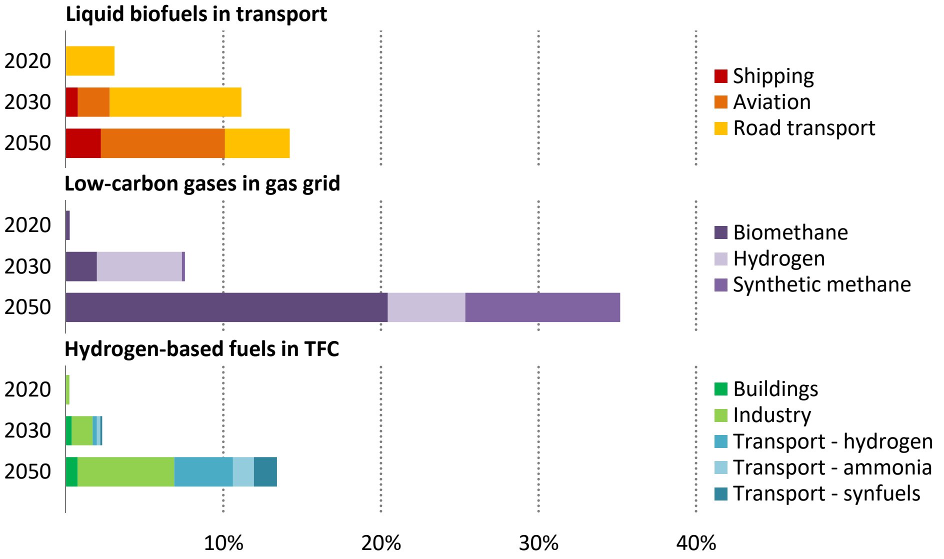
[3] Low-emissions fuels refer to liquid biofuels, biogas and biomethane, and hydrogen-based fuels (hydrogen, ammonia and synthetic hydrocarbon fuels) that do not emit CO_2 from fossil fuels directly when used and also emit very little when being produced. For example, hydrogen produced from natural gas with CCUS and high capture rates (90% or higher) is considered a low-emissions fuel, but not if produced without CCUS.

Figure 3.6 ▻ Global supply of low-emissions fuels by sector in the NZE



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Low-emissions fuels in the form of liquid biofuels, biomethane, hydrogen-based fuels help to decarbonise sectors where direct electrification is challenging

Notes: TFC = total final consumption. Low-carbon gases in the gas grid refers to the blending of biomethane, hydrogen and synthetic methane with natural gas in a gas network for use in buildings, industry, transport and electricity generation. Synfuels refer to synthetic hydrocarbon fuels produced from hydrogen and CO_2. Final energy consumption of hydrogen includes, in addition to the final energy consumption of hydrogen, ammonia and synthetic hydrocarbon fuels, the on-site hydrogen production in the industry sector.

3.3.2 Biofuels[4]

Around 10% of the global primary supply of modern bioenergy (biomass excluding traditional uses for cooking) was consumed as liquid biofuels for road transport and 6% was consumed as biogases (biogas and biomethane) to provide power and heat in 2020, with the rest directly used for electricity generation and heating in the residential sector. Supply accelerates sharply in the NZE with liquid biofuels expanding by a factor of almost four and biogases increasing by a factor of six by 2050.

All but about 7% of liquid biofuels for transport are currently produced from conventional crops such as sugarcane, corn and soybeans. Such crops directly compete with arable land that can be used for food production, which limits the scope for expanding output. So most of the growth in biofuels in the NZE comes from advanced feedstocks such as wastes and residues and woody energy crops grown on marginal lands and cropland not suitable for food

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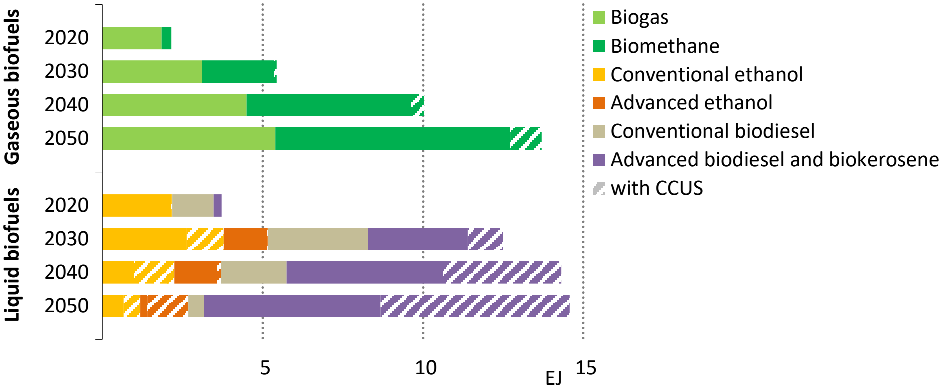
[4] Liquids and gases produced from bioenergy.

production (see section 2.7.2). Advanced liquid biofuel production technology using woody feedstock expands rapidly over the next decade in the NZE, and its contribution to liquid biofuels jumps from less than 1% in 2020 to almost 45% in 2030 and 90% in 2050 (Figure 3.7). By 2030, production reaches 2.7 million barrels of oil equivalent per day (mboe/d) by 2030, underpinned by biomass gasification using the Fischer-Tropsch process (bio-FT) and cellulosic ethanol, mostly to produce drop-in substitutes for diesel and jet kerosene. Advanced liquid biofuel production increases by an additional 130% to more than 6 mboe/d in 2050, the bulk of which is biokerosene.

Figure 3.7 ⊳ Global biofuels production by type and technology in the NZE



Liquid biofuel production quadruples while that of biogases expands sixfold between 2020 and 2050, underpinned by the development of sustainable biomass supply chains

Notes: EJ = exajoules; CCUS = carbon capture, utilisation and storage. Conventional ethanol refers to production using food energy crops. Advanced ethanol refers to production using wastes and residues and non-food energy crops grown on marginal and non-arable land. Conventional biodiesel includes fatty acid and methyl esters (FAME) route using food energy crops. Advanced biodiesel includes biomass-based Fischer-Tropsch and HEFA routes using wastes, residues and non-food energy crops grown on marginal and non-arable land. Biomethane includes biogas upgrading and biomass gasification-based routes.

Production using these feedstocks is mostly under development today. Current output capacity, principally cellulosic ethanol, is about 2.5 thousand barrels of oil equivalent per day (kboe/d). The NZE assumes that projects currently in the pipeline in Japan, the United Kingdom and the United States will bring these technologies to the market within the next few years. The scale up required for all advanced liquid biofuels (including from waste oils) over the next decade is equivalent to building one 55 kboe/d biorefinery every ten weeks (the world's largest biorefinery has capacity of 28 kboe/d).

The supply of these biofuels after 2030 shifts rapidly in the NZE from passenger vehicles and light trucks, where electrification is increasingly the order of the day, to heavy road freight, shipping and aviation. Ammonia makes inroads into shipping. Advanced liquid biofuels increase their share of the global aviation fuel market from 15% in 2030 to 45% in 2050.

Advanced biofuels such as hydrogenated esters and fatty acids (HEFA) and bio-FT are able to adjust their product slates (up to a point) from renewable diesel to biokerosene, and existing ethanol plants, especially those that can be retrofitted with CCUS or integrated with cellulosic feedstock, also make a contribution.

The supply of biogases increases even more than liquid biofuels. Injection into gas networks expands from under 1% of total gas volume in 2020 to almost 20% in 2050, reducing the emissions intensity of the network-based gas. Biomethane is mostly produced by upgrading biogas produced from anaerobic digestion of feedstocks such as agricultural residues like manure and biogenic municipal solid waste, thereby avoiding methane emissions that would otherwise be released. Due to the dispersed nature of these feedstocks, this assumes the construction of thousands of injection sites and associated distribution lines every year. Biogas and biomethane are also used as clean cooking fuels and in electricity generation in the NZE.

The production of biofuels can be combined with CCUS at a relatively low cost in some biofuel production routes (ethanol, bio-FT, biogas upgrading) because the processes involved release very pure streams of CO_2. In the NZE, the use of biofuels with CCUS results in annual carbon dioxide removal (CDR) of 0.6 Gt CO_2 in 2050, which offset residual emissions in transport and industry.

3.3.3 Hydrogen and hydrogen-based fuels

Hydrogen use in the energy sector today is largely confined to oil refining and the production of ammonia and methanol in the chemicals industry. Global hydrogen demand was around 90 million tonnes (Mt) in 2020, mainly produced from fossil fuels (mostly natural gas) and emitting close to 900 Mt CO_2. Both the amount needed and the production route of hydrogen change radically in the NZE. Demand increases almost sixfold to 530 Mt in 2050, of which half is used in heavy industry (mainly steel and chemicals production) and in the transport sector; 30% is converted into other hydrogen-based fuels, mainly ammonia for shipping and electricity generation, synthetic kerosene for aviation and synthetic methane blended into gas networks; and 17% is used in gas-fired power plants to balance increasing electricity generation from solar PV and wind and to provide seasonal storage. Overall, hydrogen-based fuels[5] account for 13% of global final energy demand in 2050 (Figure 3.8).

Ammonia is used today as feedstock in the chemical industry, but in the NZE it is also used as fuel in various energy applications, benefitting from its lower transport cost and higher energy density than hydrogen. Ammonia accounts for around 45% of global energy demand for shipping in 2050 in the NZE. Co-firing with ammonia is also a potential early option to reduce CO_2 emissions in existing coal-fired power plants. The toxicity of ammonia means that its handling is likely to be limited to professionally trained operators, which could restrict its potential.

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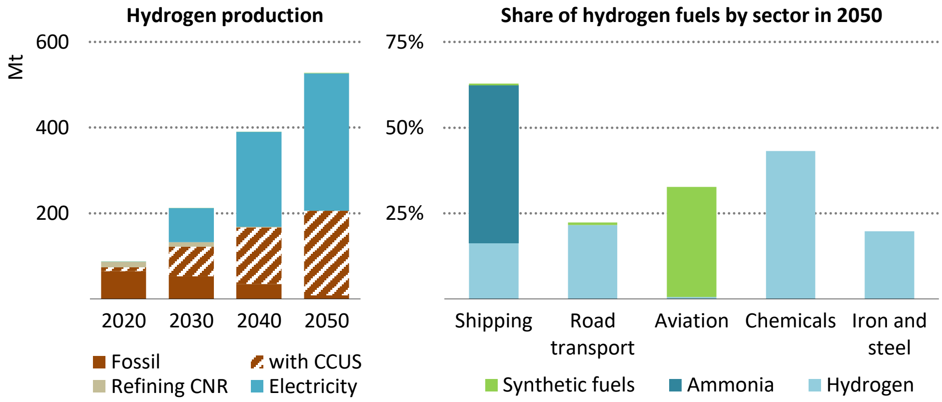
[5] Hydrogen-based fuels are defined as hydrogen, ammonia as well as synthetic hydrocarbon fuels produced from hydrogen and CO_2.

Figure 3.8 ▹ **Global production of hydrogen by fuel and hydrogen demand by sector in the NZE**



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Hydrogen production jumps sixfold by 2050, driven by water electrolysis and natural gas with CCUS, to meet rising demand in shipping, road transport and heavy industry

Note: Refining CNR = hydrogen by-product from catalytic naphtha reforming at refineries.

Synthetic kerosene meets around one-third of global aviation fuel demand in 2050 in the NZE. Its manufacture at bioenergy-fired power or biofuel production plants requires CO_2 captured from the atmosphere. CO_2 from these sources can be considered carbon neutral, as it results in no net emissions when the fuel is used. There is scope for the co-production of advanced liquid biofuels and synthetic liquid fuels from hydrogen and CO_2, with the integration of the two processes reducing the overall liquid fuel production costs. Alongside synthetic liquid fuels, enough synthetic methane is produced from hydrogen and CO_2 in 2050 to meet 10% of demand for network supplied gas in the buildings, industry and transport sectors.

By 2050, hydrogen production in the NZE is almost entirely based on low-carbon technologies: water electrolysis accounts for more than 60% of global production, and natural gas in combination with CCUS for almost 40%. Global electrolyser capacity reaches 850 gigawatts (GW) by 2030 and 3 600 GW by 2050, up from around 0.3 GW today. Electrolysis absorbs close to 15 000 terawatt-hours (TWh), or 20% of global electricity supply in 2050, largely from renewable resources (95%), but also from nuclear power (3%) and fossil fuels with CCUS (2%). Natural gas use for hydrogen production with CCUS is 925 bcm in 2050, or around 50% of global natural gas demand, with 1.8 Gt CO_2 being captured.

Scaling up deployment of technologies and related manufacturing capacity will be critical to reducing costs. Water electrolysers are available on the market today and hydrogen production from natural gas with CCUS has been demonstrated at a commercial scale (there are seven plants in operation around the world). The choice between the two depends on economic factors, mainly the cost of natural gas and electricity, and on whether CO_2 storage is available. For natural gas with CCUS, production costs in the NZE are around USD 1-2 per kilogramme (kg) of hydrogen in 2050, with gas costs typically accounting for 15-55% of total production costs. For water electrolysis, learning effects and economies of scale result in CAPEX cost reductions of 60% in the NZE by 2030 compared to 2020. Production cost reductions hinge on lowering the cost of low-carbon electricity, as electricity accounts for 50-85% of total production costs, depending on the electricity source and region. The average cost of producing hydrogen from renewables drops in the NZE from USD 3.5-7.5/kg today to around USD 1.5-3.5/kg in 2030 and USD 1-2.5/kg in 2050 – essentially about the same as the cost of producing with natural gas with CCUS.

Converting hydrogen into other energy carriers, such as ammonia or synthetic hydrocarbon fuels, involves even higher costs. But it results in fuels that can be more easily transported and stored, and which are also often compatible with existing infrastructure or end-use technologies (as in the case of ammonia for shipping or synthetic kerosene for aviation). For ammonia, the additional synthesis step increases the production costs by around 15% compared with hydrogen (mainly due to additional conversion losses and equipment costs).

The relatively high cost of synthetic hydrocarbon fuels explains why their use is largely restricted to aviation in the NZE, where alternative low-carbon options are limited. Synthetic kerosene costs were USD 300-700/barrel in 2020: although these costs fall to USD 130-300/barrel by 2050 in the NZE as the costs of electricity from renewables and CO_2 feedstocks decline, the cost of synthetic kerosene remains far higher than the projected USD 25/barrel cost of conventional kerosene in 2050 in the NZE. The supply of CO_2, captured from bioenergy equipped with CCUS or direct air capture (DAC), needed to make these fuels is a relevant cost factor, accounting for USD 15-70/barrel of the cost of synthetic hydrocarbon fuels in 2050. Closing these cost gaps implies penalties for fossil kerosene or support measures for synthetic kerosene corresponding to a CO_2 price of USD 250-400/tonne.

Increasing global demand for low-carbon hydrogen in the NZE provides a means for countries to export renewable electricity resources that could not otherwise be exploited. For example, Chile and Australia announced ambitions to become major exporters in their national hydrogen strategies. With declining demand for natural gas in the NZE, gas-producing countries could join this market by exporting hydrogen produced from natural gas with CCUS. Long-distance transport of hydrogen, however, is difficult and costly because of its low energy density, and can add around USD 1-3/kg of hydrogen to its price. This means that, depending on each country’s own circumstances, producing hydrogen domestically may be cheaper than importing it, even if domestic production costs from low-carbon electricity or natural gas with CCUS are relatively high. International trade nevertheless becomes increasingly important in the NZE: around half of global ammonia and a third of synthetic liquid fuels are traded in 2050.

3.3.4 Key milestones and decision points

Table 3.1 ▷ Key milestones in transforming low-emissions fuels

Sector	2020	2030	2050
Bioenergy			
Share of modern biofuels in modern bioenergy (excluding conversion losses)	20%	45%	48%
Advanced liquid biofuels (mboe/d)	0.1	2.7	6.2
Share of biomethane in total gas networks	<1%	2%	20%
CO_2 captured and stored from biofuels production (Mt CO_2)	1	150	625
Hydrogen			
Production (Mt H_2)	87	212	528
of which: low-carbon (Mt H_2)	9	150	520
Electrolyser capacity (GW)	<1	850	3 585
Electricity demand for hydrogen-related production (TWh)	1	3 850	14 500
CO_2 captured from hydrogen production (Mt CO_2)	135	680	1 800
Number of export terminals at ports for hydrogen and ammonia trade	0	60	150

Note: mboe/d = million barrels of oil equivalent per day; Mt = million tonnes; H_2 = hydrogen.

Biofuels

Several sustainability frameworks considering net lifecycle GHG emissions and other sustainability indicators exist in different regions, e.g. the Renewable Energy Directive II in the European Union, RenovaBio in Brazil and the Low-C Fuel Standards in California. However, the scope, methodology and sustainability metrics of these frameworks differ. Global consensus on a sustainability framework and indicators within the next few years would help stimulate investment; this should be a priority. Such a framework should cover all forms of bioenergy (liquid, gaseous and solid) and other low-emissions fuels, and should strive for continuous environmental performance improvement. Certification schemes ideally should be developed in parallel.

Another early priority is for governments to assess national sustainable biomass feedstock potential as soon as possible to establish the quantities and types of wastes, residues and marginal lands suitable for energy crops. Assessments should provide the basis for national roadmaps for all liquid and gaseous biofuels, and strategies for low-emissions fuels. Early decisions will be needed in this context about how to support the sustainable collection of wastes and residues from the forestry, agriculture, animal and food industries and from advanced municipal solid waste sorting systems: in the NZE, support measures are in place by 2025. Measures might usefully include low-emissions fuels standards that incentivise the use of biofuels as feedstock. International knowledge-sharing would help with the design of such measures and assist efficient dissemination of best practices from regions with existing collection systems, e.g. for forestry residues in Nordic countries and used cooking oil collection in Europe, China and Southeast Asia countries.

Governments will also need to decide how best to support biogas installations and distribution in order to move away from traditional uses of biomass for cooking and heating by 2030. Such practices remain widespread in some developing countries. They are best tackled as part of broader programmes to promote clean cooking alongside improving access to electricity and LPG.

Decisions will be needed by 2025 on how best to create markets for sustainable biofuels and close the cost gap between biofuels and fossil fuels. Measures will need to incentivise the rapid development and deployment of advanced liquid biofuel technologies in end-use sectors (particularly heavy-duty trucking, shipping and aviation), using mechanisms such as low-carbon fuel standards, biofuel mandates and CO_2 removal credits. Measures that could boost the scaling up of advanced biofuels production in the next four years include: incentives for co-processing bio-oil in existing oil refineries or fully converting oil refineries to biorefineries; retrofitting ethanol plants with CCUS; and integrating cellulosic ethanol production with existing ethanol plants.

New infrastructure will be needed to provide for the injection of more biomethane into gas networks and to transport and store the CO_2 captured from ethanol and bio-FT biofuel plants. Governments should prioritise the co-development of biogas upgrading facilities and biomethane injection sites by 2030, ensuring that particular attention is paid to minimising fugitive biomethane emissions from the supply chain. Where biomass availability allows, governments may see value in encouraging the deployment of biofuel plants with CCUS near existing industrial hubs where integrated CCUS projects are planned, such as the Humber region in the United Kingdom.

Hydrogen-based fuels

An immediate priority should be for governments to assess the opportunities and challenges of developing a low-carbon hydrogen industry as part of national hydrogen strategies or roadmaps. Decisions will be needed on whether to produce hydrogen domestically from low-carbon electricity via water electrolysis or from gas with CCUS or a combination of both, or whether to rely on imported hydrogen-based fuels. Building technology leadership along the hydrogen supply chain could help create jobs and stimulate economic growth.

Decisions will be needed during the next decade on how best to bring down the costs of low-carbon hydrogen production. Switching existing hydrogen production in industry and oil refining from unabated fossil fuels to low-carbon hydrogen is one possible way to ramp up low-carbon hydrogen production in applications that have large demand already available. Financial support instruments, such as contracts for differences, could help to reduce the current cost gap of low-carbon hydrogen production compared to existing unabated production from fossil fuels.

Decisions will also be needed on how best to scale up hydrogen. Industrial ports could be a good starting point, since they may provide access to low-carbon hydrogen supply in the form of offshore wind or CO_2 storage. They also offer scope to promote new port-related uses for hydrogen, e.g. shipping and delivery trucks, and they could become the first nodes of an international hydrogen trade network. The establishment of hydrogen trade will require the development of methodologies to determine the carbon footprint of the different hydrogen production routes and the adoption of guarantees of origin and certification schemes for low-carbon hydrogen (and hydrogen-based fuels).

Blending hydrogen into existing gas networks offers another early avenue to scale up low-carbon hydrogen production and trigger cost reductions. International harmonisation of safety standards and national regulations on allowed concentrations of hydrogen in gas grids would help with this, as would the adoption of blending quotas or low-emissions fuel standards.

Repurposing existing gas pipelines, where technically feasible, with declining natural gas demand and connecting large hydrogen demand hubs to transport hydrogen could result in low cost and low regret opportunities to kick-start the development of new hydrogen infrastructure. Developing the infrastructure for hydrogen at the pace required in the NZE would involve considerable investment risks along the value chain of production, transport and demand ranging from hydrogen production technologies through to low-emissions electricity generation and CO_2 transport and storage. Governments and local authorities could play an important role by co-ordinating the planning processes among the various stakeholders; direct public investment or public-private partnerships could help to develop necessary shared infrastructure for hydrogen; and international co-operation and cross-border initiatives could help to share investment burdens and risks and so facilitate large-scale deployments, as in the EU Important Projects of Common European Interest.

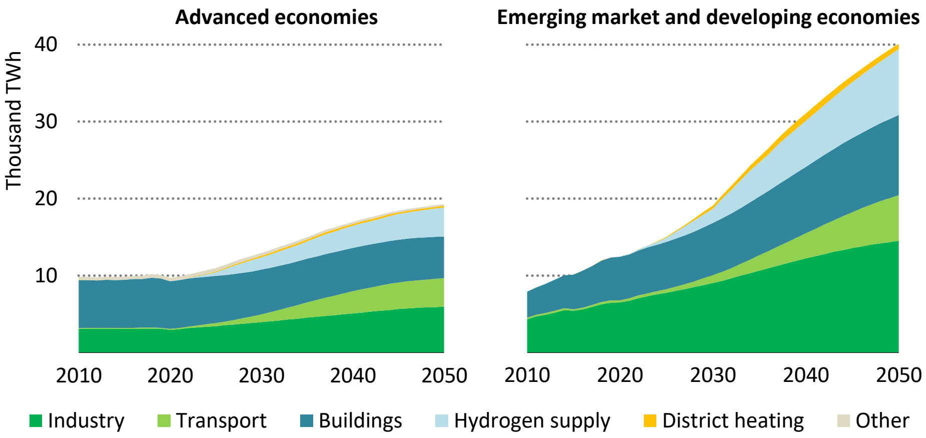
3.4 Electricity sector

3.4.1 Energy and emissions trends in the Net-Zero Emissions Scenario

The NZE involves both a significant increase in electricity needs – the result of an increase in economic activity, rapid electrification of end-uses and expansion of hydrogen production by electrolysis – and a radical transformation in the way electricity is generated. Global electricity demand was 23 230 TWh in 2020 with an average growth rate of 2.3% per year over the previous decade. It climbs to 60 000 TWh in 2050 in the NZE, an average increase of 3.2% per year.

Emerging market and developing economies account for 75% of the projected global increase in electricity demand to 2050 (Figure 3.9). Their demand increases by half by 2030 and triples by 2050, driven by expanding population and rising incomes and living standards, as well new sources of demand linked to decarbonisation. In advanced economies, electricity demand returns to growth after a decade-long lull, nearly doubling between 2020 and 2050, driven mostly by end-use electrification and hydrogen production.

Figure 3.9 ▻ **Electricity demand by sector and regional grouping in the NZE**



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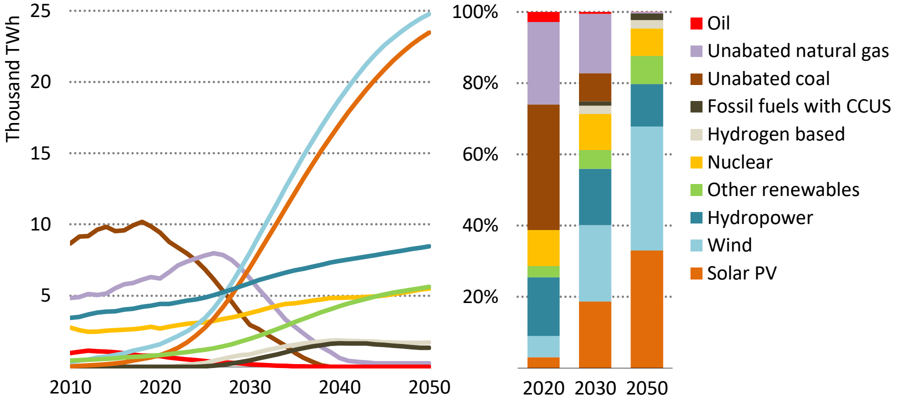
Electrification of end-uses and hydrogen production raise electricity demand worldwide, with a further boost to expand services in emerging market and developing economies

The transformation of the electricity sector is central to achieving net-zero emissions in 2050. Electricity generation is the single largest source of energy-related CO_2 emissions today, accounting for 36% of total energy-related emissions. CO_2 emissions from electricity generation worldwide totalled 12.3 Gt in 2020, of which 9.1 Gt was from coal-fired generation, 2.7 Gt from gas-fired plants and 0.6 Gt from oil-fired plants. In the NZE, CO_2 emissions from electricity generation fall to zero in aggregate in advanced economies in the 2030s. They fall to zero in emerging market and developing economies around 2040.

Renewables contribute most to decarbonising electricity in the NZE: global generation from renewables nearly triples by 2030 and grows eightfold by 2050 (Figure 3.10). This raises the share of renewables in total output from 29% in 2020 to over 60% in 2030 and nearly 90% in 2050. Solar PV and wind race ahead, becoming the leading sources of electricity globally before 2030: each generates over 23 000 TWh by 2050, equivalent to about 90% of all electricity produced in the world in 2020. Pairing battery storage systems with solar PV and wind to improve power system flexibility and maintain electricity security becomes commonplace in the late 2020s, complemented by demand response for short duration flexibility and hydropower or hydrogen for flexibility across days or even seasons. Hydropower is the largest low-carbon source of electricity today and steadily grows in the NZE, doubling by 2050. Generation using bioenergy – in dedicated plants and as biomethane delivered through gas networks – doubles to 2030 and increases nearly fivefold by 2050.

Figure 3.10 ▷ Global electricity generation by source in the NZE



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Solar and wind power race ahead, raising the share of renewables in total generation from 29% in 2020 to nearly 90% in 2050, complemented by nuclear, hydrogen and CCUS

Nuclear power also makes a significant contribution in the NZE, its output rising steadily by 40% to 2030 and doubling by 2050, though its overall share of generation is below 10% in 2050. At its peak in the early 2030s, global nuclear capacity additions reach 30 GW per year, five-times the rate of the past decade. In advanced economies, lifetime extensions for existing reactors are pursued in many countries as they are one of the most cost-effective sources of low-carbon electricity (IEA, 2019), while new construction expands to about 4.5 GW per year on average from 2021 to 2035, with an increasing emphasis on small modular reactors. Despite these efforts, the nuclear share of total generation in advanced economies falls from 18% in 2020 to 10% in 2050. Two-thirds of new nuclear power capacity in the NZE is built in emerging market and developing economies mainly in the form of large-scale reactors, where the fleet of reactors quadruples to 2050. This raises the share of nuclear in electricity generation in those countries from 5% in 2020 to 7% in 2050 (as well as nuclear meeting 4% of commercial heat demand in 2050).

Nuclear power technologies have advanced in recent years, with several first-of-a-kind large-scale reactors completed that include enhanced safety features. While projects have been completed on schedule in China, Russia and the United Arab Emirates, there have been substantial delays and cost overruns in Europe and the United States. Small modular reactors and other advanced reactor designs are moving towards full-scale demonstration, with scalable designs, lower upfront costs and the potential to improve the flexibility of nuclear power in terms of both operations and outputs, e.g. electricity, heat or hydrogen.

Retrofitting coal- and gas-fired capacity with CCUS or co-firing with hydrogen-based fuels enables existing assets to contribute to the transition while cutting emissions and supporting electricity security. The best opportunities for CCUS are at large, young facilities with available space to add capture equipment and in locations with CO_2 storage options or demand for use. Opportunities are concentrated in China for coal-fired power plants and the United States for gas-fired capacity. While they provide just 2% of total generation from 2030 to 2050 in the NZE, retrofitted plants capture a total of 15 Gt CO_2 emissions over the period.

Carbon capture technologies remain at an early stage of commercialisation. Two commercial power plants have been equipped with CCUS over the past five years, and there are currently 18 CCUS power projects in development worldwide. Completing these projects in a timely manner and driving down costs through learning-by-doing will be critical to further expansion. An alternative would be to retrofit existing coal- and gas-fired power plants to co-fire high shares of hydrogen-based fuels. In the NZE, hydrogen-based fuels generate 900 TWh of electricity in 2030 and 1 700 TWh in 2050 in this way (about 2.5% of global generation in both years). A large-scale (1 GW) demonstration project to co-fire with 20% ammonia is underway in 2021, with aims to move towards ammonia-only combustion. Manufacturers have signalled that future gas turbine designs will be capable of co-firing high shares of hydrogen. While the investment needed to co-fire hydrogen-based fuels looks to be modest, relatively high fuel costs point to targeted applications to support power system stability and flexibility rather than bulk power.

The global use of unabated fossil fuels in electricity generation is sharply reduced in the NZE. Unabated coal-fired generation is cut by 70% by 2030, including the phase-out of unabated coal in advanced economies, and phased out in all other regions by 2040. Large-scale oil-fired generation is phased out in the 2030s. Generation using natural gas without carbon capture rises in the near term, replacing coal, but starts falling by 2030 and is 90% lower by 2040 compared with 2020.

The electricity sector is the first to achieve net-zero emissions mainly because of the low costs, widespread policy support and maturity of an array of renewable energy technologies. Solar PV is first among them: it is the cheapest new source of electricity in most markets and has policy support in more than 130 countries. Onshore wind is also a market-ready low cost technology that is widely supported and can be scaled up quickly, rivalling the low costs of solar PV where conditions are good, though it faces public opposition and extensive permitting and licensing processes in several markets. Offshore wind technology has been maturing rapidly in recent years; its deployment is poised to accelerate in the near term. The current focus is on fixed-bottom installations, but floating offshore wind starts to make a major contribution from around 2030 in the NZE, helping to unlock the enormous potential that exists around the world. Hydropower, bioenergy and geothermal technologies are well established, mature and flexible renewable energy sources. As dispatchable generating options, they will be critical to electricity security, complemented by batteries, which have seen sharp cost reductions, have proven their ability to provide high-value grid services and can be built in a matter of months in most locations. Concentrating solar and marine power are less mature technologies, but innovation could see them make important contributions in the long term.

3.4.2 Key milestones and decision points

Table 3.2 ▻ Key milestones in transforming global electricity generation

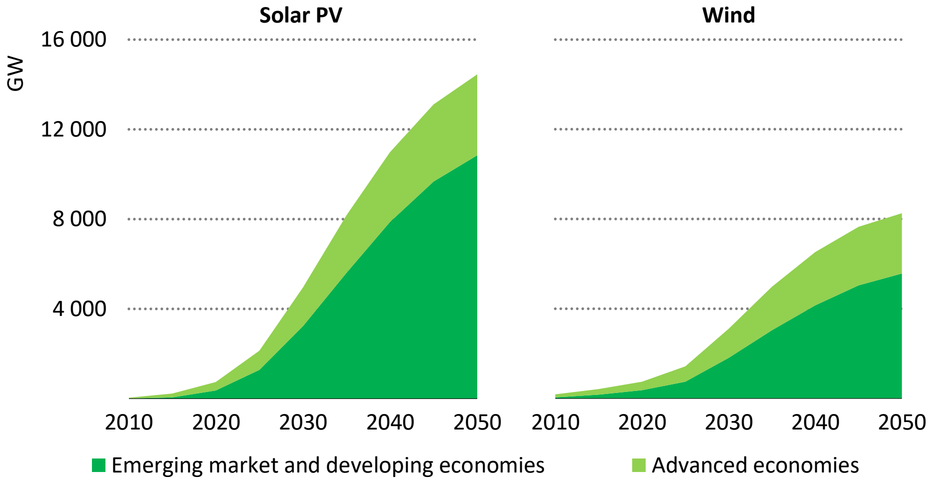
Category	
Decarbonisation of electricity sector	• Advanced economies in aggregate: 2035. • Emerging market and developing economies: 2040.
Hydrogen-based fuels	• Start retrofitting coal-fired power plants to co-fire with ammonia and gas turbines to co-fire with hydrogen by 2025.
Unabated fossil fuel	• Phase out all subcritical coal-fired power plants by 2030 (870 GW existing plants and 14 GW under construction). • Phase out all unabated coal-fired plants by 2040. • Phase out large oil-fired power plants in the 2030s. • Unabated natural gas-fired generation peaks by 2030 and is 90% lower by 2040.

Category	2020	2030	2050
Total electricity generation (TWh)	26 800	37 300	71 200
Renewables			
Installed capacity (GW)	2 990	10 300	26 600
Share in total generation	29%	61%	88%
Share of solar PV and wind in total generation	9%	40%	68%
Carbon capture, utilisation and storage (CCUS) generation (TWh)			
Coal and gas plants equipped with CCUS	4	460	1 330
Bioenergy plants with CCUS	0	130	840
Hydrogen and ammonia			
Average blending in global coal-fired generation (without CCUS)	0%	3%	100%
Average blending in global gas-fired generation (without CCUS)	0%	9%	85%
Unabated fossil fuels			
Share of unabated coal in total electricity generation	35%	8%	0.0%
Share of unabated natural gas in total electricity generation	23%	17%	0.4%
Nuclear power	*2016-20*	*2021-30*	*2031-50*
Average annual capacity additions (GW)	7	17	24
Infrastructure			
Electricity networks investment in USD billion (2019)	260	820	800
Substations capacity (GVA)	55 900	113 000	290 400
Battery storage (GW)	18	590	3 100
Public EV charging (GW)	46	1 780	12 400

Note: GW = gigawatts; GVA = gigavolt amperes.

Transforming the electricity sector in the way envisioned in the NZE involves large capacity additions for all low-emissions fuels and technologies. Global renewables capacity more than triples to 2030 and increases ninefold to 2050. From 2030 to 2050, this means adding more than 600 GW of solar PV capacity per year on average and 340 GW of wind capacity per year including replacements (Figure 3.11), while offshore wind becomes increasingly important over time (over 20% of total wind additions from 2021 to 2050, compared with 7% in 2020). The annual deployment of battery capacity in the electricity sector needs to scale up in parallel, from 3 GW in 2019 to 120 GW in 2030 and over 240 GW in 2040. Retrofitting existing coal- and gas-fired power plants also needs to get underway.

Figure 3.11 ▷ Solar PV and wind installed capacity in the NZE



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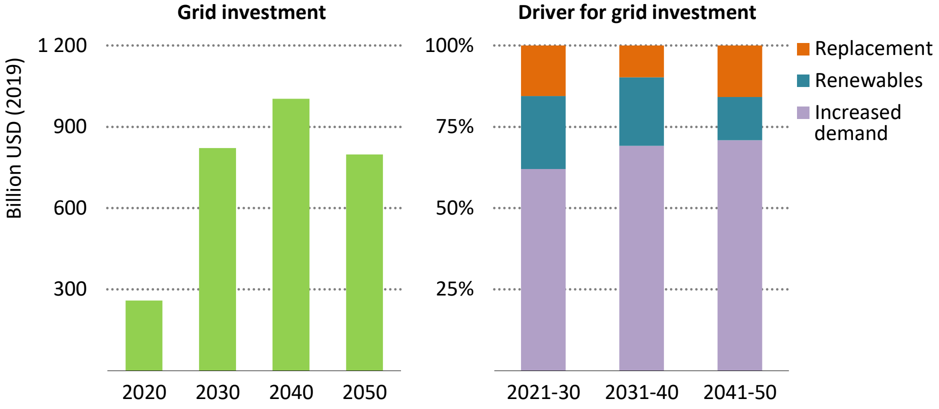
Solar PV and wind need to scale up rapidly to decarbonise electricity, with total solar PV capacity growing 20-fold and wind 11-fold by 2050

Figure 3.12 ▷ Global investment in electricity networks in the NZE



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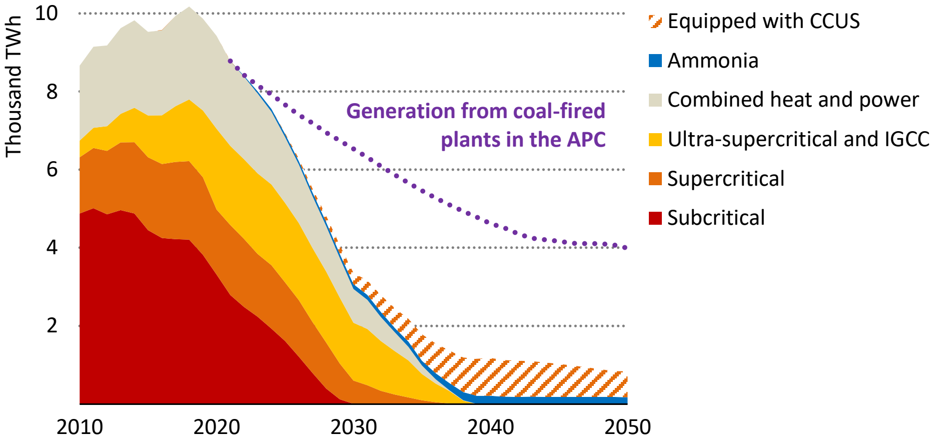
Electricity network investment triples to 2030 and remains elevated to 2050, meeting new demand, replacing ageing infrastructure and integrating more renewables

Investment in electricity networks will be crucial to achieving this transformation. Global electricity networks that took over 130 years to build need to more than double in total length by 2040 and increase by another 25% by 2050. Total grid investment needs to rise to USD 820 billion by 2030, and USD 1 trillion in 2040, before falling back after electricity is fully decarbonised and the growth of renewables slows to match demand growth (Figure 3.12). Replacing ageing infrastructure is an important part of network investment through to 2050 in the NZE.

Governments face several key decisions in the electricity sector if they are to follow the pathway to net-zero emissions by 2050 envisioned in the NZE particularly about how to best use existing power plants. For retrofits of coal- or gas-fired capacity, either with carbon capture or co-firing with hydrogen-based fuels (or full conversion), decisions are needed to support first-of-a-kind projects before 2030 before widespread retirement of unabated plants becomes necessary. For other fossil fuel power stations, decisions about phase outs are needed. Coal-fired power plants should be phased out completely by 2040 unless retrofitted, starting with the least-efficient designs by 2030 (Figure 3.13). This would require shutting 870 GW of existing subcritical coal capacity globally (11% of all power capacity) and international collaboration to facilitate substitutes. By 2040, all large-scale oil-fired power plants should be phased out. Natural gas-fired generation remains an important part of electricity supply through to 2050, but strong government support will be needed to ensure that CCUS is deployed soon and on a large scale.

Figure 3.13 ⊳ **Coal-fired electricity generation by technology in the NZE**



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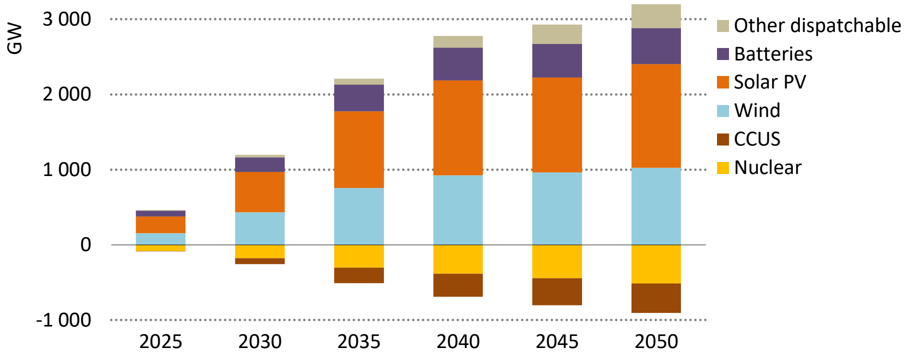
Coal-fired power accounted for 27% of global energy CO_2 emissions in 2020, and in the NZE, all subcritical plants are phased out by 2030 and all plants without CCUS by 2040

Notes: APC = Announced Pledges Case; IGCC = integrated gasification combined-cycle. Ammonia includes co-firing and full conversion of coal plants.

The path to net-zero emissions could be facilitated by early government action to help move several technologies that provide power system flexibility through the demonstration phases and bring them to market. Expanding the set of energy storage technologies to complement batteries and addressing emerging needs for longer duration seasonal storage would be of particular value. Technical solutions to support the stability of power grids with high shares of solar and wind would also benefit from research and development (R&D) support.

There are three important sets of decisions to be made concerning nuclear power: lifetime extensions; pace of new construction; and advances in nuclear power technology. In advanced economies, decisions need to be made about new construction and the large number of nuclear power plants that may be retired over the next decade absent action to extend their lifetimes and make the required investment. Without further lifetime extensions and new projects beyond those already under construction, nuclear power output in advanced economies will decline by two-thirds over the next two decades (IEA, 2019). In emerging market and developing economies, there are decisions to be made about the pace of new nuclear power construction. From 2011 to 2020, an average of 6 GW of new nuclear capacity came online each year. By 2030, the rate of new construction increases to 24 GW per year in the NZE. The third set of decisions concerns the extent of government support for advanced nuclear technologies, particularly those related to small modular reactors and high-temperature gas reactors, both of which can expand markets for nuclear power beyond electricity.

Figure 3.14 ▷ Additional global alternative capacity needed in a Low Nuclear and CCUS Case



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Sharply reducing the roles of nuclear power and carbon capture would require even faster growth in solar PV and wind, making achieving the net zero goal more costly and less likely

Note: The Low Nuclear and CCUS Case assumes that global nuclear power output is about 60% lower in 2050 than in the NZE due to no additional lifetime extensions or new nuclear projects in advanced economies and no expansion of the current pace of construction in emerging market and developing economies, and that the amount of coal- and gas-fired capacity equipped with CCUS is 99% lower than in the NZE.

Failing to take timely decisions on nuclear power and CCUS would raise the costs of a net-zero emissions pathway and add to the risk of not meeting the goal by placing an additional burden on wind and solar to scale up even more quickly than in the NZE (Figure 3.14). In a *Low Nuclear and CCUS Case*, we assume that global nuclear power output is 60% lower in 2050 than in the NZE as a result of no additional nuclear lifetime extensions or new projects in advanced economies and no expansion of the current pace of construction in emerging market and developing economies, and that only the announced CCUS projects are completed (representing 1% of the CCUS capacity added in the NZE).

Our analysis indicates that the burden of replacing those sources of low-carbon generation would fall mainly on solar PV and wind power, calling for 2 400 GW more capacity than in the NZE – an amount far exceeding their combined global capacity in operation in 2020 (Figure 3.14). There would also be a need for about 480 GW of battery capacity above and beyond the 3 100 GW deployed in the NZE, plus more than 300 GW of other dispatchable capacity to meet demand in all seasons and ensure system adequacy. This would call for an additional USD 2 trillion investment in power plants and related grid assets (net of lower investment in nuclear and CCUS). Taking account of avoided fuel costs, the estimated total additional cost of electricity to consumers between 2021 and 2050 is USD 260 billion.

3.5 Industry

3.5.1 Energy and emission trends in the Net-Zero Emissions Scenario

As the second-largest global source of energy sector CO_2 emissions, industry has a vital contribution to make in achieving the net zero goal. Industrial CO_2 emissions[6] (including from energy use and production processes) totalled about 8.4 Gt in 2020. Advanced economies accounted for around 20% and emerging market and developing economies for around 80%, although complex global supply chains for the production of materials and manufacturing mean that advanced economies generally consume far more finished goods than they produce.

Three heavy industries – chemicals, steel and cement – account for nearly 60% of all industrial energy consumption and around 70% of CO_2 emissions from the industry sector. Production is highly concentrated in emerging market and developing economies, which account for 70-90% of the combined output of these commodities (Figure 3.15). China alone was responsible for almost 60% of both steel and cement production in 2020. These bulk materials are essential inputs to our modern way of life, with few cost-competitive substitutes; the challenge is to carry on producing these materials without emitting CO_2.

The outlook for global materials demand in the NZE is one of plateaus and small increases. This is in stark contrast with the growth seen during the last two decades when global steel

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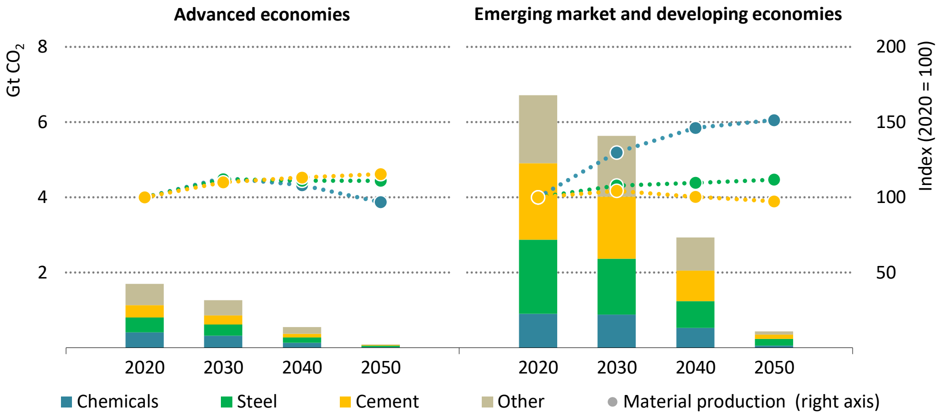
[6] All CO_2 emissions in this section refer to direct CO_2 emissions from the industry sector unless otherwise specified.

demand rose by 2.1-times, cement by 2.4-times and plastics (a key group of material outputs from the chemical sector) by 1.9-times in response to global economic and population expansion. When economies are developing, per capita material demand tends to rise rapidly to build up stocks of goods and infrastructure. As economies mature, future demand stems primarily from the need to refurbish and replace these stocks, the levels of which tend to saturate. In the NZE, flattening or even declining demand in many countries around the world leads to slower global demand growth. Some countries such as India see higher growth in steel and cement production, while production in China declines considerably following its industrial boom period after the turn of the millennium.

Figure 3.15 ▷ Global CO_2 emissions from industry by sub-sector in the NZE



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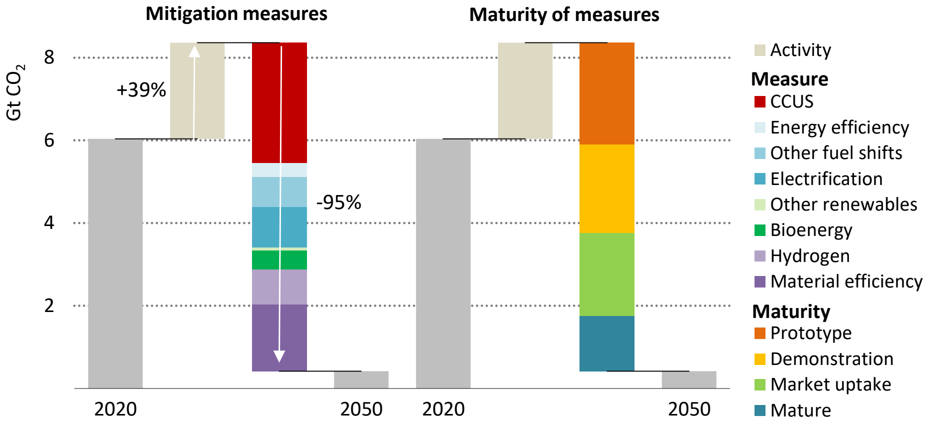
The majority of residual emissions in industry in 2050 come from heavy industries in emerging market and developing economies

Note: Other includes the production of aluminium, paper, other non-metallic minerals and other non-ferrous metals, and a series of light industries.

Certain segments of material demand increase rapidly to support the required expansion of energy-related infrastructure in the NZE, notably renewable electricity generation and transport infrastructure. The additional infrastructure required for these two segments by 2050 relative to today alone contributes roughly 10% of steel demand in 2050. But co-ordinated cross-sectoral strategies, including modal shifts in transport and building renovation, as well as other changes in design, manufacturing methods, construction practices and consumer behaviour, more than offset this increase. Overall, global demand for steel in 2050 is 12% higher than today, primary chemicals is 30% higher and cement demand is broadly flat.

CO_2 emissions from heavy industry decline by 20% by 2030 and 93% by 2050 in the NZE. Optimising the operational efficiency of equipment, adopting the best available technologies for new capacity additions and measures to improve material efficiency play an important part in this. However, there are limits to how much emissions can be reduced by these measures. Almost 60% of emissions reductions in 2050 in the NZE are achieved using technologies that are under development today (large prototype or demonstration scale) (Figure 3.16).

Figure 3.16 ▻ Global CO_2 emissions in heavy industry and reductions by mitigation measure and technology maturity category in the NZE



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An array of measures reduces emissions in heavy industry, with innovative technologies like CCUS and hydrogen playing a critical role

Hydrogen and CCUS technologies together contribute around 50% of the emissions reductions in heavy industry in 2050 in the NZE. These technologies enable the provision of large amounts of high-temperature heat, which in many cases cannot be easily provided by electricity with current technologies, and help to reduce process emissions from the chemical reactions inherent in some industrial production. Bioenergy also makes a contribution in a wide array of industrial applications.

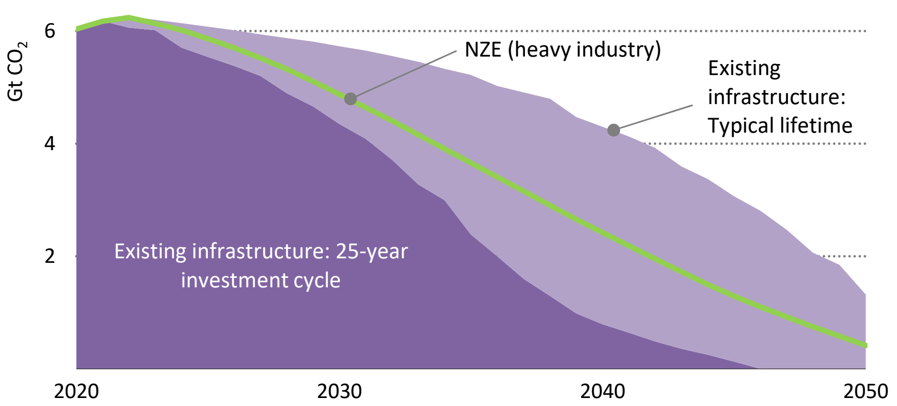
Aside from the need for high-temperature heat and process emissions, two factors explain the slower pace of emissions reductions in heavy industries relative to other areas of the energy system. First, the ease with which many industrial materials and products can be traded globally means that markets are competitive and margins are low. This leaves little room to absorb additional costs stemming from the adoption of more expensive production pathways. It will take time to develop robust global co-operation and technology transfer frameworks or domestic solutions to enable a level playing field for these technologies. Second, heavy industries use capital-intensive and long-lived equipment, which slows the deployment of innovative low-emission technologies. Capacity additions in the period to 2030 – before a large-scale roll-out of innovative processes can take place – largely explain the persistence of industrial emissions in 2050, more than 80% of which are in emerging market and developing economies. Strategically timed investment in low-carbon technologies could help minimise early retirements (Box 3.1).

Box 3.1 ▻ Investment cycles in heavy industry

For heavy industry, the year 2050 is just one investment cycle away. Average lifetimes of emissions-intensive assets such as blast furnaces and cement kilns are around 40 years. After about 25 years of operation, however, plants often undergo a major refurbishment to extend their lifetimes.

The challenge is to ensure that innovative near-zero emissions industrial technologies that are at large prototype and demonstration stage today reach markets within the next decade, when around 30% of existing assets will have reached 25 years of age and thus face an investment decision. If these innovative technologies are not ready, or not used even if ready, this would have a major negative impact on the pace of emissions reductions or risk an increase in stranded assets (Figure 3.17). Conversely, if they are ready, and if existing plants are retrofit or replaced with them at the 25-year investment decision point, this could reduce projected cumulative emissions to 2050 from existing heavy industry assets by around 40%. The critical window of opportunity from now to 2030 should not be missed.

Figure 3.17 ▻ CO_2 emissions from existing heavy industrial assets in the NZE



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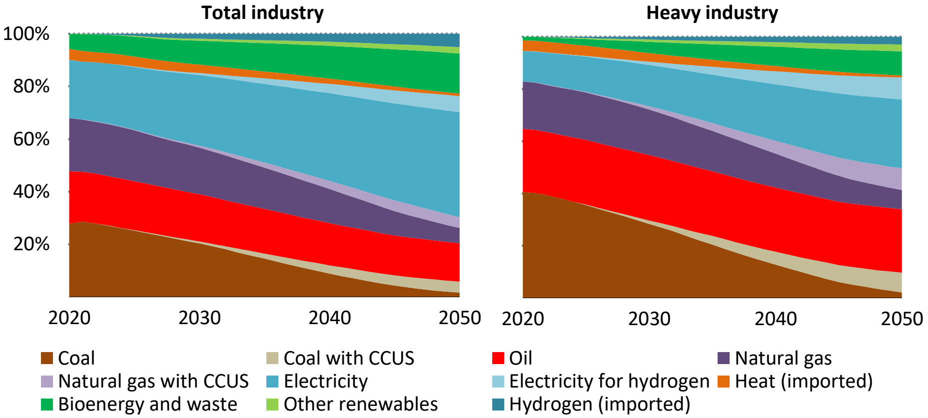
Intervening at the end of the next 25-year investment cycle could help unlock 60 Gt CO_2, around 40% of projected emissions from existing heavy industry assets

The energy mix in industry changes radically in the NZE. The share of fossil fuels in total energy use declines from around 70% today to 30% in 2050. The vast majority of fossil fuels still being used then are in heavy industries, mainly as chemical feedstock (50%) or in plants equipped with CCUS (around 30%). Electricity is the dominant fuel in industrial energy demand growth, with its share of total industrial energy consumption rising from 20% in 2020 to 45% in 2050. Some 15% of this electricity is used to produce hydrogen. Bioenergy plays an important role, contributing 15% of total energy use in 2050, but sustainable supplies are limited, and it is also in high demand in the power and transport sectors. Renewable solar and geothermal technologies to provide heat make a small but fast growing contribution (Figure 3.18).

Figure 3.18 ▹ Global final industrial energy demand by fuel in the NZE



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Fossil fuel use in industry is halved by 2050, replaced primarily by electricity and bioenergy

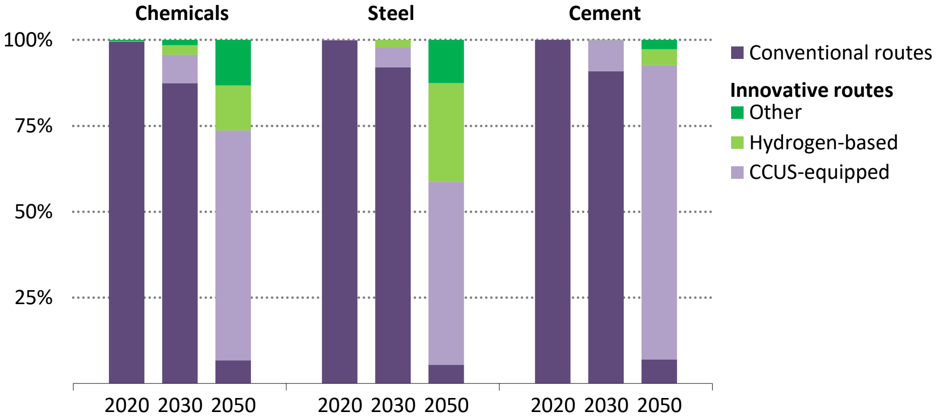
Notes: Industrial energy consumption includes chemical feedstock and energy consumed in blast furnaces and coke ovens. Hydrogen refers to imported hydrogen and excludes captive hydrogen generation. Electricity for hydrogen refers to electricity used in the production of captive hydrogen via electrolysis.

Chemicals production

In the NZE, emissions from the chemicals sub-sector fall from 1.3 Gt in 2020 to 1.2 Gt in 2030 and around 65 Mt in 2050. The share of fossil fuels in total energy use falls from 83% in 2020 (mostly oil and natural gas), to 76% in 2030 and 61% in 2050. Oil remains the largest fuel used in primary chemicals production by 2050 in the NZE, along with smaller quantities of gas and coal.

Technologies that are currently available on the market account for almost 80% of the emissions savings achieved globally in the chemical industry by 2030 in the NZE relative to today. They include recycling and re-use of plastics and more efficient use of nitrogen fertilisers, which reduce the demand for primary chemicals, and measures to increase energy efficiency. Beyond 2030, the bulk of emissions reductions result from the use of technologies whose integration in chemical processes is under development today, including certain CCUS applications and electrolytic hydrogen generated directly from variable renewable electricity (Figure 3.19). CCUS-equipped conventional routes and pyrolysis technologies are most competitive in regions with access to low cost natural gas, while electrolysis is the favoured option in regions where the deployment of CCUS is impeded by a lack of infrastructure or public acceptance.

Figure 3.19 ▷ Global industrial production of bulk materials by production route in the NZE



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Near-zero emissions routes dominate cement, primary steel and chemicals production by 2050, with key roles for CCUS and hydrogen-based technologies

Notes: CCUS = carbon capture, utilisation and storage. Chemicals refers to the production of primary chemicals (ethylene, propylene, benzene, toluene, mixed xylenes, ammonia and methanol). Steel refers to primary steel production. Other includes innovative processes that utilise bioenergy and directly electrify production. Hydrogen-based refers to electrolytic hydrogen. Fossil fuel-based hydrogen with CCUS is included in the CCUS-equipped category.

Iron and steel production

In the NZE, global CO_2 emissions from the iron and steel sub-sector fall from 2.4 Gt in 2020 to 1.8 Gt in 2030 and 0.2 Gt in 2050, as the unabated use of fossil fuels falls sharply. Their share of the overall fuel mix drops from 85% today to just over 30% in 2050. The steel industry remains one of the last sectors using significant amounts of coal in 2050, primarily due to its importance as a chemical reduction agent, albeit mostly in conjunction with CCUS.

The NZE sees a radical technological transformation of the iron and steel sub-sector based largely on a major shift from coal to electricity. By 2050, electricity and other non-fossil fuels account for nearly 70% of final energy demand in the sector, up from just 15% in 2020. This shift is driven by technologies such as scrap-based electric arc furnaces (EAF), hydrogen-based direct reduced iron (DRI) facilities, iron ore electrolysis and the electrification of ancillary equipment. The share of coal in total energy use drops from 75% in 2020 to 22% by 2050 in the NZE, of which 90% is used in conjunction with CCUS.

Technologies that are currently on the market deliver around 85% of emissions savings in steel production to 2030. They include material and energy efficiency measures and a major increase in scrap-based production – which requires only around one-tenth of the energy of primary steel production – driven primarily by increased scrap availability as more products reach their end-of-life. Partial hydrogen injection into commercial blast furnaces and DRI furnaces gain pace in the mid-2020s, building on pilot projects testing the practice today. After 2030, the bulk of emission reductions come from the use of technologies that are under development, including hydrogen-based DRI and iron ore electrolysis. Several CCUS-equipped process technologies are deployed in parallel, including innovative smelting reduction, natural gas-based DRI production (particularly in regions with low natural gas prices) and innovative blast furnace retrofit arrangements in regions with relatively young plants.

Cement production

Producing a tonne of cement today generates around 0.6 tonnes CO_2 on average, two-thirds of which are process emissions generated from carbon released from the raw materials used. Fossil fuels – mostly coal plus some petroleum coke – account for 90% of thermal energy needs.

Increased blending of alternative materials into cement to replace a portion of clinker (the active and most emissions-intensive ingredient), lower demand for cement and energy efficiency measures deliver around 40% of the emissions savings in 2030 compared with 2020. Through use of blended cements, the global clinker-to-cement ratio declines from 0.71 in 2020 to 0.65 in 2030. The ratio continues to decline after 2030, but more slowly, reaching 0.57 in 2050 (blended cements could reach a clinker-to-cement ratio as low as 0.5, but market application potential depends on regional contexts). Limestone and calcined clay are the main alternative materials used in blended cements by 2050. Since 0.5 is the lowest technically achievable clinker-to-cement ratio, other measures are needed to achieve deeper emission reductions.

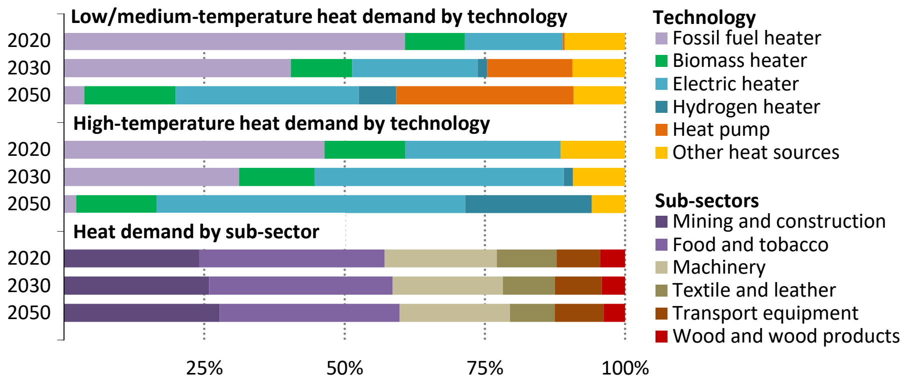
After 2030 in the NZE, the bulk of emissions reductions come from the use of technologies that are under development today. CCUS is the most important, accounting for 55% of reductions in 2050 relative to today. In many cases, it is more cost-effective in the NZE to apply CCUS to fossil fuel combustion emissions than to switch to zero-emissions energy sources. Coal use is eliminated from cement production by 2050, when natural gas accounts for about 40% of thermal energy (up from 15% today), biomass and renewable waste for a further 35% (up from less than 5% today), hydrogen and direct electrification for just about 15%, and oil products and non-renewable waste for the remainder. Constraints on the availability of sustainable biomass supplies prevent it from claiming a higher share. Direct electrification of cement kilns is at the small prototype stage today, and so only starts to be deployed after 2040 on a small scale. From the 2040s, hydrogen provides around 10% of thermal energy needs in cement kilns, although blending of small amounts begins earlier. Innovative types of cement based on alternative binding materials that limit or avoid the generation of process emissions, and even enable CO_2 capture during the curing process, are either still at much earlier stages of development relative to other options like CCUS, or have limited applicability.

Box 3.2 ▷ What about other industry sub-sectors?

Steel, cement and chemicals are not the only outputs from the industry sector. It also includes other energy-intensive sub-sectors such as aluminium, paper, other non-metallic minerals and non-ferrous metals, as well as light industries that produce vehicles, machinery, food, timber, textiles and other consumer goods, together with the energy consumed in construction and mining operations.

Emissions from the light industries decline by around 30% by 2030 and around 95% by 2050 in the NZE. In contrast to the heavy industries, most of the technologies required for deep emission reductions in these sub-sectors are available on the market and ready to deploy. This is in part because more than 90% of total heat demand is low/medium-temperature, which can be more readily and efficiently electrified.

Figure 3.20 ▷ Share of heating technology by temperature level in light industries in the NZE



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The share of electricty in satisfying heat demand for light industries rises from less than 20% today to around 40% in 2030 and about 65% in 2050

Notes: Light industries excludes non-specified industrial energy consumption. Low/medium-temperature heat corresponds to 0-400 °C and high-temperature heat to >400 °C. Other heat sources includes solar thermal and geothermal heaters, as well as imported heat from the power and fuel transformation sector.

Electricity accounts for around 40% of heat demand by 2030 and about 65% by 2050. For low- (<100 °C) and some medium- (100-400 °C) temperature heat, electrification includes an important role for heat pumps (accounting for about 30% of total heat demand in 2050). In the NZE, around 500 MW of heat pumps need to be installed every month over the next 30 years. Along with electrification, there are smaller roles for hydrogen and bioenergy for high-temperature heat (>400 °C), accounting for around 20% and around 15% respectively of total energy demand in 2050 (Figure 3.20). The rate of electrolyser capacity deployment is much lower than heavy industries, but the unit sizes will also be much smaller. About 5% of heat demand is satisfied by direct use of renewables, including solar thermal and geothermal heating technologies.

Energy efficiency also plays a critical role in these manufacturing industries, notably through increased efficiency in electric motors (conveyers, pumps and other driven systems). By 2030, 90% of the motor sales in other industries are Class 3 or above.

3.5.2 Key milestones and decision points

Table 3.3 ▷ Key milestones in transforming global heavy industry sub-sectors

Category	
Heavy industry	• 2035: virtually, all capacity additions are innovative low-emissions routes.
Industrial motors	• 2035: all electric motors sales are best in class.

Category		2020	2030	2050
Total industry				
Share of electricity in total final consumption		21%	28%	46%
Hydrogen demand (Mt H_2)		51	93	187
CO_2 captured (Mt CO_2)		3	375	2 800
Chemicals				
Share of recycling:	reuse in plastics collection	17%	27%	54%
	reuse in secondary production	8%	14%	35%
Hydrogen demand (Mt H_2)		46	63	83
with on-site electrolyser capacity (GW)		0	38	210
Share of production via innovative routes		1%	13%	93%
CO_2 captured (Mt CO_2)		2	70	540
Steel				
Recycling, re-use: scrap as share of input		32%	38%	46%
Hydrogen demand (Mt H_2)		5	19	54
with on-site electrolyser capacity (GW)		0	36	295
Share of primary steel production:	hydrogen-based DRI-EAF	0%	2%	29%
	iron ore electrolysis-EAF	0%	0%	13%
	CCUS-equipped processes	0%	6%	53%
CO_2 captured		1	70	670
Cement				
Clinker to cement ratio		0.71	0.65	0.57
Hydrogen demand (Mt H_2)		0	2	12
Share of production via innovative routes		0%	9%	93%
CO_2 captured (Mt CO_2)		0	215	1 355

Note: DRI = direct reduced iron; EAF = electric arc furnace.

From 2030 onwards, all new capacity additions in industry in the NZE feature near-zero emissions technologies. Much of the heavy industry capacity that will be added and replaced in the coming years is in emerging market and developing economies; they may expect financial support from advanced economies. Each month from 2030 to 2050, the NZE implies an additional 10 industrial plants equipped with CCUS, three additional fully hydrogen-based industrial plants and 2 GW of extra electrolyser capacity at industrial sites. While challenging, this is achievable. For comparison, about 12 heavy industrial facilities were built from scratch on average per month in China alone from 2000 to 2015. By 2050, nearly all production in heavy industry is with near-zero emissions technologies.

Decisive action from governments is imperative to achieve clean energy transitions in heavy industry at the scale and pace envisioned in the NZE. Within the next two years, governments in advanced economies will need to take decisions about funding for R&D for critical near-zero emissions industrial technologies and for mitigating the investment risks associated with demonstrating them at scale. This should lead to at least two or three commercial demonstration projects for each technology in different regions, and to market deployment by the mid-2020s. International co-ordination and co-operation would facilitate better use of resources and help prevent gaps in funding.

Governments also need to take early decisions on large-scale deployment of near-zero emissions technologies. By 2024 in advanced economies and 2026 in emerging market and developing economies, governments should have in place a strategy for incorporating near-zero emissions technologies into the next series of capacity additions and replacements for steel and chemical plants, which should include decisions about whether to pursue CCUS, hydrogen or a combination of both. If they are to succeed, those strategies need to include concrete plans for developing and financing the necessary infrastructure for CCUS and/or hydrogen, together with clean electricity generation for hydrogen production. The construction of the required infrastructure should begin as soon as possible given the long lead-times involved.

Within a similar timeframe, governments of countries that produce cement should decide how to develop the necessary CCUS infrastructure for that sub-sector, including the necessary legal and regulatory frameworks. Importing countries should make plans to move progressively to exclusive use of low-emissions cement, which may involve the need to support the development of CCUS-equipped facilities elsewhere in order to ensure supplies and to avoid a disproportionate burden being placed on other countries.

Strategies must be underpinned by specific policies. By 2025, all countries should have a long-term CO_2 emissions reduction policy framework in place to provide certainty that the next wave of investment in capacity additions will feature near-zero emissions technologies. Successful strategies are likely to require initial measures such as carbon contracts for difference, public procurement and incentives to encourage private sector procurement. As new technologies are deployed and costs decline, there is likely to be a strong case by about 2030 for replacing these initial measures with others such as CO_2 taxes, emissions trading systems and emissions performance standards. Financing support for near-zero emissions capacity additions may also have an important role to play through measures such as low interest and concessional loans and blended finance, as well as through contributions by advanced economies to funds that support projects in emerging market and developing economies. Strategies should also include measures to reduce industrial emissions through material efficiency, for example by revising design regulations, adopting incentives to promote longer product and building lifetimes, and improving systems for collecting and sorting materials for recycling.

There is a strong case for an international agreement on the transition to near-zero emissions for globally traded products by the mid-2020s so as to establish a level playing field. Alternatively, countries may need to resort to measures to shield domestic near-zero emissions production from competition from products that create emissions. Any such policy would need to be designed to respect the regulatory frameworks governing international trade, such as those of the World Trade Organization.

Even with accelerated innovation timelines and strong policies in place, some high-emitting capacity additions will be needed to meet demand in the next decade before near-zero emissions technologies are available. It would make sense for governments to require any new capacity to incorporate retrofit-ready designs so that unabated capacity added in the next few years has the technical capacity and space requirement to integrate near-zero emissions technologies in coming years. Beyond 2030, investment in the NZE is confined to innovative near-zero emissions process routes.

Governments should not overlook the need for measures to spur deployment of already available near-zero emissions technologies in light manufacturing industries. Adopting a carbon price and then sufficiently increasing the price over time – through carbon taxes or emissions trading systems for larger manufacturers – may be the simplest way to achieve that objective. Other regulatory measures such as tradeable low-carbon fuel and emissions standards could yield the same outcome, but may involve greater administrative complexity. Technology mandates are likely to be needed to achieve the energy efficiency savings in the NZE, such as minimum energy performance standards for new motors and boilers. Tailored programmes and incentives for small and medium enterprises could also play a helpful role.

3.6 Transport

3.6.1 Energy and emission trends in the Net-Zero Emissions Scenario

The global transport sector emitted over 7 Gt CO_2 in 2020, and nearly 8.5 Gt in 2019 before the Covid-19 pandemic.[7] In the NZE, transport sector CO_2 emissions are slightly over 5.5 Gt in 2030. By 2050 they are around 0.7 Gt – a 90% drop relative to 2020 levels. CO_2 emissions decline even with rapidly rising passenger travel, which nearly doubles by 2050, and rising freight activity, which increases by two-and-a-half-times from current levels, and an increase in the global passenger car fleet from 1.2 billion vehicles in 2020 to close to 2 billion in 2050.

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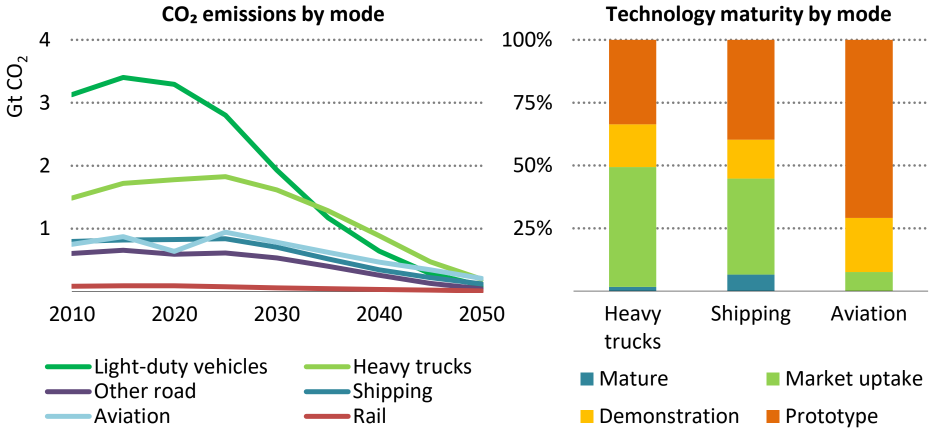
[7] Unless otherwise noted, CO_2 emissions reported here are direct emissions from fossil fuel combusted during the operation of vehicles.

The transport modes do not decarbonise at the same rate because technology maturity varies markedly between them (Figure 3.21). CO_2 emissions from two/three-wheelers almost cease by 2040, followed by cars, vans and rail in the late 2040s. Emissions from heavy trucks, shipping and aviation fall by an annual average of 6% between 2020 and 2050, but still collectively amount to more than 0.5 Gt CO_2 in 2050. This reflects projected activity growth and that many of the technologies needed to reduce CO_2 emissions in long distance transport are currently under development and do not start to make substantial inroads into the market in the coming decade.

Figure 3.21 ▹ Global CO_2 transport emissions by mode and share of emissions reductions to 2050 by technology maturity in the NZE



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Passenger cars can make use of low-emissions technologies on the market, but major advances are needed for heavy trucks, shipping and aviation to reduce their emissions

Notes: Other road = two/three wheelers and buses. Shipping and aviation include both domestic and international operations. See Box 2.4 for details on the maturity categories.

Decarbonisation of the transport sector in the NZE relies on policies to promote modal shifts and more efficient operations across passenger transport modes (see sections 2.5.7 and 4.4.3),[8] as well as improvements in energy efficiency. It also depends on two major technology transitions: shifts towards electric mobility (electric vehicles [EVs] and fuel cell electric vehicles [FCEVs])[9] and shifts towards higher fuel blending ratios and direct use of

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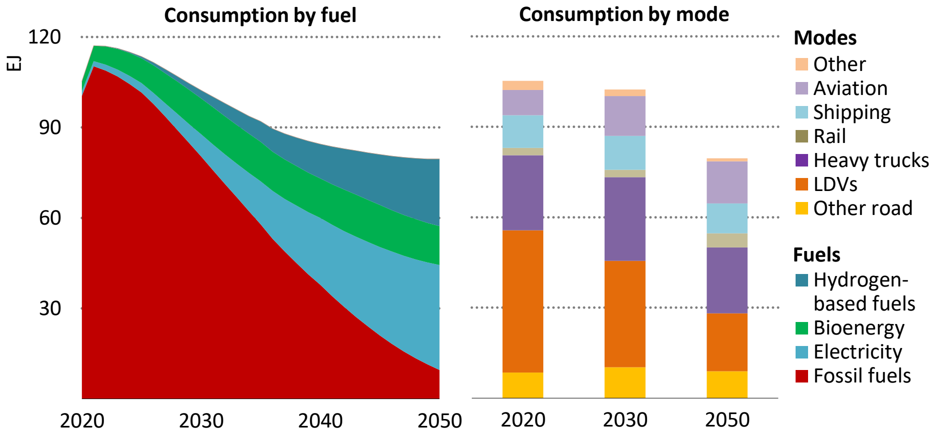
[8] Examples of efficient operations include: seamless integration of various modes (inter-modality) and "Mobility as a Service" in passenger transport; logistics measures in road freight, e.g. backhauling, night-time deliveries, real-time routing; slow steaming in shipping; and air traffic management, e.g. landing and take-off scheduling in aviation.

[9] EVs include battery electric vehicles, plug-in hybrid electric-gasoline vehicles and plug-in hybrid electric-diesel vehicles. FCEVs contain a battery and electric motor and are capable of operating without tailpipe emissions.

low-carbon fuels (biofuels and hydrogen-based fuels). These shifts are likely to require interventions to stimulate investment in supply infrastructure and to incentivise consumer uptake.

Transport has traditionally been heavily reliant on oil products, which accounted for more than 90% of transport sector energy needs in 2020 despite inroads from biofuels and electricity (Figure 3.22). In the NZE, the share of oil drops to less than 75% in 2030 and slightly over 10% by 2050. By the early 2040s, electricity becomes the dominant fuel in the transport sector worldwide in the NZE: it accounts for nearly 45% of total final consumption in 2050, followed by hydrogen-based fuels (28%) and bioenergy (16%). Biofuels almost reach a 15% blending share in oil products by 2030 in road transport, which reduces oil needs by around 4.5 million barrels of oil equivalent per day (mboe/d). Beyond 2030, biofuels are increasingly used for aviation and shipping, where the scope for using electricity and hydrogen is more limited. Hydrogen carriers (such as ammonia) and low-emissions synthetic fuels also supply increasing shares of energy demand in these modes.

Figure 3.22 ▷ Global transport final consumption by fuel type and mode in the NZE



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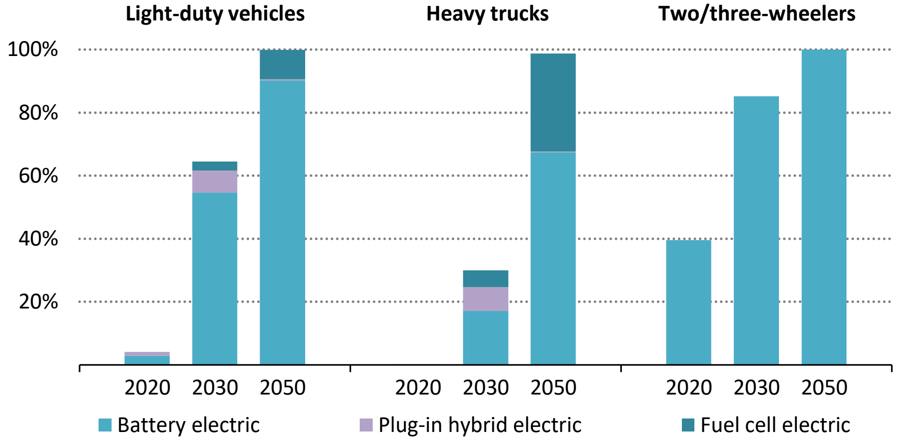
Electricity and hydrogen-based fuels account for more than 70% of transport energy demand by 2050

Note: LDVs = Light-duty vehicles; Other road = two/three wheelers and buses.

Road vehicles

Electrification plays a central role in decarbonising road vehicles in the NZE. Battery cost declines of almost 90% in a decade have boosted sales of electric passenger cars by 40% on average over the past five years. Battery technology is already relatively commercially competitive. FCEVs start to make inroads in the 2020s in the NZE. The electrification of heavy trucks moves more slowly due to the weight of the batteries, high energy and power requirements required for charging, and limits on driving ranges. But fuel cell heavy trucks make significant progress, mainly after 2030 (Figure 3.23). The number of battery electric, plug-in hybrid and fuel cell electric light-duty vehicles (cars and vans) on the world's roads reaches 350 million in 2030 and almost 2 billion in 2050, up from 11 million in 2020. The number of electric two/three-wheelers also rises rapidly, from just under 300 million today to 600 million in 2030 and 1.2 billion in 2050. The electric bus fleet expands from 0.5 million in 2020 to 8 million in 2030 and 50 million in 2050.

Figure 3.23 ▹ Global share of battery electric, plug-in hybrid and fuel cell electric vehicles in total sales by vehicle type in the NZE



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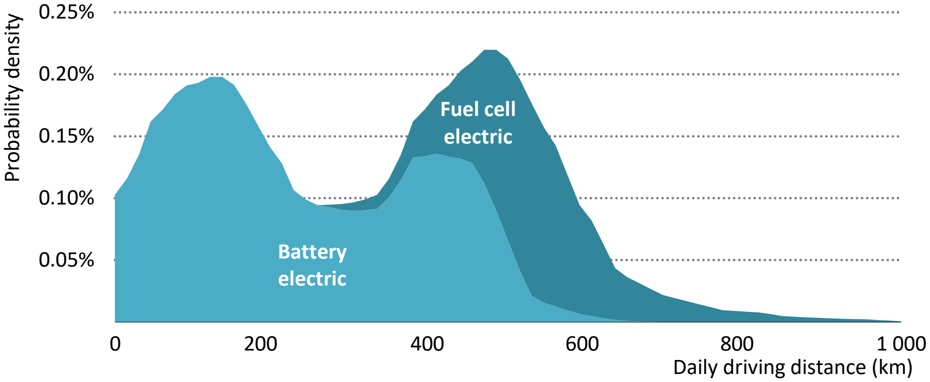
Sales of battery electric, plug-in hybrid and fuel cell electric vehicles soar globally

Note: Light-duty vehicles = passenger cars and vans; Heavy trucks = medium- and heavy-freight trucks.

Light-duty vehicles are electrified faster in advanced economies over the medium term and account for around 75% of sales by 2030. In emerging and developing economies, they account for about 50% of sales. Almost all light-duty vehicle sales in advanced economies are battery electric, plug-in hybrid or fuel cell electric by the early 2030s and in emerging and developing economies by the mid-2030s.

For heavy trucks that operate over long distances, currently biofuels are the main viable commercial alternative to diesel, and they play an important role in lowering emissions from heavy-duty trucks over the 2020s. Beyond 2030, the number of electric and hydrogen-powered heavy trucks increases in the NZE as supporting infrastructure is built and as costs decline (lower battery costs, energy density improvements and lower costs to produce and deliver hydrogen) (IEA, 2020b). This coincides with a reduction in the availability of sustainable bioenergy, as limited supplies increasingly go to hard-to-abate segments such as aviation and shipping, though biofuels still meet about 10% of fuel needs for heavy-duty trucks in 2050 (see Chapter 2). Advanced economies have a higher market share of battery electric and fuel cell electric heavy-duty trucks sales in 2030, more than twice the level in emerging market and developing economies, although this gap closes towards 2050.

Figure 3.24 ▷ Heavy trucks distribution by daily driving distance, 2050



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Driving distance is the key factor affecting powertrain choice for trucks

Realising the objectives of the NZE depends on rapid scaling up of battery manufacturing (current announced production capacity for 2030 would cover only 50% of required demand in that year), and on the rapid introduction on the market of next generation battery technology (solid state batteries) between 2025 and 2030. Electrified road systems using conductive or inductive power transfer to provide electricity to trucks offer an alternative for battery electric and fuel cell electric trucks on long-distance operations, but these systems too would need rapid development and deployment.

Aviation[10]

The NZE assumes that air travel, measured in revenue-passenger kilometres, increases by only around 3% per year to 2050 relative to 2020. This compares with about around 6% over the 2010-19 period. The NZE assumes that aviation growth is constrained by comprehensive government policies that promote a shift towards high-speed rail and rein in expansion of long-haul business travel, e.g. through taxes on commercial passenger flights (see section 2.5.2).

Global CO_2 emissions from aviation rise in the NZE from about 640 Mt in 2020 (down from around 1 Gt in 2019) to a peak of 950 Mt by around 2025. Emissions then fall to 210 Mt in 2050 as the use of low-emissions fuels grows. Emissions are hard to abate because aviation

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[10] Aviation considered here includes both domestic and international flights. While the focus here is on commercial passenger aviation, dedicated freight and general (military and private) aviation, which collectively account for more than 10% of fuel use and emissions, are also included in the energy and emissions accounting.

requires fuel with a high energy density. Emissions in aviation comprise just over 10% of unabated CO_2 emissions from fossil fuels and industrial processes in 2050.

In the NZE, the global use of jet kerosene declines to about 3 EJ in 2050 from 9 EJ in 2020 (and around 14.5 EJ in 2019 before the Covid-19 crisis), and its share of total energy use falls from almost 100% to just over 20%. The use of sustainable aviation fuel (SAF) starts to increase significantly in the late-2020s. In 2030, around 15% of total fuel consumption in aviation is SAF, most of which is biojet kerosene (a type of liquid biofuel). This is estimated to increase the ticket price for a mid-haul flight (1 200 km) by about USD 3 per passenger. By 2050, biojet kerosene meets 45% of total fuel consumption in aviation and synthetic hydrogen-based fuels meet about 30%. This is estimated to increase the ticket price for a mid-haul flight in 2050 by about USD 10 per passenger. The NZE also sees the adoption of commercial battery electric and hydrogen aircraft from 2035, but they account for less than 2% of fuel consumption in 2050.

Operational improvements, together with fuel efficiency technologies for airframes and engines, also help to reduce CO_2 emissions by curbing the pace of fuel demand growth in the NZE. These improvements are incremental, but revolutionary technologies such as open rotors, blended wing-body airframes and hybridisation could bring further gains and enable the industry to meet the International Civil Aviation Organization's (ICAO) ambitious 2050 efficiency targets (IEA, 2020b).

Maritime shipping[11]

Maritime shipping was responsible for around 830 Mt CO_2 emissions worldwide in 2020 (880 Mt CO_2 in 2019), which is around 2.5% of total energy sector emissions. Due to a lack of available low-carbon options on the market and the long lifetime of vessels (typically 25-35 years), shipping is one of the few transport modes that does not achieve zero emissions by 2050 in the NZE. Nevertheless, emissions from shipping decline by 6% annually to 120 Mt CO_2 in 2050.

In the short term, there is considerable potential for curbing fuel consumption in shipping through measures to optimise operational efficiency and improve energy efficiency. Such approaches include slow steaming and the use of wind-assistance technologies (IEA, 2020b). In the medium to long term, significant emissions reductions are achieved in the NZE by switching to low-carbon fuels such as biofuels, hydrogen and ammonia. Ammonia looks likely to be a particularly good candidate for scaling up, and a critical fuel for long-range transoceanic journeys that need fuel with high energy density.

Ammonia and hydrogen are the main low-carbon fuels for shipping adopted over the next three decades in the NZE, their combined share of total energy consumption in shipping reaching around 60% in 2050. The 20 largest ports in the world account for more than half of global cargo (UNCTAD, 2018); they could become industrial hubs to produce hydrogen and

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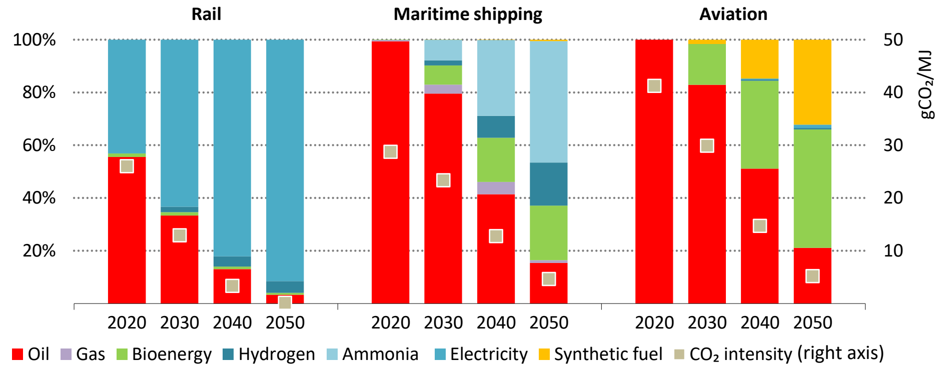
[11] Maritime shipping here includes both domestic and international operations.

ammonia for use in both chemical and refining industries, as well as for refuelling ships. Internal combustion engines for ammonia-fuelled vessels are currently being developed by two of the largest manufacturers of maritime engines and are expected to become available on the market by 2024. Sustainable biofuels provide almost 20% of total shipping energy needs in 2050. Electricity plays a very minor role, as the relatively low energy density of batteries compared with liquid fuels makes it suitable only for shipping routes of up to 200 km. Even with an 85% increase in battery energy density in the NZE as solid state batteries come to market, only short-distance shipping routes can be electrified.

Rail

Rail transport is the most energy-efficient and least carbon-intensive way to move people and second only to shipping for carrying goods. Passenger rail almost doubles its share of total transport activity to 20% by 2050 in the NZE, with particularly rapid growth in urban and high-speed rail (HSR), the latter of which contributes to curbing growth in air travel. Global CO_2 emissions from the rail sector fall from 95 Mt CO_2 in 2020 (100 Mt CO_2 in 2019) to almost zero by 2050 in the NZE, driven primarily by rapid electrification.

Figure 3.25 ▷ Global energy consumption by fuel and CO_2 intensity in non-road sectors in the NZE



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Railways rely heavily on electricity to decarbonise, while shipping and aviation curb emissions mainly by switching to low-emissions fuels

Note: Synthetic fuel = low-emissions synthetic hydrogen-based fuels.

In the NZE, all new tracks on high-throughput corridors are electrified from now on, while hydrogen and battery electric trains, which have recently been demonstrated in Europe, are adopted on rail lines where throughput is too low to make electrification economically viable. Oil use, which accounted for 55% of total energy consumption in the rail sector in 2020, falls to almost zero in 2050: it is replaced by electricity, which provides over 90% of rail energy needs and by hydrogen which provides another 5%.

3.6.2 Key milestones and decision points

Table 3.4 ▻ Key milestones in transforming the global transport sector

Category	
Road transport	• 2035: no new passenger internal combustion engine car sales globally
Aviation and shipping	• Implementation of strict carbon emissions intensity reduction targets as soon as possible.

Category		2020	2030	2050
Road transport				
Share of PHEV, BEV and FCEV in sales:	cars	5%	64%	100%
	two/three-wheelers	40%	85%	100%
	bus	3%	60%	100%
	vans	0%	72%	100%
	heavy trucks	0%	30%	99%
Biofuel blending in oil products		5%	13%	41%
Rail				
Share of electricity and hydrogen in total energy consumption		43%	65%	96%
Activity increase due to modal shift (index 2020=100)		100	100	130
Aviation				
Synthetic hydrogen-based fuels share in total aviation energy consumption		0%	2%	33%
Biofuels share in total aviation energy consumption		0%	16%	45%
Avoided demand from behaviour measures (index 2020=100)		0	20	38
Shipping				
Share in total shipping energy consumption:	Ammonia	0%	8%	46%
	Hydrogen	0%	2%	17%
	Bioenergy	0%	7%	21%
Infrastructure				
EV public charging (million units)		1.3	40	200
Hydrogen refuelling units		540	18 000	90 000
Share of electrified rail lines		34%	47%	65%

Note: PHEV = plug-in hybrid electric vehicles; BEV = battery electric vehicles; FCEV = fuel cell electric vehicles.

Electrification is the main option to reduce CO_2 emissions from road and rail modes, the technologies are already on the market and should be accelerated immediately, together with the roll-out of recharging infrastructure for EVs. Deep emission reductions in the hard-to-abate sectors (heavy trucks, shipping and aviation) require a massive scale up of the required technologies over the next decade, which today are largely at the prototype and demonstration stages, together with plans for the development of associated infrastructure, including hydrogen refuelling stations.

The transformation of transport required to be on track to reduce emissions in line with the NZE calls for a range of government decisions over the next decade. In the next few years, all governments need to eliminate fossil fuel subsidies and encourage switching to low-carbon technologies and fuels across the entire transport sector. Before 2025, governments need to define clear R&D priorities for all the technologies that can contribute to decarbonise transport in line with their strategic priorities and needs. Ideally this would be informed by international dialogue and collaboration. R&D is critical in particular for battery technology, which should be an immediate priority.

To achieve the emissions reductions required by the NZE, governments also need to move quickly to signal the end of sales of new internal combustion engine cars. Early commitments would help the private sector to make the necessary investment in new powertrains, relative supply chains and refuelling infrastructure (see section 4.3.4). This is particularly important for the supply of battery metals, which require long-term planning (IEA, 2021a).

By 2025, the large-scale deployment of EV public charging infrastructure in urban areas needs to be sufficiently advanced to allow households without access to private chargers to opt for EVs. Governments should ensure sustainable business models for companies installing chargers, remove barriers to planning and construction, and put in place regulatory, fiscal and technological measures to enable and encourage smart charging, and to ensure that EVs support electricity grid stability and stimulate the adoption of variable renewables (IEA, 2021b).

For heavy trucks, battery electric trucks are just beginning to become available on the market, and fuel cell electric technologies are expected to come to market in the next few years. Working in collaboration with truck manufacturers, governments should take steps in the near term to prioritise the rapid commercial adoption of battery electric and fuel cell electric trucks. By 2030, they should take stock of the competitive prospects for these technologies, so as to focus R&D on the most important challenges and allow adequate time for strategic infrastructure deployment, thus paving the way for large-scale adoption during the 2030s.

Governments need to define their strategies for low-carbon fuels in shipping and aviation by 2025 at the latest, given the slow turnover rate of the fleets, after which they should rapidly implement them. International co-operation and collaboration will be crucial to success. Priority action should target the most heavily used ports and airports so as to maximise the impact of initial investment. Harbours near industrial areas are ideally placed to become low-carbon fuel hubs.

Box 3.3 ▷ What would be the implications of an all-electric approach to emissions reductions in the road transport sector?

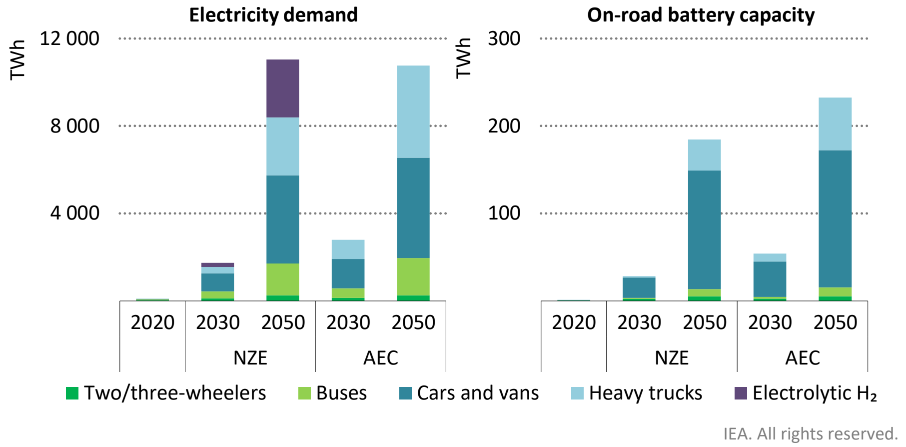
The use of a variety of fuels in road transport is a core component of the NZE. However, governments might want to consider an all-electric route to eliminate CO_2 emissions from transport, especially if other technologies such as FCEVs and advanced biofuels fail to develop as projected. We have therefore developed an *All-Electric Case* which looks at the implications of electrifying all road vehicle modes. In the NZE, decarbonisation of road transport occurs primarily via the adoption of plug-in hybrid electric vehicles (PHEVs), battery electric vehicles (BEVs), fuel cell electric vehicles (FCEVs) and advanced biofuels. The All-Electric Case assumes the same rate of road transport decarbonisation as the NZE, but achieved via battery electric vehicles alone.

The All-Electric Case depends on even further advances in battery technologies than the NZE that lead to energy densities of at least 400 Watt hours per kilogramme (Wh/kg) by the 2030s at costs that would make BEV trucks preferable to FCEV trucks in long-haul operations. This would mean 30% more BEVs (an additional 350 million) on the road in 2030 than in the NZE. Over sixty five million public chargers would be needed to support the vehicles, requiring a cumulative investment of around USD 300 billion, 35% higher than the NZE. This would require faster expansion of battery manufacturing. The annual global battery capacity additions for BEVs in 2030 would be almost 9 TWh, requiring 80 giga-factories (assuming 35 GWh per year output) more than in the NZE, or an average of over two per month from now to 2030.

The increased use of electricity for road transport would also create additional challenges for the electricity sector. The total electricity demand for road transport (11 000 TWh or 15% of total electricity consumption in 2050), would be roughly the same in both cases, when account is taken of demand for electrolytic hydrogen. However, the electrolytic hydrogen in the NZE can be produced flexibly, in regions and at times with surplus renewables-based capacity and from dedicated (off-grid) renewable power. Peak power demand in the All-Electric Case, taking into consideration the flexibility that enables smart charging of cars, is about one-third (2 000 GW) higher than in the NZE, mainly due to the additional evening/overnight charging of buses and trucks. If not coupled with energy storage devices, ultra-fast chargers for heavy-duty vehicles could cause additional spikes in demand, putting even more strain on electricity grids.

While full electrification of road transport is possible, it could involve additional challenges and undesirable side effects. For example, it could increase pressure on electricity grids, requiring significant additional investment, and increasing the vulnerability of the transport system to power disruptions. Fuel diversification could bring benefits in terms of resilience and energy security.

Figure 3.26 ⊳ Global electricity demand and battery capacity for road transport in the NZE and the All-Electric Case



Both direct electricity consumption and vehicle battery capacity in 2050 increase by about a quarter in the All-Electric Case relative to the NZE

Note: AEC = All-Electric Case.

3.7 Buildings

3.7.1 Energy and emission trends in the Net-Zero Emissions Scenario

Floor area in the buildings sector worldwide is expected to increase 75% between 2020 and 2050, of which 80% is in emerging market and developing economies. Globally, floor area equivalent to the surface of the city of Paris is added every week through to 2050. Moreover, buildings in many advanced economies have long lifetimes and around half of the existing buildings stock will still be standing in 2050. Demand for appliances and cooling equipment continues to grow, especially in emerging market and developing economies where 650 million air conditioners are added by 2030 and another 2 billion by 2050 in the NZE. Despite this demand growth, total CO_2 emissions from the buildings sector decline by more than 95% from almost 3 Gt in 2020 to around 120 Mt in 2050 in the NZE.[12]

Energy efficiency and electrification are the two main drivers of decarbonisation of the buildings sector in the NZE (Figure 3.27). That transformation relies primarily on technologies

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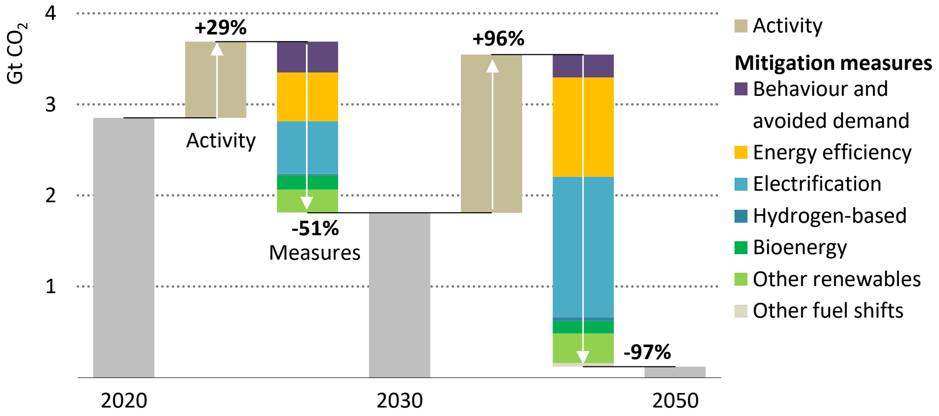
[12] All CO_2 emissions in this section refer to direct CO_2 emissions unless otherwise specified. The NZE also pursues reductions in emissions linked to construction materials used in buildings. These embodied emissions are cut by 40% per square metre of new floor area by 2030, with material efficiency strategies cutting cement and steel use by 50% by 2050 relative to today through measures at the design, construction, use and end-of-life phases.

already available on the market, including improved envelopes for new and existing buildings, heat pumps, energy-efficient appliances, and bioclimatic and material-efficient building design. Digitalisation and smart controls enable efficiency gains that reduce emissions from the buildings sector by 350 Mt CO_2 by 2050. Behaviour changes are also important in the NZE, with a reduction of almost 250 Mt CO_2 in 2030 reflecting changes in temperature settings for space heating or reducing excessive hot water temperatures. Additional behaviour changes such as greater use of cold temperature clothes washing and line drying, facilitate the decarbonisation of electricity supply. There is scope for these reductions to be achieved rapidly and at no cost.

Figure 3.27 ▷ Global direct CO_2 emissions reductions by mitigation measure in buildings in the NZE



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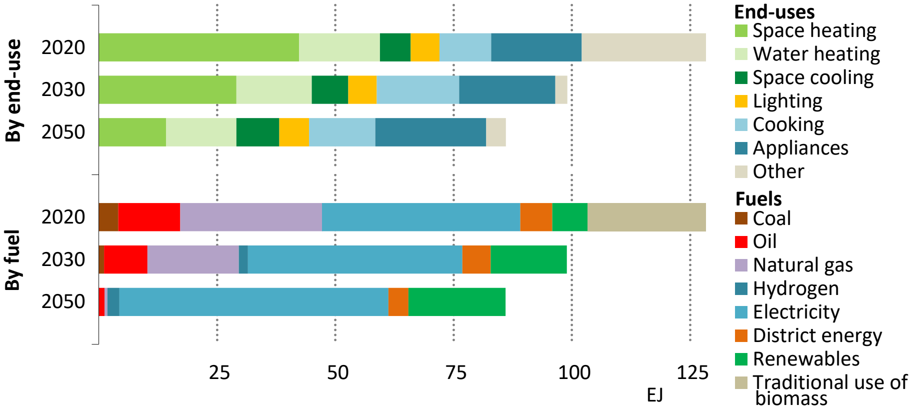
Electrification and energy efficiency account for nearly 70% of buildings-related emissions reductions through to 2050, followed by solar thermal, bioenergy and behaviour

Notes: Activity = change in energy service demand related to rising population, increased floor area and income per capita. Behaviour = change in energy service demand from user decisions, e.g. changing heating temperatures. Avoided demand = change in energy service demand from technology developments, e.g. digitalisation.

Rapid shifts to zero-carbon-ready technologies see the share of fossil fuels in energy demand in the buildings sector drop to 30% by 2030, and to 2% by 2050 in the NZE. The share of electricity in the energy mix reaches almost 50% by 2030 and 66% by 2050, up from 33% in 2020 (Figure 3.28). All end-uses today dominated by fossil fuels are increasingly electrified in the NZE, with the share of electricity in space heating, water heating and cooking increasing from less than 20% today to more than 40% in 2050. District energy networks and low-carbon gases, including hydrogen-based fuels, remain significant in 2050 in regions with high heating needs, dense urban populations and existing gas or district heat networks. Bioenergy meets nearly one-quarter of overall heat demand in the NZE by 2050, over 50% of bioenergy use is for cooking, nearly all in emerging market and developing economies, where 2.7 billion people gain access to clean cooking by 2030 in the NZE. Space heating demand drops by two-thirds between 2020 and 2050, driven by improvement in energy efficiency and behavioural changes such as the adjustment of temperature set points.

Figure 3.28 ▷ Global final energy consumption by fuel and end-use application in buildings in the NZE



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Fossil fuel use in the buildings sector declines by 96% and space heating energy needs by two-thirds to 2050, thanks mainly to energy efficiency gains

Note: Other includes desalination and traditional use of solid biomass which is not allocated to a specific end-use.

Zero-carbon-ready buildings

The NZE pathway for the buildings sector requires a step change improvement in the energy efficiency and flexibility of the stock and a complete shift away from fossil fuels. To achieve this, more than 85% of buildings need to comply with zero-carbon-ready building energy codes by 2050 (Box 3.4). This means that mandatory zero-carbon-ready building energy codes for all new buildings need to be introduced in all regions by 2030, and that retrofits need to be carried out in most existing buildings by 2050 to enable them to meet zero-carbon-ready building energy codes.

Retrofit rates increase from less than 1% per year today to about 2.5% per year by 2030 in advanced economies: this means that around 10 million dwellings are retrofitted every year. In emerging market and developing economies, building lifetimes are typically lower than in advanced economies, meaning that retrofit rates by 2030 in the NZE are lower, at around 2% per year. This requires the retrofitting of 20 million dwellings per year on average to 2030. To achieve savings at the lowest cost and to minimise disruption, retrofits need to be comprehensive and one-off.

Box 3.4 ▷ Towards zero-carbon-ready buildings

Achieving decarbonisation of energy use in the sector requires almost all existing buildings to undergo a single in-depth retrofit by 2050, and new construction to meet stringent efficiency standards. Building energy codes covering new and existing buildings are the fundamental policy instrument to drive such changes. Building energy codes currently exist or are under development in only 75 countries, and codes in around 40 of these countries are mandatory for both the residential and services sub-sectors. In the NZE, comprehensive zero-carbon-ready building codes are implemented in all countries by 2030 at the latest.

What is a zero-carbon-ready building?

A zero-carbon-ready building is highly energy efficient and either uses renewable energy directly, or uses an energy supply that will be fully decarbonised by 2050, such as electricity or district heat. This means that a zero-carbon-ready building will become a zero-carbon building by 2050, without any further changes to the building or its equipment.

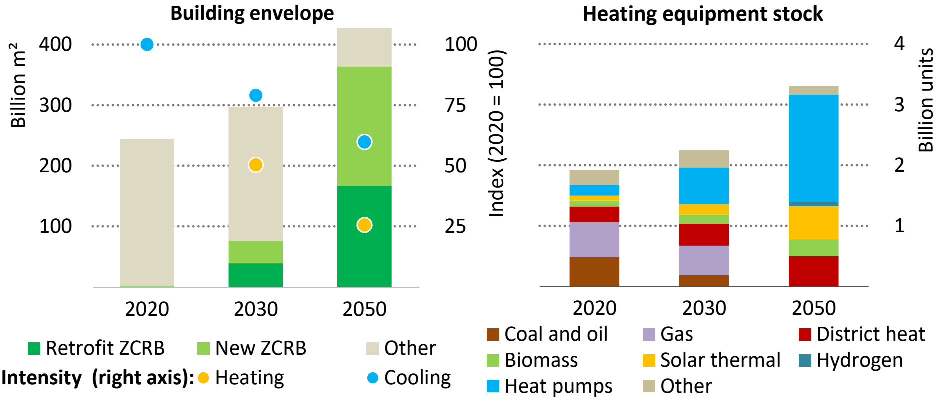
Zero-carbon-ready buildings should adjust to user needs and maximise the efficient and smart use of energy, materials and space to facilitate the decarbonisation of other sectors. Key considerations include:

- **Scope.** Zero-carbon-ready building energy codes should cover building operations (scope 1 and 2) as well as emissions from the manufacturing of building construction materials and components (scope 3 or embodied carbon emissions).
- **Energy use.** Zero-carbon-ready energy codes should recognise the important part that passive design features, building envelope improvements and high energy performance equipment play in lowering energy demand, reducing both the operating cost of buildings and the costs of decarbonising the energy supply.
- **Energy supply.** Whenever possible, new and existing zero-carbon-ready buildings should integrate locally available renewable resources, e.g. solar thermal, solar PV, PV thermal and geothermal, to reduce the need for utility-scale energy supply. Thermal or battery energy storage may be needed to support local energy generation.
- **Integration with power systems.** Zero-carbon-ready building energy codes need buildings to become a flexible resource for the energy system, using connectivity and automation to manage building electricity demand and the operation of energy storage devices, including EVs.
- **Buildings and construction value chain.** Zero-carbon-ready building energy codes should also target net-zero emissions from material use in buildings. Material efficiency strategies can cut cement and steel demand in the buildings sector by more than a third relative to baseline trends, and embodied emissions can be further reduced by more robust uptake of bio-sourced and innovative construction materials.

Heating and cooling

Building envelope improvements in zero-carbon-ready retrofit and new buildings account for the majority of heating and cooling energy intensity reductions in the NZE, but heating and cooling technology also makes a significant contribution. Space heating is transformed in the NZE, with homes heated by natural gas falling from nearly 30% of the total today to less than 0.5% in 2050, while homes using electricity for heating rise from nearly 20% of the total today to 35% in 2030 and about 55% in 2050 (Figure 3.29). High efficiency electric heat pumps become the primary technology choice for space heating in the NZE, with worldwide heat pump installations per month rising from 1.5 million today to around 5 million by 2030 and 10 million by 2050. Hybrid heat pumps are also used in some of the coldest climates, but meet no more than 5% of heating demand in 2050.

Figure 3.29 ▹ Global building and heating equipment stock by type and useful space heating and cooling demand intensity changes in the NZE



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By 2050, over 85% of buildings are zero-carbon-ready, reducing average useful heating intensity by 75%, with heat pumps meeting over half of heating needs

Notes: ZCRB refers to buildings meeting zero-carbon-ready building energy codes. Other for building envelope refers to envelopes that do not meet zero-carbon-ready building energy codes. Other for heating equipment stock includes resistive heaters, and hybrid and gas heat pumps.

Not all buildings are best decarbonised with heat pumps, however, and bioenergy boilers, solar thermal, district heat, low-carbon gases in gas networks and hydrogen fuel cells all play a role in making the global building stock zero-carbon-ready by 2050. Bioenergy meets 10% of space heating needs by 2030 and more than 20% by 2050. Solar thermal is the preferred renewable technology for water heating, especially where heat demand is low; in the NZE it meets 35% of demand by 2050, up from 7% today. District heat networks remain an attractive option for many compact urban centres where heat pump installation is impractical, in the NZE they provide more than 20% of final energy demand for space heating in 2050, up from a little over 10% today.

There are no new coal and oil boilers sold globally from 2025 in the NZE. Sales of gas boilers fall by more than 40% from current levels by 2030 and by 90% by 2050. By 2025 in the NZE, any gas boilers that are sold are capable of burning 100% hydrogen and therefore are zero-carbon-ready. The share of low-carbon gases (hydrogen, biomethane, synthetic methane) in gas distributed to buildings rises from almost zero to 10% by 2030 to above 75% by 2050.

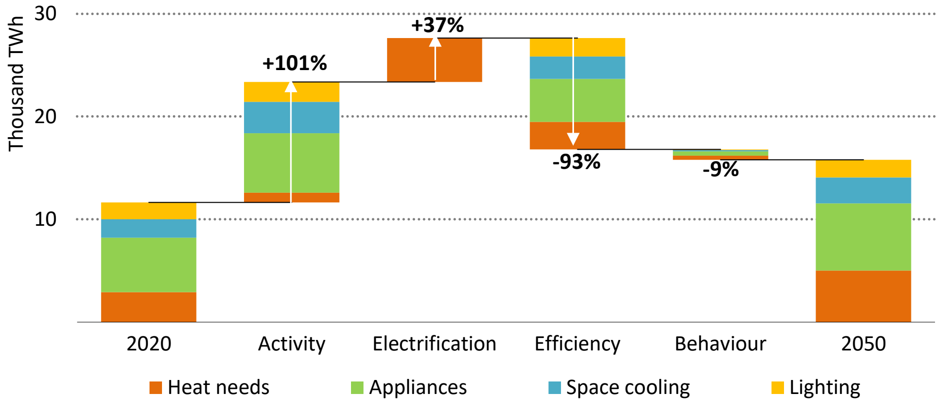
Buildings that meet the standards of zero-carbon-ready building energy codes drive down the need not only for space heating but also for space cooling – the fastest growing end-use in buildings since 2000. Space cooling represented only 5% of total buildings energy consumption worldwide in 2020, but demand for cooling is likely to grow strongly in the coming decades with rising incomes and a hotter climate. In the NZE, 60% of households have an air conditioner in 2050, up from 35% in 2020. High-performance building envelopes, including bioclimatic designs and insulation, can reduce the demand for space cooling by 30-50%, while providing greater resilience during extreme heat events. In the NZE, electricity demand for space cooling grows annually by 1% to reach 2 500 TWh in 2050. Without 2 000 TWh of savings from residential building envelope improvements and higher efficiency equipment, space cooling demand would be almost twice as high.

Appliances and lighting

Electric appliances and lighting become much more efficient over the next three decades in the NZE thanks to policy measures and technical advances. By 2025 in the NZE, over 80% of all appliances and air conditioners sold in advanced economies are the best available technologies today in these markets, and this share increases to 100% by the mid-2030s. In emerging market and developing economies, which account for over half of appliances and air conditioners by 2050, the NZE assumes a wave of policy action over the next decade which leads to 80% of equipment sold in these markets in 2030 being as efficient as the best available technologies in advanced economies today, increasing to close to 100% by 2050 (Figure 3.30). The share of light-emitting diode (LED) lamps in total lightbulb sales reaches 100% by 2025 in all regions. Minimum energy performance standards are complemented by requirements for smart control of appliances to facilitate demand-side response in all regions.

Energy use in buildings will be increasingly focused on electric, electronic and connected equipment and appliances. The share of electricity in energy consumption in buildings rises from 33% in 2020 to around two-thirds in 2050 in the NZE, with many buildings incorporating decentralised electricity generation using local solar PV panels, battery storage and EV chargers. The number of residential buildings with solar PV panels increases from 25 million to 240 million over the same period. In the NZE, smart control systems shift flexible uses of electricity in time to correspond with generation from local renewables, or to provide flexibility services to the power system, while optimised home battery and EV charging allow households to interact with the grid. These developments help improve electricity supply security and lower the cost of the energy transition by making it easier and cheaper to integrate renewables into the system.

Figure 3.30 ⊳ Global change in electricity demand by end-use in the buildings sector



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Energy efficiency is critical to mitigate electricity demand growth for appliances and air conditioning, with savings more than offsetting the impact of electrifying heat

3.7.2 Key milestones and decision points

Table 3.5 ⊳ Key milestones in transforming global buildings sector

Category	
New buildings	• From 2030: all new buildings are zero-carbon-ready.
Existing buildings	• From 2030: 2.5% of buildings are retrofitted to be zero-carbon-ready each year.

Category	2020	2030	2050
Buildings			
Share of existing buildings retrofitted to the zero-carbon-ready level	<1%	20%	>85%
Share of zero-carbon-ready new buildings construction	5%	100%	100%
Heating and cooling			
Stock of heat pumps (million units)	180	600	1 800
Million dwellings using solar thermal	250	400	1 200
Avoided residential energy demand from behaviour	n.a.	12%	14%
Appliances and lighting			
Appliances: unit energy consumption (index 2020=100)	100	75	60
Lighting: share of LED in sales	50%	100%	100%
Energy access			
Population with access to electricity (billion people)	7.0	8.5	9.7
Population with access to clean cooking (billion people)	5.1	8.5	9.7
Energy infrastructure in buildings			
Distributed solar PV generation (TWh)	320	2 200	7 500
EV private chargers (million units)	270	1 400	3 500

Near-term government decisions are required for energy codes and standards for buildings, fossil fuel phase out, use of low-carbon gases, acceleration of retrofits and financial incentives to encourage investment in building sector energy transitions. Decisions will be most effective if they focus on decarbonising the entire value chain, taking into account not only buildings but also the energy and infrastructure networks that supply them, as well as wider considerations including the role of the construction sector and urban planning. Such decisions are likely to bring wider benefits, notably in reducing fuel poverty.

Near-term government action is needed to ensure that zero-carbon-ready buildings become the new norm across the world before 2030 for both new construction and retrofits. This requires governments to act before 2025 to ensure that zero-carbon-ready compliant building energy codes are implemented by 2030 at the latest. While this goal applies to all regions, ways to achieve zero-carbon-ready buildings vary significantly across regions and climate zones, and the same is true for heating and cooling technology strategies. Governments should consider paving the way by making public buildings zero-carbon-ready in the coming decade.

Governments will need to find ways to make new zero-carbon-ready buildings and retrofits affordable and attractive to owners and occupants by overcoming financial barriers, addressing split incentive barriers and minimising disruption to building use. Building energy performance certificates, green lease agreements, green bond financing and pay-as-you save models could all play a part.

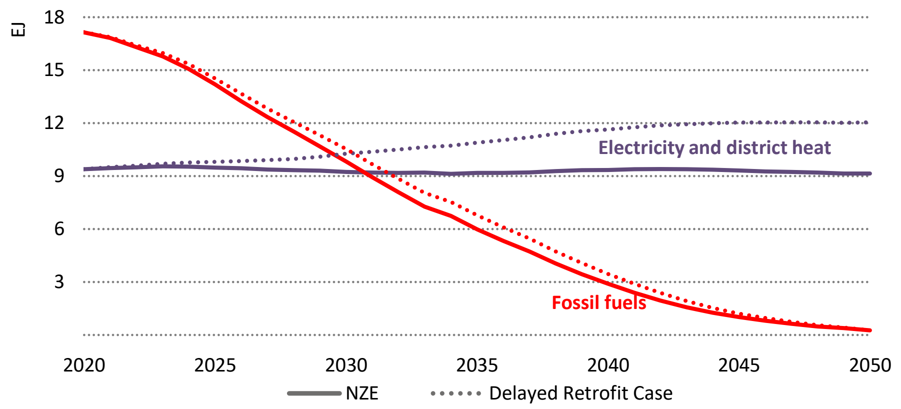
Making zero-carbon-ready building retrofits a central pillar of economic recovery strategies in the early 2020s is a no-regrets action to jumpstart progress towards a zero-emissions building sector. Foregoing the opportunity to make energy use in buildings more efficient would drive up electricity demand linked to electrification of energy use in the buildings sector and make decarbonising the energy system significantly more difficult and more costly (Box 3.5).

Box 3.5 ▹ What would be the impact of global retrofit rates not rising to 2.5%?

Decarbonising heating in existing buildings in the NZE rests upon a deep retrofit of the majority of the existing building stock. Having almost all buildings meet zero-carbon-ready building energy codes by 2050 would require retrofit rates of 2.5% each year by 2030, up from less than 1% today. Retrofits can be disruptive for occupants, require high upfront investment and may face permitting difficulties. These issues make achieving the required pace and depth of retrofits in the coming years the biggest challenge facing the buildings sector.

Any delay in reaching 2.5% of annual retrofits by 2030 would require such a steep subsequent ramp up as to make retrofitting the vast majority of buildings by 2050 virtually impossible. Modelling indicates that a delay of ten years in the acceleration of retrofitting, would increase residential space heating energy demand by 25% and space cooling demand by more than 20%, translating to a 20% increase in electricity demand in 2050 relative to the NZE (Figure 3.31). This would put more strain on the power sector, which would need to install more low-carbon generation capacity. Policies and fuel switching would still drive down fossil fuel demand in the *Delayed Retrofit Case*, but an additional 15 EJ of fossil fuels would be burned by 2050, emitting 1 Gt of CO_2.

Figure 3.31 ⊳ **Global residential space heating and cooling energy demand in the NZE and Delayed Retrofit Case**



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Delays in the ramp up of retrofit rates and depth would be almost impossible to catch up, placing further strain on the power sector and pushing up fossil fuel demand

Governments need to establish policies for coal and oil boilers and furnaces for space and water heating, which in the NZE are no longer available for sale from 2025. They also need to take action to ensure that new gas boilers are able to operate with low-carbon gases (hydrogen ready) in decarbonised gas networks. This puts a premium on the availability of compelling alternatives to the types of boilers being phased out, including the use of heat pumps, efficient wood stoves (using sustainable supplies of wood), district energy, solar PV, solar thermal and other renewable energy technologies. Which alternatives are best will depend to some extent on local conditions, but electrification will be the most energy-efficient and cost-effective low-carbon option in most cases, and decarbonising and expanding district energy networks is likely to make sense where densities allow. The use of biomethane or hydrogen in existing or upgraded gas networks may be the best option in areas where more efficient alternatives are not possible.

Governments also face decisions on minimum energy performance standards (MEPS). The NZE sees all countries introduce MEPS for all main appliance categories set at the most stringent levels prevailing in advanced economies by 2025 at the latest. Among others, this would mean ending the sale of incandescent, halogen and compact fluorescent lamps by that time. Setting MEPS at the right level will require careful planning; international collaboration to align standards and objectives could play a helpful role in keeping costs down.

The systemic nature of the NZE means that strategies and policies for buildings will work best if they are aligned with those being adopted for power systems, urban planning and mobility. This would help to ensure the successful scaling up of building-integrated PV technologies, battery storage and smart controls to make buildings active service providers to grids. It would also help to foster the deployment of smart EV charging infrastructure. Policies incentivising dense and mixed-use urban planning coupled with easy access to local services and public transport could reduce reliance on personal vehicles (see Chapter 2). There are also links between buildings strategies and measures to reduce the embodied carbon emissions of new construction, which falls by 95% by 2050 in the NZE.

Wider implications of achieving net-zero emissions

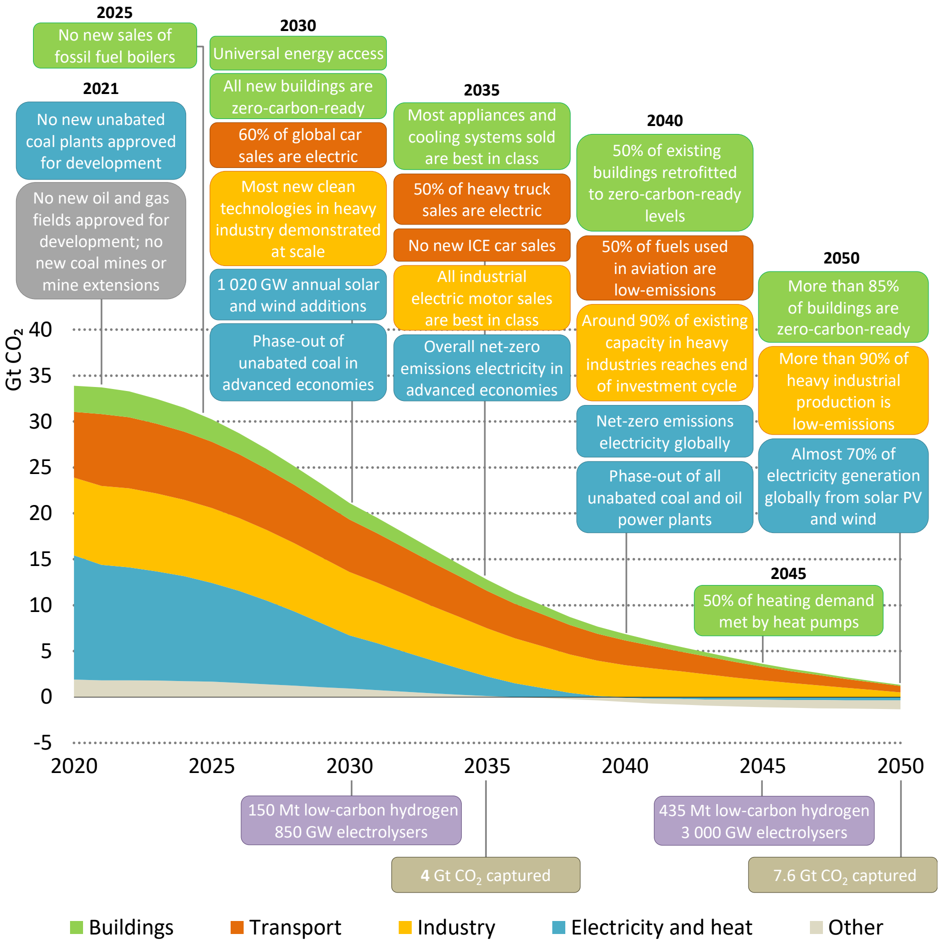
SUMMARY

- **Economy:** In our Net-Zero Emissions by 2050 Scenario (NZE), global CO_2 emissions reach net zero by 2050 and investment rises across electricity, low-emissions fuels, infrastructure and end-use sectors. Clean energy employment increases by 14 million to 2030, but employment in oil, gas and coal declines by around 5 million. There are varying results for different regions, with job gains not always occurring in the same place, or matching the same skill set, as job losses. The increase in jobs and investment stimulates economic output, resulting in a net increase in global GDP to 2030. But oil and gas revenues in producer economies are 80% lower in 2050 than in recent years and tax revenues from retail oil and gas sales in importing countries are 90% lower.
- **Energy industry:** There is a major contraction in fossil fuel production, but companies that produce these fuels have skills and resources that could play a key role in developing new low-emissions fuels and technologies. The electricity industry scales up to meet demand rising over two-and-a-half-fold to 2050 and becomes more capital intensive, focusing on renewables, sources of flexibility and grids. Large energy-consuming companies, vehicle manufacturers and their suppliers adjust designs and retool factories while improving efficiency and switching to alternative fuel supplies.
- For **citizens** who lack access to electricity and clean cooking, the NZE delivers universal access by 2030. This costs around USD 40 billion a year over the next decade and adds less than 0.2% to CO_2 emissions. For citizens the world over, the NZE brings profound changes, and their active support is essential if it is to succeed. Around three-quarters of behavioural changes in the NZE can be directly influenced or mandated by government policies. The cost of energy is also an important issue for citizens, and the proportion of disposable household income spent on energy over the period to 2050 remains stable in emerging market and developing economies, despite a large increase in demand for modern energy services.
- **Government** action is central to achieve net-zero emissions globally by 2050; it underpins the decisions made by all other actors. Four particular points are worth stressing. First, the NZE depends on actions that go far beyond the remit of energy ministers, and requires a co-ordinated cross-government approach. Second, the fall in oil and gas demand in the NZE may reduce some traditional energy security risks, but they do not disappear, while potential new vulnerabilities emerge from increasing reliance on electricity systems and critical minerals. Third, accelerated innovation is needed. The emissions cuts to 2030 in the NZE can be mostly achieved with technologies on the market today, but almost half of the reductions in 2050 depend on technologies that are currently under development. Fourth, an unprecedented level of international co-operation is needed. This helps to accelerate innovation, develop international standards and facilitate new infrastructure to link national markets. Without the co-operation assumed in the NZE, the transition to net-zero emissions would be delayed by decades.

4.1 Introduction

Achieving net-zero emissions by 2050 is a monumental task, especially against a backdrop of increasing economic and population growth. It calls for an unwavering focus from all governments, working together with industries and citizens, to ensure that the transition to global net-zero emissions proceeds in a co-ordinated way without delay. In this chapter, we look at what the changes that deliver net-zero emissions globally by 2050 in the NZE would mean for the economy, the energy industry, citizens and governments.

Figure 4.1 ▻ Selected global milestones for policies, infrastructure and technology deployment in the NZE



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There are multiple milestones on the way to global net-zero emissions by 2050. If any sector lags, it may prove impossible to make up the difference elsewhere.

Wide-ranging measures and regulations in the NZE help to influence or change the purchases that individuals make, the way they heat and cool their homes, and their means of transport. Many industries, especially those that are currently involved in the production of energy or are large-scale users of energy, also face change. Some of the shifts for individuals and industries may be unpopular, underscoring the fact that it is essential to ensure that the energy transition is transparent, just and cost-effective, and to persuade citizens of the need for reform. These changes deliver significant benefits. There are around 790 million people who do not have access to electricity today and 2.6 billion people who do not have access to clean cooking options. The NZE shows how emissions reductions can go hand-in-hand with efforts to provide universal access to electricity and clean cooking, and to improve air quality. It provides significant opportunities too, with clean energy technologies providing many new business opportunities and jobs, and with innovations that stimulate new industrial capacities.

Underpinning all of these changes are decisions taken by governments. This will require wholehearted buy-in from all levels of government and from all countries. The magnitude of the changes required to reach global net-zero emissions by 2050 are not within the power of government energy or environment departments alone to deliver, nor within the power of individual countries. It will involve an unprecedented level of global collaboration, with recognition of and sensitivity to differences in the stages of development of individual countries, and an appreciation of the difficulties faced by particular communities and members of society, especially those who may be negatively affected by the transition to net-zero emissions. In the NZE, governments start by setting unequivocal long-term targets, ensuring that these are fully supported from the outset by explicit, near-term targets and policy measures that clearly set out the pathway, and that recognise each country’s unique starting conditions, to support the deployment of new infrastructure and technologies (Figure 4.1).

4.2 Economy

4.2.1 Investment and financing

The transition to net-zero emissions by 2050 requires a substantial ramp up in the investment of electricity, infrastructure and the end-use sectors. The largest increase over the next decade is in electricity generation: annual investment increases from about USD 0.5 trillion over the past five years to USD 1.6 trillion in 2030 (Figure 4.2). By 2030, annual investment in renewables in the electricity sector is around USD 1.3 trillion, slightly more than the highest level ever spent on fossil fuel supply (USD 1.2 trillion in 2014). Annual investment in clean energy infrastructure increases from around USD 290 billion over the past five years to about USD 880 billion in 2030. This is for electricity networks, public electric vehicle (EV) charging stations, hydrogen refuelling stations and import and export terminals, direct air capture and CO_2 pipelines and storage facilities. Annual investment in low-carbon technologies in end-use sectors rises from USD 530 billion in recent years to USD 1.7 trillion in 2030.[1] This includes spending on deep retrofitting of buildings, transformation of industrial processes, and the purchase of new low-emissions vehicles and more efficient appliances.

After 2030, annual electricity generation investment falls by one-third to 2050. A lot of infrastructure for a low-emissions electricity sector is established within the first decade of the NZE, and the cost of renewables continues to decline after 2030. In end-use sectors, there are continued increases in investment in EVs, carbon capture, utilisation and storage (CCUS) and hydrogen use in industry and transport, and more efficient buildings and appliances.

Global investment in fossil fuel supply falls steadily from about USD 575 billion on average over the past five years to USD 110 billion in 2050 in the NZE, with upstream fossil fuel investment restricted to maintaining production at existing oil and natural gas fields. This investment reflects the fact that fossil fuels are still used in 2050 in the NZE in processes where they are paired with CCUS, in non-emitting processes (such as petrochemical manufacturing), and in sectors where emissions reductions are most challenging (with emissions offset by carbon dioxide removal). Investment in low-emissions fuels increases more than thirty-fold between 2020 and 2050, reaching about USD 135 billion in 2050. This is split roughly equally between the production of hydrogen and hydrogen-based fuels, and the production of biofuels.

Over the 2021-50 period in the NZE, annual average total energy sector investment as a share of gross domestic product (GDP) is around 1% higher than over the past five years. The private sector is central to finance higher investment needs. It requires enhanced collaboration between developers, investors, public financial institutions and governments. Collaboration will be especially important over the next five to ten years for the development of large infrastructure projects and for technologies in the demonstration or prototype phase today such as some hydrogen and CCUS applications. Companies and investors have declared strong interest to invest in clean energy technologies, but turning interest into actual investment at the levels required in the NZE also depends on public policies.

Some obstacles to investment need to be tackled. Many emerging market and developing economies are reliant on public sources to finance energy projects and new industrial facilities. In some cases, improvements in regulatory and policy frameworks would facilitate the international flow of long-term capital to support the development of both new and existing clean energy technologies. The rapid growth in investment in transport and buildings in the NZE presents a different kind of challenge for policy makers. In many cases, an increase in capital spending for an efficient appliance or low-emissions vehicle would be more than offset by lower expenditure on fuels and electricity over the product lifetime, but some low-income households and small and medium enterprises may not be able to afford the upfront capital required.

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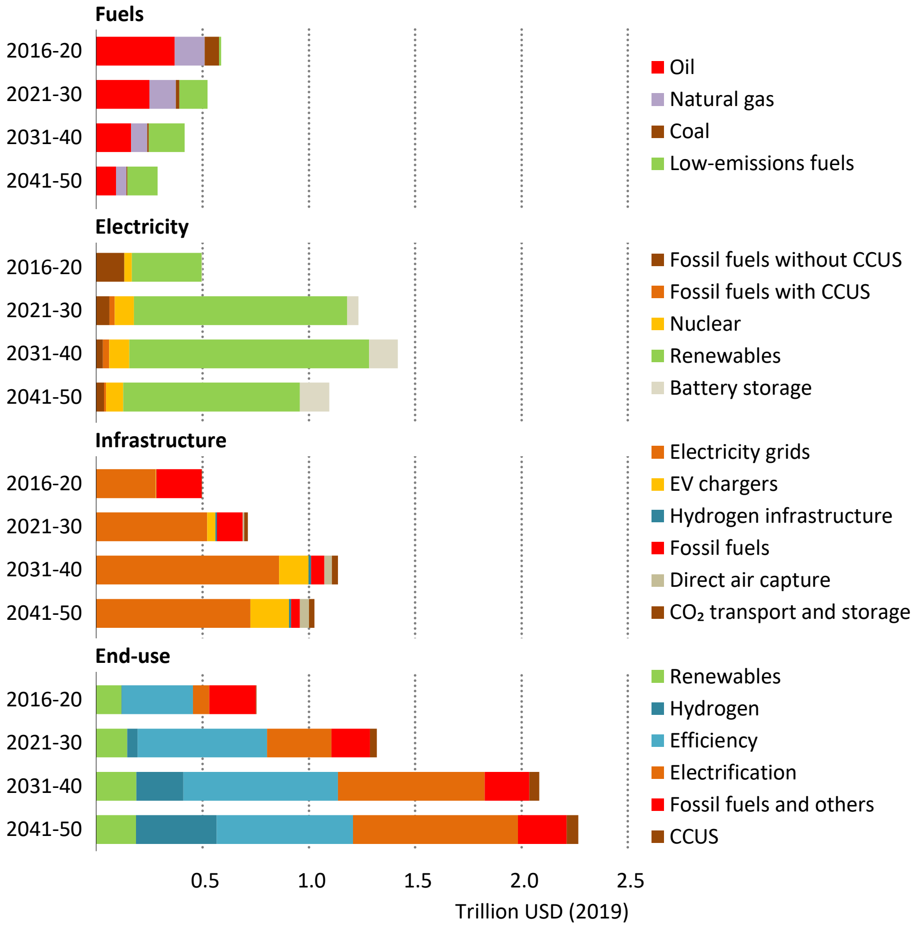
[1] Investment levels presented in this report include a broader accounting of efficiency improvements in buildings and differ from that reported in the IEA World Energy Investment report (IEA, 2020a). End-use efficiency investments are the incremental cost of improving the energy performance of equipment relative to a conventional design.

Figure 4.2 ▷ Global average annual energy investment needs by sector and technology in the NZE



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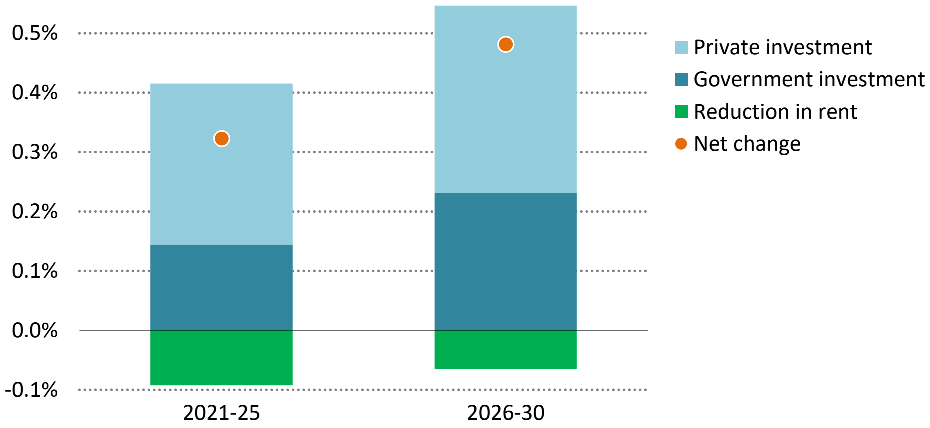
Investment increases rapidly in electricity generation, infrastructure and end-use sectors. Fossil fuel investment drops sharply, partly offset by a rise in low-emissions fuels.

Notes: CCUS = carbon capture, utilisation and storage; EV = electric vehicle. Infrastructure includes electricity networks, public EV charging, CO_2 pipelines and storage facilities, direct air capture and storage facilities, hydrogen refuelling stations, and import and export terminals for hydrogen and fossil fuels pipelines and terminals. End-use efficiency investments are the incremental cost of improving the energy performance of equipment relative to a conventional design.

4.2.2 Economic activity

The energy transition required for net-zero emissions by 2050 will affect all economic activities directly or indirectly. In co-ordination with the International Monetary Fund, we have modelled the medium-term global macroeconomic impact of the changes in the energy sector that occur in the NZE. This analysis shows that the surge in private and government spending on clean energy technologies in the NZE creates a large number of jobs and stimulates economic output in the engineering, manufacturing and construction industries. This results in annual GDP growth that is nearly 0.5% higher than the levels in the Stated Policies Scenario (STEPS)[2] during latter half of the 2020s (Figure 4.3).[3]

Figure 4.3 ▷ Change in annual growth rate of global GDP in the NZE relative to the STEPS



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The surge in government and private investment in the NZE has a positive impact on global GDP, but there are large differences between regions

Notes: GDP = gross domestic product. Reduction in rents stem mainly from lower fossil fuel income.

Source: IEA analysis based on IMF.

There are large differences in macroeconomic impacts between regions. The decline in fossil fuel use and prices results in a fall in GDP in the producer economies,[4] where revenues from oil and gas sales often cover a large share of public spending on education, health care and other public services. The drop in oil and gas demand, and the consequent fall in international prices for oil and gas, cause net income in producer economies to drop to historic lows (Figure 4.4). Some countries with the lowest cost oil resources (including members of the

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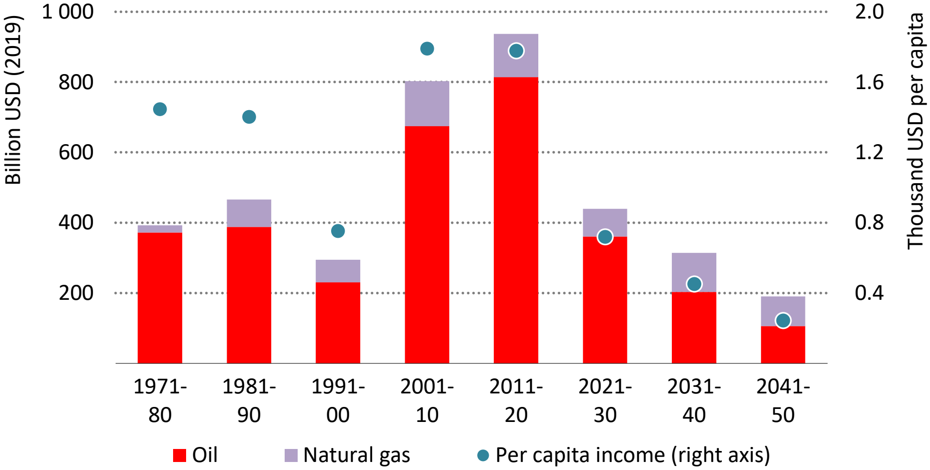
[2] The IEA Stated Policies Scenario is the projection for the global energy system based on the policies and measures that governments around the world have already put in place and on announced policies as expressed in official targets and plans, such as Nationally Determined Contributions put forward under the Paris Agreement (see Chapter 1).

[3] The estimated general equilibrium macroeconomic impact of the increase in public and private investment and the reduction in oil-related revenue contained in the NZE has been provided by the International Monetary Fund using its Global Integrated Monetary and Fiscal Model (GIMF).

[4] Producer economies are large oil and gas exporters that rely on hydrocarbon revenues to finance a significant proportion of their national budgets, including countries in the Middle East, Russia and the Caspian region.

Organization of the Petroleum Exporting Countries [OPEC]) gain market share in these circumstances, but even they would see large falls in revenues. Structural reforms would be needed to address the societal challenges, including those to accelerate the process of reforming inefficient fossil fuel subsidies and to speed up moves to use hydrocarbon resources to produce low-emissions fuels, e.g. hydrogen and hydrogen-based fuels (see section 4.3.1).

Figure 4.4 ▷ Income from oil and gas sales in producer economies in the NZE



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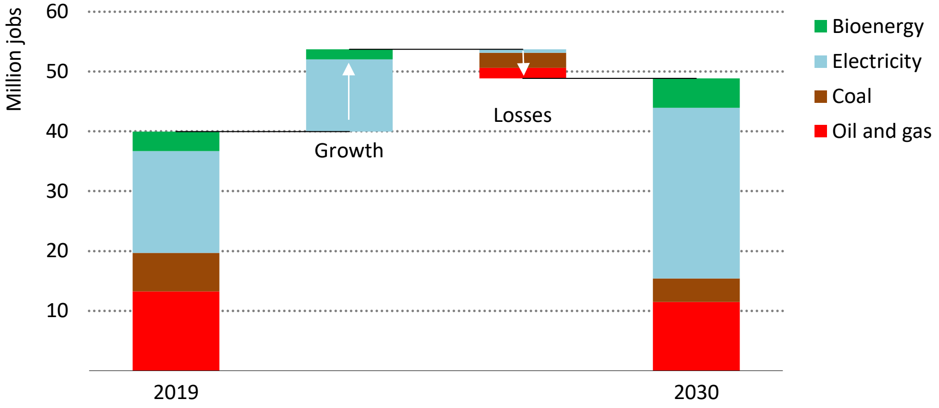
Structural reforms and new sources of revenue are needed in producer economies, but these are unlikely to compensate fully for a large drop in oil and gas income

The macroeconomic effects of the NZE are very uncertain. They depend on a host of factors including: how government expenditure is financed; benefits from improvements to health; changes in consumer bills; broad impact of changes in consumer behaviour; and potential for productivity spill-overs from accelerated energy innovation. Nonetheless, impacts are likely to be lower than assessments of the cost of climate change damages (OECD, 2015). It is also likely that a co-ordinated, orderly transition can be executed without major global systemic financial impacts, but this will require close attention from governments, financial regulators and the corporate sector.

4.2.3 Employment

Employment in the energy sector shifts markedly in the NZE in response to changes in investment and spending on energy. We estimate that today roughly 40 million people around the world work directly in the oil, gas, coal, renewables, bioenergy and energy network industries (IEA, 2020b). In the NZE, clean energy employment increases by 14 million to 2030, while employment in oil, gas and coal fuel supply and power plants declines by around 5 million, leading to a net increase of nearly 9 million jobs (Figure 4.5).

Figure 4.5 ▹ Global energy sector employment in the NZE, 2019-2030



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Overall employment in the energy sector increases by almost 9 million to 2030 as jobs created in clean energy sectors outpace losses in fossil fuels

Jobs created would not necessarily be in the same area where jobs are lost, plus the skill sets required for the clean energy jobs may not be directly transferable. Job losses would be most pronounced in communities that are heavily dependent on fossil energy production or transformation activities. Even where the number of direct energy jobs lost is small, the impact on the local economy may be significant. Government support would almost certainly be needed to manage these transitions in a just, people-centred way. In preparation, a better understanding of current energy industry employment is needed. A useful action would be for governments to adopt more detailed surveying approaches for energy industry employment, such as those used in the *US Energy & Employment Report* (NASEO and Energy Futures Initiative, 2021).

In addition to the 14 million new clean energy jobs created in the NZE, other new jobs are created by changes in spending on more efficient appliances, electric and fuel cell vehicles, and building retrofits and energy-efficient construction. These changes would require a further 16 million workers, meaning that there would be 30 million more people working in clean energy, efficiency and low-emissions technologies by 2030 in the NZE (Figure 4.6).[5] Investment in electricity generation, electricity networks, EV manufacturing and energy efficiency are among the areas that will open up new employment opportunities. For example, jobs in solar and wind more than quadruple in the NZE over current levels. Nearly two-thirds of workers in these sectors by 2030 in the NZE would be highly skilled and the

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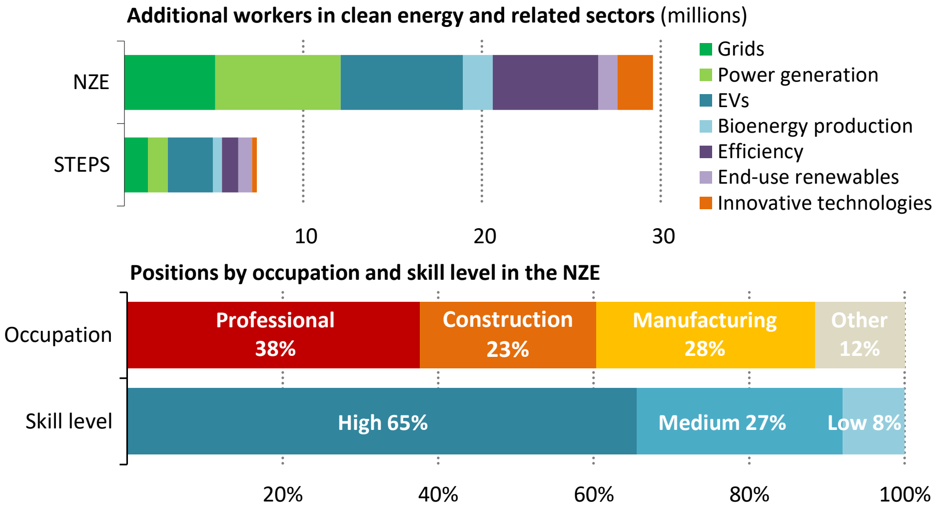
[5] This includes new jobs and jobs filled by moving current employment from one type of production to another.

majority require substantial training. In addition, with the more than doubling of total energy investment, new employment opportunities will arise in associated areas such as wholesale trading, financial and legal services.

In many cases it may be possible to shift workers to new product lines within the same company, for example in vehicle manufacturing as production reconfigures to EVs. However, there would be larger risks for specialised supply chain companies that provide products and services, e.g. internal combustion engines that are replaced by new components such as batteries.

Figure 4.6 ▷ New workers in clean energy and related sectors and shares by skill level and occupation in the NZE and the STEPS in 2030



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About 30 million new workers are needed by 2030 to meet increased demand for clean energy, efficiency, and low-emissions technologies; over half are highly skilled positions

Note: EVs = electric vehicles.

The new jobs created in the NZE tend to have more geographic flexibility and a wider distribution than is the case today. Around 40% are jobs located close to where the work is being done, e.g. building efficiency improvements or wind turbine installation, and the remaining are jobs tied to manufacturing sites. Today the manufacturing capacity for a number of clean energy technologies, such as batteries and solar photovoltaic panels, is concentrated in particular areas, notably China. The rapid increase in demand for clean energy technologies in the NZE requires new production capacity to come online that could be located in any region. Those countries and companies that move first may enjoy strategic advantages in capturing burgeoning demand.

4.3 Energy industry

4.3.1 Oil and gas

The energy transition envisioned in the NZE involves a major contraction of oil and gas production with far-reaching implications for all the companies that produce these fuels. Oil demand falls from around 90 million barrels per day (mb/d) in 2020 to 24 mb/d in 2050, while natural gas demand falls from 3 900 billion cubic metres (bcm) to around 1 700 bcm. No fossil fuel exploration is required in the NZE as no new oil and natural gas fields are required beyond those that have already been approved for development. This represents a clear threat to company earnings, but there are also opportunities. The resources and skills of the oil and gas industry are a good match with some of the new technologies needed to tackle emissions in sectors where reductions are likely to be most challenging, and to produce some of the low-emissions liquids and gases for which there is a rapid increase in demand in the NZE (see Chapter 2). By partnering with governments and other stakeholders, the oil and gas industry could play a leading role in developing these fuels and technologies at scale, and in establishing new business models.

The oil and gas industry is highly diverse, and various companies could pursue very different strategies in the transition to net-zero emissions. Minimising emissions from core oil and gas operations however should be a first-order priority for all oil and gas companies. This includes tackling methane emissions that occur during operations (they fall by 75% between 2020 and 2030 in the NZE) and eliminating flaring. Companies should also electrify operations using renewable electricity wherever possible, either by purchasing electricity from the grid or by integrating off-grid renewable energy sources into upstream facilities or transport infrastructure. Producers that can demonstrate strong and effective action to reduce emissions can credibly argue that their oil and gas resources should be preferred over higher emissions options.

Some oil and gas companies may choose to become “energy companies” focused on low-emissions technologies and fuels, including renewable electricity, electricity distribution, EV charging and batteries. Several technologies that are critical to the achievement of net-zero emissions, such as CCUS, hydrogen, bioenergy and offshore wind, look especially well-suited to some of the existing skills, competencies and resources of oil and gas companies.

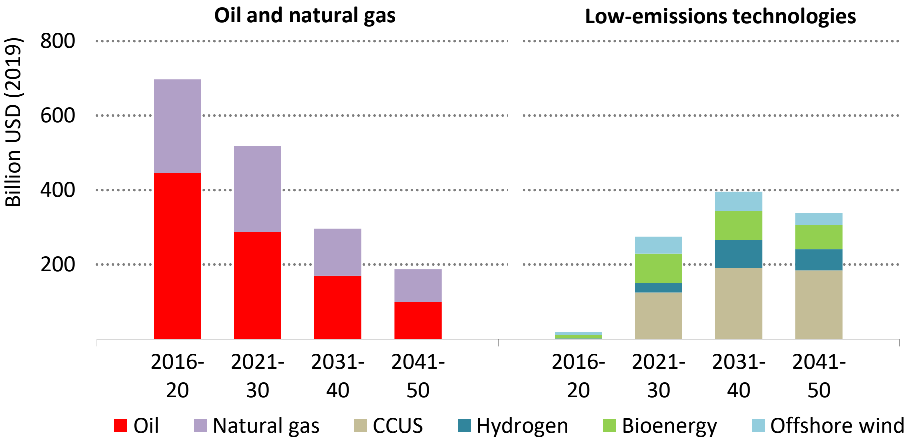
- **Carbon capture, utilisation and storage**. The oil and gas industry is already the global leader in developing and deploying CCUS. Of the 40 million tonnes (Mt) of CO_2 captured today at large-scale facilities, around three-quarters is captured from oil and gas operations, which often produce concentrated streams of CO_2 that are relatively easy and cost effective to capture (IEA, 2020c). The oil and gas industry also has the large-scale engineering, pipeline, sub-surface and project management skills and capabilities to handle large volumes of CO_2 and to help scale up the deployment of CCUS.

- **Low-emissions hydrogen and hydrogen-based fuels**. Oil and gas companies could contribute to developing and deploying low-emissions hydrogen in several ways (IEA, 2019a). Nearly 40% of hydrogen production in 2050 in the NZE is from natural gas in facilities equipped with CCUS, providing an important opportunity for companies and countries to utilise their natural gas resources in a way that is consistent with net-zero emissions. Of the total output of 530 Mt of hydrogen in 2050, about 30% is processed into ammonia and synthetic fuels (equivalent to around 7.5 mboe/d). The transformation processes involved have many potential synergies with the skills and equipment used in oil and gas processing and refining. Oil and gas companies also have long experience of transporting liquids and gases by pipeline and ships.
- **Advanced biofuels and biomethane**. The production of advanced biofuels grows substantially in the NZE, but this depends critically on continued technological innovation. Many oil and gas companies have active R&D programmes in these areas and could become leading producers. Biomethane – a low-emissions alternative to natural gas – can be produced in large centralised facilities, which could be a good fit with the knowledge and technical expertise of existing gas producers (IEA, 2020d).
- **Offshore wind**. About 40% of the lifetime costs of a standard offshore wind project involve significant synergies with the offshore oil and gas sector (IEA, 2019b). The oil and gas industry has considerable experience of working in offshore locations, which could be of value in the construction of foundations and subsea structures for offshore wind farms, especially when using vessels during installation and operation. The experience of maintaining safety standards in oil and gas companies could also be helpful during maintenance and inspection of offshore wind farms once they are in operation.

Oil and gas companies are well-placed to accelerate the pace of development and deployment of these technologies, and to gain a commercial edge over other companies. In the NZE, investment in low-emissions technologies suited to the skills and expertise of oil and gas companies exceeds that in traditional oil and gas operations by 2030. Total capital spending on these technologies and on traditional oil and gas operations averages USD 650 billion per year over 2021-50, just less than annual investment in oil and gas projects between 2016 and 2020 (Figure 4.7).

Not all oil and gas companies will choose to follow a strategy of diversifying into other types of energy. For example, it is far from certain that national oil companies will be charged by their state owners to diversify and develop low-emissions energy sources outside their core area of activity; other companies may decide simply to concentrate on supplying oil and natural gas as cleanly and efficiently as possible, and to return income to shareholders. What is clear, however, is that no oil and gas company would be unaffected by the NZE and that all parts of the industry need to decide how to respond (IEA, 2020e).

Figure 4.7 ▷ **Annual average investment in oil and gas and low-emissions technologies with synergies for the oil and gas industry in the NZE**



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Investment in low-emissions technologies suited to the skills and expertise of oil and gas companies exceeds investment in traditional operations by 2030

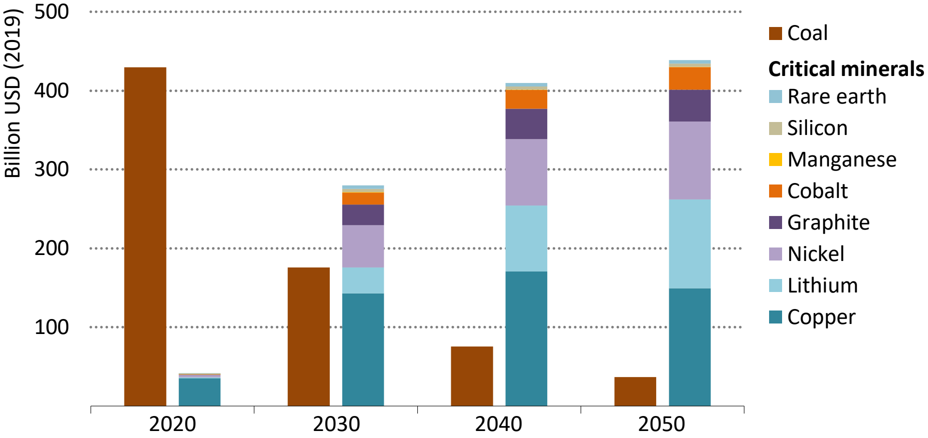
Note: CCUS = carbon capture, utilisation and storage.

4.3.2 Coal

The precipitous decline in coal use projected in the NZE would have major implications for the future of mining companies and countries with large existing production capacities. Around 470 million tonnes of coal equivalent (Mtce) of coal used in the NZE in 2050 is in facilities equipped with CCUS (80% of global coal demand in 2050), which prevents an even sharper decline in demand. But no new coal mines or mine extensions are needed in the NZE. Retraining and regional revitalisation programmes would be essential to reduce the social impact of job losses at the local level and to enable workers and communities to find alternative livelihoods. There could also be opportunities to locate new clean energy facilities, including the new processing facilities that are needed for critical minerals, in the areas most affected by mine closures.

For mining companies, however, the contraction in coal demand in the NZE could be offset by the need to increase mining of other raw minerals, including those vital to many clean energy technologies, such as copper, lithium and nickel (IEA, 2021a). Global demand for these critical minerals rises rapidly in the NZE (Figure 4.8). For example, demand for lithium for use in batteries expands by a factor of 30 by 2030, while demand for rare earths, primarily used for making EV motors and wind turbines, increases by a factor of ten by 2030. Critical mineral resources are not always located in the same locations or countries as existing coal mines, but the skills and experience of mining companies will be essential to ensure that the supply of these minerals is able to match demand at reasonable prices. By the 2040s, the size of the global market for these minerals approaches that for coal today.

Figure 4.8 ⊳ Global value of coal and selected critical minerals in the NZE



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The market for critical minerals approaches that of coal today in the 2040s

Notes: Includes total revenue for coal and for selected critical minerals used in clean energy technologies. The prices of critical minerals are based on conservative assumptions about cost increases (around a 10%-20% increase from current levels to 2050).

4.3.3 Electricity

Getting to net-zero emissions calls for a massive expansion of the electricity sector to power the needs of a growing global economy, the electrification of end-uses that previously used fossil fuels, and the production of hydrogen from electrolysis. While electricity demand increases more than two-and-a-half times, the rapid transformation of the industry means that total electricity supply costs triple from 2020 to 2050 in the NZE, raising average costs per unit of electricity generation modestly (Figure 4.9).

The electricity supply industry also becomes much more capital intensive, accelerating a recent trend. The share of capital in total costs rises from less than 60% in 2020 (already ten percentage points higher than in 2010) to about 80% in 2050. This is largely due to a massive increase in renewable energy and the corresponding need for more network capacity and sources of flexibility, including battery storage. In the late 2020s and 2030s, the upgrading and replacement of existing solar and wind capacity as they come to the end of their operating lives also boosts capital needs.[6] New nuclear power capacity additions add further capital spending in the NZE. The rising capital intensity of the electricity industry increases the importance of limiting risk for new investment and ensuring sufficient revenues in all years for grid operators to fund rising investment needs – a point underlined by the financial difficulties experienced by some network companies in 2020 due to depressed electricity demand resulting from the Covid-19 crisis (IEA, 2020f).

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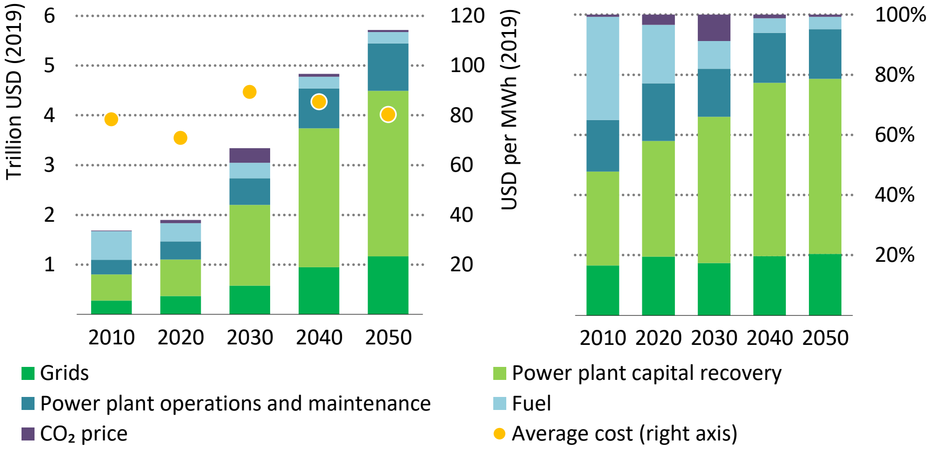
[6] They typically need replacing after 25-30 years of operation, whereas many conventional hydropower, nuclear and coal plants operate far longer albeit with periodic additional investment.

Figure 4.9 ▻ **Global electricity supply costs by component in the NZE**



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Electricity system costs triple to 2050, raising average supply costs modestly; the massive growth of renewables makes the industry more capital intensive

Notes: Electricity supply costs include all the direct costs to produce and transmit electricity to consumers. Battery storage systems are included in power plant capital recovery.

The rising share of renewables in the electricity generation mix has important implications for the design of electricity markets. When the shares of solar, wind, other variable renewables and nuclear power reach high levels, available electricity supply at no marginal cost is often above electricity demand, resulting in a wholesale price of electricity that is zero or even negative. By 2050, without changes in electricity market design, about 7% of wind and solar output in the NZE would be above and beyond what can be integrated (and so curtailed), and the share of zero-price hours in the year would increase to around 30% in major markets from close to zero today, despite the active use of demand response. If the share of renewables in the electricity generation mix is to rise as envisioned in the NZE, it would therefore be highly desirable to effect significant changes in the design of electricity markets so as to provide signals for investment, including investment in sources of flexibility such as battery storage and dispatchable power plants.

The increase in electricity use inevitably raises associated costs. Operating and maintaining power plants worldwide costs close to USD 1 trillion in 2050 in the NZE, two-and-a-half times the level in 2020. In 2020, upkeep at fossil fuel power plants accounted for USD 150 billion, and renewables required nearly as much, mostly for hydropower. By 2050, the cost of operating and maintaining renewables reaches USD 780 billion, most it needed for wind and solar photovoltaics (PV) as a result of their massive scaling up: offshore wind alone accounts for USD 90 billion.

The sharp reduction of fossil fuel use in the electricity industry and lower fuel prices mean that costs related to fuel and CO_2 prices are significantly reduced. This continues a recent trend driven by near record-low natural gas prices in many markets. Even with rising CO_2 prices over time, the rapid decarbonisation of electricity means that fuel and CO_2 make up a declining share of total costs, falling from about one-quarter in 2020 to 5% in 2050. The balance of fuel costs shifts towards low-emissions sources, mainly nuclear power and bioenergy (including with CCUS), though some still remains related to natural gas and coal used in power plants equipped with CCUS.

One challenge in this context is what to do about the coal-fired power plants in operation. In 2020, over 2 100 gigawatts (GW) of power plants worldwide used coal to produce electricity and heat, and they emitted nearly 30% of all energy-related CO_2 emissions. Options include retrofitting coal-fired power plants with CCUS technologies, co-firing with biomass or ammonia; repurposing coal plants to focus on providing flexibility; and, where feasible, phasing them out. In the NZE, all unabated coal-fired power plants are phased out in advanced economies by 2030 and in emerging market and developing economies by 2040. As a result, emissions from coal-fired power plants fall from 9.8 gigatonnes (Gt) in 2020 to 3.0 Gt in 2030 and to just 0.1 Gt by 2040 (residual emissions from coal with CCUS plants).[7]

Another challenge is related to the scale of capacity retirements envisaged and associated site rehabilitation, starting with coal. The pace of retirement of coal-fired power plants over 2020-50 is nearly triple that of the past decade. Decommissioning at each site can often last a decade and entail significant cost, and may involve closing a mine as well. In some cases, it may be financially attractive to build a renewable energy project on the same site, taking advantage of the grid connection and limiting the cost of rehabilitation. Thousands of natural gas-fired and oil-fired power plants are also retired by 2050, though these sites are often strategically located on the grid and many are likely to be replaced directly with battery storage systems.

The large fleet of ageing nuclear reactors in advanced economies means their decommissioning increases, despite many reactor lifetime extensions. In the NZE, annual average nuclear retirements globally are 60% higher over the next 30 years than in the last decade. Each nuclear decommissioning project can span decades, with costs ranging from several hundred million dollars to well over USD 1 billion for large reactors (NEA, 2016).

4.3.4 Energy-consuming industries

The changes in the NZE would have an enormous impact on industries that manufacture vehicles and their material and component suppliers. Around 95% of all the cars and nearly all of the trucks sold worldwide in 2020 were conventional vehicles with an internal combustion engine. In the NZE, about 60% of global car sales in 2030 are EVs, and 85% of

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[7] A CO_2 capture rate of 90% is assumed, though higher rates are technically possible with reduced efficiencies and additional costs (IEA, 2020g).

heavy-duty trucks sold in 2040 are EVs or fuel cell vehicles. In the NZE, vehicle component suppliers and vehicle manufacturers alike retool factories, change designs to incorporate batteries and fuel cells, and adjust supply chains to minimise the lifecycle emissions intensities of vehicles. This provides opportunities to redesign existing parts and manufacturing processes to improve efficiency and lower costs.

The rapid increase in EV sales in the NZE requires an immediate scale up of new supply chains for batteries as well as recharging and low-emissions refuelling infrastructure. In the NZE, battery production capacity increases to more than 6.5 terawatt-hours (TWh) by 2030, compared with less than 0.2 TWh in 2020. Any delay in expanding battery manufacturing capacity would have a detrimental impact on the roll-out of EVs and slow cost reductions for other clean energy technologies that benefit in the NZE from having similar manufacturing processes and know-how (such as fuel cell vehicles and electrolysers).

In aviation and shipping, liquid low-emissions fuels are central to cut emissions. Switching to some of these would have little impact on vessel design: the use of hydrogen-based fuels or biofuels in shipping would only require changes to the motor and fuel system, and bio-kerosene or synthetic kerosene can operate with existing aircraft. New bunkering and refuelling infrastructure are needed in the NZE, however, and the use of these low-emissions fuels also requires new safety and standardisation standards, protocols for permitting, construction and design, as well as international regulation, monitoring, reporting and verification of their production and use.

In heavy industrial sectors – steel, cement and chemicals – most deep emissions reduction technologies are not available on the market today. In the NZE, material producers soon demonstrate near-zero emission processes, aided by government risk-sharing mechanisms, and start to adapt their existing production assets. For multinational companies, this includes developing technology transfer strategies to roll-out processes across plants. International co-operation would help to ensure a level playing field for all. Within countries, efforts focus on industrial hubs in order to accelerate emissions reductions across multiple industrial sectors by promoting economies of scale for new infrastructure (such as CO_2 transport and storage) and supplies of low-emissions energy.

Materials producers work with governments in the NZE to create an international certification system for near-zero emission materials to differentiate them from conventional ones. This would enable buyers of materials such as vehicle manufacturers and construction companies to enter into commercial agreements to purchase near-zero emissions materials at a price premium. In most cases, the premium would result in only a modest impact on the final price of the product price given that materials generally account for a small portion of manufacturing costs (Material Economics, 2019).

4.4 Citizens

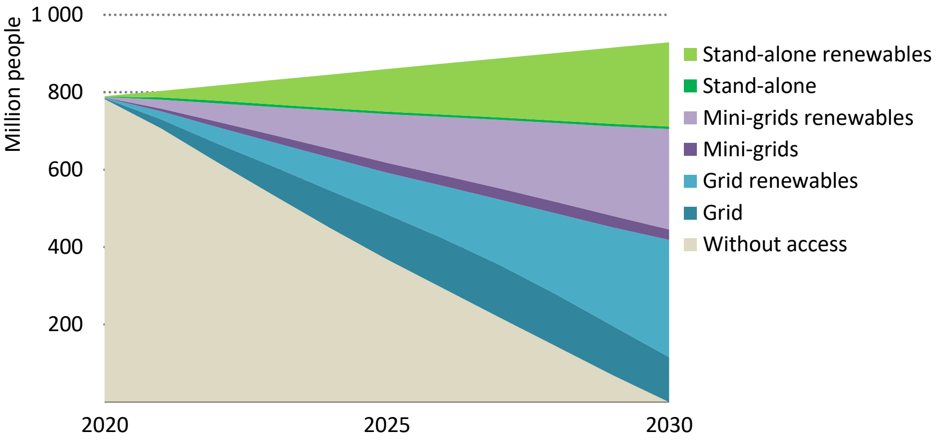
4.4.1 *Energy-related Sustainable Development Goals*

An inclusive and people-centred transition is key to the world moving rapidly, collectively and consistently toward net-zero emissions by mid-century. The NZE achieves the United Nations energy-related Sustainable Development Goals (SDGs) of universal access to clean modern energy by 2030 (SDG 7.1) and reducing premature deaths caused by air pollution (SDG 3.9). The technologies, options and measures used to achieve full access to low-emissions electricity and clean cooking solutions by 2030 in the NZE also help to reduce greenhouse gas (GHG) emissions from household energy use.

Energy access

About 790 million people worldwide did not have access to electricity in 2020, most of them living in sub-Saharan Africa and developing Asia. Around 2.6 billion people did not have access to clean cooking options: 35% of them were in sub-Saharan Africa, 25% in India and 15% in China. A lack of access to energy not only impedes economic development, but also causes serious harm to health and is a barrier to progress on gender equality and education.[8]

Figure 4.10 ▷ People gaining access to electricity by type of connection in emerging market and developing economies in the NZE



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More than 80% of people gaining access to electricity by 2030 are supplied renewable power and just over half via off-grid systems

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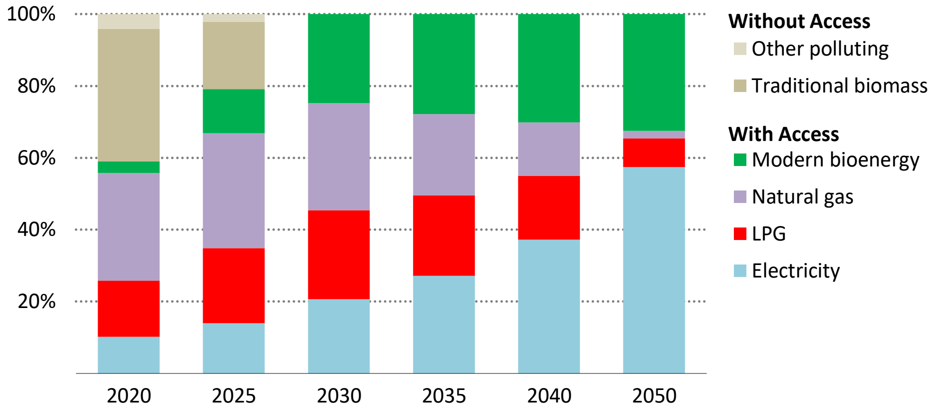
[8] Households relying on the traditional use of biomass for cooking dedicate around 1.4 hours each day collecting firewood and several hours cooking with inefficient stoves, a burden largely borne by women (IEA, 2017).

Around 45% of those who lack access to electricity by 2030 gain it via a connection to a main grid, while the rest are served by mini-grids (30%) and stand-alone solutions (25%) (Figure 4.10). Almost all off-grid or mini-grid solutions are 100% renewable. Decentralised systems that rely on diesel generators, which are also deployed in some grid-connected systems to compensate for low reliability, are phased out later and replaced with solar storage systems. Achieving full access does not lead to a significant increase in global emissions: in 2030 it adds less than 0.2% to CO_2 emissions. Achieving full access to electricity also brings efficiency gains and accelerates the electrification of appliances, which become critical to emissions reductions in buildings after 2030 in emerging market and developing economies.

For clean cooking, 55% of those gaining access by 2030 in the NZE do so through improved biomass cookstoves (ICS) fuelled by modern biomass, biogas or ethanol, 25% through the use of liquefied petroleum gas (LPG) and 20% via electric cooking solutions (Figure 4.11). LPG is the main fuel adopted in urban areas and ICS is the main option in rural areas. The use of LPG results in a slight increase in CO_2 emissions in 2030 but a net reduction in overall GHG emissions due to reduced methane, nitrous oxides and black carbon emissions from the traditional use of biomass. In addition, LPG is increasingly decarbonised after 2030 using bio-sourced butane and propane (bioLPG) produced sustainably from municipal solid waste (MSW) and other renewable feedstocks. The technical potential of bioLPG production from MSW in 2050 in Africa could be enough to satisfy the cooking needs of more than 750 million people (GLPGP, 2020; Liquid Gas Europe, 2021).

Figure 4.11 ▻ Primary cooking fuel by share of population in emerging market and developing economies in the NZE



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Traditional biomass is entirely replaced with modern energy by 2030, mainly in the form of bioenergy and LPG; by 2050, electricity, bioenergy and bioLPG meet most cooking needs

Notes: Modern bioenergy includes improved cook stoves, biogas and ethanol. Liquefied petroleum gas (LPG) includes fossil and renewable fuel.

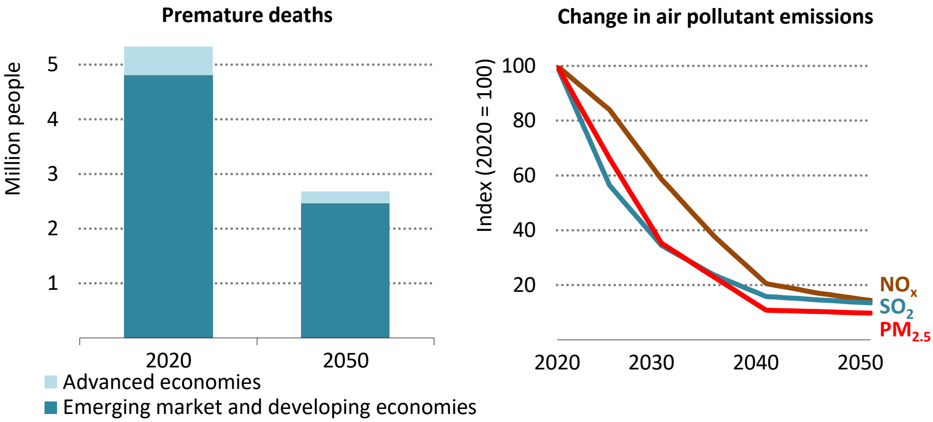
The achievement of universal access to clean energy by 2030 requires governments and donors to put expanding access at the heart of recovery plans and programmes. There would be multiple benefits: investing heavily in energy access would provide an immediate economic boost, create local jobs and bring durable improvements to social well-being by modernising health services and food chains. In the NZE, around USD 35 billion is spent each year improving access to electricity and almost USD 7 billion each year on clean cooking solutions for people in low-income countries from now to 2030.

Air pollution and health

More than 90% of people around the world are exposed to polluted air today. Such pollution led to around 5.4 million premature deaths in 2020, undermining economic productivity and placing extra stress on healthcare systems. Most of these deaths were in emerging market and developing economies. Just over half were caused by exposure to outdoor air pollution; the remainder resulted from breathing polluted air indoors, caused mainly by the traditional use of biomass for cooking and heating.

Energy-related emissions of the three major air pollutants – sulphur dioxide (SO_2), nitrogen oxides (NO_X) and fine particulate matter ($PM_{2.5}$) – fall rapidly in the NZE. SO_2 emissions fall by 85% between 2020 and 2050, mainly as a result of the large-scale phase-out of coal-fired power plants and industrial facilities. NO_X emissions also drop by around 85% as a result of the increased use of electricity, hydrogen and ammonia in the transport sector. The increased uptake of clean cooking fuels in developing countries, together with air pollution control measures in industry and transport, results in a 90% drop in $PM_{2.5}$ emissions (Figure 4.12). The reduction in air pollution in the NZE leads to roughly a halving in premature deaths in 2050 compared with 2020, saving the lives of about 2 million people per year, around 85% of them in emerging market and developing economies.

Figure 4.12 ▻ Global premature deaths and air pollutant emissions in the NZE



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Reductions in major air pollutants mean 2 million fewer premature deaths per year

Sources: IEA analysis based on IIASA.

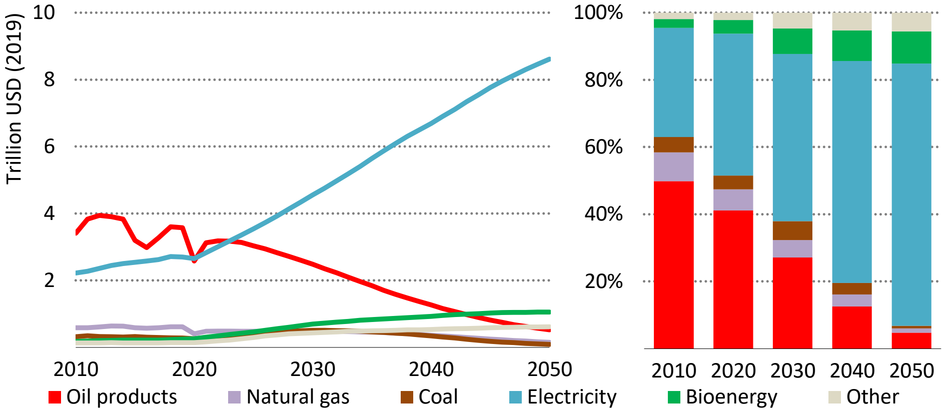
4.4.2 Affordability

Total spending on energy

Energy affordability is a key concern for governments, businesses and households. Global direct spending on energy, i.e. the total fuel bills paid by all end users, which totalled USD 6.3 trillion in 2020, increases by 45% to 2030 and 75% to 2050, in large part reflecting population and GDP growth over this period. As a share of global GDP, the figures look rather different: total direct spending on energy holds steady at around 8% out to 2030 (similar to the average over the last five years), but then declines to 6% in 2050. This decline offsets a significant share of the higher cost of buying new, more efficient energy-consuming equipment.

A portion of the increase in energy spending in the NZE is related to rising CO_2 prices and the removal of consumption subsidies for fossil fuels and electricity. CO_2 pricing (taxes and trading schemes) paid by end users at its peak generates global revenues in the NZE of close to USD 700 billion each year between 2030 and 2035, before declining steadily due to declining overall emissions: these revenues could be recycled into economies or otherwise used to improve consumer welfare, particularly for low-income households. The NZE also sees the progressive removal of consumption subsidies for fossil fuels, many of which disproportionally benefit wealthier segments of the population that use more of the subsidised fuel. Phasing out the subsidies would provide more efficient price signals for consumers, and spur more energy conservation and measures to improve energy efficiency. The impact of phasing out subsidies on lower income households could be offset through direct payment schemes or other means at lower overall costs to the economy.

Figure 4.13 ▷ Global energy spending by fuel in the NZE



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Total energy spending increases by 75% to 2050, mainly on electricity

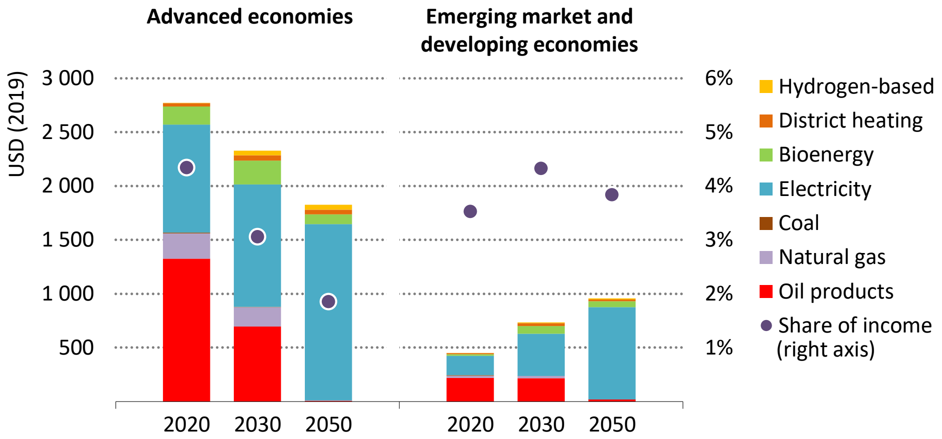
Note: Other = hydrogen-based and synthetic fuels, and district heating.

The transformation of the global energy system in the NZE drives a major shift in the composition of energy spending. Spending on electricity at USD 2.7 trillion in 2020 (45% of total energy spending) exceeded spending on oil products for the first time and it rises to over USD 8.5 trillion in 2050 (80% of total energy spending) (Figure 4.13). Retail electricity prices increase by 50% on average, contributing to the total increase. Spending on oil, which has dominated overall energy spending for decades, goes into long-term decline in the 2020s, its share of spending falling from 40% in 2020 to just 5% in 2050. Spending on natural gas and coal also declines in the long term, offset by higher spending on low-emissions fuels. Spending on bioenergy reaches about USD 900 billion per year by 2040, while other low-emissions fuels, including hydrogen-based products, gain a foothold and establish a market worth of around USD 600 billion per year by 2050.

Household spending on energy

Direct spending by households on energy, including for heating, cooling, electricity and fuel for passenger cars, falls as a share of disposable income in the NZE, though there are large differences between countries (Figure 4.14).

Figure 4.14 ▷ Average annual household energy bill in the NZE



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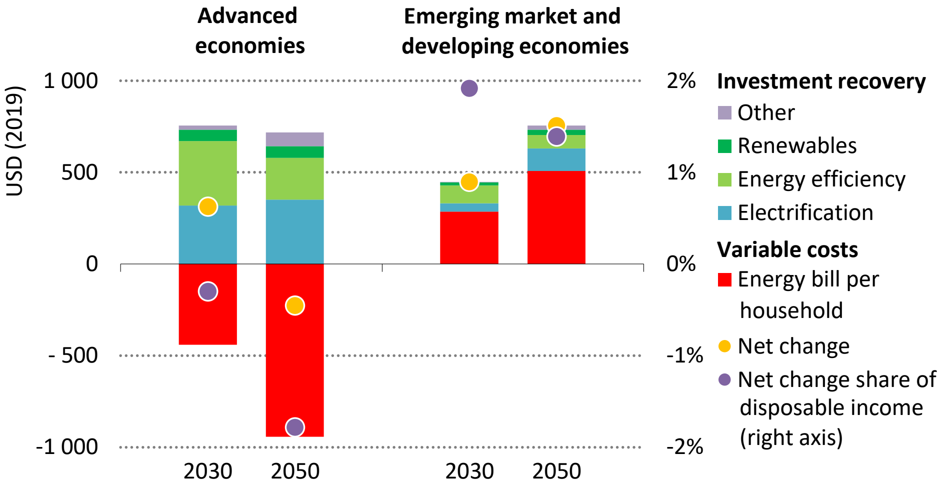
The proportion of disposable household income spent on energy is stable in emerging market and developing economies, and drops substantially in advanced economies

Note: Hydrogen-based includes hydrogen, ammonia and synthetic fuels.

In advanced economies, the average annual bill declines from about USD 2 800 in 2020 to USD 2 300 in 2030, thanks to a strong push on energy efficiency and cost-effective electrification. Oil products make up close to half of household energy bills in 2020, but this falls to 30% in 2030 and almost zero in 2050, due to a rapid shift to EVs and to downward pressure on oil prices. Natural gas bills, which make up almost 10% of the total today, also fall to almost zero in 2050 with the electrification of heating and cooking. Electricity rises from about 35% of household fuel bills in 2020 to 90% in 2050, increasing the sensitivity of households to electricity prices and consumption. Increasing incomes mean that household spending on energy as a share of disposable income drops from 4% in 2020 to 2% in 2050.

In emerging market and developing economies, there is a huge increase in demand for modern energy services linked to expanding populations, economic growth, rising incomes and universal access to electricity and clean cooking options. As in advanced economies, electricity accounts for the vast majority of energy bills in 2050. The use of more efficient appliances and equipment curbs some of the increase in demand, but household bills still increase in the NZE by over 60% to 2030 and more than double by 2050. As a percentage of disposable income, however, bills in emerging market and developing economies remain around 4%, and there are large social and economic benefits from increased energy use.

Figure 4.15 ▷ Change in household spending on energy plus energy-related investment in the NZE relative to 2020



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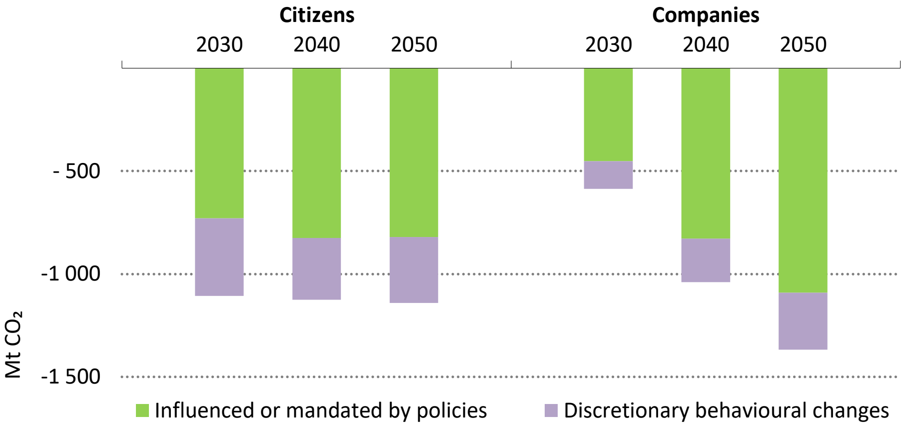
Total household spending on energy increases modestly in emerging market and developing economies, leaving over 90% of additional income available for other uses

Taking into account additional investment in electricity-consuming equipment such as efficient appliances and electric vehicles, spending on energy plus related investment is USD 1.30 higher per day per household globally in 2050 than in 2020 in the NZE. This modest increase means that expenditure on energy makes up a smaller share of disposable income in 2050 than it does today, though the impacts vary by country. In advanced economies, additional investment in electrification, energy efficiency and renewable energy costs about USD 750 per household by 2030 and USD 720 in 2050, which is fully offset by reductions in the level of energy bills (Figure 4.15). In emerging market and developing economies, a growing basket of energy services means increased use of energy, and total energy-related household spending increases. Additional investment moderates the change in energy bills, with the result that total energy-related spending takes 2 percentage points more of household disposable income in 2030 and 1 percentage point more in 2050 than today.

4.4.3 Behavioural changes

Behavioural changes play an important part in reducing energy demand and emissions in the NZE, especially in sectors where technical options for cutting emissions are limited in 2050. While it is citizens and companies that modify their behaviour, the changes are mostly enabled by the policies and investments made by governments, and in some instances, they are required by laws or regulations. The Covid-19 pandemic has increased general awareness of the potential effectiveness of behavioural changes, such as mask-wearing, and working and schooling at home. The crisis demonstrated that people can make behavioural changes at significant speed and scale if they understand the changes to be justified, and that it is necessary for governments to explain convincingly and to provide clear guidance about what changes are needed and why they are needed.

Figure 4.16 ▷ Emissions reductions from policy-driven and discretionary behavioural changes by citizens and companies in the NZE



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Three-quarters of the emissions saved by behavioural changes could be directly influenced or mandated by government policies

Around three-quarters of the emissions saved by behavioural changes between 2020 and 2050 in the NZE could be directly influenced or mandated by government policy (Figure 4.16). They include mitigation measures such as phasing out polluting cars from large cities and reducing speed limits on motorways. The other one-quarter involves more discretionary behavioural changes, such as reducing wasteful energy use in homes and offices, though even these types of changes could be promoted through awareness campaigns and other means. Around 10% of emissions savings directly influenced or mandated by government policy would require new or redirected investment in infrastructure. For example, the shift in the NZE from regional flights to high-speed rail would necessitate building around 170 000 kilometres of new track globally by 2050 (a tripling of 2020 levels).

Behavioural changes made by citizens and companies play a roughly equal role in reducing emissions in the NZE. Most changes in road transport and energy-saving in homes would depend on individuals, whereas the private sector has the primary role in reducing energy demand in commercial buildings and pursuing materials efficiency in manufacturing. Companies can also influence behavioural changes indirectly, for example, by promoting the use of public transport by employees that commute or encouraging working from home. However, a simple distinction between the role for individuals and companies masks a complex underlying dynamic: it is ultimately citizens as consumers of energy-related goods and services who shape corporate strategies, but at the same time companies do much to influence and generate consumer demand through marketing and advertising. In the NZE, consumers and companies move together in adopting behavioural changes, with governments setting the direction of those changes and facilitating them via effective and sustained policy support.

The behavioural changes in the NZE happen to different extents in different regions, and reflect a range of geographical and infrastructure constraints, as well as existing behavioural norms and cultural preferences. In countries with low rates of car ownership or energy service demand in buildings, many of the behavioural changes in advanced economies in NZE would not be relevant or appropriate. As a result, around half of the emissions savings from behavioural changes are in emerging market and developing economies, despite around 95% of activity growth in buildings and road transport between 2020 and 2050 occurring there. Nevertheless, there are significant opportunities in emerging market and developing economies for materials efficiency and urban design to decouple growth in economic prosperity and energy services from increases in emissions. For example, around 85% of CO_2 emissions reductions from cement and steel making in 2050 are due to gains in materials efficiency in emerging market and developing economies.

Cities are important to the behavioural changes in the NZE. Urban design can reduce the average city dweller's carbon footprint by up to 60% by shaping lifestyle choices and influencing day-to-day behaviour. For example, compact cities with clustered amenities can shorten average trip lengths; digitalisation can help shared private mobility to become the de facto option to accommodate much of the growth in service demand; and urban green infrastructure can reduce cooling demand (Feyisa, Dons & Meilby, 2014).

4.5 Governments

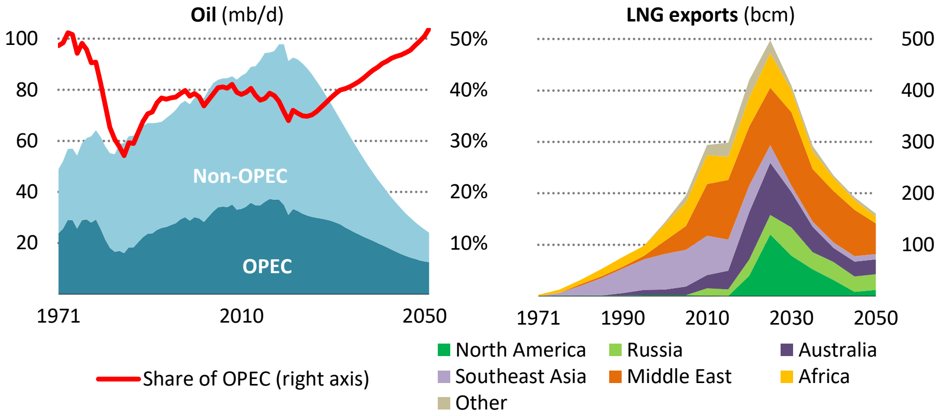
4.5.1 Energy security

Energy security is an important consideration for governments and those they serve, and the pathway to net-zero emissions must take account of it. Concerns about energy security have traditionally been associated with oil and natural gas supplies. The drop in oil and gas demand and the increased diversity of the energy sources used in the NZE may reduce some risks, but they do not disappear. There are also new potential vulnerabilities associated with the need to maintain reliable, flexible and secure electricity systems, and with the increase in demand for raw minerals for clean energy technologies. Improving energy efficiency remains the central measure for increasing energy security – even with rapid growth in low-emissions electricity generation, the safest energy supplies are those that are not needed.

Oil and gas security

No new oil and natural gas fields are required in the NZE beyond those already approved for development, and supplies become increasingly concentrated in a small number of low-cost producers. For oil, OPEC's share of global oil supply grows from around 37% in recent years to 52% in 2050, a level higher than at any point in the history of oil markets (Figure 4.17). For natural gas, inter-regional liquefied natural gas (LNG) trade increases from 420 bcm in 2020 over the next five years but it then falls to around 160 bcm in 2050. Nearly all exports in 2050 come from the lowest cost and lowest emissions producers. This means that the importance of ensuring adequate supplies of oil and natural gas to the smooth functioning of the global energy system would be quantitatively lower in 2050 than today, but it does not suggest that the risk of a shortfall in supply or sudden price rise is necessarily going to diminish, and a shortfall or sudden price rise would still have large repercussions for a number of sectors.

Figure 4.17 ⊳ Global oil supply and LNG exports by region in the NZE



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Increased reliance on OPEC and other producer economies suffering from falling oil and gas revenues could pose a risk to supply security in consuming countries

Even if the timing and ambition of emission reduction policies are clear, the changes in the NZE clearly have implications for producers and consumers alike. Many producer economies would see oil and gas revenues drop to some of the lowest ever levels (see section 4.2.2). Even if these producers increase their market share, and diversify their economies and sources of tax revenue, they are likely to struggle to finance essential spending at current levels. This could have knock-on effects for social stability, and that in turn could potentially threaten the smooth delivery of oil and gas to consuming countries. Moves on the part of producer economies to gain market share or a failure to maintain upstream operations while managing the extreme strains that would be placed on their fiscal balances could lead to turbulent and volatile markets, greatly complicating the task facing policy makers.

Electricity security

The rapid electrification of all sectors in the NZE, and the associated increase in electricity's share of total final consumption from 20% in 2020 to nearly 50% in 2050, puts electricity even more at the heart of energy security across the world than it already is (IEA, 2020h). Greater reliance on electricity has both positive and negative implications for overall energy security. One advantage for energy-importing countries is that they become more self-sufficient, since a much higher share of electricity supply is based on domestic sources in the NZE than is the case for other fuels. However the increased importance of electricity means that any electricity system disruption would have larger impacts. Electricity infrastructure is often more vulnerable to physical shocks such as extreme weather events than pipelines and underground storage facilities, and climate change is likely to put increasing pressure on electricity systems, for example through more frequent droughts that might decrease the availability of water for hydropower and for cooling at thermal power plants. The resilience of electricity systems needs to be enhanced to mitigate these risks and maintain electricity security, including through more robust contingency planning, with solutions based on digital technologies and physical system hardening (IEA, 2021b).

Cybersecurity could pose an even greater risk to electricity security as systems incorporate more digitalised monitoring and controls in a growing number of power plants, electricity network assets and storage facilities. Policy makers have a central part to play in ensuring that the cyber resilience of electricity is enhanced, and there are a number of ways in which they can pursue this (IEA, 2021c).

Maintaining electricity security also requires a range of measures to ensure flexibility, adequacy and reliability at all times. Enhanced electricity system flexibility is of particular importance as the share of variable renewables in the generation mix rises. As a consequence, electricity system flexibility quadruples globally in the NZE in parallel with a more than two-and-a half-fold increase in electricity supply.[9] A portfolio of flexibility sources – including power plants, energy storage and demand response supported by electricity

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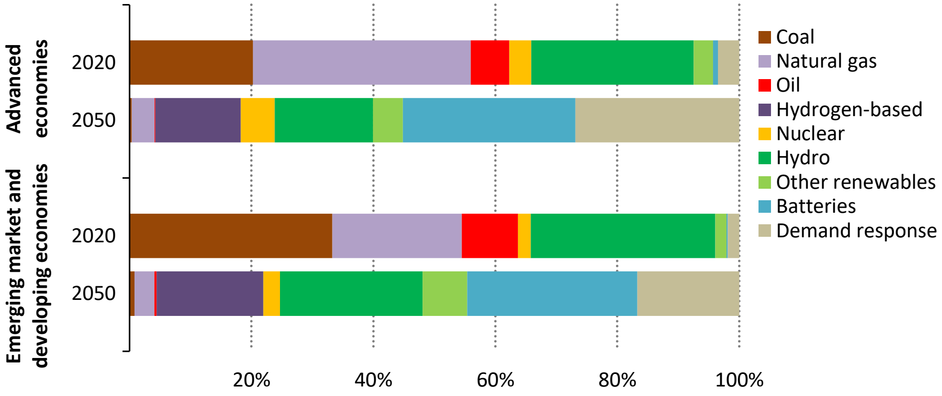
[9] Electricity system flexibility is quantified here based on hour-to-hour ramping needs, which is only one aspect of flexibility that also includes actions on much shorter time scales to maintain frequency and other ancillary services.

networks – is used to match supply and demand at all times of the year, under varying weather conditions and levels of demand. There is a significant shift in the NZE from using coal- and gas-fired power plants for the provision of flexibility to the use of renewables, hydrogen, battery storage, and demand-side response (Figure 4.18).

Figure 4.18 ▷ Electricity system flexibility by source in the NZE



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To meet four-times the amount of hour-to-hour flexibility needs, batteries and demand response step up to become the primary sources of flexibility

Electricity demand also becomes much more flexible as a result of the use of demand response measures, e.g. to shift consumption to times when renewable energy is plentiful. Conventional sources of demand response such as moderating industry activities remain important, but new areas of demand response such as smart charging of EVs unlock valuable new ways of supplementing them.[10] As the EV fleet expands in the NZE, EVs provide a significant portion of total electricity system flexibility. Although the technology already exists, the roll-out of smart charging has been slow to date due to institutional and regulatory barriers; these hurdles are overcome in the NZE. Measures are also implemented to ensure that the digitalisation of charging and other sources of flexibility does not compromise cybersecurity, and that potential social acceptance issues are addressed.

Energy storage also plays an important role in the provision of flexibility in the NZE. The deployment of battery storage systems is already starting to accelerate and to contribute to the management of short-duration flexibility needs, but the massive scale up to 3 100 GW of storage in 2050 (with four hour duration on average) envisaged in the NZE hinges on overcoming current regulatory and market design barriers. Pumped hydropower offers an attractive means of providing flexibility over a matter of hours and days, while hydrogen has

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[10] Smart chargers share real-time data with a centralised platform to allow system operators to optimise charging profiles based on how much energy the vehicle needs over a specified span of time, how much is available, the price of wholesale electricity, grid congestion and other parameters.

the potential to play an important part in longer term seasonal storage since it can be stored in converted gas storage facilities that have several orders of magnitude more capacity than battery storage projects.

Dispatchable power is essential to the secure transition of electricity systems, and in the NZE this comes increasingly from low-emissions sources. Hydropower provides a significant part of flexibility in many electricity systems today, and this continues in the future, with particular emphasis on expanding pumped hydro facilities. Nuclear power and geothermal plants, though designed for baseload generation, also provide a degree of flexibility in the NZE, but there are constraints on how much these sources can be expanded. This leaves an important role for thermal power plants that are equipped with carbon capture or use low-emissions fuels. For example, the use of sustainable biomass or low-emissions ammonia in existing coal plants offers a way of allowing these facilities to continue to contribute to flexibility and capacity adequacy, while at the same time reducing CO_2 emissions. Additional measures will also be necessary to maintain power system stability (Box 4.1).

Box 4.1 ▹ Power system stability with high shares of variable renewables

Stability is a key feature of electricity security, allowing systems to remain in balance and withstand disturbances such as sudden generator or grid outages. Historically, conventional generators such as nuclear, hydro and fossil fuels have been central to electricity system stability, providing inertia with rotating machines that allow stored kinetic energy to be instantly converted into power in case of a system disturbance, and generating a voltage signal that helps all generators remain synchronous.

In contrast, newer technologies such as solar PV, wind and batteries are connected to the system through converters. They generally do not contribute to system inertia and are configured as “grid-following” units, synchronising to conventional generators. Maintaining system stability will call for new approaches as the share of converter based resources, and in particular variable renewables, rises much higher in electricity systems.

There is a growing body of knowledge and studies on stability in systems with high shares of variable renewables. For example, a recent joint study by the IEA and RTE, the transmission system operator in France, analyses the conditions under which it would be technically feasible to integrate high shares of variable renewables in France (IEA, 2021d). Based on the findings of this study:

- One option to ensure stability for a net zero power system is to maintain a minimum amount of conventional generation from low-carbon technologies during hours of high shares VRE output. This approach to maintain stability comes at the cost of solar and wind curtailment at high shares.
- Updated grid codes can be used to call for variable renewables and batteries to provide fast frequency response services, which can help reduce the amount of conventional generation needed for stability.

- Synchronous condensers are able to provide inertia without generating electricity. The technology is already proven at GW-scale in Denmark and also in South Australia, but experience needs to be expanded at larger scale.
- Grid-forming converters can allow variable renewables and batteries to generate a voltage signal, though experience with this approach needs to move beyond micro-grids and small islands to large interconnected systems.

Demonstration projects, stakeholder consultations and international collaboration will be critical to fully understand the merits of each of these four approaches and the scope for a portfolio of options that would most cost-effectively achieve net zero emissions while maintaining electricity security.

Electricity networks support and enable the use of all sources of flexibility, balancing demand and supply over large areas. Timely investment in grids to minimise congestion and expand the size of the areas where supply and demand are balanced will be critical to making the best use of solar PV and wind projects, and ensuring affordable and reliable supplies of electricity. Expanding long-distance transmission also makes a key contribution in the NZE, since a lack of available land near demand centres and other factors mean new sources of generation are often located in remote areas. It is important that new transmission systems are built with variable, bidirectional operation in mind in order to maximise the use of available flexibility sources, and that regulatory and market arrangements support flexible connections between systems. The key value of interconnections comes from complementary electricity demand and wind patterns: solar PV output is more highly correlated than wind over large areas.

The NZE sees a major increase in demand for critical minerals such as copper, lithium, nickel, cobalt and rare earth elements that are essential for many clean energy technologies. There are several potential vulnerabilities that could hinder the adequate supply of these minerals and lead to price volatility (IEA, 2021a). Today's production and processing operations for many minerals are highly concentrated in a small number of countries, making supplies vulnerable to political instability, geopolitical risks and possible export restrictions. In many cases, there are also concerns about land-use changes, competition for scarce water resources, corruption and misuse of government resources, fatalities and injuries to workers, and human rights abuses, including the use of child labour. New critical mineral projects can have long lead times, so the rapid increase in demand in the NZE could lead to a mismatch in timing between supply and demand. The international trade and investment regime is key to maintaining reliable mineral supplies, but policy support and international co-ordination will be needed to ensure the application of rigorous environmental and social regulations.

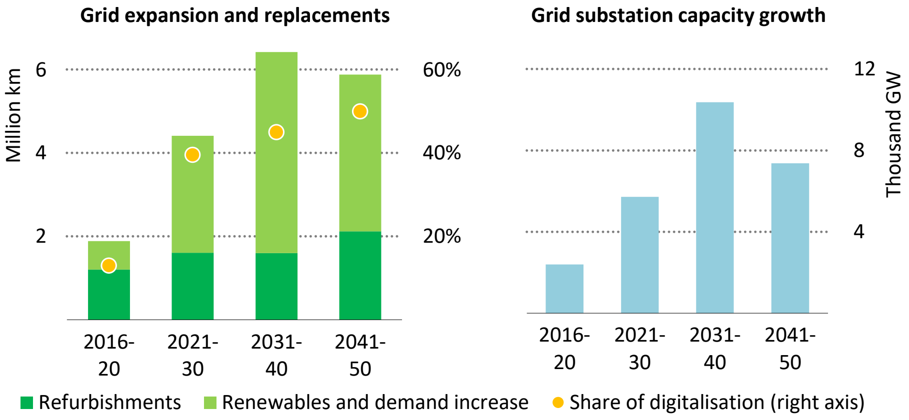
4.5.2 Infrastructure

Getting to net-zero emissions will require huge amounts of new infrastructure and lots of modifications to existing assets. Energy infrastructure is transformed in the NZE as all countries and regions move from systems supporting the use of fossil fuels and the distribution of conventionally generated electricity to systems based largely on renewable electricity and low-emissions fuels. In many emerging market and developing economies, the provision of large amounts of infrastructure would be necessary in the coming decades in any case, creating a window of opportunity to support the transition to a net-zero emissions economy. In all countries, governments will play a central role in planning, financing and regulating the development of infrastructure. Some of the main infrastructure components – electricity networks and EV charging, pipelines systems for low-emissions fuels and CO_2, and transport infrastructure – are discussed below.

The rapid increase in electricity demand in the NZE and the transition to renewable energy call for an expansion and modernisation of electricity networks (Figure 4.19). This would require a sharp reversal in the recent trend of declining investment: failure to achieve this would almost certainly make the energy transition for net-zero emissions impossible. Tariff design and permitting procedures also need to be revised to reflect fundamental changes in the provision and uses of electricity. Some of the main considerations include:

- **Long-distance transmission**. Most of the growth in renewables in the NZE comes from centralised sources. Yet the best solar and wind resources are often in remote regions, requiring new transmission connections. Ultra high-voltage direct current systems are likely to play an important role in supporting transmission over long distances.
- **Local distribution**. Energy efficiency gains in households and wider use of rooftop solar PV mean surplus electricity will be available more often, while electric heat pumps and residential EV charging points will require electricity to be more widely available. Together these developments point to the need for substantial increases in distribution network capacity.
- **Grid substations**. The massive expansion of solar PV and wind requires new grid substations: their capacity expands by more than 57 000 GW in the NZE by 2030, doubling current capacity globally.
- **EV charging**. Major new public charging networks are built in the NZE, including in work places, highway service stations and residential complexes, to support EV expansion and long-distance driving on highways.
- **Digitalisation of networks**. With a large increase in the use of connected devices, the digitalisation of grid assets supports more flexible grid operations, better management of variable renewables and more efficient demand response.

Figure 4.19 ▷ Annual average electricity grid expansion, replacement and substation capacity growth in the NZE



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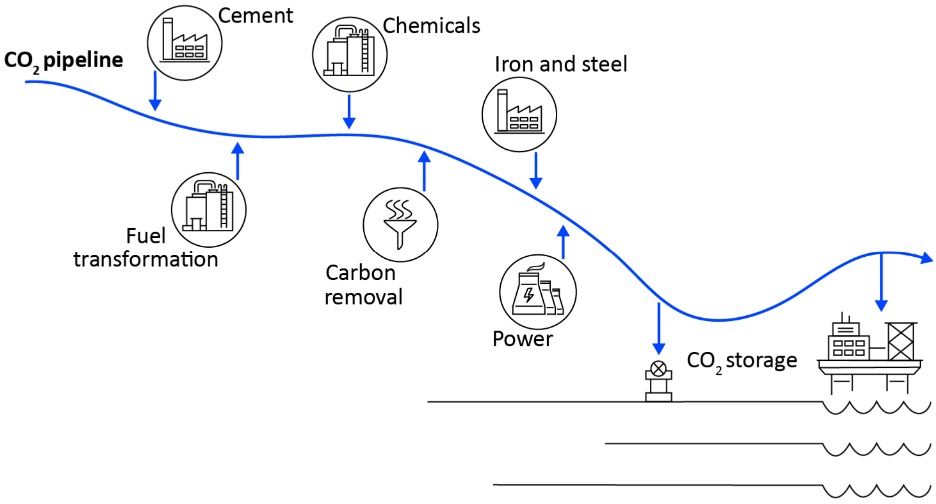
Grid and substation expansion is driven largely by the massive deployment of renewables and electrification of end-uses, with a rising digital share of infrastructure

Note: Substation capacity here assumes active electricity is equal to apparent electricity.

Pipelines continue to play a key role in the transmission and distribution of energy in the NZE:

- Given the rapid decline of fossil fuels, significant investment in new oil and gas pipelines are not needed in the NZE. However investment is needed to link the production of low-emissions liquids and gases with consumption centres, and to convert existing pipelines and associated distribution infrastructure for the use of these low-emissions fuels. Some low-emissions fuels, such as biomethane and synthetic hydrogen-based fuels, can make use of existing infrastructure without any modifications, but pure hydrogen requires a retrofit of existing pipelines. New dedicated hydrogen infrastructure is also needed in the NZE, for example to move hydrogen produced in remote areas with excellent renewable resources to demand centres.
- The expansion of CCUS in the NZE requires investment in CO_2 transport and storage capacity. By 2050, 7.6 Gt of CO_2 is captured worldwide, requiring a large amount of pipeline and shipping infrastructure linking the facilities where CO_2 is captured with storage sites. Industrial clusters, including ports, may offer the best near-term opportunities to build CO_2 pipeline and hydrogen infrastructure, as the various industries in those clusters using the new infrastructure would be able to share the upfront investment needs (Figure 4.20).

Figure 4.20 ▷ Illustrative example of a shared CO_2 pipeline in an industrial cluster



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Deployment of technologies like CCUS and hydrogen and their enabling infrastructure would benefit strongly from a cross-sectoral approach in industrial clusters

Transforming transport infrastructure represents both a challenge and an opportunity. The challenge arises from the potential increase in the energy and carbon intensity of economic growth during the infrastructure development phase.[11] Steel and cement are the two main components of virtually all infrastructure projects, but they are also among the most challenging sectors to decarbonise. The opportunity comes from the scope that exists in some countries to develop infrastructure from scratch in a way that is compatible with the net zero goal. Countries undergoing rapid urbanisation today can design and steer new infrastructure development towards higher urban density and high-capacity mass transit in tandem with EV charging and low-emissions fuelling systems.

Rail has an important part to play as transport infrastructure is developed. The NZE sees large-scale investment in all regions in high-speed trains to replace both long-distance car driving and short-haul aviation. It also sees large-scale investment in all regions in track, control systems, rolling stock modernisation and combined freight facilities to improve speed and flexibility for just-in-time logistical operations and thus support a shift of freight from road to rail, especially for container traffic.

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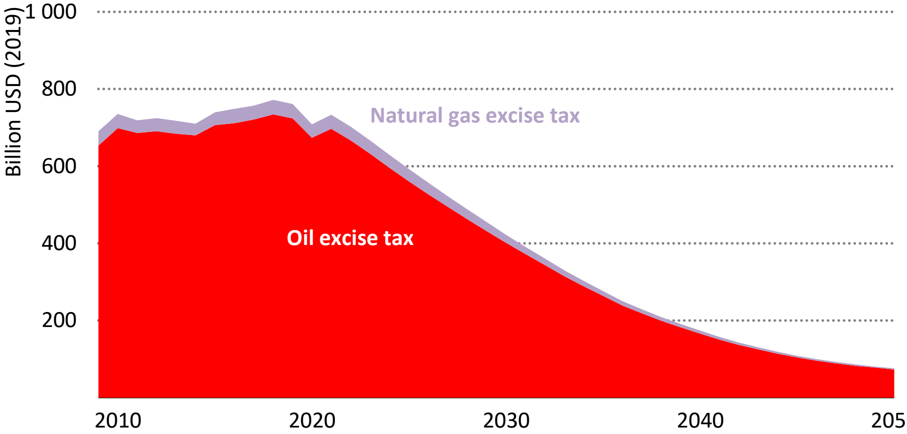
[11] The modelling for the NZE incorporates the increase in steel and cement that is required to build additional transport infrastructure (roads, cars and trucks) and energy infrastructure, e.g. power plants and wind turbines.

4.5.3 Tax revenues from retail energy sales

The slump in the consumption of fossil fuels required to get to net-zero emissions would result in the loss of a large amount of tax revenue in many countries, given that fuels such as oil-based transport fuels and natural gas are often subject to high excise or other special taxes. In recent years, energy-related taxes accounted for around 4% of total government tax revenues in advanced economies on average and 3.5% in emerging market and developing economies, but they provided as much as 10% in some countries (OECD, 2020).

Figure 4.21 ▻ Global revenues from taxes on retail sales of oil and gas in the NZE



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Tax revenues slump from retail sales of oil and gas

Tax revenue from oil and natural gas retail sales falls by close to 90% between 2020 and 2050 in the NZE (Figure 4.21). Governments are likely to need to rely on some combination of other tax revenues and public spending reforms to compensate. Some taxation measures focused on the energy sector could be useful. However, any such taxes would need to be carefully designed to minimise their impact on low-income households, as poorer households spend a higher percentage of their disposable income on electricity and heating. Options for energy-related taxes include:

- **CO_2 prices**. These are introduced in all regions in the NZE, albeit at different levels for countries and sectors, which provide additional revenue streams. The reduction in oil and natural gas excise taxes is more than compensated over the next 15 years by higher revenues from CO_2 prices related to these fuels paid by end users and other sectors, but these too fall as the global energy system moves towards net-zero emissions.
- **Road fees and congestion charges**. These would have the added benefit of discouraging driving and encouraging switching to other less carbon-intensive modes of transport.

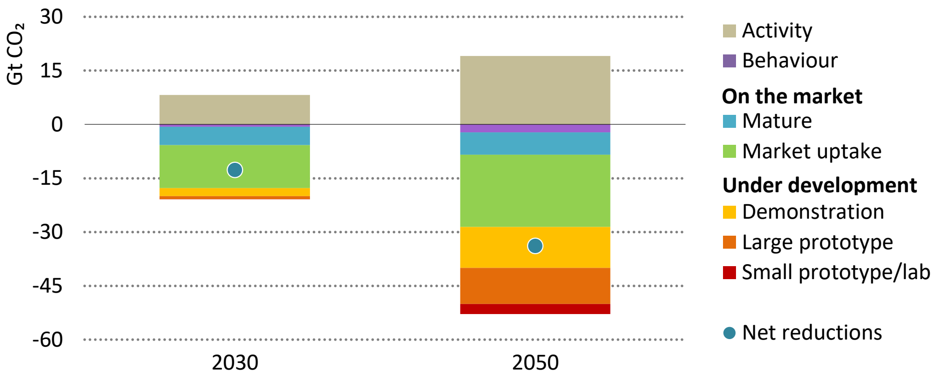
- **Increasing taxation on electricity**. Higher taxes on all electricity sales could generate substantial revenues, especially since large increases in price often have little effect on consumption. This might be counterproductive, however, as it would reduce the cost-effectiveness of both EVs and heat pumps, which could slow their adoption, although this risk could be mitigated by the introduction of CO_2 prices.

Natural gas is currently less taxed than transport fuels in most countries. Introducing and raising CO_2 prices for natural gas used in buildings, mostly for heating, would accelerate energy efficiency improvements and boost government revenues, although care would be needed to avoid disproportionately impacting low-income households. Taxing natural gas used in industry would improve the competitiveness of less carbon-intensive fuels and technologies such as hydrogen, but would run the risk of undermining the international competitiveness of energy-intensive sectors and carbon leakage in the absence of co-ordinated global action or border carbon-tax adjustments.

4.5.4 Innovation

Without a major acceleration in clean energy innovation, reaching net-zero emissions by 2050 will not be achievable. Technologies that are available on the market today provide nearly all of the emissions reductions required to 2030 in the NZE to put the world on track for net-zero emissions by 2050. However, reaching net-zero emissions will require the widespread use after 2030 of technologies that are still under development today. In 2050, almost 50% of CO_2 emissions reductions in the NZE come from technologies currently at demonstration or prototype stage (Figure 4.22). This share is even higher in sectors such as heavy industry and long-distance transport. Major innovation efforts are vital in this decade so that the technologies necessary for net-zero emissions reach markets as soon as possible.

Figure 4.22 ▷ Global CO_2 emissions changes by technology maturity category in the NZE



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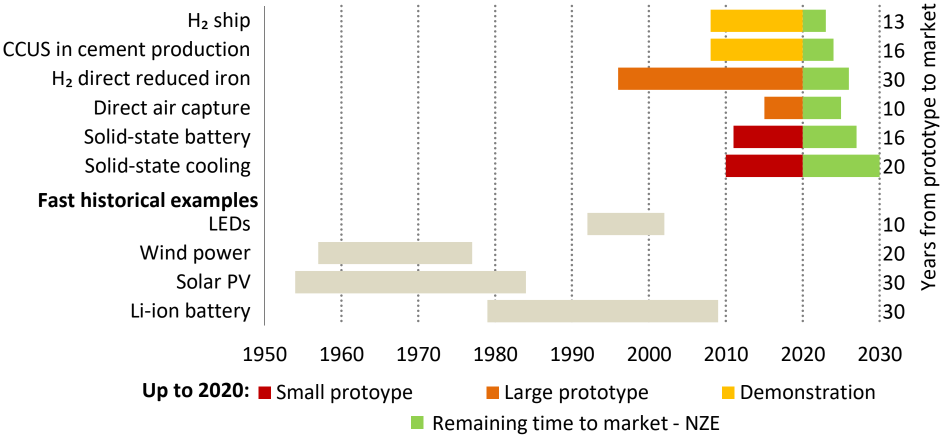
While the emissions reductions in 2030 mostly rely on technologies on the market, those under development today account for almost half of the emissions reductions in 2050

Innovation cycles for early stage clean energy technologies are much more rapid in the NZE than what has typically been achieved historically, and most clean energy technologies that have not been demonstrated at scale today reach markets by 2030 at the latest. This means the time from first prototype to market introduction is on average 20% faster than the fastest energy technology developments in the past, and around 40% faster than was the case for solar PV (Figure 4.23). Technologies at the demonstration stage, such as CCUS in cement production or low-emissions ammonia-fuelled ships, are brought into the market in the next three to four years. Hydrogen-based steel production, direct air capture (DAC) and other technologies at the large prototype stage reach the market in about six years, while most technologies at small prototype stage – such as solid state refrigerant-free cooling or solid state batteries – do so within the coming nine years.

Figure 4.23 ▻ Time from first prototype to market introduction for selected technologies in the NZE and historical examples



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Technology development cycles are cut by around 20% from the fastest developments seen in the past

Note: H_2 = hydrogen; CCUS = carbon capture, utilisation and storage; LED = light-emitting diode; Li-ion = lithium-ion.

Sources: IEA analysis based on Carbon Engineering, 2021; Greco, 2019; Tenova, 2018; Gross, 2018; European Cement Research Academy, 2012; Kamaya, 2011; Zemships, 2008.

An acceleration of this magnitude is clearly ambitious. It requires technologies that are not yet available on the market to be demonstrated very quickly at scale in multiple configurations and in various regional contexts. In most cases, these demonstrations are run in parallel in the NZE. This is in stark contrast with typical practice in technology development: learning is usually transferred across consecutive demonstration projects in different contexts to build confidence before widespread deployment commences.

The acceleration that is needed also requires a large increase in investment in demonstration projects. In the NZE, USD 90 billion is mobilised as soon as possible to complete a portfolio of demonstration projects before 2030: this is much more than the roughly USD 25 billion budgeted by governments to 2030. Most of these projects are concerned with the electrification of end-uses, CCUS, hydrogen and sustainable bioenergy, mainly for long-distance transport and heavy industrial applications.

Increased public funding helps to manage the risks of such first-of-a-kind projects and to leverage private investment in research and development (R&D) in the NZE. This represents a reversal of recent trends: government spending on energy R&D worldwide, including demonstration projects, has fallen as a share of GDP from a peak of almost 0.1% in 1980 to just 0.03% in 2019. Public funding also becomes better aligned with the innovations needed to reach net-zero emissions. In the NZE, electrification, CCUS, hydrogen and sustainable bioenergy account for nearly half of the cumulative emissions reductions to 2050. Just three technologies are critical in enabling around 15% of the cumulative emissions reductions in the NZE between 2030 and 2050: advanced high-energy density batteries, hydrogen electrolysers and DAC.

Governments drive innovation in the NZE

Bringing new energy technologies to market can often take several decades, but the imperative of reaching net-zero emissions globally by 2050 means that progress has to be much faster. Experience has shown that the role of government is crucial in shortening the time needed to bring new technology to market and to diffuse it widely (IEA, 2020i). The government role includes educating people, funding R&D, providing networks for knowledge exchange, protecting intellectual property, using public procurement to boost deployment, helping companies innovate, investing in enabling infrastructure and setting regulatory frameworks for markets and finance.

Knowledge transfer from first-mover countries can also help in the acceleration needed, and is particularly important in the early phases of adoption when new technologies are typically not competitive with incumbent technologies. For example, in the case of solar PV, national laboratories played a key role in the early development phase in the United States, projects supported directly by government in Japan created market niches for initial deployment and government procurement and incentive policies in Germany, Italy, Spain, United States, China, Australia and India fostered a global market. Lithium-ion (Li-ion) batteries were initially developed through public and private research that took place mostly in Japan, their first energy-related commercial operation was made possible in the United States, and mass manufacturing today is primarily in China.

Many of the biggest clean energy technology challenges could benefit from a more targeted approach to speed up progress (Diaz Anadon, 2012; Mazzucato, 2018). In the NZE, concerted government action leverages private sector investment and leads to advances in clean energy technologies that are currently at different stages of development.

- To 2030, the focus of government action is on bringing new zero- or low-emissions technologies to market. For example, in the NZE, steel starts to be produced using low-emissions hydrogen at the scale of a conventional steel plant, large ships start to be fuelled by low-emissions ammonia and electric trucks begin operating on solid state batteries. In parallel, there is rapid acceleration in the deployment of low-emissions technologies that are already available on the market but that have not yet reached mass market scale, bringing down the costs of manufacturing, construction and operating such technologies due to learning-by-doing and economies of scale.

- From 2030 to 2040, technology advances are consolidated to scale up nascent low-emissions technologies and expand clean energy infrastructure. Clean energy technologies that are in the laboratory or at small prototype stage today become commercial. For example, fuels are replaced by electricity in cement kilns and steam crackers for high value chemicals production.
- From 2040 to 2050, technologies at a very early stage of development today are adopted in promising niche markets. By 2050, clean energy technologies that are at demonstration or large prototype stage today become mainstream for purchases and new installations, and they compete with present conventional technologies in all regions. For example, ultra high-energy density batteries are used in aircraft for short flights.

4.5.5 International co-operation

The pathway to net-zero emissions by 2050 will require an unprecedented level of international co-operation between governments. This is not only a matter of all countries participating in efforts to meet the net zero goal, but also of all countries working together in an effective and mutually beneficial manner. Achieving net-zero emissions will be extremely challenging for all countries, but the challenges are toughest and the solutions least easy to deliver in lower income countries, and technical and financial support will be essential to ensure the early stage deployment of key mitigation technologies and infrastructure in many of these countries. Without international co-operation, emissions will not fall to net zero by 2050.

There are four aspects of international co-operation that are particularly important (Victor, Geels and Sharpe, 2019).

- **International demand signals and economies of scale**. International co-operation has been critical to the cost reductions seen in the past for many key energy technologies. It can accelerate knowledge transfer and promote economies of scale. It can also help align the creation of new demand for clean energy technologies and fuels in one region with the development of supply in other regions. These benefits need to be weighed against the importance of creating domestic jobs and industrial capacities, and of ensuring supply chain resilience.
- **Managing trade and competitiveness**. Industries that operate in a number of countries need standardisation to ensure inter-operability. Progress on innovation and clean energy technology deployment in sectors such as heavy industry has been inhibited in the past by uncoordinated national policies and a lack of internationally agreed

standards. The development of such standards could accelerate energy technology development and deployment.

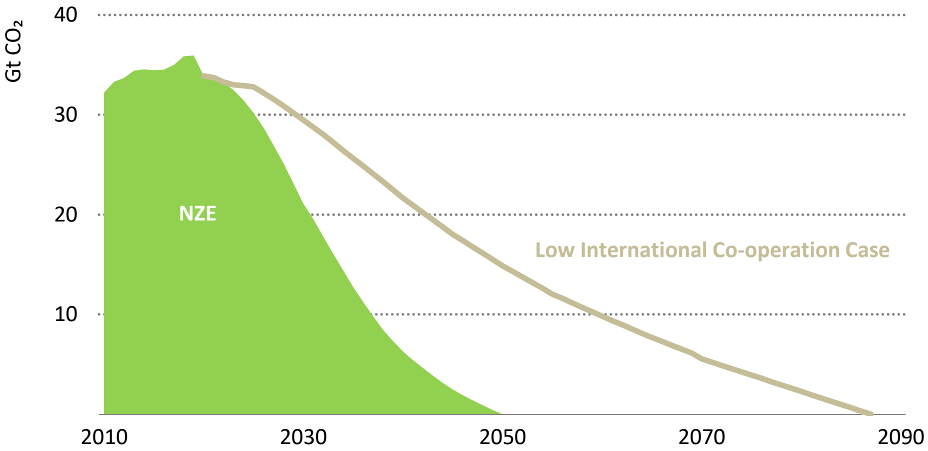
- **Innovation, demonstration and diffusion**. Clean energy R&D and patenting is currently concentrated in a handful of places: United States, Europe, Japan, Korea and China accounted for more than 90% of clean energy patents in 2014-18. Progress towards net-zero emissions would be increased by moving swiftly to extend experience and knowledge of clean energy technologies in countries that are not involved in their initial development, and by funding first-of-a-kind demonstration projects in emerging market and developing economies. International programmes to fund demonstration projects, especially in sectors where technologies are large and complex, would accelerate the innovation process (IEA, 2020i).
- **Carbon dioxide removal (CDR) programmes**. CDR technologies such as bioenergy and DAC equipped with CCUS are essential to provide emissions reductions at a global level. International co-operation is needed to fund and certify these programmes, so as to make the most of suitable land, renewable energy potential and storage resources, wherever they may be. International emissions trading mechanisms could play a role in offsetting emissions in some sectors or areas with negative emissions, though any such mechanisms would require a high degree of co-ordination to ensure market functioning and integrity.

The NZE assumes that international co-operation policies, measures and efforts are introduced to overcome these hurdles. To explore the potential implications of a failure to do so, we have devised a *Low International Co-operation Case* (Box 4.2). This examines what would happen if national efforts to mitigate climate change ramp up in line with the level of effort in the NZE but co-operation frameworks are not developed at the same speed. It shows that the lack of international co-operation has a major impact on innovation, technology demonstration, market co-ordination and ultimately on the emissions pathway.

Box 4.2 ▻ Framing the Low International Co-operation Case

To develop the *Low International Co-operation Case*, technologies and mitigation options were assessed and grouped based on their current degree of maturity and the importance of international co-operation to their deployment. Mature technologies in markets that are firmly established and that have a low exposure to international co-operation are assumed to have the same deployment pathways as in the NZE. Technologies and mitigation options where co-operation is needed to achieve scale and avoid duplication, that have a large exposure to international trade and competitiveness, that depend on large and very capital-intensive demonstration programmes, or that require support to create market pull and standardisation to ensure inter-operability, are assumed to be deployed more slowly (Malhotra and Schmidt, 2020). Compared with the NZE, these technologies are delayed by 5-10 years in their initial deployment in advanced economies and by 10-15 years in emerging market and developing economies.

Figure 4.24 ▷ CO_2 emissions in the Low International Co-operation Case and the NZE



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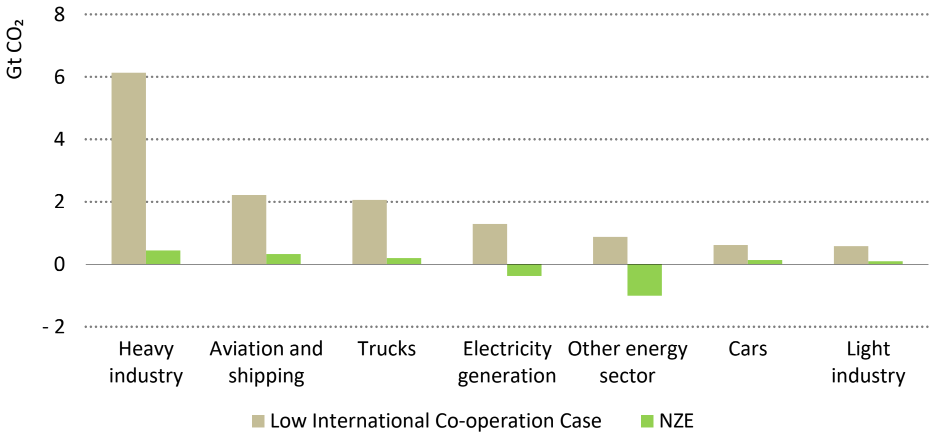
Without international co-operation, the transition to net zero would be delayed by decades

Weak international co-operation slows the deployment of mitigation options that are currently in the demonstration phase (Figure 4.24). This includes emissions reductions in heavy industry, trucks, aviation, shipping and CDR. The energy transition proceeds unevenly as a result. Over the next 20 years in the Low International Co-operation Case, emissions decline at a rapid but still slower pace than in the NZE in electricity generation, cars, light industry and buildings. However, emissions reductions are much slower in other areas. After the mid-2030s, the pace of emissions reductions worldwide slows markedly relative to the NZE, and the transition to net zero is delayed by decades. Just over 40% of the 15 Gt CO_2 of emissions remaining in 2050 are in heavy industry, where the slower pace of demonstration and diffusion of mitigation technologies is particularly significant (Figure 4.25). A further one-third of the residual emissions in 2050 are from aviation, shipping and trucks. Here the slower scale up and diffusion of advanced biofuels, hydrogen-based fuels and high-energy density batteries hinders progress. The absence of co-operation to support the deployment of new projects in emerging market and developing economies means that emissions reductions there are much slower than in the NZE.

These results highlight the importance for governments of strengthening international co-operation. A strong push is needed to accelerate innovation and the demonstration of key technologies, especially for complex technologies in emerging market and developing economies where costs for first-of-a-kind projects are generally higher, and to address concerns about international trade and competitiveness so as to ensure a just transition for all.

Figure 4.25 ▻ CO_2 emissions in the Low International Co-operation Case and the NZE in selected sectors in 2050



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CO_2 emissions in 2050 in the Low International Co-operation Case are concentrated in the industry and transport sectors

Note: Other energy sector = fuel production and direct air capture.

ANNEXES

Tables for scenario projections

General note to the tables

This annex includes global historical and projected data for the Net-Zero Emissions by 2050 scenario for the following data sets: energy supply, energy demand, gross electricity generation and electrical capacity, carbon dioxide (CO_2) emissions from fossil fuel combustion and industrial processes, and selected economic and activity indicators.

The definitions for fuels and sectors are in Annex C. Common abbreviations used in the tables include: EJ = exajoules; CAAGR = compound average annual growth rate; CCUS = carbon capture, utilisation and storage. Consumption of fossil fuels in facilities without CCUS are classified as "unabated".

Both in the text of this report and in the tables, rounding may lead to minor differences between totals and the sum of their individual components. Growth rates are calculated on a compound average annual basis and are marked "n.a." when the base year is zero or the value exceeds 200%. Nil values are marked "-".

To download the tables in Excel format go to: **iea.li/nzedata**.

Data sources

The formal base year for the scenario projections is 2019, as this is the last year for which a complete picture of energy demand and production is available. However, we have used more recent data when available, and we include our 2020 estimates for energy production and demand in this annex. Estimates for the year 2020 are based on updates of the IEA's Global Energy Review reports which are derived from a number of sources, including the latest monthly data submissions to the IEA's Energy Data Centre, other statistical releases from national administrations, and recent market data from the IEA Market Report Series that cover coal, oil, natural gas, renewables and power.

Historical data for gross electrical capacity are drawn from the S&P Global Market Intelligence World Electric Power Plants Database (March 2020 version) and the International Atomic Energy Agency PRIS database.

Definitional note: A.1. Energy supply and transformation table

Total energy supply (TES) is equivalent to electricity and heat generation plus "other energy sector" excluding electricity and heat, plus total final consumption (TFC) excluding electricity and heat. TES does not include ambient heat from heat pumps or electricity trade. Solar in TES includes solar PV generation, concentrating solar power and final consumption of solar thermal. Other renewables in TES include geothermal, and marine (tide and wave) energy for electricity and heat generation. Hydrogen production and biofuels production in the other energy sector account for the energy input required to produce merchant hydrogen (mainly natural gas and electricity) and for the conversion losses to produce biofuels (mainly primary solid biomass) used in the energy sector. While not itemised separately, non-renewable waste and other sources are included in TES.

Definitional note: A.2. Energy demand table

Sectors comprising total final consumption (TFC) include industry (energy use and feedstock), transport, buildings (residential, services and non-specified other) and other (agriculture and other non-energy use). Energy demand from international marine and aviation bunkers are included in transport totals.

Definitional note: A.3. Electricity tables

Electricity generation expressed in terawatt-hours (TWh) and installed electrical capacity data expressed in gigawatts (GW) are both provided on a gross basis (i.e. includes own use by the generator). Projected gross electrical capacity is the sum of existing capacity and additions, less retirements. While not itemised separately, other sources are included in total electricity generation.

Definitional note: A.4. CO_2 emissions table

Total CO_2 includes carbon dioxide emissions from the combustion of fossil fuels and non-renewable wastes, from industrial and fuel transformation processes (process emissions) as well as CO_2 removals. Three types of CO_2 removals are presented:

- Captured and stored emissions from the combustion of bioenergy and renewable wastes (typically electricity generation).
- Captured and stored process emissions from biofuels production.
- Captured and stored carbon dioxide from the atmosphere, which is reported as direct air carbon capture and storage (DACCS).

The first two entries are often reported as bioenergy with carbon capture and storage (BECCS). Note that some of the CO_2 captured from biofuels production and direct air capture is used to produce synthetic fuels, which is not included as CO_2 removal.

Total CO_2 captured includes the carbon dioxide captured from CCUS facilities (such as electricity generation or industry) and atmospheric CO_2 captured through direct air capture but excludes that captured and used for urea production.

Definitional note: A.5. Economic and activity indicators

The emission intensity expressed in kilogrammes of carbon dioxide per kilowatt-hour (kg CO_2/kWh) is calculated based on electricity-only plants and the electricity component of combined heat and power (CHP) plants. [1]

Other abbreviations used include: PPP = purchasing power parity; GJ = gigajoules; Mt = million tonnes; pkm = passenger-kilometres; tkm = tonnes-kilometres; m^2 = square metres.

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[1] To derive the associated electricity-only emissions from CHP plants, we assume that the heat production of a CHP plant is 90% efficient and the remainder of the fuel input is allocated to electricity generation.

Table A.1: Energy supply and transformation

	Energy supply (EJ)					Shares (%)			CAAGR (%)	
	2019	2020	2030	2040	2050	2020	2030	2050	2020-2030	2020-2050
Total energy supply	**612**	**587**	**547**	**535**	**543**	**100**	**100**	**100**	**-0.7**	**-0.3**
Renewables	67	69	167	295	362	12	30	67	9.3	5.7
Solar	4	5	32	78	109	1	6	20	21	11
Wind	5	6	29	67	89	1	5	16	17	9.6
Hydro	15	16	21	27	30	3	4	6	2.9	2.2
Modern solid bioenergy	31	32	54	73	73	5	10	14	5.3	2.8
Modern liquid bioenergy	4	3	12	14	15	1	2	3	14	4.9
Modern gaseous bioenergy	2	2	5	10	14	0	1	3	10	6.4
Other renewables	4	5	13	24	32	1	2	6	11	6.7
Traditional use of biomass	25	25	-	-	-	4	-	-	n.a.	n.a.
Nuclear	30	29	41	54	61	5	8	11	3.5	2.4
Unabated natural gas	139	136	116	44	17	23	21	3	-1.6	-6.6
Natural gas with CCUS	0	1	13	31	43	0	2	8	37	16
Oil	190	173	137	79	42	29	25	8	-2.3	-4.6
of which non-energy use	28	27	32	31	29	5	6	5	1.4	0.2
Unabated coal	160	154	68	16	3	26	12	1	-7.9	-12
Coal with CCUS	0	0	4	16	14	0	1	3	60	22
Electricity and heat sectors	**233**	**230**	**240**	**308**	**371**	**100**	**100**	**100**	**0.4**	**1.6**
Renewables	36	38	107	220	284	17	44	77	11	6.9
Solar PV	2	3	25	61	84	1	10	23	24	12
Wind	5	6	29	67	89	2	12	24	17	9.6
Hydro	15	16	21	27	30	7	9	8	2.9	2.2
Bioenergy	9	10	18	35	39	4	8	10	6.3	4.6
Other renewables	4	4	14	30	42	2	6	11	14	8.5
Hydrogen	-	-	5	11	11	-	2	3	n.a.	n.a.
Ammonia	-	-	1	2	2	-	0	0	n.a.	n.a.
Nuclear	30	29	41	54	61	13	17	16	3.5	2.4
Unabated natural gas	56	55	49	4	2	24	21	0	-1.1	-11
Natural gas with CCUS	-	-	1	5	5	-	1	1	n.a.	n.a.
Oil	9	8	2	0	0	4	1	0	-12	-14
Unabated coal	102	100	30	0	0	43	12	0	-11	-34
Coal with CCUS	0	0	3	10	7	0	1	2	55	19
Other energy sector	**57**	**57**	**61**	**76**	**91**	**100**	**100**	**100**	**0.7**	**1.5**
Hydrogen production	-	0	21	49	70	0	35	77	66	23
Biofuels production	5	6	12	15	12	10	20	13	8	2.7

Table A.2: Energy demand

	Energy demand (EJ)					Shares (%)			CAAGR (%)	
	2019	2020	2030	2040	2050	2020	2030	2050	2020-2030	2020-2050
Total final consumption	**435**	**412**	**394**	**363**	**344**	**100**	**100**	**100**	**-0.4**	**-0.6**
Electricity	82	81	103	140	169	20	26	49	2.4	2.5
Liquid fuels	175	158	143	96	66	38	36	19	-1.0	-2.9
Biofuels	4	3	12	14	15	1	3	4	14	4.9
Ammonia	-	-	1	3	5	-	0	1	n.a.	n.a.
Synthetic oil	-	-	0	2	5	-	0	1	n.a.	n.a.
Oil	171	154	129	77	42	37	33	12	-1.8	-4.2
Gaseous fuels	70	68	68	60	53	16	17	15	0.1	-0.8
Biomethane	0	0	2	5	8	0	1	2	25	13
Hydrogen	0	0	6	12	20	0	2	6	54	20
Synthetic methane	-	-	0	1	4	-	0	1	n.a.	n.a.
Natural gas	70	67	58	40	20	16	15	6	-1.4	-4.0
Solid fuels	92	89	61	46	35	22	16	10	-3.6	-3.0
Biomass	39	39	24	25	25	9	6	7	-4.8	-1.4
Coal	53	50	38	21	10	12	10	3	-2.8	-5.3
Heat	13	13	12	9	6	3	3	2	-1.2	-2.7
Other	3	3	7	11	15	1	2	4	8.2	5.2
Industry	**162**	**157**	**170**	**169**	**160**	**100**	**100**	**100**	**0.8**	**0.1**
Electricity	35	35	47	62	74	22	28	46	3.0	2.5
Liquid fuels	31	31	31	27	23	20	18	15	-0.2	-0.9
Oil	31	31	31	27	23	20	18	15	-0.2	-0.9
Gaseous fuels	32	32	35	34	28	20	21	18	1.0	-0.4
Biomethane	0	0	1	2	4	0	0	3	22	15
Hydrogen	-	0	3	4	5	0	2	3	44	15
Unabated natural gas	32	32	30	22	9	20	18	6	-0.5	-4.0
Natural gas with CCUS	0	0	1	5	7	0	1	4	38	18
Solid fuels	58	52	51	40	30	34	30	18	-0.3	-1.9
Biomass	10	9	15	19	20	6	9	13	5.2	2.8
Unabated coal	48	44	35	15	3	28	20	2	-2.3	-9.0
Coal with CCUS	0	0	1	5	7	0	1	4	91	31
Heat	6	6	6	3	2	4	3	1	-1.2	-4.5
Other	0	0	1	3	4	0	1	2	33	14
Iron and steel	36	33	37	36	32	21	22	20	1.1	-0.2
Chemicals	22	20	26	26	25	13	15	15	2.7	0.7
Cement	12	16	11	11	10	10	7	7	-3.3	-1.3

Table A.2: Energy demand

	Energy demand (EJ)					Shares (%)			CAAGR (%)	
	2019	2020	2030	2040	2050	2020	2030	2050	2020-2030	2020-2050
Transport	**122**	**105**	**102**	**85**	**80**	**100**	**100**	**100**	**-0.3**	**-0.9**
Electricity	1	1	7	22	35	1	7	44	17	11
Liquid fuels	115	99	89	53	30	94	87	38	-1.0	-3.9
Biofuels	4	3	11	12	11	3	11	14	14	4.3
Oil	111	96	76	35	9	91	74	12	-2.2	-7.4
Gaseous fuels	5	5	6	10	15	5	6	18	2.1	3.7
Biomethane	0	0	1	1	2	0	0	2	23	11
Hydrogen	0	0	1	6	13	0	1	16	92	34
Natural gas	5	5	4	2	0	5	4	0	-1.5	-11
Road	90	81	73	57	50	77	72	63	-0.9	-1.6
Passenger cars	47	41	30	19	17	39	29	21	-3.1	-2.9
Trucks	27	25	28	24	22	24	27	28	1.1	-0.4
Aviation	14	8	13	13	14	8	13	18	4.6	1.7
Shipping	12	11	11	10	10	10	11	12	0.4	-0.3
Buildings	**129**	**127**	**99**	**89**	**86**	**100**	**100**	**100**	**-2.4**	**-1.3**
Electricity	43	42	45	51	57	33	46	66	0.7	1.0
Liquid fuels	13	13	9	4	2	10	10	2	-3.2	-6.0
Biofuels	0	0	0	1	1	0	0	1	26	12
Oil	13	13	9	4	1	10	9	1	-3.4	-7.7
Gaseous fuels	30	28	23	13	6	22	23	7	-2.1	-4.9
Biomethane	0	0	1	2	2	0	1	2	29	11
Hydrogen	-	0	2	2	2	0	2	2	103	27
Natural gas	30	28	19	7	1	22	20	1	-3.8	-12
Solid fuels	34	34	10	7	6	27	10	7	-11	-5.5
Modern biomass	5	5	9	7	6	4	9	7	6.9	0.9
Traditional use of biomass	25	25	-	-	-	20	-	-	n.a.	n.a.
Coal	4	4	1	0	0	3	1	0	-12	-21
Heat	7	7	6	5	4	5	6	5	-1.2	-1.6
Other	2	3	5	8	11	2	5	12	7.1	4.8
Residential	91	90	67	59	58	71	67	67	-3.0	-1.5
Services	38	36	32	30	28	29	33	33	-1.2	-0.9
Other	**22**	**23**	**22**	**20**	**18**	**100**	**100**	**100**	**-0.5**	**-0.9**

Table A.3: Electricity

	Electricity Generation (TWh)					Shares (%)			CAAGR (%)	
	2019	2020	2030	2040	2050	2020	2030	2050	2020-2030	2020-2050
Total generation	**26 922**	**26 778**	**37 316**	**56 553**	**71 164**	**100**	**100**	**100**	**3.4**	**3.3**
Renewables	7 153	7 660	22 817	47 521	62 333	29	61	88	12	7.2
Solar PV	665	821	6 970	17 031	23 469	3	19	33	24	12
Wind	1 423	1 592	8 008	18 787	24 785	6	21	35	18	9.6
Hydro	4 294	4 418	5 870	7 445	8 461	17	16	12	2.9	2.2
Bioenergy	665	718	1 407	2 676	3 279	3	4	5	7.0	5.2
of which BECCS	-	-	*129*	*673*	*842*	-	*0*	*1*	*n.a.*	*n.a.*
CSP	14	14	204	880	1 386	0	1	2	31	17
Geothermal	92	94	330	625	821	0	1	1	13	7.5
Marine	1	2	27	77	132	0	0	0	28	14
Nuclear	2 792	2 698	3 777	4 855	5 497	10	10	8	3.4	2.4
Hydrogen-based	-	-	875	1 857	1 713	-	2	2	n.a.	n.a.
Fossil fuels with CCUS	1	4	459	1 659	1 332	0	1	2	61	21
Coal with CCUS	1	4	289	966	663	0	1	1	54	19
Natural gas with CCUS	-	-	170	694	669	-	0	1	n.a.	n.a.
Unabated fossil fuels	16 941	16 382	9 358	632	259	61	25	0	-5.4	-13
Coal	9 832	9 426	2 947	0	0	35	8	0	-11	-40
Natural gas	6 314	6 200	6 222	626	253	23	17	0	0.0	-10
Oil	795	756	189	6	6	3	1	0	-13	-15

	Electrical Capacity (GW)					Shares (%)			CAAGR (%)	
	2019	2020	2030	2040	2050	2020	2030	2050	2020-2030	2020-2050
Total capacity	**7 484**	**7 795**	**14 933**	**26 384**	**33 415**	**100**	**100**	**100**	**6.7**	**5.0**
Renewables	2 707	2 994	10 293	20 732	26 568	38	69	80	13	7.5
Solar PV	603	737	4 956	10 980	14 458	9	33	43	21	10
Wind	623	737	3 101	6 525	8 265	9	21	25	15	8.4
Hydro	1 306	1 327	1 804	2 282	2 599	17	12	8	3.1	2.3
Bioenergy	153	171	297	534	640	2	2	2	5.7	4.5
of which BECCS	-	-	*28*	*125*	*152*	-	*0*	*0*	*n.a.*	*n.a.*
CSP	6	6	73	281	426	0	0	1	28	15
Geothermal	15	15	52	98	126	0	0	0	13	7.4
Marine	1	1	11	32	55	0	0	0	34	16
Nuclear	415	415	515	730	812	5	3	2	2.2	2.3
Hydrogen-based	-	-	139	1 455	1 867	-	1	6	n.a.	n.a.
Fossil fuels with CCUS	0	1	81	312	394	0	1	1	66	25
Coal with CCUS	0	1	53	182	222	0	0	1	59	22
Natural gas with CCUS	-	-	28	130	171	-	0	1	n.a.	n.a.
Unabated fossil fuels	4 351	4 368	3 320	1 151	677	56	22	2	-2.7	-6.0
Coal	2 124	2 117	1 192	432	158	27	8	0	-5.6	-8.3
Natural gas	1 788	1 829	1 950	679	495	23	13	1	0.6	-4.3
Oil	440	422	178	39	25	5	1	0	-8.3	-9.0
Battery storage	11	18	585	2 005	3 097	0	4	9	42	19

Table A.4: CO_2 emissions

	CO_2 emissions (Mt CO_2)					CAAGR (%)	
	2019	2020	2030	2040	2050	2020-2030	2020-2050
Total CO_2*	**35 926**	**33 903**	**21 147**	**6 316**	**0**	**-4.6**	**n.a.**
Combustion activities (+)	**33 499**	**31 582**	**19 254**	**6 030**	**940**	**-4.8**	**-11**
Coal	14 660	14 110	5 915	1 299	195	-8.3	-13
Oil	11 505	10 264	7 426	3 329	928	-3.2	-7.7
Natural gas	7 259	7 138	5 960	1 929	566	-1.8	-8.1
Bioenergy and waste	75	71	- 48	- 528	- 748	n.a.	n.a.
Industry removals (-)	**1**	**1**	**214**	**914**	**1 186**	**75**	**28**
Biofuels production	1	1	142	385	553	68	24
Direct air capture	-	-	71	528	633	n.a.	n.a.
Electricity and heat sectors	**13 821**	**13 504**	**5 816**	**- 81**	**- 369**	**-8.1**	**n.a.**
Coal	10 035	9 786	2 950	102	69	-11	-15
Oil	655	628	173	6	6	-12	-14
Natural gas	3 131	3 089	2 781	268	128	-1.0	-10
Bioenergy and waste	-	-	- 87	- 457	- 572	n.a.	n.a.
Other energy sector*	**1 457**	**1 472**	**679**	**- 85**	**- 368**	**-7.4**	**n.a.**
Final consumption*	**20 647**	**18 928**	**14 723**	**7 011**	**1 370**	**-2.5**	**-8.4**
Coal	4 486	4 171	2 935	1 186	117	-3.5	-11
Oil	10 272	9 077	6 973	3 242	880	-2.6	-7.5
Natural gas	3 451	3 332	2 668	1 453	303	-2.2	-7.7
Bioenergy and waste	75	71	40	- 70	- 176	-5.6	n.a.
Industry*	8 903	8 478	6 892	3 485	519	-2.0	-8.9
Iron and steel	2 507	2 349	1 778	859	220	-2.7	-7.6
Chemicals	1 344	1 296	1 199	654	66	-0.8	-9.5
Cement	2 461	2 334	1 899	906	133	-2.0	-9.1
Transport	8 290	7 153	5 719	2 686	689	-2.2	-7.5
Road	6 116	5 483	4 077	1 793	340	-2.9	-8.9
Passenger cars	3 121	2 746	1 626	547	85	-5.1	-11
Trucks	1 835	1 721	1 614	890	198	-0.6	-6.9
Aviation	1 019	621	783	469	210	2.4	-3.5
Shipping	883	800	705	348	122	-1.3	-6.1
Buildings	3 007	2 860	1 809	685	122	-4.5	-10
Residential	2 030	1 968	1 377	541	108	-3.5	-9.2
Services	977	892	432	144	14	-7.0	-13
Total CO_2 removals	**1**	**1**	**317**	**1 457**	**1 936**	**79**	**29**
Total CO_2 captured	**40**	**40**	**1 665**	**5 619**	**7 602**	**45**	**19**

**Includes industrial process emissions.*

Table A.5: Economic and Activity Indicators

	Indicator					CAAGR (%)	
	2019	2020	2030	2040	2050	2020-2030	2020-2050
Population (million)	7 672	7 753	8 505	9 155	9 692	0.9	0.7
GDP (USD 2019 billion, PPP)	134 710	128 276	184 037	246 960	316 411	3.7	3.1
GDP per capita (USD 2019, PPP)	17 558	16 545	21 638	26 975	32 648	2.7	2.3
TES/GDP (GJ per USD 1 000, PPP)	4.543	4.578	2.973	2.164	1.716	-4.2	-3.2
TFC/GDP (GJ per USD 1 000, PPP)	3.231	3.208	2.139	1.468	1.086	-4.0	-3.5
TES per capita (GJ)	79.77	75.74	64.33	58.38	56.03	-1.6	-1.0
CO_2 intensity of electricity generation (kg CO_2 per kWh)	0.468	0.438	0.138	-0.001	-0.005	-11	n.a.

	Activity					CAAGR (%)	
	2019	2020	2030	2040	2050	2020-2030	2020-2050
Industrial production							
Primary chemicals (Mt)	538	529	641	686	688	1.9	0.9
Steel (Mt)	1 869	1 781	1 937	1 958	1 987	0.8	0.4
Cement (Mt)	4 215	4 054	4 258	4 129	4 032	0.5	-0.0
Transport							
Passenger cars (billion vkm)	15 300	14 261	15 775	19 159	24 517	1.0	1.8
Trucks (billion tkm)	26 646	25 761	38 072	49 756	59 990	4.0	2.9
Aviation (billion pkm)	8 506	5 474	10 271	11 573	14 566	6.5	3.3
Shipping (billion tkm)	107 225	109 153	155 621	209 905	291 032	3.6	3.3
Buildings							
Services floor area (million m^2)	49 670	49 825	58 867	68 576	78 157	1.7	1.5
Residential floor area (million m^2)	190 062	192 558	235 745	290 696	345 183	2.0	2.0
Million households	2 095	2 116	2 435	2 765	3 051	1.4	1.2

Annex B

Technology costs

Electricity generation

Table B.1 ▹ Electricity generation technology costs by selected region in the NZE

	Financing rate (%)	Capital costs ($/kW)			Capacity factor (%)			Fuel, CO$_2$ and O&M ($/MWh)			LCOE ($/MWh)		
	All	2020	2030	2050	2020	2030	2050	2020	2030	2050	2020	2030	2050
United States													
Nuclear	8.0	5 000	4 800	4 500	90	80	75	30	30	30	105	110	110
Coal	8.0	2 100	2 100	2 100	20	*n.a.*	*n.a.*	90	170	235	220	*n.a.*	*n.a.*
Gas CCGT	8.0	1 000	1 000	1 000	55	25	*n.a.*	50	80	105	70	125	*n.a.*
Solar PV	3.7	1 140	620	420	21	22	23	10	10	10	50	30	20
Wind onshore	3.7	1 540	1 420	1 320	42	43	44	10	10	10	35	35	30
Wind offshore	4.5	4 040	2 080	1 480	42	46	48	35	20	15	115	60	40
European Union													
Nuclear	8.0	6 600	5 100	4 500	75	75	70	35	35	35	150	120	115
Coal	8.0	2 000	2 000	2 000	20	*n.a.*	*n.a.*	120	205	275	250	*n.a.*	*n.a.*
Gas CCGT	8.0	1 000	1 000	1 000	40	20	*n.a.*	65	95	120	100	150	*n.a.*
Solar PV	3.2	790	460	340	13	14	14	10	10	10	55	35	25
Wind onshore	3.2	1 540	1 420	1 300	29	30	31	15	15	15	55	45	40
Wind offshore	4.0	3 600	2 020	1 420	51	56	59	15	10	5	75	40	25
China													
Nuclear	7.0	2 800	2 800	2 500	80	80	80	25	25	25	65	65	60
Coal	7.0	800	800	800	60	*n.a.*	*n.a.*	75	135	195	90	*n.a.*	*n.a.*
Gas CCGT	7.0	560	560	560	45	35	*n.a.*	75	100	120	90	115	*n.a.*
Solar PV	3.5	750	400	280	17	18	19	10	5	5	40	25	15
Wind onshore	3.5	1 220	1 120	1 040	26	27	27	15	10	10	45	40	40
Wind offshore	4.3	2 840	1 560	1 000	34	41	43	25	15	10	95	45	30
India													
Nuclear	7.0	2 800	2 800	2 800	70	70	70	30	30	30	75	75	75
Coal	7.0	1 200	1 200	1 200	50	*n.a.*	*n.a.*	35	50	75	65	*n.a.*	*n.a.*
Gas CCGT	7.0	700	700	700	55	50	*n.a.*	45	45	50	55	60	*n.a.*
Solar PV	5.8	580	310	220	20	21	21	5	5	5	35	20	15
Wind onshore	5.8	1 040	980	940	26	28	29	10	10	10	50	45	40
Wind offshore	6.6	2 980	1 680	1 180	32	37	38	25	15	10	130	70	45

Notes: O&M = operation and maintenance; LCOE = levelised cost of electricity; kW = kilowatt; MWh = megawatt-hour; CCGT = combined-cycle gas turbine; n.a. = not applicable. Cost components and LCOE figures are rounded.

Sources: IEA analysis; IRENA Renewable Costing Alliance; IRENA (2020).

- Major contributors to the LCOE include: overnight capital costs; capacity factor that describes the average output over the year relative to the maximum rated capacity (typical values provided); the cost of fuel inputs; plus operation and maintenance. Economic lifetime assumptions are 25 years for solar PV, onshore and offshore wind.
- Weighted average costs of capital (WACC) reflect analysis for utility-scale solar PV in the *World Energy Outlook 2020* (IEA, 2020) and for offshore wind from the *Offshore Wind Outlook 2019* (IEA, 2019). Onshore wind was assumed to have the same WACC as utility-scale solar PV. A standard WACC was assumed for nuclear power, coal- and gas-fired power plants (7-8% based on the stage of economic development).
- Fuel, CO_2 and O&M costs reflect the average over the ten years following the indicated date in the projections.
- The capital costs for nuclear power represent the "nth-of-a-kind" costs for new reactor designs, with substantial cost reductions from the first-of-a-kind projects.

Batteries and hydrogen

Table B.2 ▷ Capital costs for batteries and hydrogen production technologies in the NZE

	2020	2030	2050
Battery packs for transport applications (USD/kWh)	130 - 155	75 - 90	55 - 80
Low-temperature electrolysers (USD/kW_e)	835 - 1 300	255 - 515	200 - 390
Natural gas with CCUS (USD/kW H_2)	1 155 - 2 010	990 - 1 725	935 - 1 625

Notes: kWh = kilowatt-hour; kW_e = kilowatt electric; CCUS = carbon capture, utilisation and storage; H_2 = hydrogen. Capital costs for electrolysers and hydrogen production from natural gas with CCUS are overnight costs.

Source: IEA analysis.

Annex C

Definitions

This annex provides general information on terminology used throughout this report including: units and general conversion factors; definitions of fuels, processes and sectors; regional and country groupings; and abbreviations and acronyms.

Units

Area	km^2	square kilometre
	Mha	million hectares
Batteries	Wh/kg	Watt hours per kilogramme
Coal	Mtce	million tonnes of coal equivalent (equals 0.7 Mtoe)
Distance	km	kilometre
Emissions	ppm	parts per million (by volume)
	tCO_2	tonnes of carbon dioxide
	$\text{Gt CO}_2\text{-eq}$	gigatonnes of carbon-dioxide equivalent (using 100-year global warming potentials for different greenhouse gases)
	$\text{kg CO}_2\text{-eq}$	kilogrammes of carbon-dioxide equivalent
	$\text{g CO}_2\text{/km}$	grammes of carbon dioxide per kilometre
	$\text{kg CO}_2\text{/kWh}$	kilogrammes of carbon dioxide per kilowatt-hour
Energy	EJ	exajoule
	PJ	petajoule
	TJ	terajoule
	GJ	gigajoule
	MJ	megajoule
	boe	barrel of oil equivalent
	toe	tonne of oil equivalent
	ktoe	thousand tonnes of oil equivalent
	Mtoe	million tonnes of oil equivalent
	MBtu	million British thermal units
	kWh	kilowatt-hour
	MWh	megawatt-hour
	GWh	gigawatt-hour
	TWh	terawatt-hour
Gas	bcm	billion cubic metres
	tcm	trillion cubic metres
Mass	kg	kilogramme (1 000 kg = 1 tonne)
	kt	kilotonnes (1 tonne x 10^3)
	Mt	million tonnes (1 tonne x 10^6)
	Gt	gigatonnes (1 tonne x 10^9)

Monetary	USD million	1 US dollar x 10^6
	USD billion	1 US dollar x 10^9
	USD trillion	1 US dollar x 10^{12}
	USD/tCO_2	US dollars per tonne of carbon dioxide
Oil	kb/d	thousand barrels per day
	mb/d	million barrels per day
	mboe/d	million barrels of oil equivalent per day
Power	W	watt (1 joule per second)
	kW	kilowatt (1 watt x 10^3)
	MW	megawatt (1 watt x 10^6)
	GW	gigawatt (1 watt x 10^9)
	TW	terawatt (1 watt x 10^{12})

General conversion factors for energy

		Multiplier to convert to:				
		EJ	**Gcal**	**Mtoe**	**MBtu**	**GWh**
Convert from:	**EJ**	1	238.8 x 10^6	23.88	9.47.8 x 10^3	2.778 x 10^5
	Gcal	4.1868 x 10^{-9}	1	10^{-7}	3.968	1.163 x 10^{-3}
	Mtoe	4.1868 x 10^{-2}	10^7	1	3.968 x 10^7	11 630
	MBtu	1.0551 x 10^{-9}	0.252	2.52 x 10^{-8}	1	2.931 x 10^{-4}
	GWh	3.6 x 10^{-6}	860	8.6 x 10^{-5}	3 412	1

Note: There is no generally accepted definition of boe; typically the conversion factors used vary from 7.15 to 7.40 boe per toe.

Currency conversions

Exchange rates *(2019 annual average)*	**1 US dollar (USD) equals:**
British Pound	0.78
Chinese Yuan Renminbi	6.91
Euro	0.89
Indian Rupee	70.42
Indonesian Rupiah	14 147.67
Japanese Yen	109.01
Russian Ruble	64.74
South African Rand	14.45

Source: OECD National Accounts Statistics: purchasing power parities and exchange rates dataset, July 2020.

Definitions

Advanced bioenergy: Sustainable fuels produced from non-food crop feedstocks, which are capable of delivering significant lifecycle greenhouse gas emissions savings compared with fossil fuel alternatives, and which do not directly compete with food and feed crops for agricultural land or cause adverse sustainability impacts. This definition differs from the one used for "advanced biofuels" in US legislation, which is based on a minimum 50% lifecycle greenhouse gas reduction and which, therefore, includes sugar cane ethanol.

Agriculture: Includes all energy used on farms, in forestry and for fishing.

Agriculture, forestry and other land use (AFOLU) **emissions:** Includes greenhouse gas emissions from agriculture, forestry and other land use.

Ammonia (NH_3)**:** Is a compound of nitrogen and hydrogen. It can be used directly as a fuel in direct combustion process, and in fuel cells or as a hydrogen carrier. To be a low-carbon fuel, ammonia must be produced from low-carbon hydrogen, the nitrogen separated via the Haber process, and electricity needs are met by low-carbon electricity.

Aviation: This transport mode includes both domestic and international flights and their use of aviation fuels. Domestic aviation covers flights that depart and land in the same country; flights for military purposes are also included. International aviation includes flights that land in a country other than the departure location.

Back-up generation capacity: Households and businesses connected to a main power grid may also have back-up electricity generation capacity that, in the event of disruption, can provide electricity. Back-up generators are typically fuelled with diesel or gasoline and capacity can be as little as a few kilowatts. Such capacity is distinct from mini-grid and off-grid systems that are not connected to a main power grid.

Biodiesel: Diesel-equivalent, processed fuel made from the transesterification (a chemical process that converts triglycerides in oils) of vegetable oils and animal fats.

Bioenergy: Energy content in solid, liquid and gaseous products derived from biomass feedstocks and biogas. It includes solid biomass, liquid biofuels and biogases.

Biogas: A mixture of methane, carbon dioxide and small quantities of other gases produced by anaerobic digestion of organic matter in an oxygen-free environment.

Biogases: Include biogas and biomethane.

Biomethane: Biomethane is a near-pure source of methane produced either by upgrading biogas (a process that removes any CO_2 and other contaminants present in the biogas) or through the gasification of solid biomass followed by methanation. It is also known as renewable natural gas.

Buildings: The buildings sector includes energy used in residential, commercial and institutional buildings and non-specified other. Building energy use includes space heating and cooling, water heating, lighting, appliances and cooking equipment.

Bunkers: Includes both international marine bunkers and international aviation bunkers.

Capacity credit: Proportion of the capacity that can be reliably expected to generate electricity during times of peak demand in the grid to which it is connected.

Carbon capture, utilisation and storage (CCUS): The process of capturing CO_2 emissions from fuel combustion, industrial processes or directly from the atmosphere. Captured CO_2 emissions can be stored in underground geological formations, onshore or offshore or used as an input or feedstock to create products.

Clean energy: Includes renewables, energy efficiency, low-carbon fuels, nuclear power, battery storage and carbon capture, utilisation and storage.

Clean cooking facilities: Cooking facilities that are considered safer, more efficient and more environmentally sustainable than the traditional facilities that make use of solid biomass (such as a three-stone fire). This refers primarily to improved solid biomass cookstoves, biogas systems, liquefied petroleum gas stoves, ethanol and solar stoves.

Coal: Includes both primary coal (including lignite, coking and steam coal) and derived fuels (including patent fuel, brown-coal briquettes, coke-oven coke, gas coke, gas-works gas, coke-oven gas, blast furnace gas and oxygen steel furnace gas). Peat is also included.

Concentrating solar power (CSP): Solar thermal power/electric generation systems that collect and concentrate sunlight to produce high temperature heat to generate electricity.

Conventional liquid biofuels: Fuels produced from food crop feedstocks. These liquid biofuels are commonly referred to as first generation and include sugar cane ethanol, starch-based ethanol, fatty acid methyl esther (FAME) and straight vegetable oil (SVO).

Decomposition analysis: Statistical approach that decomposes an aggregate indicator to quantify the relative contribution of a set of pre-defined factors leading to a change in the aggregate indicator. This report uses an additive index decomposition of the type Logarithmic Mean Divisia Index (LMDI).

Demand-side integration (DSI): Consists of two types of measures: actions that influence load shape such as energy efficiency and electrification; and actions that manage load such as demand-side response.

Demand-side response (DSR): Describes actions which can influence the load profile such as shifting the load curve in time without affecting the total electricity demand, or load shedding such as interrupting demand for short duration or adjusting the intensity of demand for a certain amount of time.

Dispatchable generation: Refers to technologies whose power output can be readily controlled - increased to maximum rated capacity or decreased to zero - in order to match supply with demand.

Electricity demand: Defined as total gross electricity generation less own use generation, plus net trade (imports less exports), less transmissions and distribution losses.

Electricity generation: Defined as the total amount of electricity generated by power only or combined heat and power plants including generation required for own use. This is also referred to as gross generation.

Energy sector CO_2 emissions: Carbon dioxide emissions from fuel combustion (excluding non-renewable waste). Note that this does not include fugitive emissions from fuels, CO_2 from transport, storage emissions or industrial process emissions.

Energy sector GHG emissions: CO_2 emissions from fuel combustion plus fugitive and vented methane, and nitrous oxide (N_2O) emissions from the energy and industry sectors.

Energy services: See useful energy.

Ethanol: Refers to bio-ethanol only. Ethanol is produced from fermenting any biomass high in carbohydrates. Today, ethanol is made from starches and sugars, but second-generation technologies will allow it to be made from cellulose and hemicellulose, the fibrous material that makes up the bulk of most plant matter.

Fischer-Tropsch synthesis: Catalytic production process for the production of synthetic fuels. Natural gas, coal and biomass feedstocks can be used.

Gases: Includes natural gas, biogases, synthetic methane and hydrogen.

Geothermal: Geothermal energy is heat derived from the sub-surface of the earth. Water and/or steam carry the geothermal energy to the surface. Depending on its characteristics, geothermal energy can be used for heating and cooling purposes or be harnessed to generate clean electricity if the temperature is adequate.

Heat (end-use): Can be obtained from the combustion of fossil or renewable fuels, direct geothermal or solar heat systems, exothermic chemical processes and electricity (through resistance heating or heat pumps which can extract it from ambient air and liquids). This category refers to the wide range of end-uses, including space and water heating, and cooking in buildings, desalination and process applications in industry. It does not include cooling applications.

Heat (supply): Obtained from the combustion of fuels, nuclear reactors, geothermal resources and the capture of sunlight. It may be used for heating or cooling, or converted into mechanical energy for transport or electricity generation. Commercial heat sold is reported under total final consumption with the fuel inputs allocated under electricity and heat sectors.

Hydrogen: Hydrogen is used in the energy system to refine hydrocarbon fuels and as an energy carrier in its own right. It is also produced from other energy products for use in chemicals production. As an energy carrier it can be produced from hydrocarbon fuels or from the electrolysis of water with electricity, and can be burned or used in fuel cells for electricity and heat in a wide variety of applications. To be low-carbon hydrogen, either the emissions associated with fossil-based hydrogen production must be prevented (for example by carbon capture, utilisation and storage) or the electricity input to hydrogen produced from water must be low-carbon electricity. In this report, final consumption of hydrogen includes demand for pure hydrogen and excludes hydrogen produced and consumed onsite by the same entity. Demand for hydrogen-based fuels such as ammonia or synthetic hydrocarbons are considered separately.

Hydrogen-based fuels: Include ammonia and synthetic hydrocarbons (gases and liquids). Hydrogen-based is used in figures to refer to hydrogen and hydrogen-based fuels.

Hydropower: The energy content of the electricity produced in hydropower plants, assuming 100% efficiency. It excludes output from pumped storage and marine (tide and wave) plants.

Industry: The sector includes fuel used within the manufacturing and construction industries. Key industry branches include iron and steel, chemicals and petrochemicals, cement, and pulp and paper. Consumption of fuels for the transport of goods is reported as part of the transport sector, while consumption by off-road vehicles is reported under industry.

International aviation bunkers: Includes the deliveries of aviation fuels to aircraft for international aviation. Fuels used by airlines for their road vehicles are excluded. The domestic/international split is determined on the basis of departure and landing locations and not by the nationality of the airline. For many countries this incorrectly excludes fuels used by domestically owned carriers for their international departures.

International marine bunkers: Covers fuels delivered to ships of all flags that are engaged in international navigation. The international navigation may take place at sea, on inland lakes and waterways, and in coastal waters. Consumption by ships engaged in domestic navigation is excluded. The domestic/international split is determined on the basis of port of departure and port of arrival, and not by the flag or nationality of the ship. Consumption by fishing vessels and by military forces is excluded and included in residential, services and agriculture.

Investment: All investment data and projections reflect spending across the lifecycle of a project, i.e. the capital spent is assigned to the year when it is incurred. Investments for oil, gas and coal include production, transformation and transportation; those for the power sector include refurbishments, uprates, new builds and replacements for all fuels and technologies for on-grid, mini-grid and off-grid generation, as well as investment in transmission and distribution, and battery storage. Investment data are presented in real terms in year-2019 US dollars unless otherwise stated.

Light-duty vehicles (LDV)**:** include passenger cars and light commercial vehicles (gross vehicle weight <3.5 tonnes).

Liquid biofuels: Liquid fuels derived from biomass or waste feedstocks and include ethanol and biodiesel. They can be classified as conventional and advanced liquid biofuels according to the bioenergy feedstocks and technologies used to produce them and their respective maturity. Unless otherwise stated, liquid biofuels are expressed in energy-equivalent volumes of gasoline and diesel.

Liquids: Includes oil, liquid biofuels (expressed in energy-equivalent volumes of gasoline and diesel), synthetic oil and ammonia.

Low-carbon electricity: Includes renewable energy technologies, hydrogen-based generation, nuclear power and fossil fuel power plants equipped with carbon capture, utilisation and storage.

Low-emissions fuels: Include liquid biofuels, biogas and biomethane, hydrogen, and hydrogen-based fuels that do not emit any CO_2 from fossil fuels directly when used and also emit very little when being produced.

Marine: Represents the mechanical energy derived from tidal movement, wave motion or ocean current and exploited for electricity generation.

Merchant hydrogen: Hydrogen produced by one company to sell to others; equivalent to hydrogen reported in total final consumption.

Mini-grids: Small grid systems linking a number of households or other consumers.

Modern bioenergy: Includes modern solid biomass, liquid biofuels and biogases harvested from sustainable sources. It excludes the traditional use of biomass.

Modern energy access: Includes household access to a minimum level of electricity; household access to safer and more sustainable cooking and heating fuels, and stoves; access that enables productive economic activity; and access for public services.

Modern renewables: Includes all uses of renewable energy with the exception of traditional use of solid biomass.

Modern solid biomass: Refers to the use of solid biomass in improved cookstoves and modern technologies using processed biomass such as pellets.

Natural gas: Comprises gases occurring in deposits, whether liquefied or gaseous, consisting mainly of methane. It includes both "non-associated" gas originating from fields producing hydrocarbons only in gaseous form, and "associated" gas produced in association with crude oil as well as methane recovered from coal mines (colliery gas). Natural gas liquids (NGLs), manufactured gas (produced from municipal or industrial waste, or sewage) and quantities vented or flared are not included. Gas data in cubic metres are expressed on a gross calorific value basis and are measured at 15 °C and at 760 mm Hg ("Standard Conditions"). Gas data expressed in tonnes of oil equivalent, mainly for comparison reasons with other fuels, are on a net calorific basis. The difference between the net and the gross calorific value is the latent heat of vaporisation of the water vapour produced during combustion of the fuel (for gas the net calorific value is 10% lower than the gross calorific value).

Natural gas liquids (NGLs): Liquid or liquefied hydrocarbons produced in the manufacture, purification and stabilisation of natural gas. These are those portions of natural gas which are recovered as liquids in separators, field facilities or gas processing plants. NGLs include but are not limited to ethane (when it is removed from the natural gas stream), propane, butane, pentane, natural gasoline and condensates.

Network gases: Includes natural gas, biomethane, synthetic methane and hydrogen blended in a gas network.

Non-energy use: Fuels used for chemical feedstocks and non-energy products. Examples of non-energy products include lubricants, paraffin waxes, asphalt, bitumen, coal tars and oils as timber preservatives.

Nuclear: Refers to the primary energy equivalent of the electricity produced by a nuclear plant, assuming an average conversion efficiency of 33%.

Off-grid systems: Stand-alone systems for individual households or groups of consumers.

Offshore wind: Refers to electricity produced by wind turbines that are installed in open water, usually in the ocean.

Oil: Oil production includes both conventional and unconventional oil. Petroleum products include refinery gas, ethane, liquid petroleum gas, aviation gasoline, motor gasoline, jet fuels, kerosene, gas/diesel oil, heavy fuel oil, naphtha, white spirit, lubricants, bitumen, paraffin, waxes and petroleum coke.

Other energy sector: Covers the use of energy by transformation industries and the energy losses in converting primary energy into a form that can be used in the final consuming sectors. It includes losses by gas works, petroleum refineries, coal and gas transformation and liquefaction, biofuels production and the production of hydrogen and hydrogen-based fuels. It also includes energy own use in coal mines, in oil and gas extraction, in direct air capture, in biofuels production and in electricity and heat production. Transfers and statistical differences are also included in this category.

Power generation: Refers to fuel use in electricity plants, heat plants and combined heat and power (CHP) plants. Both main activity producer plants and small plants that produce fuel for their own use (auto-producers) are included.

Productive uses: Energy used towards an economic purpose: agriculture, industry, services and non-energy use. Some energy demand from the transport sector, e.g. freight, could also be considered as productive, but is treated separately.

Renewables: Includes bioenergy, geothermal, hydropower, solar photovoltaics (PV), concentrating solar power (CSP), wind and marine (tide and wave) energy for electricity and heat generation.

Residential: Energy used by households including space heating and cooling, water heating, lighting, appliances, electronic devices and cooking equipment.

Services: Energy used in commercial facilities, e.g. hotels, offices, catering, shops, and institutional buildings, e.g. schools, hospitals, offices. Energy use in services includes space heating and cooling, water heating, lighting, equipment, appliances and cooking equipment.

Shale gas: Natural gas contained within a commonly occurring rock classified as shale. Shale formations are characterised by low permeability, with more limited ability of gas to flow through the rock than is the case with a conventional reservoir. Shale gas is generally produced using hydraulic fracturing.

Shipping/navigation: This transport sub-sector includes both domestic and international navigation and their use of marine fuels. Domestic navigation covers the transport of goods or persons on inland waterways and for national sea voyages (starts and ends in the same country without any intermediate foreign port). International navigation includes quantities of fuels delivered to merchant ships (including passenger ships) of any nationality for consumption during international voyages transporting goods or passengers.

Solar photovoltaic (PV)**:** Electricity produced from solar photovoltaic cells.

Solid biomass: Includes charcoal, fuelwood, dung, agricultural residues, wood waste and other solid wastes.

Steam coal: Type of coal that is mainly used for heat production or steam-raising in power plants and, to a lesser extent, in industry. Typically, steam coal is not of sufficient quality for steel making. Coal of this quality is also commonly known as thermal coal.

Synthetic methane: Low-carbon synthetic methane is produced through the methanation of low-carbon hydrogen and carbon dioxide from a biogenic or atmospheric source.

Synthetic oil: Low-carbon synthetic oil produced through Fischer Tropsch conversion or methanol synthesis from syngas, a mixture of hydrogen (H_2) and carbon monoxide (CO).

Total energy supply (TES)**:** Represents domestic demand only and is broken down into electricity and heat generation, other energy sector and total final consumption.

Total final consumption (TFC)**:** Is the sum of consumption by the various end-use sectors. TFC is broken down into energy demand in the following sectors: industry (including manufacturing and mining), transport, buildings (including residential and services) and other (including agriculture and non-energy use). It excludes international marine and aviation bunkers, except at world level where it is included in the transport sector.

Total final energy consumption (TFEC)**:** Is a variable defined primarily for tracking progress towards target 7.2 of the UN Sustainable Development Goals. It incorporates total final consumption (TFC) by end-use sectors but excludes non-energy use. It excludes international marine and aviation bunkers, except at world level. Typically this is used in the context of calculating the renewable energy share in total final energy consumption (Indicator 7.2.1 of the Sustainable Development Goals), where TFEC is the denominator.

Total primary energy demand (TPED)**:** See total energy supply

Traditional use of solid biomass: Refers to the use of solid biomass with basic technologies, such as a three-stone fire, often with no or poorly operating chimneys.

Transport: Fuels and electricity used in the transport of goods or people within the national territory irrespective of the economic sector within which the activity occurs. This includes fuel and electricity delivered to vehicles using public roads or for use in rail vehicles; fuel delivered to vessels for domestic navigation; fuel delivered to aircraft for domestic aviation; and energy consumed in the delivery of fuels through pipelines. Fuel delivered to international marine and aviation bunkers is presented only at the world level and is excluded from the transport sector at a domestic level.

Trucks: Includes medium trucks (gross vehicle weight 3.5-15 tonnes) and heavy trucks (>15 tonnes).

Useful energy: Refers to the energy that is available to end-users to satisfy their needs. This is also referred to as energy services demand. As result of transformation losses at the point of use, the amount of useful energy is lower than the corresponding final energy demand for most technologies. Equipment using electricity often has higher conversion efficiency than equipment using other fuels, meaning that for a unit of energy consumed electricity can provide more energy services.

Wind: electricity produced by wind turbines from the kinetic energy of wind.

Woody energy crops: Short-rotation plantings of woody biomass for bioenergy production, such as coppiced willow and miscanthus.

Variable renewable energy (VRE)**:** Refers to technologies whose maximum output at any time depends on the availability of fluctuating renewable energy resources. VRE includes a broad array of technologies such as wind power, solar PV, run-of-river hydro, concentrating solar power (where no thermal storage is included) and marine (tidal and wave).

Zero-carbon-ready buildings: A zero-carbon-ready building is highly energy efficient and either uses renewable energy directly, or an energy supply that can be fully decarbonised, such as electricity or district heat.

Zero-emissions vehicles (ZEVs)**:** Vehicles which are capable of operating without tailpipe CO_2 emissions (battery electric vehicles and fuel cell vehicles).

Regional and country groupings

Advanced economies: OECD regional grouping and Bulgaria, Croatia, Cyprus[1,2], Malta and Romania.

Africa: North Africa and sub-Saharan Africa regional groupings.

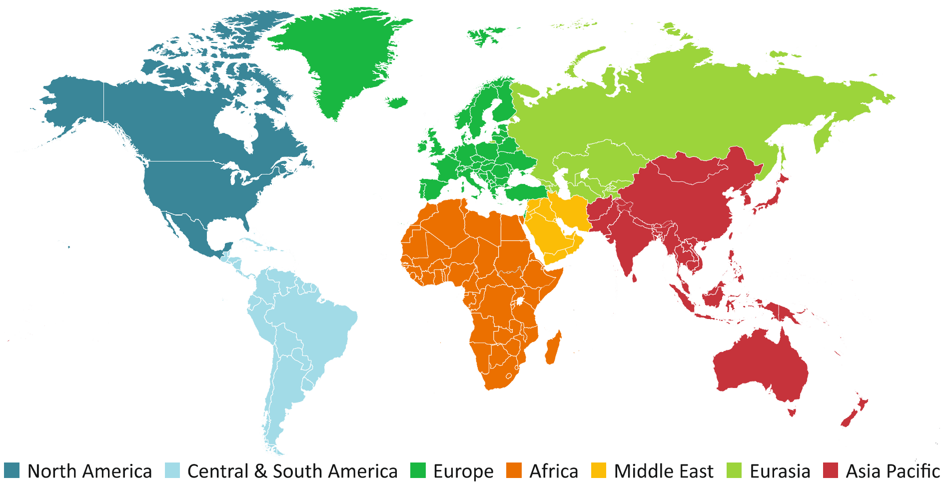
Asia Pacific: Southeast Asia regional grouping and Australia, Bangladesh, China, India, Japan, Korea, Democratic People's Republic of Korea, Mongolia, Nepal, New Zealand, Pakistan, Sri Lanka, Chinese Taipei, and other Asia Pacific countries and territories.[3]

Caspian: Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan.

Central and South America: Argentina, Plurinational State of Bolivia (Bolivia), Brazil, Chile, Colombia, Costa Rica, Cuba, Curaçao, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Nicaragua, Panama, Paraguay, Peru, Suriname, Trinidad and Tobago, Uruguay, Bolivarian Republic of Venezuela (Venezuela), and other Central and South American countries and territories.[4]

China: Includes the (People's Republic of) China and Hong Kong, China.

Figure C.1 ▷ Main country groupings



Note: This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Developing Asia: Asia Pacific regional grouping excluding Australia, Japan, Korea and New Zealand.

Emerging market and developing economies: All other countries not included in the advanced economies regional grouping.

Eurasia: Caspian regional grouping and the Russian Federation (Russia).

Europe: European Union regional grouping and Albania, Belarus, Bosnia and Herzegovina, North Macedonia, Gibraltar, Iceland, Israel[5], Kosovo, Montenegro, Norway, Serbia, Switzerland, Republic of Moldova, Turkey, Ukraine and United Kingdom.

European Union: Austria, Belgium, Bulgaria, Croatia, Cyprus[1,2], Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain and Sweden.

IEA (International Energy Agency)**:** OECD regional grouping excluding Chile, Colombia, Iceland, Israel, Latvia, Lithuania and Slovenia.

Latin America: Central and South America regional grouping and Mexico.

Middle East: Bahrain, Islamic Republic of Iran (Iran), Iraq, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syrian Arab Republic (Syria), United Arab Emirates and Yemen.

Non-OECD: All other countries not included in the OECD regional grouping.

Non-OPEC: All other countries not included in the OPEC regional grouping.

North Africa: Algeria, Egypt, Libya, Morocco and Tunisia.

North America: Canada, Mexico and United States.

OECD (Organisation for Economic Co-operation and Development)**:** Australia, Austria, Belgium, Canada, Chile, Colombia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States.

OPEC (Organisation of the Petroleum Exporting Countries)**:** Algeria, Angola, Republic of the Congo (Congo), Equatorial Guinea, Gabon, the Islamic Republic of Iran (Iran), Iraq, Kuwait, Libya, Nigeria, Saudi Arabia, United Arab Emirates and Bolivarian Republic of Venezuela (Venezuela).

Southeast Asia: Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic (Lao PDR), Malaysia, Myanmar, Philippines, Singapore, Thailand and Viet Nam. These countries are all members of the Association of Southeast Asian Nations (ASEAN).

Sub-Saharan Africa: Angola, Benin, Botswana, Cameroon, Republic of the Congo (Congo), Côte d'Ivoire, Democratic Republic of the Congo, Eritrea, Ethiopia, Gabon, Ghana, Kenya, Mauritius, Mozambique, Namibia, Niger, Nigeria, Senegal, South Africa, South Sudan, Sudan, United Republic of Tanzania (Tanzania), Togo, Zambia, Zimbabwe and other African countries and territories.[6]

Country notes

[1] Note by Turkey: The information in this document with reference to "Cyprus" relates to the southern part of the island. There is no single authority representing both Turkish and Greek Cypriot people on the island. Turkey recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of the United Nations, Turkey shall preserve its position concerning the "Cyprus issue".

[2] Note by all the European Union Member States of the OECD and the European Union: The Republic of Cyprus is recognised by all members of the United Nations with the exception of Turkey. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

[3] Individual data are not available and are estimated in aggregate for: Afghanistan, Bhutan, Cook Islands, Fiji, French Polynesia, Kiribati, Macau (China), Maldives, New Caledonia, Palau, Papua New Guinea, Samoa, Solomon Islands, Timor-Leste and Tonga and Vanuatu.

[4] Individual data are not available and are estimated in aggregate for: Anguilla, Antigua and Barbuda, Aruba, Bahamas, Barbados, Belize, Bermuda, Bonaire, British Virgin Islands, Cayman Islands, Dominica, Falkland Islands (Malvinas), French Guiana, Grenada, Guadeloupe, Guyana, Martinique, Montserrat, Saba, Saint Eustatius, Saint Kitts and Nevis, Saint Lucia, Saint Pierre and Miquelon, Saint Vincent and Grenadines, Saint Maarten, Turks and Caicos Islands.

[5] The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD and/or the IEA is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

[6] Individual data are not available and are estimated in aggregate for: Burkina Faso, Burundi, Cabo Verde, Central African Republic, Chad, Comoros, Djibouti, Kingdom of Eswatini, Gambia, Guinea, Guinea-Bissau, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Réunion, Rwanda, Sao Tome and Principe, Seychelles, Sierra Leone, Somalia and Uganda.

Abbreviations and Acronyms

AFOLU	agriculture forestry and other land use
APC	Announced Pledges Case
ASEAN	Association of Southeast Asian Nations
BECCS	bioenergy equipped with CCUS
BEV	battery electric vehicles
CCUS	carbon capture, utilisation and storage
CDR	carbon dioxide removal
CFL	compact fluorescent lamp
CH_4	methane
CHP	combined heat and power; the term co-generation is sometimes used
CNG	compressed natural gas
CO	carbon monoxide
CO_2	carbon dioxide
CO_2-eq	carbon-dioxide equivalent
COP	Conference of Parties (UNFCCC)
CSP	concentrating solar power
DAC	direct air capture
DACCS	direct air capture with carbon capture and storage
DER	distributed energy resources
DSI	demand-side integration
DSO	distribution system operator
DSR	demand-side response
EAF	electric arc furnaces
EHOB	extra-heavy oil and bitumen
ETP	Energy Technology Perspectives
EU	European Union
EV	electric vehicle
FCEV	fuel cell electric vehicle
GDP	gross domestic product
GHG	greenhouse gases
GTL	gas-to-liquids
HEFA	hydrogenated esters and fatty acids
ICE	internal combustion engine
IEA	International Energy Agency
IIASA	International Institute for Applied Systems Analysis
IMF	International Monetary Fund
IOC	international oil company
IPCC	Intergovernmental Panel on Climate Change
LCC	Low CCUS Case
LDVs	light-duty vehicles
LCV	light-commercial vehicle
LED	light-emitting diode

LNG	liquefied natural gas
LPG	liquefied petroleum gas
MEPS	minimum energy performance standards
NDCs	Nationally Determined Contributions
NEA	Nuclear Energy Agency (an agency within the OECD)
NGLs	natural gas liquids
NGV	natural gas vehicle
NOC	national oil company
NO_X	nitrogen oxides
N_2O	nitrous oxide
NZE	Net-Zero Emissions Scenario
OECD	Organisation for Economic Co-operation and Development
OPEC	Organization of the Petroleum Exporting Countries
PHEV	plug-in hybrid electric vehicles
PLDV	passenger light-duty vehicle
PM	particulate matter
$PM_{2.5}$	fine particulate matter
PPP	purchasing power parity
PV	photovoltaics
R&D	research and development
RD&D	research, development and demonstration
SAF	sustainable aviation fuel
SDG	Sustainable Development Goals (United Nations)
SO_2	sulphur dioxide
SR1.5	IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels
STEPS	Stated Policies Scenario
T&D	transmission and distribution
TES	total energy supply
TFC	total final consumption
TFEC	total final energy consumption
TPED	total primary energy demand
UEC	unit energy consumption
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UK	United Kingdom
US	United States
VRE	variable renewable energy
WEO	*World Energy Outlook*
WHO	World Health Organization
ZEV	Zero-emissions vehicle

References

Chapter 1: Announced net zero pledges and the energy sector

climatewatchdata (2021), https://www.climatewatchdata.org/ndc-overview.

European Commission (2018), 2018 - *Vision for a long-term EU strategy for reducing greenhouse gas emissions*, https://ec.europa.eu/clima/policies/strategies/2050_en.

IEA (International Energy Agency) (2021), *Global Energy Review 2021*, https://www.iea.org/reports/global-energy-review-2021.

– (2020a), *Sustainable Recovery*, https://www.iea.org/reports/sustainable-recovery/a-sustainable-recovery-plan-for-the-energy-sector.

– (2020b), *World Energy Outlook 2020*, https://www.iea.org/reports/world-energy-outlook-2020.

– (2020c), *Energy Technology Perspectives 2020*, https://www.iea.org/reports/energy-technology-perspectives-2020.

– (2020c), *World Energy Balances 2020 edition: database documentation*, http://wds.iea.org/wds/pdf/WORLDBAL_Documentation.pdf.

– (2020e), *Special Report on Clean Energy Innovation*, https://www.iea.org/reports/clean-energy-innovation.

IPCC (Intergovernmental Panel on Climate Change) (2018), *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels*, IPCC, https://www.ipcc.ch/sr15/.

WRI and WBCSD (World Resources Institute and World Business Council for Sustainable Development) (2004), *The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard*, WRI and WBCSD, Washington, DC, https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf.

Chapter 2: A global pathway to net-zero CO_2 emissions in 2050

Amann, M. et al. (2011), "Cost-effective control of air quality and greenhouse gases in Europe: Modelling and policy applications", *Environmental Modelling*, Vol 26, pp. 1489-1501.

Anderson et al. (2013), *Getting to know GIMF: The Simulation Properties of the Global Integrated Monetary and Fiscal Model*, International Monetary Fund, Washington, DC, https://www.imf.org/external/pubs/ft/wp/2013/wp1355.pdf.

Assemblee Nationale (2021), (Proposed law aiming to replace domestic flights by train), *PROPOSITION DE LOI visant à replacer les vols intérieurs par le train*, https://www.assemblee-nationale.fr/dyn/15/textes/l15b2005_proposition-loi.

Aydin, E., D. Brounen and N. Kok (2018), "Information provision and energy consumption: Evidence from a field experiment", *Energy Economics*, Vol. 71, pp. 403-411., https://doi.org/10.1016/j.eneco.2018.03.008.

Byars, M., Y. Wei and S. Handy (2017), *State-Level Strategies for Reducing Vehicle Miles of Travel*, https://bit.ly/2LvA6nn.

Climate Assembly United Kingdom (2020), *The path to net zero*, https://www.climateassembly.uk/report/read/final-report.pdf.

Convention Citoyenne pour le Climat (2021), (Proposals of the Citizens Climate Convention), *Les Propositions de la Convention Citoyenne pour le Climat*, https://propositions.conventioncitoyennepourleclimat.fr/.

DEFRA (UK Department for Environment, Food & Rural Affairs) (2012), *London congestion charge detailed assessment*, https://uk-air.defra.gov.uk/assets/documents/reports/cat09/0505171128_London_Congestion_Charge_Detailed_Assessment.doc.

European Commission (2021), *Urban Access Regulations in Europe*, https://urbanaccessregulations.eu/countries-mainmenu-147.

Frank, S. (2021), "Land-based climate change mitigation potentials within the agenda for sustainable development", *Environmental Research Letters*, Vol. 16/2, https://doi.org/10.1088/1748-9326/abc58a.

IEA (International Energy Agency) (2021), *The Role of Critical Minerals in Clean Energy Transitions*, IEA, https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions.

– (2020a), *World Energy Balances 2020 edition: database documentation*, http://wds.iea.org/wds/pdf/WORLDBAL_Documentation.pdf.

– (2020b), *Outlook for Biogas and Biomethane: Prospects for organic growth*, https://www.iea.org/reports/outlook-for-biogas-and-biomethane-prospects-for-organic-growth.

– (2020c), *World Energy Investment, 2020*, https://www.iea.org/reports/world-energy-investment-2020.

– (2020d), *Energy Technology Perspectives 2020: Special Report on Clean Energy Innovation*, https://www.iea.org/reports/clean-energy-innovation.

– (2019), *The Future of Rail*, https://www.iea.org/reports/the-future-of-rail.

IMF (International Monetary Fund) (2020a), *June 2020: A Crisis Like No Other, An Uncertain Recovery*, https://www.imf.org/-/media/Files/Publications/WEO/2020/Update/June/English/WEOENG202006.ashx

– (2020b), *World Economic Outlook Database*, April 2020 Edition, Washington DC.

IPCC (Intergovernmental Panel on Climate Change) (2019), *Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems*, https://www.ipcc.ch/srccl/.

– (2018), *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development and efforts to eradicate poverty*, https://www.ipcc.ch/sr15/.

– (2014), *Climate Change 2014: Synthesis Report, Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, https://www.ipcc.ch/report/ar5/syr/.

Jochem et al. (2020), "Does free-floating carsharing reduce private vehicle ownership? The case of SHARE NOW in European cities", *Transportation Research Part A: Policy and Practice*, Vol. 141, pp. 373-295, https://doi.org/10.1016/j.tra.2020.09.016.

Laxton, D. et al. (2010), *The Global Integrated Monetary and Fiscal Model (GIMF) – Theoretical Structure*, International Monetary Fund, Washington, DC, https://www.imf.org/~/media/Websites/IMF/imported-full-text-pdf/external/pubs/ft/wp/2010/_wp1034.ashx.

Martin, Shaheen and Lidiker (2010), "Carsharings impact on household vehicle holdings: Results for a North American shared-use vehicle survey", Presented at 89th Annual Meeting of the Transportation Research Board, Washington DC, https://doi.org/10.3141/2143-19.

Newgate Research and Cambridge Zero (2021), *Net Zero Public Dialogue*, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/969401/net-zero-public-dialogue.pdf.

Oxford Economics (2020), *Oxford Economics Global Economic Model*, (database), https://www.oxfordeconomics.com/global-economic-model, August 2020 update, Oxford.

TFL (Transport for London) (2021), *Congestion charge factsheet*, https://content.tfl.gov.uk/congestion-charge-factsheet.pdf.pdf.

Tools of Change (2014), *Stockholm's Congestion Pricing*, https://www.toolsofchange.com/userfiles/Stockholm%20Congestion%20Pricing%20-%20FINAL%202014.pdf.

UNDESA (United Nations Department of Economic and Social Affairs) (2019), *2019 Revision of World Population Prospects*, https://population.un.org/wpp/.

Wu, W. H. (2019), "Global advanced bioenergy potential under environmental protection policies and societal transformation measures", *GCB Bioenergy*, Vol. 11, pp. 1041-1055, https://doi.org/10.1111/gcbb.12614.

Chapter 3: Sectoral pathways to net-zero emissions by 2050

IEA (International Energy Agency) (2021a), *The Role of Critical Minerals in Clean Energy Transitions*, https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions.

– (2021b), *Global EV Outlook 2020,* https://www.iea.org/reports/global-ev-outlook-2021.

– (2020a), *The Oil and Gas Industry in Energy Transitions,* https://www.iea.org/reports/the-oil-and-gas-industry-in-energy-transitions.

– (2020b), *Energy Technology Perspectives 2020*, IEA, https://www.iea.org/reports/energy-technology-perspectives-2020.

– (2019), *Nuclear Power in a Clean Energy System*, https://www.iea.org/reports/nuclear-power-in-a-clean-energy-system.

UNCTAD (United Nations Conference on Trade and Development) (2018), *Review of Maritime Transport 2018*, UNCTAD, https://unctad.org/en/PublicationsLibrary/rmt2018_en.pdf.

Chapter 4: Wider implications of achieving net-zero emissions

Carbon Engineering (2021), https://carbonengineering.com/our-story/.

Diaz Anadon, L. (2012), “Missions-oriented RD&D institutions in energy between 2000 and 2010: A comparative analysis of China, the United Kingdom, and the United States”, *Research Policy*, Vol. 41, pp. 1742-1756, https://doi.org/10.1016/j.respol.2012.02.015.

European Cement Research Academy (2012), *ECRA CCS Project: Report on phase III*, https://ecraonline.org/fileadmin/redaktion/files/pdf/ECRA_Technical_Report_CCS_Phase_III.pdf.

Feyisa, Dons & Meilby (2014), "Efficiency of parks in mitigating urban heat island effect: an example from Addis Ababa", *Landscape and Urban Planning*, Vol. 123, pp. 87–95, https://doi.org/10.1016/j.landurbplan.2013.12.008.

GLPGP (The Global LPG Partnership) (2020), *Assessing Potential for BioLPG Production and use within the Cooking Energy Sector in Africa*, https://mecs.org.uk/wp-content/uploads/2020/09/GLPGP-Potential-for-BioLPG-Production-and-Use-as-Clean-Cooking-Energy-in-Africa-2020.pdf.

Greco, A. et al. (2019), "A review of the state of the art of solid-state caloric cooling processes at room-temperature before 2019", *International Journal of Refrigeration*, pp. 66-88, https://doi.org/10.1016/j.ijrefrig.2019.06.034.

Gross, R. (2018), “How long does innovation and commercialisation in the energy sector take? Historical case studies of the timescale from invention to widespread commercialisation in the energy supply and end-use technology”, *Energy Policy*, Vol. 123, pp. 682-299, https://doi.org/10.1016/j.enpol.2018.08.061.

IEA (International Energy Agency) (2021a), *The Role of Critical Minerals in Clean Energy Transitions*, https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions.

– (2021b), *Climate Resilience*, https://www.iea.org/reports/climate-resilience.

– (2021c), *Enhancing Cyber Resilience in Electricity Systems*, https://www.iea.org/reports/enhancing-cyber-resilience-in-electricity-systems.

– (2021d), *Conditions and requirements for the technical feasibility of a power system with a high share of renewables in France towards 2050*, https://www.iea.org/reports/conditions-and-requirements-for-the-technical-feasibility-of-a-power-system-with-a-high-share-of-renewables-in-france-towards-2050.

– (2020a), *World Energy Investment, 2020*, https://www.iea.org/reports/world-energy-investment-2020.

– (2020b), *Sustainable Recovery: World Energy Outlook Special Report*, https://www.iea.org/reports/sustainable-recovery.

– (2020c), *Energy Technology Perspectives: Special Report on Carbon Capture Utilisation and Storage*, https://www.iea.org/reports/ccus-in-clean-energy-transitions.

– (2020d), *Outlook for Biogas and Biomethane: Prospects for organic growth*, https://www.iea.org/reports/outlook-for-biogas-and-biomethane-prospects-for-organic-growth.

– (2020e), *The Oil and Gas Industry in Energy Transitions*, https://www.iea.org/reports/the-oil-and-gas-industry-in-energy-transitions.

– (2020f), *World Energy Outlook 2020*, https://www.iea.org/reports/world-energy-outlook-2020.

– (2020g), *The Role of CCUS in Low-Carbon Power Systems*, https://www.iea.org/reports/the-role-of-ccus-in-low-carbon-power-systems.

– (2020h), *Power Systems in Transition*, https://www.iea.org/reports/power-systems-in-transition/electricity-security-matters-more-than-ever.

– (2020i), *Energy Technology Perspectives 2020: Special Report on Clean Energy Innovation*, https://www.iea.org/reports/clean-energy-innovation.

– (2019a), *The Future of Hydrogen*, https://www.iea.org/reports/the-future-of-hydrogen.

– (2019b), Offshore Wind Outlook 2019, https://www.iea.org/reports/offshore-wind-outlook-2019.

– (2017), *Energy Access Outlook 2017: from Poverty to Prosperity: World Energy Outlook Special Report*, https://www.iea.org/reports/energy-access-outlook-2017

Kamaya, N. (2011), "A lithium superionic conductor", *Nature Materials*, pp. 682-686, https://doi.org/10.1038/nmat3066.

Liquid Gas Europe (2021), *BioLPG: A Renewable Pathway Towards 2050*, https://www.liquidgaseurope.eu/news/biolpg-a-renewable-pathway-towards-2050.

Malhotra, A. and T. Schmidt (2020), "Accelerating Low-Carbon Innovation", *Joule*, pp. 2259-2267, https://doi.org/10.1016/j.joule.2020.09.004.

Material Economics (2019), *Industrial Transformation 2050: Pathways to Net-Zero Emissions from EU Heavy Industry*, University of Cambridge for Sustainability Leadership, Cambridge, United Kingdom.

Mazzucato, M. (2018), "Mission-oriented Innovation Policies: Challenges and Opportunities", Industrial and Corporate Change, Vol. 27/5, pp. 803-815, https://doi.org/10.1093/icc/dty034.

NASEO and Energy Futures Initiative (2021), *United States Energy & Employment Report*, https://www.usenergyjobs.org/.

NEA (Nuclear Energy Agency) (2016), *Cost Benchmarking for Nuclear Power Plant Decommissioning*, https://doi.org/10.1787/acae0e3b-en.

OECD (Organisation for Economic Co-operation and Development) (2020), *Environmentally related tax revenue*, OECD Statistics, https://stats.oecd.org/.

– (2015), *The Economic Consequences of Climate Change*, https://www.oecd.org/env/the-economic-consequences-of-climate-change-9789264235410-en.htm.

Tenova (2018), HYL News, https://www.tenova.com/fileadmin/user_upload/HYL_News_-_December_2018.pdf.

Victor, D., Geels, F. and S. Sharpe (2019), *Accelerating the Low Carbon Transition: The case for stronger, more targeted and co-ordinated international action*, The Energy Transitions Commission, London.

Zemships (2008), *One Hundred Passengers and Zero Emissions: The first-ever passenger vessel to sail propelled by fuel cells*, https://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=home.s.

Annex B: Technology costs

IEA (International Energy Agency) (2020), *World Energy Outlook 2020*, https://www.iea.org/reports/world-energy-outlook-2020.

– (2019), Offshore Wind Outlook 2019, IEA, Paris, https://www.iea.org/reports/offshore-wind-outlook-2019.

IRENA (International Renewable Energy Agency) (2020), Renewable Costing Alliance, IRENA, Abu Dhabi, https://www.irena.org/statistics, accessed 15 July 2020.

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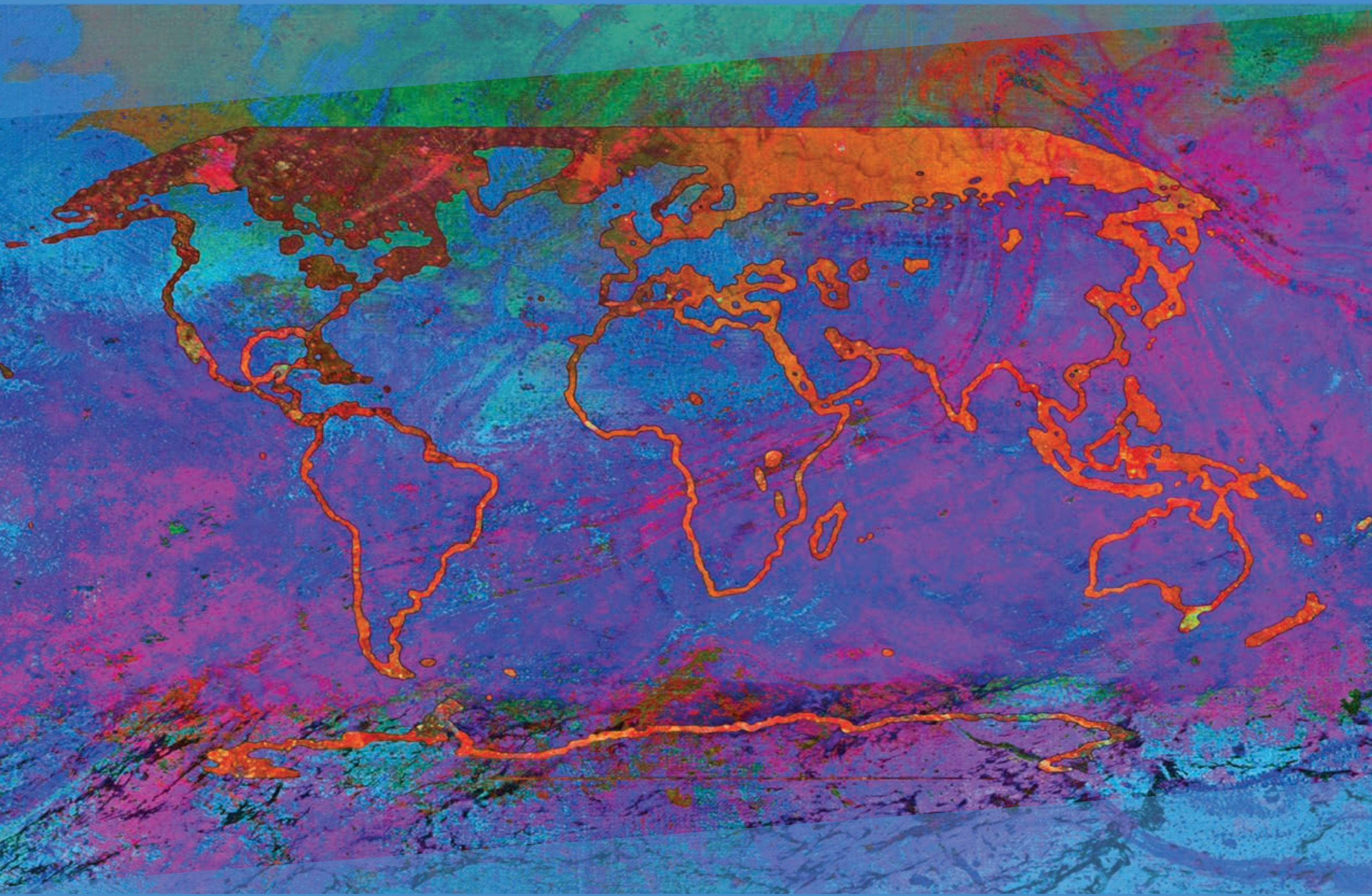
Climate Change 2021
The Physical Science Basis
Summary for Policymakers



WGI

Working Group I Contribution to the
Sixth Assessment Report of the
Intergovernmental Panel on Climate Change

WMO UNEP

Climate Change 2021
The Physical Science Basis

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SPM

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Introduction

This Summary for Policymakers (SPM) presents key findings of the Working Group I (WGI) contribution to the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6)[1] on the physical science basis of climate change. The report builds upon the 2013 Working Group I contribution to the IPCC's Fifth Assessment Report (AR5) and the 2018–2019 IPCC Special Reports[2] of the AR6 cycle and incorporates subsequent new evidence from climate science.[3]

This SPM provides a high-level summary of the understanding of the current state of the climate, including how it is changing and the role of human influence, the state of knowledge about possible climate futures, climate information relevant to regions and sectors, and limiting human-induced climate change.

Based on scientific understanding, key findings can be formulated as statements of fact or associated with an assessed level of confidence indicated using the IPCC calibrated language.[4]

The scientific basis for each key finding is found in chapter sections of the main Report and in the integrated synthesis presented in the Technical Summary (hereafter TS), and is indicated in curly brackets. The AR6 WGI Interactive Atlas facilitates exploration of these key synthesis findings, and supporting climate change information, across the WGI reference regions.[5]

A. The Current State of the Climate

Since AR5, improvements in observationally based estimates and information from paleoclimate archives provide a comprehensive view of each component of the climate system and its changes to date. New climate model simulations, new analyses, and methods combining multiple lines of evidence lead to improved understanding of human influence on a wider range of climate variables, including weather and climate extremes. The time periods considered throughout this section depend upon the availability of observational products, paleoclimate archives and peer-reviewed studies.

A.1 It is unequivocal that human influence has warmed the atmosphere, ocean and land. Widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred.
{2.2, 2.3, Cross-Chapter Box 2.3, 3.3, 3.4, 3.5, 3.6, 3.8, 5.2, 5.3, 6.4, 7.3, 8.3, 9.2, 9.3, 9.5, 9.6, Cross-Chapter Box 9.1} (Figure SPM.1, Figure SPM.2)

A.1.1 Observed increases in well-mixed greenhouse gas (GHG) concentrations since around 1750 are unequivocally caused by human activities. Since 2011 (measurements reported in AR5), concentrations have continued to increase in the atmosphere, reaching annual averages of 410 parts per million (ppm) for carbon dioxide (CO_2), 1866 parts per billion (ppb) for methane (CH_4), and 332 ppb for nitrous oxide (N_2O) in 2019.[6] Land and ocean have taken up a near-constant proportion (globally about 56% per year) of CO_2 emissions from human activities over the past six decades, with regional differences (*high confidence*).[7]
{2.2, 5.2, 7.3, TS.2.2, Box TS.5}

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[1] Decision IPCC/XLVI-2.

[2] The three Special Reports are: Global Warming of 1.5°C: An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty (SR1.5); Climate Change and Land: An IPCC Special Report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems (SRCCL); IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC).

[3] The assessment covers scientific literature accepted for publication by 31 January 2021.

[4] Each finding is grounded in an evaluation of underlying evidence and agreement. A level of confidence is expressed using five qualifiers: very low, low, medium, high and very high, and typeset in italics, for example, *medium confidence*. The following terms have been used to indicate the assessed likelihood of an outcome or result: virtually certain 99–100% probability; very likely 90–100%; likely 66–100%; about as likely as not 33–66%; unlikely 0–33%; very unlikely 0–10%; and exceptionally unlikely 0–1%. Additional terms (extremely likely 95–100%; more likely than not >50–100%; and extremely unlikely 0–5%) are also used when appropriate. Assessed likelihood is typeset in italics, for example, *very likely*. This is consistent with AR5. In this Report, unless stated otherwise, square brackets [x to y] are used to provide the assessed *very likely* range, or 90% interval.

[5] The Interactive Atlas is available at https://interactive-atlas.ipcc.ch

[6] Other GHG concentrations in 2019 were: perfluorocarbons (PFCs) – 109 parts per trillion (ppt) CF_4 equivalent; sulphur hexafluoride (SF_6) – 10 ppt; nitrogen trifluoride (NF_3) – 2 ppt; hydrofluorocarbons (HFCs) – 237 ppt HFC-134a equivalent; other Montreal Protocol gases (mainly chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs)) – 1032 ppt CFC-12 equivalent). Increases from 2011 are 19 ppm for CO_2, 63 ppb for CH_4 and 8 ppb for N_2O.

[7] Land and ocean are not substantial sinks for other GHGs.

A.1.2 Each of the last four decades has been successively warmer than any decade that preceded it since 1850. Global surface temperature[8] in the first two decades of the 21st century (2001–2020) was 0.99 [0.84 to 1.10] °C higher than 1850–1900.[9] Global surface temperature was 1.09 [0.95 to 1.20] °C higher in 2011–2020 than 1850–1900, with larger increases over land (1.59 [1.34 to 1.83] °C) than over the ocean (0.88 [0.68 to 1.01] °C). The estimated increase in global surface temperature since AR5 is principally due to further warming since 2003–2012 (+0.19 [0.16 to 0.22] °C). Additionally, methodological advances and new datasets contributed approximately 0.1°C to the updated estimate of warming in AR6.[10]
{2.3, Cross-Chapter Box 2.3} (Figure SPM.1)

A.1.3 The *likely* range of total human-caused global surface temperature increase from 1850–1900 to 2010–2019[11] is 0.8°C to 1.3°C, with a best estimate of 1.07°C. It is *likely* that well-mixed GHGs contributed a warming of 1.0°C to 2.0°C, other human drivers (principally aerosols) contributed a cooling of 0.0°C to 0.8°C, natural drivers changed global surface temperature by –0.1°C to +0.1°C, and internal variability changed it by –0.2°C to +0.2°C. It is *very likely* that well-mixed GHGs were the main driver[12] of tropospheric warming since 1979 and *extremely likely* that human-caused stratospheric ozone depletion was the main driver of cooling of the lower stratosphere between 1979 and the mid-1990s.
{3.3, 6.4, 7.3, TS.2.3, Cross-Section Box TS.1} (Figure SPM.2)

A.1.4 Globally averaged precipitation over land has *likely* increased since 1950, with a faster rate of increase since the 1980s (*medium confidence*). It is *likely* that human influence contributed to the pattern of observed precipitation changes since the mid-20th century and *extremely likely* that human influence contributed to the pattern of observed changes in near-surface ocean salinity. Mid-latitude storm tracks have *likely* shifted poleward in both hemispheres since the 1980s, with marked seasonality in trends (*medium confidence*). For the Southern Hemisphere, human influence *very likely* contributed to the poleward shift of the closely related extratropical jet in austral summer.
{2.3, 3.3, 8.3, 9.2, TS.2.3, TS.2.4, Box TS.6}

A.1.5 Human influence is *very likely* the main driver of the global retreat of glaciers since the 1990s and the decrease in Arctic sea ice area between 1979–1988 and 2010–2019 (decreases of about 40% in September and about 10% in March). There has been no significant trend in Antarctic sea ice area from 1979 to 2020 due to regionally opposing trends and large internal variability. Human influence *very likely* contributed to the decrease in Northern Hemisphere spring snow cover since 1950. It is *very likely* that human influence has contributed to the observed surface melting of the Greenland Ice Sheet over the past two decades, but there is only *limited evidence*, with *medium agreement*, of human influence on the Antarctic Ice Sheet mass loss.
{2.3, 3.4, 8.3, 9.3, 9.5, TS.2.5}

A.1.6 It is *virtually certain* that the global upper ocean (0–700 m) has warmed since the 1970s and *extremely likely* that human influence is the main driver. It is *virtually certain* that human-caused CO_2 emissions are the main driver of current global acidification of the surface open ocean. There is *high confidence* that oxygen levels have dropped in many upper ocean regions since the mid-20th century and *medium confidence* that human influence contributed to this drop.
{2.3, 3.5, 3.6, 5.3, 9.2, TS.2.4}

A.1.7 Global mean sea level increased by 0.20 [0.15 to 0.25] m between 1901 and 2018. The average rate of sea level rise was 1.3 [0.6 to 2.1] mm yr^{-1} between 1901 and 1971, increasing to 1.9 [0.8 to 2.9] mm yr^{-1} between 1971 and 2006, and further increasing to 3.7 [3.2 to 4.2] mm yr^{-1} between 2006 and 2018 (*high confidence*). Human influence was *very likely* the main driver of these increases since at least 1971.
{2.3, 3.5, 9.6, Cross-Chapter Box 9.1, Box TS.4}

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[8] The term 'global surface temperature' is used in reference to both global mean surface temperature and global surface air temperature throughout this SPM. Changes in these quantities are assessed with *high confidence* to differ by at most 10% from one another, but conflicting lines of evidence lead to *low confidence* in the sign (direction) of any difference in long-term trend. {Cross-Section Box TS.1}

[9] The period 1850–1900 represents the earliest period of sufficiently globally complete observations to estimate global surface temperature and, consistent with AR5 and SR1.5, is used as an approximation for pre-industrial conditions.

[10] Since AR5, methodological advances and new datasets have provided a more complete spatial representation of changes in surface temperature, including in the Arctic. These and other improvements have also increased the estimate of global surface temperature change by approximately 0.1°C, but this increase does not represent additional physical warming since AR5.

[11] The period distinction with A.1.2 arises because the attribution studies consider this slightly earlier period. The observed warming to 2010–2019 is 1.06 [0.88 to 1.21] °C.

[12] Throughout this SPM, 'main driver' means responsible for more than 50% of the change.

A.1.8 Changes in the land biosphere since 1970 are consistent with global warming: climate zones have shifted poleward in both hemispheres, and the growing season has on average lengthened by up to two days per decade since the 1950s in the Northern Hemisphere extratropics (*high confidence*).
{2.3, TS.2.6}

Human influence has warmed the climate at a rate that is unprecedented in at least the last 2000 years

Changes in global surface temperature relative to 1850–1900

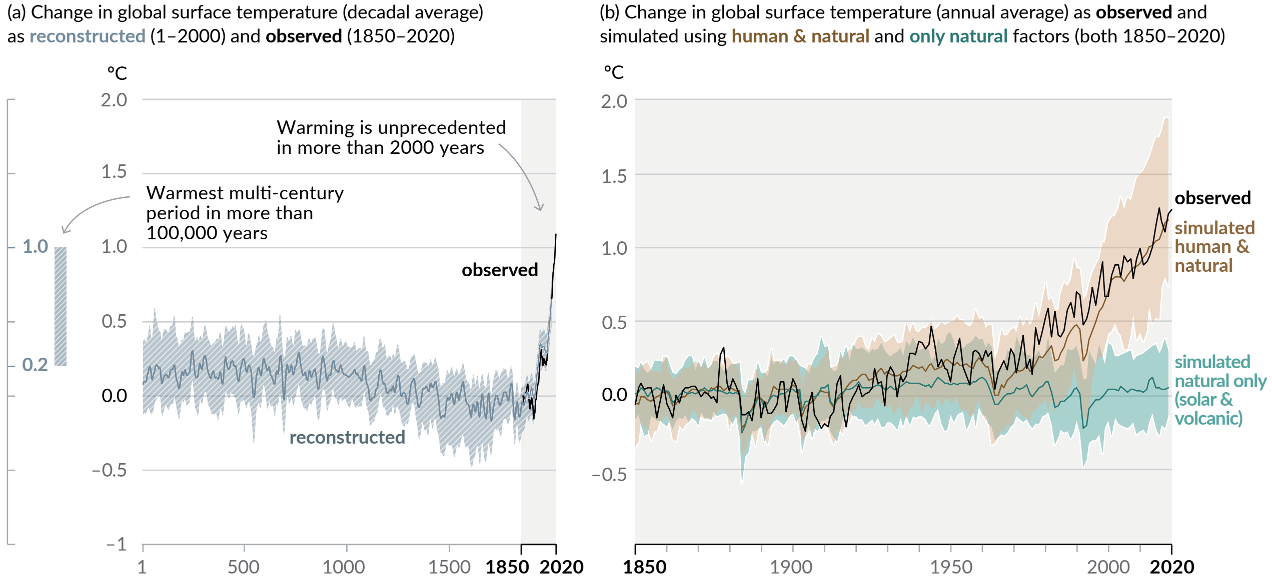

Figure SPM.1 | History of global temperature change and causes of recent warming

Panel (a) Changes in global surface temperature reconstructed from paleoclimate archives (solid grey line, years 1–2000) **and from direct observations** (solid black line, 1850–2020), both relative to 1850–1900 and decadally averaged. The vertical bar on the left shows the estimated temperature (*very likely* range) during the warmest multi-century period in at least the last 100,000 years, which occurred around 6500 years ago during the current interglacial period (Holocene). The Last Interglacial, around 125,000 years ago, is the next most recent candidate for a period of higher temperature. These past warm periods were caused by slow (multi-millennial) orbital variations. The grey shading with white diagonal lines shows the *very likely* ranges for the temperature reconstructions.

Panel (b) Changes in global surface temperature over the past 170 years (black line) relative to 1850–1900 and annually averaged, compared to Coupled Model Intercomparison Project Phase 6 (CMIP6) climate model simulations (see Box SPM.1) of the temperature response to both human and natural drivers (brown) and to only natural drivers (solar and volcanic activity, green). Solid coloured lines show the multi-model average, and coloured shades show the *very likely* range of simulations. (See Figure SPM.2 for the assessed contributions to warming).

{2.3.1; Cross-Chapter Box 2.3; 3.3; TS.2.2; Cross-Section Box TS.1, Figure 1a}

Observed warming is driven by emissions from human activities, with greenhouse gas warming partly masked by aerosol cooling

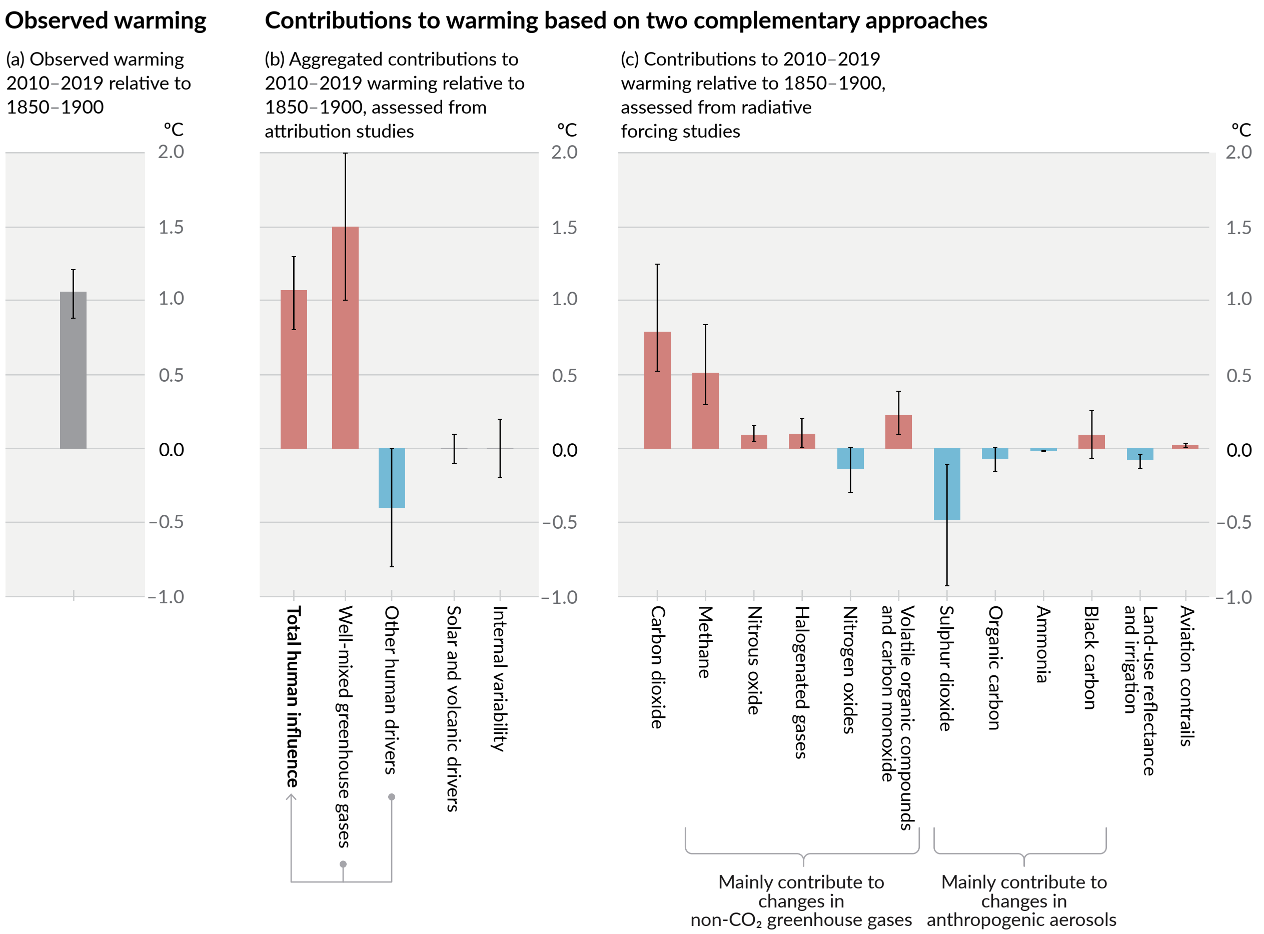

Figure SPM.2 | Assessed contributions to observed warming in 2010–2019 relative to 1850–1900

Panel (a) Observed global warming (increase in global surface temperature). Whiskers show the *very likely* range.

Panel (b) Evidence from attribution studies, which synthesize information from climate models and observations. The panel shows temperature change attributed to: total human influence; changes in well-mixed greenhouse gas concentrations; other human drivers due to aerosols, ozone and land-use change (land-use reflectance); solar and volcanic drivers; and internal climate variability. Whiskers show *likely* ranges.

Panel (c) Evidence from the assessment of radiative forcing and climate sensitivity. The panel shows temperature changes from individual components of human influence: emissions of greenhouse gases, aerosols and their precursors; land-use changes (land-use reflectance and irrigation); and aviation contrails. Whiskers show *very likely* ranges. Estimates account for both direct emissions into the atmosphere and their effect, if any, on other climate drivers. For aerosols, both direct effects (through radiation) and indirect effects (through interactions with clouds) are considered.

{Cross-Chapter Box 2.3, 3.3.1, 6.4.2, 7.3}

A.2 The scale of recent changes across the climate system as a whole – and the present state of many aspects of the climate system – are unprecedented over many centuries to many thousands of years.
{2.2, 2.3, Cross-Chapter Box 2.1, 5.1} (Figure SPM.1)

A.2.1 In 2019, atmospheric CO_2 concentrations were higher than at any time in at least 2 million years (*high confidence*), and concentrations of CH_4 and N_2O were higher than at any time in at least 800,000 years (*very high confidence*). Since 1750, increases in CO_2 (47%) and CH_4 (156%) concentrations far exceed – and increases in N_2O (23%) are similar to – the natural multi-millennial changes between glacial and interglacial periods over at least the past 800,000 years (*very high confidence*).
{2.2, 5.1, TS.2.2}

A.2.2 Global surface temperature has increased faster since 1970 than in any other 50-year period over at least the last 2000 years (*high confidence*). Temperatures during the most recent decade (2011–2020) exceed those of the most recent multi-century warm period, around 6500 years ago[13] [0.2°C to 1°C relative to 1850–1900] (*medium confidence*). Prior to that, the next most recent warm period was about 125,000 years ago, when the multi-century temperature [0.5°C to 1.5°C relative to 1850–1900] overlaps the observations of the most recent decade (*medium confidence*).
{2.3, Cross-Chapter Box 2.1, Cross-Section Box TS.1} (Figure SPM.1)

A.2.3 In 2011–2020, annual average Arctic sea ice area reached its lowest level since at least 1850 (*high confidence*). Late summer Arctic sea ice area was smaller than at any time in at least the past 1000 years (*medium confidence*). The global nature of glacier retreat since the 1950s, with almost all of the world's glaciers retreating synchronously, is unprecedented in at least the last 2000 years (*medium confidence*).
{2.3, TS.2.5}

A.2.4 Global mean sea level has risen faster since 1900 than over any preceding century in at least the last 3000 years (*high confidence*). The global ocean has warmed faster over the past century than since the end of the last deglacial transition (around 11,000 years ago) (*medium confidence*). A long-term increase in surface open ocean pH occurred over the past 50 million years (*high confidence*). However, surface open ocean pH as low as recent decades is unusual in the last 2 million years (*medium confidence*).
{2.3, TS.2.4, Box TS.4}

A.3 Human-induced climate change is already affecting many weather and climate extremes in every region across the globe. Evidence of observed changes in extremes such as heatwaves, heavy precipitation, droughts, and tropical cyclones, and, in particular, their attribution to human influence, has strengthened since AR5.
{2.3, 3.3, 8.2, 8.3, 8.4, 8.5, 8.6, Box 8.1, Box 8.2, Box 9.2, 10.6, 11.2, 11.3, 11.4, 11.6, 11.7, 11.8, 11.9, 12.3} (Figure SPM.3)

A.3.1 It is *virtually certain* that hot extremes (including heatwaves) have become more frequent and more intense across most land regions since the 1950s, while cold extremes (including cold waves) have become less frequent and less severe, with *high confidence* that human-induced climate change is the main driver[14] of these changes. Some recent hot extremes observed over the past decade would have been *extremely unlikely* to occur without human influence on the climate system. Marine heatwaves have approximately doubled in frequency since the 1980s (*high confidence*), and human influence has *very likely* contributed to most of them since at least 2006.
{Box 9.2, 11.2, 11.3, 11.9, TS.2.4, TS.2.6, Box TS.10} (Figure SPM.3)

A.3.2 The frequency and intensity of heavy precipitation events have increased since the 1950s over most land area for which observational data are sufficient for trend analysis (*high confidence*), and human-induced climate change is *likely* the main driver. Human-induced climate change has contributed to increases in agricultural and ecological droughts[15] in some regions due to increased land evapotranspiration[16] (*medium confidence*).
{8.2, 8.3, 11.4, 11.6, 11.9, TS.2.6, Box TS.10} (Figure SPM.3)

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[13] As stated in section B.1, even under the very low emissions scenario SSP1-1.9, temperatures are assessed to remain elevated above those of the most recent decade until at least 2100 and therefore warmer than the century-scale period 6500 years ago.

[14] As indicated in footnote 12, throughout this SPM, 'main driver' means responsible for more than 50% of the change.

[15] Agricultural and ecological drought (depending on the affected biome): a period with abnormal soil moisture deficit, which results from combined shortage of precipitation and excess evapotranspiration, and during the growing season impinges on crop production or ecosystem function in general (see Annex VII: Glossary). Observed changes in meteorological droughts (precipitation deficits) and hydrological droughts (streamflow deficits) are distinct from those in agricultural and ecological droughts and are addressed in the underlying AR6 material (Chapter 11).

[16] The combined processes through which water is transferred to the atmosphere from open water and ice surfaces, bare soils and vegetation that make up the Earth's surface (Glossary).

A.3.3 Decreases in global land monsoon precipitation[17] from the 1950s to the 1980s are partly attributed to human-caused Northern Hemisphere aerosol emissions, but increases since then have resulted from rising GHG concentrations and decadal to multi-decadal internal variability (*medium confidence*). Over South Asia, East Asia and West Africa, increases in monsoon precipitation due to warming from GHG emissions were counteracted by decreases in monsoon precipitation due to cooling from human-caused aerosol emissions over the 20th century (*high confidence*). Increases in West African monsoon precipitation since the 1980s are partly due to the growing influence of GHGs and reductions in the cooling effect of human-caused aerosol emissions over Europe and North America (*medium confidence*).
{2.3, 3.3, 8.2, 8.3, 8.4, 8.5, 8.6, Box 8.1, Box 8.2, 10.6, Box TS.13}

A.3.4 It is *likely* that the global proportion of major (Category 3–5) tropical cyclone occurrence has increased over the last four decades, and it is *very likely* that the latitude where tropical cyclones in the western North Pacific reach their peak intensity has shifted northward; these changes cannot be explained by internal variability alone (*medium confidence*). There is *low confidence* in long-term (multi-decadal to centennial) trends in the frequency of all-category tropical cyclones. Event attribution studies and physical understanding indicate that human-induced climate change increases heavy precipitation associated with tropical cyclones (*high confidence*), but data limitations inhibit clear detection of past trends on the global scale.
{8.2, 11.7, Box TS.10}

A.3.5 Human influence has *likely* increased the chance of compound extreme events[18] since the 1950s. This includes increases in the frequency of concurrent heatwaves and droughts on the global scale (*high confidence*), fire weather in some regions of all inhabited continents (*medium confidence*), and compound flooding in some locations (*medium confidence*).
{11.6, 11.7, 11.8, 12.3, 12.4, TS.2.6, Table TS.5, Box TS.10}

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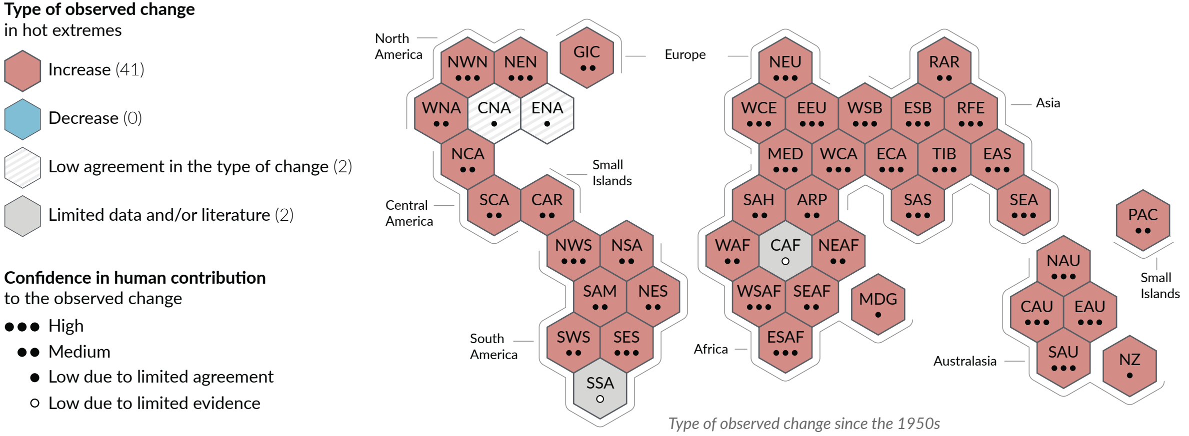
[17] The global monsoon is defined as the area in which the annual range (local summer minus local winter) of precipitation is greater than 2.5 mm day^{-1} (Glossary). Global land monsoon precipitation refers to the mean precipitation over land areas within the global monsoon.

[18] Compound extreme events are the combination of multiple drivers and/or hazards that contribute to societal or environmental risk (Glossary). Examples are concurrent heatwaves and droughts, compound flooding (e.g., a storm surge in combination with extreme rainfall and/or river flow), compound fire weather conditions (i.e., a combination of hot, dry and windy conditions), or concurrent extremes at different locations.

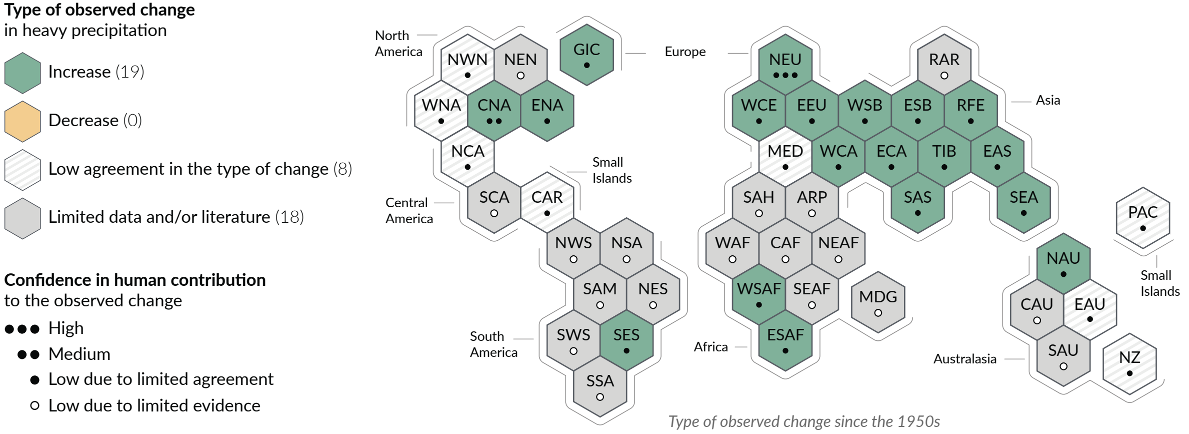
Climate change is already affecting every inhabited region across the globe, with human influence contributing to many observed changes in weather and climate extremes

(a) Synthesis of assessment of observed change in **hot extremes** and confidence in human contribution to the observed changes in the world's regions



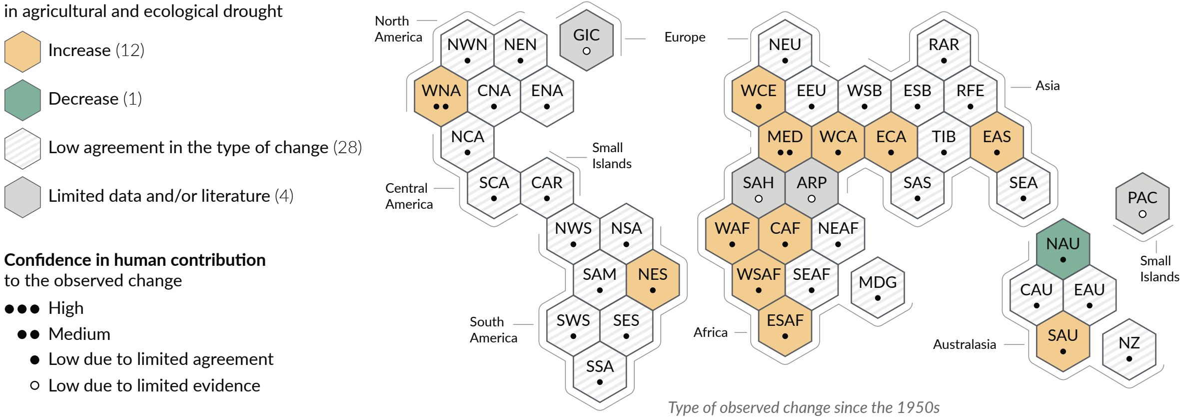
Type of observed change since the 1950s

(b) Synthesis of assessment of observed change in **heavy precipitation** and confidence in human contribution to the observed changes in the world's regions



Type of observed change since the 1950s

(c) Synthesis of assessment of observed change in **agricultural and ecological drought** and confidence in human contribution to the observed changes in the world's regions



Type of observed change since the 1950s

Each hexagon corresponds to one of the IPCC AR6 WGI reference regions

NWN *North-Western North America*

IPCC AR6 WGI reference regions: **North America: NWN** *(North-Western North America)*, **NEN** *(North-Eastern North America)*, **WNA** *(Western North America)*, **CNA** *(Central North America)*, **ENA** *(Eastern North America)*, **Central America: NCA** *(Northern Central America)*, **SCA** *(Southern Central America)*, **CAR** *(Caribbean)*, **South America: NWS** *(North-Western South America)*, **NSA** *(Northern South America)*, **NES** *(North-Eastern South America)*, **SAM** *(South American Monsoon)*, **SWS** *(South-Western South America)*, **SES** *(South-Eastern South America)*, **SSA** *(Southern South America)*, **Europe: GIC** *(Greenland/Iceland)*, **NEU** *(Northern Europe)*, **WCE** *(Western and Central Europe)*, **EEU** *(Eastern Europe)*, **MED** *(Mediterranean)*, **Africa: MED** *(Mediterranean)*, **SAH** *(Sahara)*, **WAF** *(Western Africa)*, **CAF** *(Central Africa)*, **NEAF** *(North Eastern Africa)*, **SEAF** *(South Eastern Africa)*, **WSAF** *(West Southern Africa)*, **ESAF** *(East Southern Africa)*, **MDG** *(Madagascar)*, **Asia: RAR** *(Russian Arctic)*, **WSB** *(West Siberia)*, **ESB** *(East Siberia)*, **RFE** *(Russian Far East)*, **WCA** *(West Central Asia)*, **ECA** *(East Central Asia)*, **TIB** *(Tibetan Plateau)*, **EAS** *(East Asia)*, **ARP** *(Arabian Peninsula)*, **SAS** *(South Asia)*, **SEA** *(South East Asia)*, **Australasia: NAU** *(Northern Australia)*, **CAU** *(Central Australia)*, **EAU** *(Eastern Australia)*, **SAU** *(Southern Australia)*, **NZ** *(New Zealand)*, **Small Islands: CAR** *(Caribbean)*, **PAC** *(Pacific Small Islands)*

Figure SPM.3 | Synthesis of assessed observed and attributable regional changes

The IPCC AR6 WGI inhabited regions are displayed as **hexagons** with identical size in their approximate geographical location (see legend for regional acronyms). All assessments are made for each region as a whole and for the 1950s to the present. Assessments made on different time scales or more local spatial scales might differ from what is shown in the figure. The **colours** in each panel represent the four outcomes of the assessment on observed changes. Striped hexagons (white and light-grey) are used where there is *low agreement* in the type of change for the region as a whole, and grey hexagons are used when there is limited data and/or literature that prevents an assessment of the region as a whole. Other colours indicate at least *medium confidence* in the observed change. The **confidence level** for the human influence on these observed changes is based on assessing trend detection and attribution and event attribution literature, and it is indicated by the number of dots: three dots for *high confidence*, two dots for *medium confidence* and one dot for *low confidence* (single, filled dot: limited agreement; single, empty dot: limited evidence).

Panel (a) For hot extremes, the evidence is mostly drawn from changes in metrics based on daily maximum temperatures; regional studies using other indices (heatwave duration, frequency and intensity) are used in addition. Red hexagons indicate regions where there is at least *medium confidence* in an observed increase in hot extremes.

Panel (b) For heavy precipitation, the evidence is mostly drawn from changes in indices based on one-day or five-day precipitation amounts using global and regional studies. Green hexagons indicate regions where there is at least *medium confidence* in an observed increase in heavy precipitation.

Panel (c) Agricultural and ecological droughts are assessed based on observed and simulated changes in total column soil moisture, complemented by evidence on changes in surface soil moisture, water balance (precipitation minus evapotranspiration) and indices driven by precipitation and atmospheric evaporative demand. Yellow hexagons indicate regions where there is at least *medium confidence* in an observed increase in this type of drought, and green hexagons indicate regions where there is at least *medium confidence* in an observed decrease in agricultural and ecological drought.

For all regions, Table TS.5 shows a broader range of observed changes besides the ones shown in this figure. Note that Southern South America (SSA) is the only region that does not display observed changes in the metrics shown in this figure, but is affected by observed increases in mean temperature, decreases in frost and increases in marine heatwaves.

{11.9, Atlas 1.3.3, Figure Atlas.2, Table TS.5; Box TS.10, Figure 1}

A.4 Improved knowledge of climate processes, paleoclimate evidence and the response of the climate system to increasing radiative forcing gives a best estimate of equilibrium climate sensitivity of 3°C, with a narrower range compared to AR5.

{2.2, 7.3, 7.4, 7.5, Box 7.2, 9.4, 9.5, 9.6, Cross-Chapter Box 9.1}

A.4.1 Human-caused radiative forcing of 2.72 [1.96 to 3.48] W m^{-2} in 2019 relative to 1750 has warmed the climate system. This warming is mainly due to increased GHG concentrations, partly reduced by cooling due to increased aerosol concentrations. The radiative forcing has increased by 0.43 W m^{-2} (19%) relative to AR5, of which 0.34 W m^{-2} is due to the increase in GHG concentrations since 2011. The remainder is due to improved scientific understanding and changes in the assessment of aerosol forcing, which include decreases in concentration and improvement in its calculation (*high confidence*).
{2.2, 7.3, TS.2.2, TS.3.1}

A.4.2 Human-caused net positive radiative forcing causes an accumulation of additional energy (heating) in the climate system, partly reduced by increased energy loss to space in response to surface warming. The observed average rate of heating of the climate system increased from 0.50 [0.32 to 0.69] W m^{-2} for the period 1971–2006[19] to 0.79 [0.52 to 1.06] W m^{-2} for the period 2006–2018[20] (*high confidence*). Ocean warming accounted for 91% of the heating in the climate system, with land warming, ice loss and atmospheric warming accounting for about 5%, 3% and 1%, respectively (*high confidence*).
{7.2, Box 7.2, TS.3.1}

A.4.3 Heating of the climate system has caused global mean sea level rise through ice loss on land and thermal expansion from ocean warming. Thermal expansion explained 50% of sea level rise during 1971–2018, while ice loss from glaciers contributed 22%, ice sheets 20% and changes in land-water storage 8%. The rate of ice-sheet loss increased by a factor of four between 1992–1999 and 2010–2019. Together, ice-sheet and glacier mass loss were the dominant contributors to global mean sea level rise during 2006–2018 (*high confidence*).
{9.4, 9.5, 9.6, Cross-Chapter Box 9.1}

A.4.4 The equilibrium climate sensitivity is an important quantity used to estimate how the climate responds to radiative forcing. Based on multiple lines of evidence,[21] the *very likely* range of equilibrium climate sensitivity is between 2°C (*high confidence*) and 5°C (*medium confidence*). The AR6 assessed best estimate is 3°C with a *likely* range of 2.5°C to 4°C (*high confidence*), compared to 1.5°C to 4.5°C in AR5, which did not provide a best estimate.
{7.4, 7.5, TS.3.2}

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[19] Cumulative energy increase of 282 [177 to 387] ZJ over 1971–2006 (1 ZJ = 10^{21} joules).

[20] Cumulative energy increase of 152 [100 to 205] ZJ over 2006–2018.

[21] Understanding of climate processes, the instrumental record, paleoclimates and model-based emergent constraints (Glossary).

B. Possible Climate Futures

A set of five new illustrative emissions scenarios is considered consistently across this Report to explore the climate response to a broader range of greenhouse gas (GHG), land-use and air pollutant futures than assessed in AR5. This set of scenarios drives climate model projections of changes in the climate system. These projections account for solar activity and background forcing from volcanoes. Results over the 21st century are provided for the near term (2021–2040), mid-term (2041–2060) and long term (2081–2100) relative to 1850–1900, unless otherwise stated.

Box SPM.1 | Scenarios, Climate Models and Projections

Box SPM.1.1: This Report assesses the climate response to five illustrative scenarios that cover the range of possible future development of anthropogenic drivers of climate change found in the literature. They start in 2015, and include scenarios[22] with high and very high GHG emissions (SSP3-7.0 and SSP5-8.5) and CO_2 emissions that roughly double from current levels by 2100 and 2050, respectively, scenarios with intermediate GHG emissions (SSP2-4.5) and CO_2 emissions remaining around current levels until the middle of the century, and scenarios with very low and low GHG emissions and CO_2 emissions declining to net zero around or after 2050, followed by varying levels of net negative CO_2 emissions[23] (SSP1-1.9 and SSP1-2.6), as illustrated in Figure SPM.4. Emissions vary between scenarios depending on socio-economic assumptions, levels of climate change mitigation and, for aerosols and non-methane ozone precursors, air pollution controls. Alternative assumptions may result in similar emissions and climate responses, but the socio-economic assumptions and the feasibility or likelihood of individual scenarios are not part of the assessment.
{1.6, Cross-Chapter Box 1.4, TS.1.3} (Figure SPM.4)

Box SPM.1.2: This Report assesses results from climate models participating in the Coupled Model Intercomparison Project Phase 6 (CMIP6) of the World Climate Research Programme. These models include new and better representations of physical, chemical and biological processes, as well as higher resolution, compared to climate models considered in previous IPCC assessment reports. This has improved the simulation of the recent mean state of most large-scale indicators of climate change and many other aspects across the climate system. Some differences from observations remain, for example in regional precipitation patterns. The CMIP6 historical simulations assessed in this Report have an ensemble mean global surface temperature change within 0.2°C of the observations over most of the historical period, and observed warming is within the *very likely* range of the CMIP6 ensemble. However, some CMIP6 models simulate a warming that is either above or below the assessed *very likely* range of observed warming.
{1.5, Cross-Chapter Box 2.2, 3.3, 3.8, TS.1.2, Cross-Section Box TS.1} (Figure SPM.1b, Figure SPM.2)

Box SPM.1.3: The CMIP6 models considered in this Report have a wider range of climate sensitivity than in CMIP5 models and the AR6 assessed *very likely* range, which is based on multiple lines of evidence. These CMIP6 models also show a higher average climate sensitivity than CMIP5 and the AR6 assessed best estimate. The higher CMIP6 climate sensitivity values compared to CMIP5 can be traced to an amplifying cloud feedback that is larger in CMIP6 by about 20%.
{Box 7.1, 7.3, 7.4, 7.5, TS.3.2}

Box SPM.1.4: For the first time in an IPCC report, assessed future changes in global surface temperature, ocean warming and sea level are constructed by combining multi-model projections with observational constraints based on past simulated warming, as well as the AR6 assessment of climate sensitivity. For other quantities, such robust methods do not yet exist to constrain the projections. Nevertheless, robust projected geographical patterns of many variables can be identified at a given level of global warming, common to all scenarios considered and independent of timing when the global warming level is reached.
{1.6, 4.3, 4.6, Box 4.1, 7.5, 9.2, 9.6, Cross-Chapter Box 11.1, Cross-Section Box TS.1}

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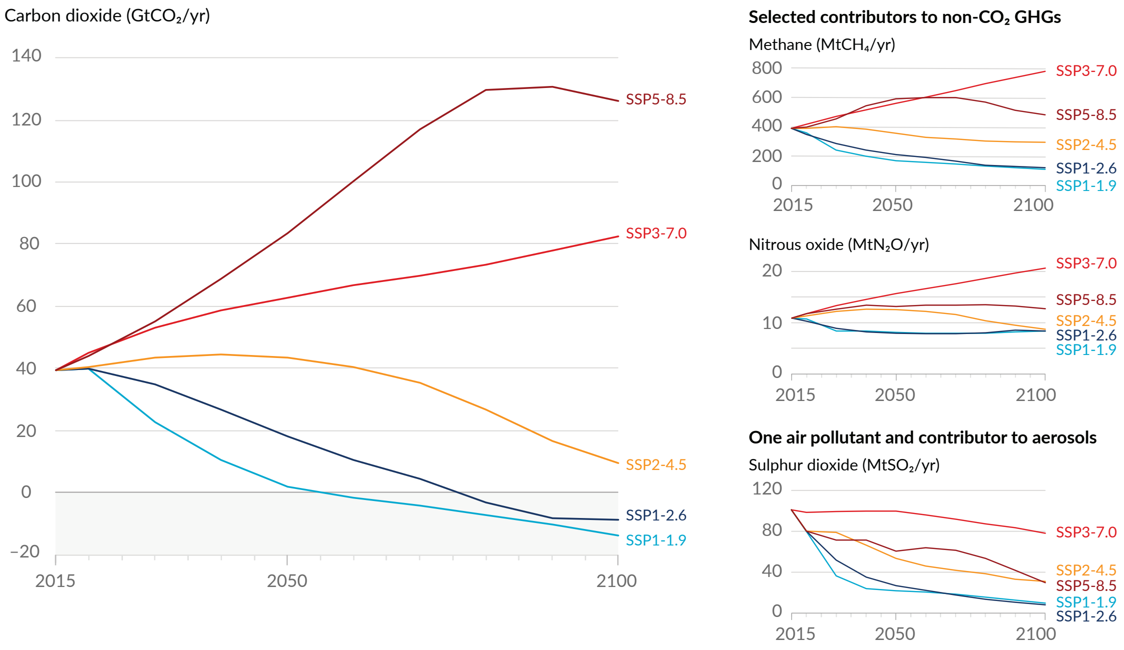
[22] Throughout this Report, the five illustrative scenarios are referred to as SSPx-y, where 'SSPx' refers to the Shared Socio-economic Pathway or 'SSP' describing the socio-economic trends underlying the scenario, and 'y' refers to the approximate level of radiative forcing (in watts per square metre, or W m^{-2}) resulting from the scenario in the year 2100. A detailed comparison to scenarios used in earlier IPCC reports is provided in Section TS.1.3, and Sections 1.6 and 4.6. The SSPs that underlie the specific forcing scenarios used to drive climate models are not assessed by WGI. Rather, the SSPx-y labelling ensures traceability to the underlying literature in which specific forcing pathways are used as input to the climate models. IPCC is neutral with regard to the assumptions underlying the SSPs, which do not cover all possible scenarios. Alternative scenarios may be considered or developed.

[23] Net negative CO_2 emissions are reached when anthropogenic removals of CO_2 exceed anthropogenic emissions (Glossary).

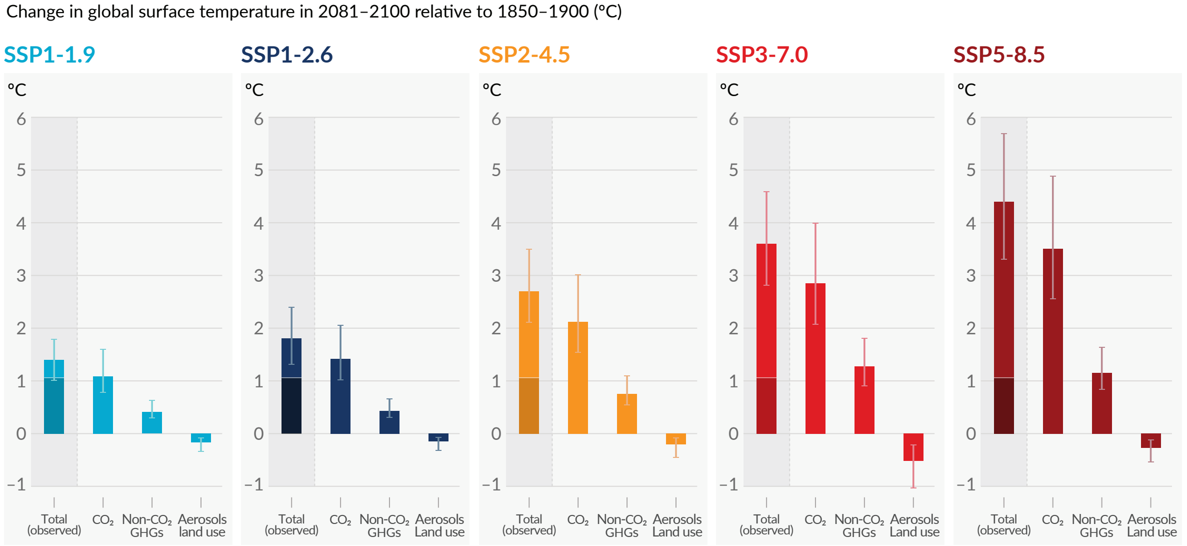
Box SPM.1 (continued)

Future emissions cause future additional warming, with total warming dominated by past and future CO_2 emissions

(a) Future annual emissions of CO_2 (left) and of a subset of key non-CO_2 drivers (right), across five illustrative scenarios



(b) Contribution to global surface temperature increase from different emissions, with a dominant role of CO_2 emissions



Total warming (observed warming to date in darker shade), warming from CO_2, warming from non-CO_2 GHGs and cooling from changes in aerosols and land use

Figure SPM.4 | Future anthropogenic emissions of key drivers of climate change and warming contributions by groups of drivers for the five illustrative scenarios used in this report

The five scenarios are SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5.

Panel (a) Annual anthropogenic (human-caused) emissions over the 2015–2100 period. Shown are emissions trajectories for carbon dioxide (CO_2) from all sectors ($GtCO_2$/yr) (left graph) and for a subset of three key non-CO_2 drivers considered in the scenarios: methane (CH_4, $MtCH_4$/yr, top-right graph); nitrous oxide (N_2O, MtN_2O/yr, middle-right graph); and sulphur dioxide (SO_2, $MtSO_2$/yr, bottom-right graph, contributing to anthropogenic aerosols in panel (b).

Panel (b) Warming contributions by groups of anthropogenic drivers and by scenario are shown as the change in global surface temperature (°C) in 2081–2100 relative to 1850–1900, with indication of the observed warming to date. Bars and whiskers represent median values and the *very likely* range, respectively. Within each scenario bar plot, the bars represent: total global warming (°C; 'total' bar) (see Table SPM.1); warming contributions (°C) from changes in CO_2 ('CO_2' bar) and from non-CO_2 greenhouse gases (GHGs; 'non-CO_2 GHGs' bar: comprising well-mixed greenhouse gases and ozone); and net cooling from other anthropogenic drivers ('aerosols and land use' bar: anthropogenic aerosols, changes in reflectance due to land-use and irrigation changes, and contrails from aviation) (see Figure SPM.2, panel c, for the warming contributions to date for individual drivers). The best estimate for observed warming in 2010–2019 relative to 1850–1900 (see Figure SPM.2, panel a) is indicated in the darker column in the 'total' bar. Warming contributions in panel (b) are calculated as explained in Table SPM.1 for the total bar. For the other bars, the contribution by groups of drivers is calculated with a physical climate emulator of global surface temperature that relies on climate sensitivity and radiative forcing assessments.

{Cross-Chapter Box 1.4; 4.6; Figure 4.35; 6.7; Figures 6.18, 6.22 and 6.24; 7.3; Cross-Chapter Box 7.1; Figure 7.7; Box TS.7; Figures TS.4 and TS.15}

B.1 Global surface temperature will continue to increase until at least mid-century under all emissions scenarios considered. Global warming of 1.5°C and 2°C will be exceeded during the 21st century unless deep reductions in CO_2 and other greenhouse gas emissions occur in the coming decades.
{2.3, Cross-Chapter Box 2.3, Cross-Chapter Box 2.4, 4.3, 4.4, 4.5} (Figure SPM.1, Figure SPM.4, Figure SPM.8, Table SPM.1, Box SPM.1)

B.1.1 Compared to 1850–1900, global surface temperature averaged over 2081–2100 is *very likely* to be higher by 1.0°C to 1.8°C under the very low GHG emissions scenario considered (SSP1-1.9), by 2.1°C to 3.5°C in the intermediate GHG emissions scenario (SSP2-4.5) and by 3.3°C to 5.7°C under the very high GHG emissions scenario (SSP5-8.5).[24] The last time global surface temperature was sustained at or above 2.5°C higher than 1850–1900 was over 3 million years ago (*medium confidence*).
{2.3, Cross-Chapter Box 2.4, 4.3, 4.5, Box TS.2, Box TS.4, Cross-Section Box TS.1} (Table SPM.1)

Table SPM.1 | Changes in global surface temperature, which are assessed based on multiple lines of evidence, for selected 20-year time periods and the five illustrative emissions scenarios considered. Temperature differences relative to the average global surface temperature of the period 1850–1900 are reported in °C. This includes the revised assessment of observed historical warming for the AR5 reference period 1986–2005, which in AR6 is higher by 0.08 [–0.01 to +0.12] °C than in AR5 (see footnote 10). Changes relative to the recent reference period 1995–2014 may be calculated approximately by subtracting 0.85°C, the best estimate of the observed warming from 1850–1900 to 1995–2014.
{Cross-Chapter Box 2.3, 4.3, 4.4, Cross-Section Box TS.1}

	Near term, 2021–2040		Mid-term, 2041–2060		Long term, 2081–2100	
Scenario	Best estimate (°C)	*Very likely* range (°C)	Best estimate (°C)	*Very likely* range (°C)	Best estimate (°C)	*Very likely* range (°C)
SSP1-1.9	1.5	1.2 to 1.7	1.6	1.2 to 2.0	1.4	1.0 to 1.8
SSP1-2.6	1.5	1.2 to 1.8	1.7	1.3 to 2.2	1.8	1.3 to 2.4
SSP2-4.5	1.5	1.2 to 1.8	2.0	1.6 to 2.5	2.7	2.1 to 3.5
SSP3-7.0	1.5	1.2 to 1.8	2.1	1.7 to 2.6	3.6	2.8 to 4.6
SSP5-8.5	1.6	1.3 to 1.9	2.4	1.9 to 3.0	4.4	3.3 to 5.7

B.1.2 Based on the assessment of multiple lines of evidence, global warming of 2°C, relative to 1850–1900, would be exceeded during the 21st century under the high and very high GHG emissions scenarios considered in this report (SSP3-7.0 and SSP5-8.5, respectively). Global warming of 2°C would *extremely likely* be exceeded in the intermediate GHG emissions scenario (SSP2-4.5). Under the very low and low GHG emissions scenarios, global warming of 2°C is *extremely unlikely* to be exceeded (SSP1-1.9) or *unlikely* to be exceeded (SSP1-2.6).[25] Crossing the 2°C global warming level in the mid-term period (2041–2060) is *very likely* to occur under the very high GHG emissions scenario (SSP5-8.5), *likely* to occur under the high GHG emissions scenario (SSP3-7.0), and *more likely than not* to occur in the intermediate GHG emissions scenario (SSP2-4.5).[26]
{4.3, Cross-Section Box TS.1} (Table SPM.1, Figure SPM.4, Box SPM.1)

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[24] Changes in global surface temperature are reported as running 20-year averages, unless stated otherwise.

[25] SSP1-1.9 and SSP1-2.6 are scenarios that start in 2015 and have very low and low GHG emissions, respectively, and CO_2 emissions declining to net zero around or after 2050, followed by varying levels of net negative CO_2 emissions.

[26] Crossing is defined here as having the assessed global surface temperature change, averaged over a 20-year period, exceed a particular global warming level.

B.1.3 Global warming of 1.5°C relative to 1850–1900 would be exceeded during the 21st century under the intermediate, high and very high GHG emissions scenarios considered in this report (SSP2-4.5, SSP3-7.0 and SSP5-8.5, respectively). Under the five illustrative scenarios, in the near term (2021–2040), the 1.5°C global warming level is *very likely* to be exceeded under the very high GHG emissions scenario (SSP5-8.5), *likely* to be exceeded under the intermediate and high GHG emissions scenarios (SSP2-4.5 and SSP3-7.0), *more likely than not* to be exceeded under the low GHG emissions scenario (SSP1-2.6) and *more likely than not* to be reached under the very low GHG emissions scenario (SSP1-1.9).[27] Furthermore, for the very low GHG emissions scenario (SSP1-1.9), it is *more likely than not* that global surface temperature would decline back to below 1.5°C toward the end of the 21st century, with a temporary overshoot of no more than 0.1°C above 1.5°C global warming.
{4.3, Cross-Section Box TS.1} (Table SPM.1, Figure SPM.4)

B.1.4 Global surface temperature in any single year can vary above or below the long-term human-induced trend, due to substantial natural variability.[28] The occurrence of individual years with global surface temperature change above a certain level, for example 1.5°C or 2°C, relative to 1850–1900 does not imply that this global warming level has been reached.[29]
{Cross-Chapter Box 2.3, 4.3, 4.4, Box 4.1, Cross-Section Box TS.1} (Table SPM.1, Figure SPM.1, Figure SPM.8)

B.2 Many changes in the climate system become larger in direct relation to increasing global warming. They include increases in the frequency and intensity of hot extremes, marine heatwaves, heavy precipitation, and, in some regions, agricultural and ecological droughts; an increase in the proportion of intense tropical cyclones; and reductions in Arctic sea ice, snow cover and permafrost.
{4.3, 4.5, 4.6, 7.4, 8.2, 8.4, Box 8.2, 9.3, 9.5, Box 9.2, 11.1, 11.2, 11.3, 11.4, 11.6, 11.7, 11.9, Cross-Chapter Box 11.1, 12.4, 12.5, Cross-Chapter Box 12.1, Atlas.4, Atlas.5, Atlas.6, Atlas.7, Atlas.8, Atlas.9, Atlas.10, Atlas.11} (Figure SPM.5, Figure SPM.6, Figure SPM.8)

B.2.1 It is *virtually certain* that the land surface will continue to warm more than the ocean surface (*likely* 1.4 to 1.7 times more). It is *virtually certain* that the Arctic will continue to warm more than global surface temperature, with *high confidence* above two times the rate of global warming.
{2.3, 4.3, 4.5, 4.6, 7.4, 11.1, 11.3, 11.9, 12.4, 12.5, Cross-Chapter Box 12.1, Atlas.4, Atlas.5, Atlas.6, Atlas.7, Atlas.8, Atlas.9, Atlas.10, Atlas.11, Cross-Section Box TS.1, TS.2.6} (Figure SPM.5)

B.2.2 With every additional increment of global warming, changes in extremes continue to become larger. For example, every additional 0.5°C of global warming causes clearly discernible increases in the intensity and frequency of hot extremes, including heatwaves (*very likely*), and heavy precipitation (*high confidence*), as well as agricultural and ecological droughts[30] in some regions (*high confidence*). Discernible changes in intensity and frequency of meteorological droughts, with more regions showing increases than decreases, are seen in some regions for every additional 0.5°C of global warming (*medium confidence*). Increases in frequency and intensity of hydrological droughts become larger with increasing global warming in some regions (*medium confidence*). There will be an increasing occurrence of some extreme events unprecedented in the observational record with additional global warming, even at 1.5°C of global warming. Projected percentage changes in frequency are larger for rarer events (*high confidence*).
{8.2, 11.2, 11.3, 11.4, 11.6, 11.9, Cross-Chapter Box 11.1, Cross-Chapter Box 12.1, TS.2.6} (Figure SPM.5, Figure SPM.6)

B.2.3 Some mid-latitude and semi-arid regions, and the South American Monsoon region, are projected to see the highest increase in the temperature of the hottest days, at about 1.5 to 2 times the rate of global warming (*high confidence*). The Arctic is projected to experience the highest increase in the temperature of the coldest days, at about three times the rate of global warming (*high confidence*). With additional global warming, the frequency of marine heatwaves will continue to increase (*high confidence*), particularly in the tropical ocean and the Arctic (*medium confidence*).
{Box 9.2, 11.1, 11.3, 11.9, Cross-Chapter Box 11.1, Cross-Chapter Box 12.1, 12.4, TS.2.4, TS.2.6} (Figure SPM.6)

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[27] The AR6 assessment of when a given global warming level is first exceeded benefits from the consideration of the illustrative scenarios, the multiple lines of evidence entering the assessment of future global surface temperature response to radiative forcing, and the improved estimate of historical warming. The AR6 assessment is thus not directly comparable to the SR1.5 SPM, which reported *likely* reaching 1.5°C global warming between 2030 and 2052, from a simple linear extrapolation of warming rates of the recent past. When considering scenarios similar to SSP1-1.9 instead of linear extrapolation, the SR1.5 estimate of when 1.5°C global warming is first exceeded is close to the best estimate reported here.

[28] Natural variability refers to climatic fluctuations that occur without any human influence, that is, internal variability combined with the response to external natural factors such as volcanic eruptions, changes in solar activity and, on longer time scales, orbital effects and plate tectonics (Glossary).

[29] The internal variability in any single year is estimated to be about ±0.25°C (5–95% range, *high confidence*).

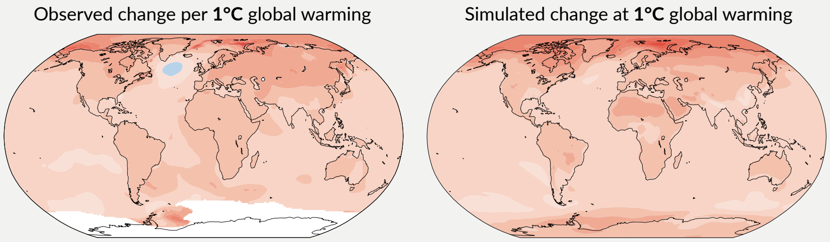
[30] Projected changes in agricultural and ecological droughts are primarily assessed based on total column soil moisture. See footnote 15 for definition and relation to precipitation and evapotranspiration.

B.2.4 It is *very likely* that heavy precipitation events will intensify and become more frequent in most regions with additional global warming. At the global scale, extreme daily precipitation events are projected to intensify by about 7% for each 1°C of global warming (*high confidence*). The proportion of intense tropical cyclones (Category 4–5) and peak wind speeds of the most intense tropical cyclones are projected to increase at the global scale with increasing global warming (*high confidence*). {8.2, 11.4, 11.7, 11.9, Cross-Chapter Box 11.1, Box TS.6, TS.4.3.1} (Figure SPM.5, Figure SPM.6)

B.2.5 Additional warming is projected to further amplify permafrost thawing and loss of seasonal snow cover, of land ice and of Arctic sea ice (*high confidence*). The Arctic is *likely* to be practically sea ice-free in September[31] at least once before 2050 under the five illustrative scenarios considered in this report, with more frequent occurrences for higher warming levels. There is *low confidence* in the projected decrease of Antarctic sea ice.
{4.3, 4.5, 7.4, 8.2, 8.4, Box 8.2, 9.3, 9.5, 12.4, Cross-Chapter Box 12.1, Atlas.5, Atlas.6, Atlas.8, Atlas.9, Atlas.11, TS.2.5} (Figure SPM.8)

With every increment of global warming, changes get larger in regional mean temperature, precipitation and soil moisture

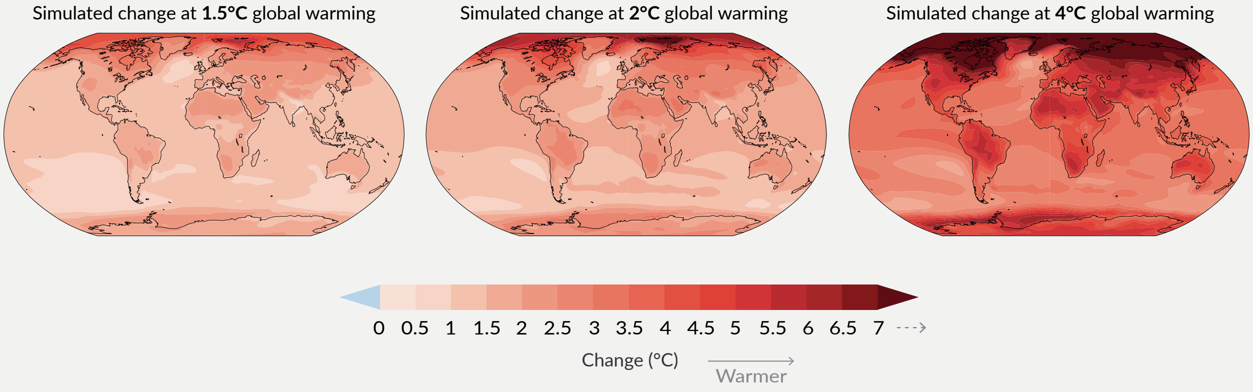
(a) Annual mean temperature change (°C) at 1°C global warming



Warming at 1°C affects all continents and is generally larger over land than over the oceans in both observations and models. Across most regions, observed and simulated patterns are consistent.

(b) Annual mean temperature change (°C) relative to 1850–1900

Across warming levels, land areas warm more than ocean areas, and the Arctic and Antarctica warm more than the tropics.



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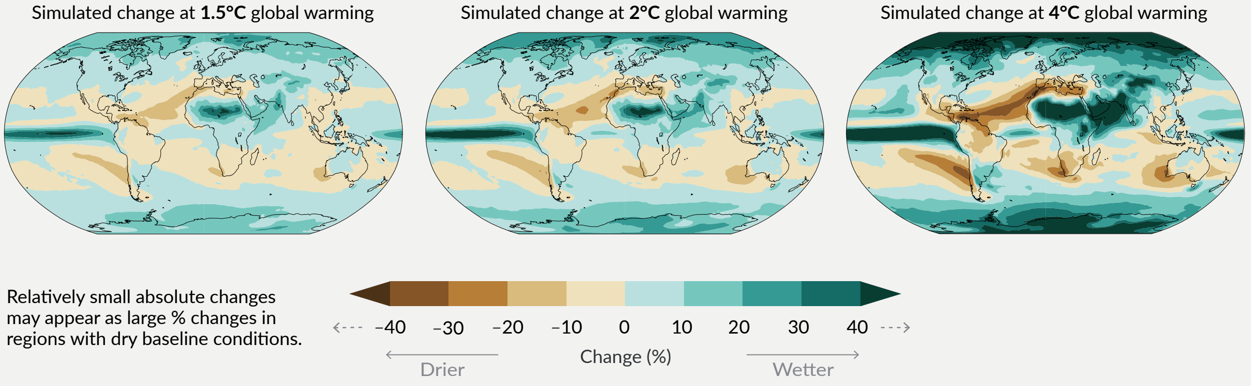
[31] Monthly average sea ice area of less than 1 million km^2, which is about 15% of the average September sea ice area observed in 1979–1988.

(c) Annual mean precipitation change (%) relative to 1850–1900

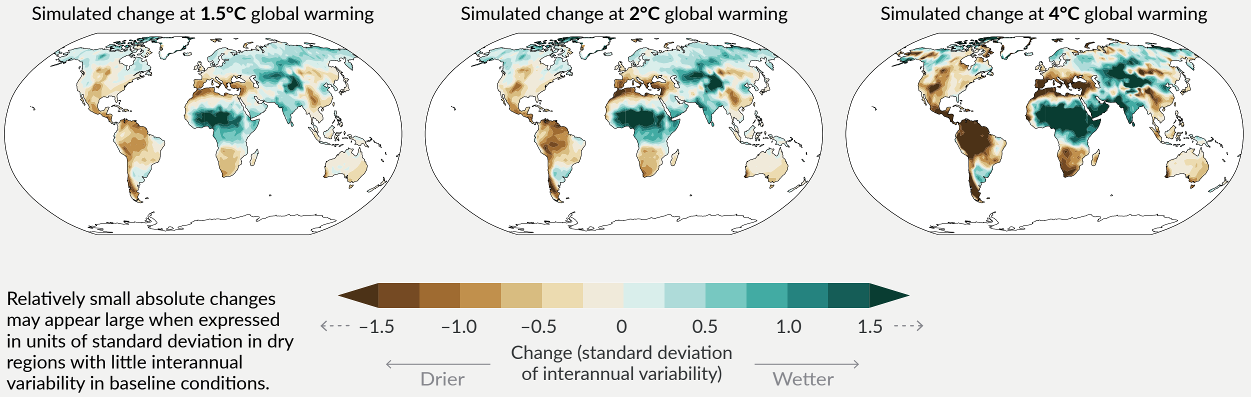
Precipitation is projected to increase over high latitudes, the equatorial Pacific and parts of the monsoon regions, but decrease over parts of the subtropics and in limited areas of the tropics.



Relatively small absolute changes may appear as large % changes in regions with dry baseline conditions.

(d) Annual mean total column soil moisture change (standard deviation)

Across warming levels, changes in soil moisture largely follow changes in precipitation but also show some differences due to the influence of evapotranspiration.



Relatively small absolute changes may appear large when expressed in units of standard deviation in dry regions with little interannual variability in baseline conditions.

Figure SPM.5 | Changes in annual mean surface temperature, precipitation, and soil moisture

Panel (a) Comparison of observed and simulated annual mean surface temperature change. The **left map** shows the observed changes in annual mean surface temperature in the period 1850–2020 per °C of global warming (°C). The local (i.e., grid point) observed annual mean surface temperature changes are linearly regressed against the global surface temperature in the period 1850–2020. Observed temperature data are from Berkeley Earth, the dataset with the largest coverage and highest horizontal resolution. Linear regression is applied to all years for which data at the corresponding grid point is available. The regression method was used to take into account the complete observational time series and thereby reduce the role of internal variability at the grid point level. White indicates areas where time coverage was 100 years or less and thereby too short to calculate a reliable linear regression. The **right map** is based on model simulations and shows change in annual multi-model mean simulated temperatures at a global warming level of 1°C (20-year mean global surface temperature change relative to 1850–1900). The triangles at each end of the colour bar indicate out-of-bound values, that is, values above or below the given limits.

Panel (b) Simulated annual mean temperature change (°C), panel (c) precipitation change (%), and panel (d) total column soil moisture change (standard deviation of interannual variability) at global warming levels of 1.5°C, 2°C and 4°C (20-year mean global surface temperature change relative to 1850–1900). Simulated changes correspond to Coupled Model Intercomparison Project Phase 6 (CMIP6) multi-model mean change (median change for soil moisture) at the corresponding global warming level, that is, the same method as for the right map in panel (a).

In **panel (c)**, high positive percentage changes in dry regions may correspond to small absolute changes. In **panel (d)**, the unit is the standard deviation of interannual variability in soil moisture during 1850–1900. Standard deviation is a widely used metric in characterizing drought severity. A projected reduction in mean soil moisture by one standard deviation corresponds to soil moisture conditions typical of droughts that occurred about once every six years during 1850–1900. In panel (d), large changes in dry regions with little interannual variability in the baseline conditions can correspond to small absolute change. The triangles at each end of the colour bars indicate out-of-bound values, that is, values above or below the given limits. Results from all models reaching the corresponding warming level in any of the five illustrative scenarios (SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5) are averaged. Maps of annual mean temperature and precipitation changes at a global warming level of 3°C are available in Figure 4.31 and Figure 4.32 in Section 4.6. Corresponding maps of panels (b), (c) and (d), including hatching to indicate the level of model agreement at grid-cell level, are found in Figures 4.31, 4.32 and 11.19, respectively; as highlighted in Cross-Chapter Box Atlas.1, grid-cell level hatching is not informative for larger spatial scales (e.g., over AR6 reference regions) where the aggregated signals are less affected by small-scale variability, leading to an increase in robustness.

{Figure 1.14, 4.6.1, Cross-Chapter Box 11.1, Cross-Chapter Box Atlas.1, TS.1.3.2, Figures TS.3 and TS.5}

Projected changes in extremes are larger in frequency and intensity with every additional increment of global warming

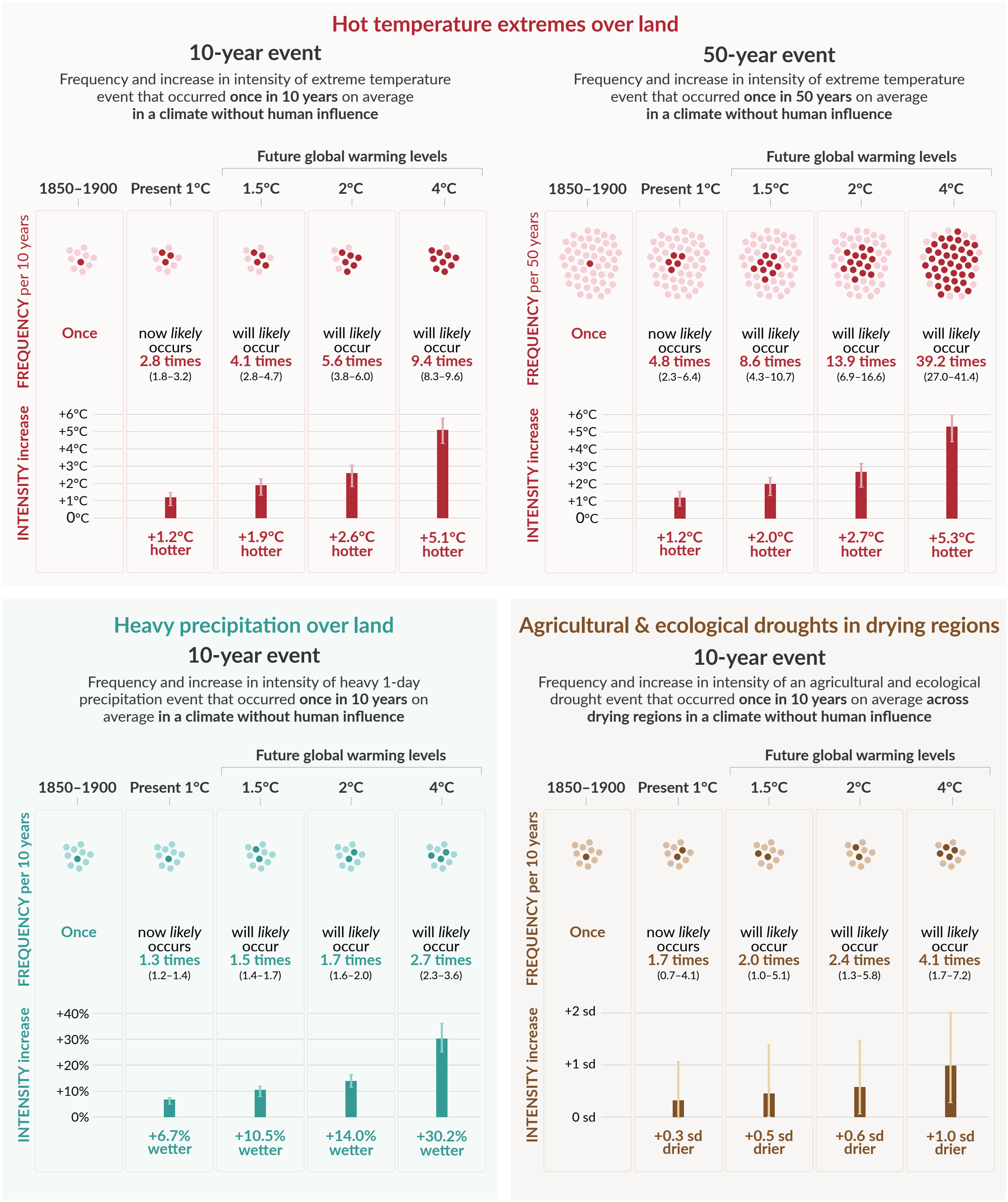


Figure SPM.6 | Projected changes in the intensity and frequency of hot temperature extremes over land, extreme precipitation over land, and agricultural and ecological droughts in drying regions

Projected changes are shown at global warming levels of 1°C, 1.5°C, 2°C, and 4°C and are relative to 1850–1900,[9] representing a climate without human influence. The figure depicts frequencies and increases in intensity of 10- or 50-year extreme events from the base period (1850–1900) under different global warming levels.

Hot temperature extremes are defined as the daily maximum temperatures over land that were exceeded on average once in a decade (10-year event) or once in 50 years (50-year event) during the 1850–1900 reference period. **Extreme precipitation events** are defined as the daily precipitation amount over land that was exceeded on average once in a decade during the 1850–1900 reference period. **Agricultural and ecological drought events** are defined as the annual average of total column soil moisture below the 10th percentile of the 1850–1900 base period. These extremes are defined on model grid box scale. For hot temperature extremes and extreme precipitation, results are shown for the global land. For agricultural and ecological drought, results are shown for drying regions only, which correspond to the AR6 regions in which there is at least *medium confidence* in a projected increase in agricultural and ecological droughts at the 2°C warming level compared to the 1850–1900 base period in the Coupled Model Intercomparison Project Phase 6 (CMIP6). These regions include Western North America, Central North America, Northern Central America, Southern Central America, Caribbean, Northern South America, North-Eastern South America, South American Monsoon, South-Western South America, Southern South America, Western and Central Europe, Mediterranean, West Southern Africa, East Southern Africa, Madagascar, Eastern Australia, and Southern Australia (Caribbean is not included in the calculation of the figure because of the too-small number of full land grid cells). The non-drying regions do not show an overall increase or decrease in drought severity. Projections of changes in agricultural and ecological droughts in the CMIP Phase 5 (CMIP5) multi-model ensemble differ from those in CMIP6 in some regions, including in parts of Africa and Asia. Assessments of projected changes in meteorological and hydrological droughts are provided in Chapter 11.

In the **'frequency' section**, each year is represented by a dot. The dark dots indicate years in which the extreme threshold is exceeded, while light dots are years when the threshold is not exceeded. Values correspond to the medians (in bold) and their respective *likely* ranges based on the 5–95% range of the multi-model ensemble from simulations of CMIP6 under different Shared Socio-economic Pathway scenarios. For consistency, the number of dark dots is based on the rounded-up median. In the **'intensity' section**, medians and their *likely* ranges, also based on the 5–95% range of the multi-model ensemble from simulations of CMIP6, are displayed as dark and light bars, respectively. Changes in the intensity of hot temperature extremes and extreme precipitation are expressed as degree Celsius and percentage. As for agricultural and ecological drought, intensity changes are expressed as fractions of standard deviation of annual soil moisture.

{11.1; 11.3; 11.4; 11.6; 11.9; Figures 11.12, 11.15, 11.6, 11.7, and 11.18}

B.3 Continued global warming is projected to further intensify the global water cycle, including its variability, global monsoon precipitation and the severity of wet and dry events.

{4.3, 4.4, 4.5, 4.6, 8.2, 8.3, 8.4, 8.5, Box 8.2, 11.4, 11.6, 11.9, 12.4, Atlas.3} (Figure SPM.5, Figure SPM.6)

B.3.1 There is strengthened evidence since AR5 that the global water cycle will continue to intensify as global temperatures rise (*high confidence*), with precipitation and surface water flows projected to become more variable over most land regions within seasons (*high confidence*) and from year to year (*medium confidence*). The average annual global land precipitation is projected to increase by 0–5% under the very low GHG emissions scenario (SSP1-1.9), 1.5–8% for the intermediate GHG emissions scenario (SSP2-4.5) and 1–13% under the very high GHG emissions scenario (SSP5-8.5) by 2081–2100 relative to 1995–2014 (*likely* ranges). Precipitation is projected to increase over high latitudes, the equatorial Pacific and parts of the monsoon regions, but decrease over parts of the subtropics and limited areas in the tropics in SSP2-4.5, SSP3-7.0 and SSP5-8.5 (*very likely*). The portion of the global land experiencing detectable increases or decreases in seasonal mean precipitation is projected to increase (*medium confidence*). There is *high confidence* in an earlier onset of spring snowmelt, with higher peak flows at the expense of summer flows in snow-dominated regions globally.

{4.3, 4.5, 4.6, 8.2, 8.4, Atlas.3, TS.2.6, TS.4.3, Box TS.6} (Figure SPM.5)

B.3.2 A warmer climate will intensify very wet and very dry weather and climate events and seasons, with implications for flooding or drought (*high confidence*), but the location and frequency of these events depend on projected changes in regional atmospheric circulation, including monsoons and mid-latitude storm tracks. It is *very likely* that rainfall variability related to the El Niño–Southern Oscillation is projected to be amplified by the second half of the 21st century in the SSP2-4.5, SSP3-7.0 and SSP5-8.5 scenarios.

{4.3, 4.5, 4.6, 8.2, 8.4, 8.5, 11.4, 11.6, 11.9, 12.4, TS.2.6, TS.4.2, Box TS.6} (Figure SPM.5, Figure SPM.6)

B.3.3 Monsoon precipitation is projected to increase in the mid- to long term at the global scale, particularly over South and South East Asia, East Asia and West Africa apart from the far west Sahel (*high confidence*). The monsoon season is projected to have a delayed onset over North and South America and West Africa (*high confidence*) and a delayed retreat over West Africa (*medium confidence*).

{4.4, 4.5, 8.2, 8.3, 8.4, Box 8.2, Box TS.13}

B.3.4 A projected southward shift and intensification of Southern Hemisphere summer mid-latitude storm tracks and associated precipitation is *likely* in the long term under high GHG emissions scenarios (SSP3-7.0, SSP5-8.5), but in the near term the effect of stratospheric ozone recovery counteracts these changes (*high confidence*). There is *medium confidence* in a continued poleward shift of storms and their precipitation in the North Pacific, while there is *low confidence* in projected changes in the North Atlantic storm tracks.

{4.4, 4.5, 8.4, TS.2.3, TS.4.2}

B.4 Under scenarios with increasing CO_2 emissions, the ocean and land carbon sinks are projected to be less effective at slowing the accumulation of CO_2 in the atmosphere.

{4.3, 5.2, 5.4, 5.5, 5.6} (Figure SPM.7)

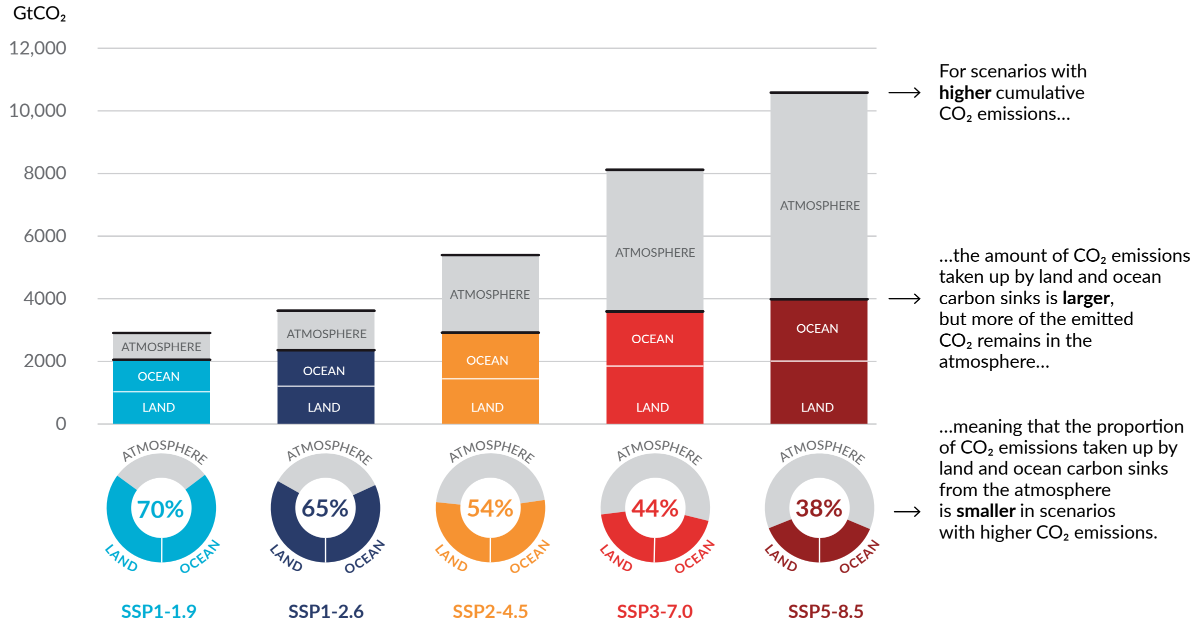
B.4.1 While natural land and ocean carbon sinks are projected to take up, in absolute terms, a progressively larger amount of CO_2 under higher compared to lower CO_2 emissions scenarios, they become less effective, that is, the proportion of emissions taken up by land and ocean decrease with increasing cumulative CO_2 emissions. This is projected to result in a higher proportion of emitted CO_2 remaining in the atmosphere (*high confidence*).
{5.2, 5.4, Box TS.5} (Figure SPM.7)

B.4.2 Based on model projections, under the intermediate GHG emissions scenario that stabilizes atmospheric CO_2 concentrations this century (SSP2-4.5), the rates of CO_2 taken up by the land and ocean are projected to decrease in the second half of the 21st century (*high confidence*). Under the very low and low GHG emissions scenarios (SSP1-1.9, SSP1-2.6), where CO_2 concentrations peak and decline during the 21st century, the land and ocean begin to take up less carbon in response to declining atmospheric CO_2 concentrations (*high confidence*) and turn into a weak net source by 2100 under SSP1-1.9 (*medium confidence*). It is *very unlikely* that the combined global land and ocean sink will turn into a source by 2100 under scenarios without net negative emissions (SSP2-4.5, SSP3-7.0, SSP5-8.5).[32]
{4.3, 5.4, 5.5, 5.6, Box TS.5, TS.3.3}

B.4.3 The magnitude of feedbacks between climate change and the carbon cycle becomes larger but also more uncertain in high CO_2 emissions scenarios (*very high confidence*). However, climate model projections show that the uncertainties in atmospheric CO_2 concentrations by 2100 are dominated by the differences between emissions scenarios (*high confidence*). Additional ecosystem responses to warming not yet fully included in climate models, such as CO_2 and CH_4 fluxes from wetlands, permafrost thaw and wildfires, would further increase concentrations of these gases in the atmosphere (*high confidence*).
{5.4, Box TS.5, TS.3.2}

The proportion of CO_2 emissions taken up by land and ocean carbon sinks is smaller in scenarios with higher cumulative CO_2 emissions

Total cumulative CO_2 emissions **taken up by land and ocean** (colours) and remaining in the atmosphere (grey) under the five illustrative scenarios from 1850 to 2100



For scenarios with **higher** cumulative CO_2 emissions…

…the amount of CO_2 emissions taken up by land and ocean carbon sinks is **larger**, but more of the emitted CO_2 remains in the atmosphere…

…meaning that the proportion of CO_2 emissions taken up by land and ocean carbon sinks from the atmosphere is **smaller** in scenarios with higher CO_2 emissions.

Figure SPM.7 | Cumulative anthropogenic CO_2 emissions taken up by land and ocean sinks by 2100 under the five illustrative scenarios

The cumulative anthropogenic (human-caused) carbon dioxide (CO_2) emissions taken up by the land and ocean sinks under the five illustrative scenarios (SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5) are simulated from 1850 to 2100 by Coupled Model Intercomparison Project Phase 6 (CMIP6) climate models in the concentration-driven simulations. Land and ocean carbon sinks respond to past, current and future emissions; therefore, cumulative sinks from 1850 to 2100 are presented here. During the historical period (1850–2019) the observed land and ocean sink took up 1430 $GtCO_2$ (59% of the emissions).

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[32] These projected adjustments of carbon sinks to stabilization or decline of atmospheric CO_2 are accounted for in calculations of remaining carbon budgets.

The bar chart illustrates the projected amount of cumulative anthropogenic CO_2 emissions ($GtCO_2$) between 1850 and 2100 remaining in the atmosphere (grey part) and taken up by the land and ocean (coloured part) in the year 2100. **The doughnut chart** illustrates the proportion of the cumulative anthropogenic CO_2 emissions taken up by the land and ocean sinks and remaining in the atmosphere in the year 2100. Values in % indicate the proportion of the cumulative anthropogenic CO_2 emissions taken up by the combined land and ocean sinks in the year 2100. The overall anthropogenic carbon emissions are calculated by adding the net global land-use emissions from the CMIP6 scenario database to the other sectoral emissions calculated from climate model runs with prescribed CO_2 concentrations.[33] Land and ocean CO_2 uptake since 1850 is calculated from the net biome productivity on land, corrected for CO_2 losses due to land-use change by adding the land-use change emissions, and net ocean CO_2 flux.

{5.2.1; Table 5.1; 5.4.5; Figure 5.25; Box TS.5; Box TS.5, Figure 1}

B.5 Many changes due to past and future greenhouse gas emissions are irreversible for centuries to millennia, especially changes in the ocean, ice sheets and global sea level.

{2.3, Cross-Chapter Box 2.4, 4.3, 4.5, 4.7, 5.3, 9.2, 9.4, 9.5, 9.6, Box 9.4} (Figure SPM.8)

B.5.1 Past GHG emissions since 1750 have committed the global ocean to future warming (*high confidence*). Over the rest of the 21st century, *likely* ocean warming ranges from 2–4 (SSP1-2.6) to 4–8 times (SSP5-8.5) the 1971–2018 change. Based on multiple lines of evidence, upper ocean stratification (*virtually certain*), ocean acidification (*virtually certain*) and ocean deoxygenation (*high confidence*) will continue to increase in the 21st century, at rates dependent on future emissions. Changes are irreversible on centennial to millennial time scales in global ocean temperature (*very high confidence*), deep-ocean acidification (*very high confidence*) and deoxygenation (*medium confidence*).
{4.3, 4.5, 4.7, 5.3, 9.2, TS.2.4} (Figure SPM.8)

B.5.2 Mountain and polar glaciers are committed to continue melting for decades or centuries (*very high confidence*). Loss of permafrost carbon following permafrost thaw is irreversible at centennial time scales (*high confidence*). Continued ice loss over the 21st century is *virtually certain* for the Greenland Ice Sheet and *likely* for the Antarctic Ice Sheet. There is *high confidence* that total ice loss from the Greenland Ice Sheet will increase with cumulative emissions. There is *limited evidence* for low-likelihood, high-impact outcomes (resulting from ice-sheet instability processes characterized by deep uncertainty and in some cases involving tipping points) that would strongly increase ice loss from the Antarctic Ice Sheet for centuries under high GHG emissions scenarios.[34]
{4.3, 4.7, 5.4, 9.4, 9.5, Box 9.4, Box TS.1, TS.2.5}

B.5.3 It is *virtually certain* that global mean sea level will continue to rise over the 21st century. Relative to 1995–2014, the *likely* global mean sea level rise by 2100 is 0.28–0.55 m under the very low GHG emissions scenario (SSP1-1.9); 0.32–0.62 m under the low GHG emissions scenario (SSP1-2.6); 0.44–0.76 m under the intermediate GHG emissions scenario (SSP2-4.5); and 0.63–1.01 m under the very high GHG emissions scenario (SSP5-8.5); and by 2150 is 0.37–0.86 m under the very low scenario (SSP1-1.9); 0.46–0.99 m under the low scenario (SSP1-2.6); 0.66–1.33 m under the intermediate scenario (SSP2-4.5); and 0.98–1.88 m under the very high scenario (SSP5-8.5) (*medium confidence*).[35] Global mean sea level rise above the *likely* range – approaching 2 m by 2100 and 5 m by 2150 under a very high GHG emissions scenario (SSP5-8.5) (*low confidence*) – cannot be ruled out due to deep uncertainty in ice-sheet processes.
{4.3, 9.6, Box 9.4, Box TS.4} (Figure SPM.8)

B.5.4 In the longer term, sea level is committed to rise for centuries to millennia due to continuing deep-ocean warming and ice-sheet melt and will remain elevated for thousands of years (*high confidence*). Over the next 2000 years, global mean sea level will rise by about 2 to 3 m if warming is limited to 1.5°C, 2 to 6 m if limited to 2°C and 19 to 22 m with 5°C of warming, and it will continue to rise over subsequent millennia (*low confidence*). Projections of multi-millennial global mean sea level rise are consistent with reconstructed levels during past warm climate periods: *likely* 5–10 m higher than today around 125,000 years ago, when global temperatures were *very likely* 0.5°C–1.5°C higher than 1850–1900; and *very likely* 5–25 m higher roughly 3 million years ago, when global temperatures were 2.5°C–4°C higher (*medium confidence*).
{2.3, Cross-Chapter Box 2.4, 9.6, Box TS.2, Box TS.4, Box TS.9}

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[33] The other sectoral emissions are calculated as the residual of the net land and ocean CO_2 uptake and the prescribed atmospheric CO_2 concentration changes in the CMIP6 simulations. These calculated emissions are net emissions and do not separate gross anthropogenic emissions from removals, which are included implicitly.

[34] Low-likelihood, high-impact outcomes are those whose probability of occurrence is low or not well known (as in the context of deep uncertainty) but whose potential impacts on society and ecosystems could be high. A tipping point is a critical threshold beyond which a system reorganizes, often abruptly and/or irreversibly. (Glossary) {1.4, Cross-Chapter Box 1.3, 4.7}

[35] To compare to the 1986–2005 baseline period used in AR5 and SROCC, add 0.03 m to the global mean sea level rise estimates. To compare to the 1900 baseline period used in Figure SPM.8, add 0.16 m.

Human activities affect all the major climate system components, with some responding over decades and others over centuries

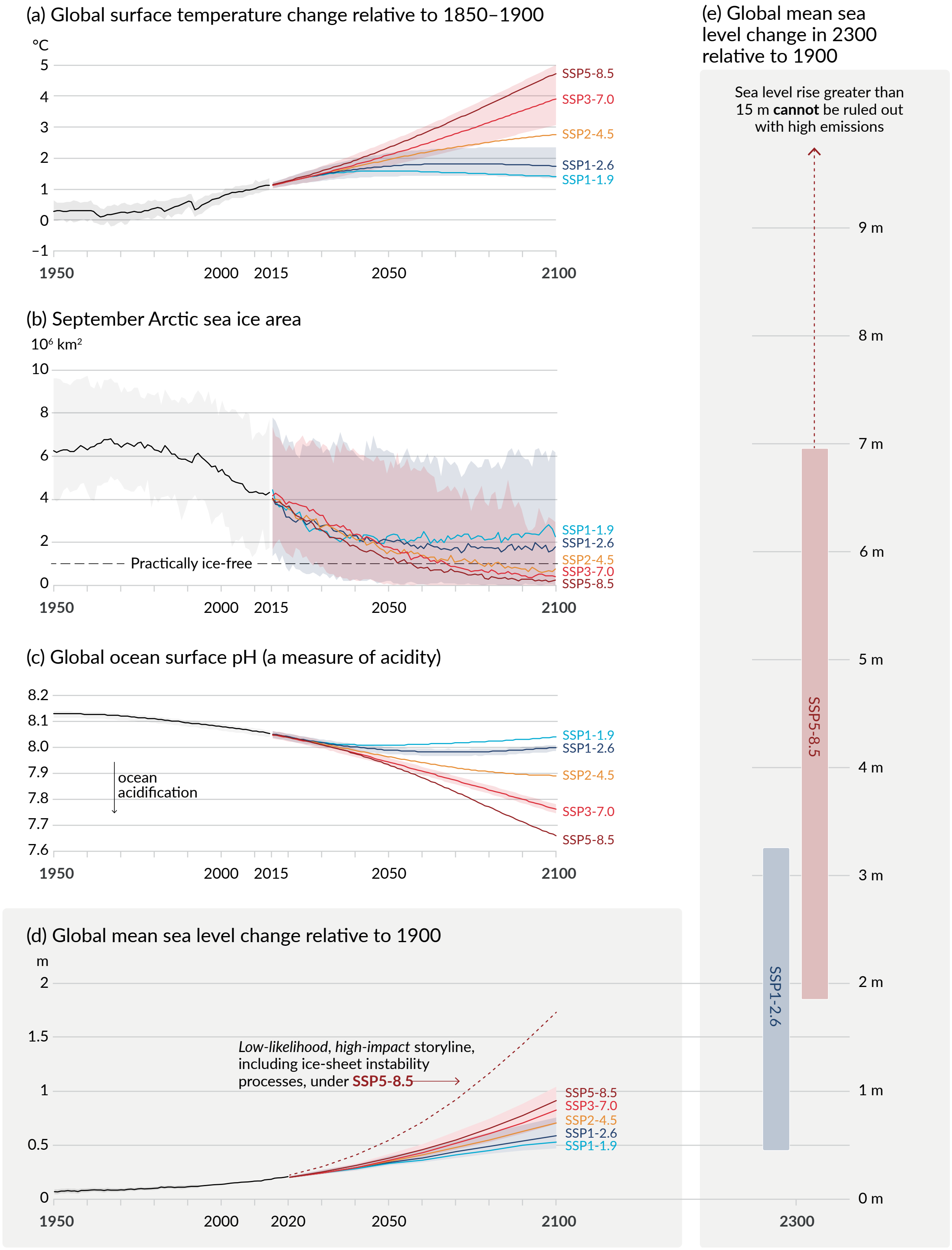

Figure SPM.8 | Selected indicators of global climate change under the five illustrative scenarios used in this Report

The projections for each of the five scenarios are shown in colour. Shades represent uncertainty ranges – more detail is provided for each panel below. The black curves represent the historical simulations (panels a, b, c) or the observations (panel d). Historical values are included in all graphs to provide context for the projected future changes.

Panel (a) Global surface temperature changes in °C relative to 1850–1900. These changes were obtained by combining Coupled Model Intercomparison Project Phase 6 (CMIP6) model simulations with observational constraints based on past simulated warming, as well as an updated assessment of equilibrium climate sensitivity (see Box SPM.1). Changes relative to 1850–1900 based on 20-year averaging periods are calculated by adding 0.85°C (the observed global surface temperature increase from 1850–1900 to 1995–2014) to simulated changes relative to 1995–2014. *Very likely* ranges are shown for SSP1-2.6 and SSP3-7.0.

Panel (b) September Arctic sea ice area in 10^6 km^2 based on CMIP6 model simulations. *Very likely* ranges are shown for SSP1-2.6 and SSP3-7.0. The Arctic is projected to be practically ice-free near mid-century under intermediate and high GHG emissions scenarios.

Panel (c) Global ocean surface pH (a measure of acidity) based on CMIP6 model simulations. *Very likely* ranges are shown for SSP1-2.6 and SSP3-7.0.

Panel (d) Global mean sea level change in metres, relative to 1900. The historical changes are observed (from tide gauges before 1992 and altimeters afterwards), and the future changes are assessed consistently with observational constraints based on emulation of CMIP, ice-sheet, and glacier models. *Likely* ranges are shown for SSP1-2.6 and SSP3-7.0. Only *likely* ranges are assessed for sea level changes due to difficulties in estimating the distribution of deeply uncertain processes. The dashed curve indicates the potential impact of these deeply uncertain processes. It shows the 83rd percentile of SSP5-8.5 projections that include low-likelihood, high-impact ice-sheet processes that cannot be ruled out; because of *low confidence* in projections of these processes, this curve does not constitute part of a *likely* range. Changes relative to 1900 are calculated by adding 0.158 m (observed global mean sea level rise from 1900 to 1995–2014) to simulated and observed changes relative to 1995–2014.

Panel (e) Global mean sea level change at 2300 in metres relative to 1900. Only SSP1-2.6 and SSP5-8.5 are projected at 2300, as simulations that extend beyond 2100 for the other scenarios are too few for robust results. The 17th–83rd percentile ranges are shaded. The dashed arrow illustrates the 83rd percentile of SSP5-8.5 projections that include low-likelihood, high-impact ice-sheet processes that cannot be ruled out.

Panels (b) and (c) are based on single simulations from each model, and so include a component of internal variability. Panels (a), (d) and (e) are based on long-term averages, and hence the contributions from internal variability are small.

{4.3; Figures 4.2, 4.8, and 4.11; 9.6; Figure 9.27; Figures TS.8 and TS.11; Box TS.4, Figure 1}

C. Climate Information for Risk Assessment and Regional Adaptation

Physical climate information addresses how the climate system responds to the interplay between human influence, natural drivers and internal variability. Knowledge of the climate response and the range of possible outcomes, including low-likelihood, high impact outcomes, informs climate services, the assessment of climate-related risks, and adaptation planning. Physical climate information at global, regional and local scales is developed from multiple lines of evidence, including observational products, climate model outputs and tailored diagnostics.

C.1 Natural drivers and internal variability will modulate human-caused changes, especially at regional scales and in the near term, with little effect on centennial global warming. These modulations are important to consider in planning for the full range of possible changes.
{1.4, 2.2, 3.3, Cross-Chapter Box 3.1, 4.4, 4.6, Cross-Chapter Box 4.1, Box 7.2, 8.3, 8.5, 9.2, 10.3, 10.4, 10.6, 11.3, 12.5, Atlas.4, Atlas.5, Atlas.8, Atlas.9, Atlas.10, Atlas.11, Cross-Chapter Box Atlas.2}

C.1.1 The historical global surface temperature record highlights that decadal variability has both enhanced and masked underlying human-caused long-term changes, and this variability will continue into the future (*very high confidence*). For example, internal decadal variability and variations in solar and volcanic drivers partially masked human-caused surface global warming during 1998–2012, with pronounced regional and seasonal signatures (*high confidence*). Nonetheless, the heating of the climate system continued during this period, as reflected in both the continued warming of the global ocean (*very high confidence*) and in the continued rise of hot extremes over land (*medium confidence*).
{1.4, 3.3, Cross-Chapter Box 3.1, 4.4, Box 7.2, 9.2, 11.3, Cross-Section Box TS.1} (Figure SPM.1)

C.1.2 Projected human-caused changes in mean climate and climatic impact-drivers (CIDs),[36] including extremes, will be either amplified or attenuated by internal variability (*high confidence*).[37] Near-term cooling at any particular location with respect to present climate could occur and would be consistent with the global surface temperature increase due to human influence (*high confidence*).
{1.4, 4.4, 4.6, 10.4, 11.3, 12.5, Atlas.5, Atlas.10, Atlas.11, TS.4.2}

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[36] Climatic impact-drivers (CIDs) are physical climate system conditions (e.g., means, events, extremes) that affect an element of society or ecosystems. Depending on system tolerance, CIDs and their changes can be detrimental, beneficial, neutral, or a mixture of each across interacting system elements and regions (Glossary). CID types include heat and cold, wet and dry, wind, snow and ice, coastal and open ocean.

[37] The main internal variability phenomena include El Niño–Southern Oscillation, Pacific Decadal Variability and Atlantic Multi-decadal Variability through their regional influence.

C.1.3 Internal variability has largely been responsible for the amplification and attenuation of the observed human-caused decadal-to-multi-decadal mean precipitation changes in many land regions (*high confidence*). At global and regional scales, near-term changes in monsoons will be dominated by the effects of internal variability (*medium confidence*). In addition to the influence of internal variability, near-term projected changes in precipitation at global and regional scales are uncertain because of model uncertainty and uncertainty in forcings from natural and anthropogenic aerosols (*medium confidence*).
{1.4, 4.4, 8.3, 8.5, 10.3, 10.4, 10.5, 10.6, Atlas.4, Atlas.8, Atlas.9, Atlas.10, Atlas.11, Cross-Chapter Box Atlas.2, TS.4.2, Box TS.6, Box TS.13}

C.1.4 Based on paleoclimate and historical evidence, it is *likely* that at least one large explosive volcanic eruption would occur during the 21st century.[38] Such an eruption would reduce global surface temperature and precipitation, especially over land, for one to three years, alter the global monsoon circulation, modify extreme precipitation and change many CIDs (*medium confidence*). If such an eruption occurs, this would therefore temporarily and partially mask human-caused climate change.
{2.2, 4.4, Cross-Chapter Box 4.1, 8.5, TS.2.1}

C.2 With further global warming, every region is projected to increasingly experience concurrent and multiple changes in climatic impact-drivers. Changes in several climatic impact-drivers would be more widespread at 2°C compared to 1.5°C global warming and even more widespread and/or pronounced for higher warming levels.
{8.2, 9.3, 9.5, 9.6, Box 10.3, 11.3, 11.4, 11.5, 11.6, 11.7, 11.9, Box 11.3, Box 11.4, Cross-Chapter Box 11.1, 12.2, 12.3, 12.4, 12.5, Cross-Chapter Box 12.1, Atlas.4, Atlas.5, Atlas.6, Atlas.7, Atlas.8, Atlas.9, Atlas.10, Atlas.11} (Table SPM.1, Figure SPM.9)

C.2.1 All regions[39] are projected to experience further increases in hot climatic impact-drivers (CIDs) and decreases in cold CIDs (*high confidence*). Further decreases are projected in permafrost; snow, glaciers and ice sheets; and lake and Arctic sea ice (*medium* to *high confidence*).[40] These changes would be larger at 2°C global warming or above than at 1.5°C (*high confidence*). For example, extreme heat thresholds relevant to agriculture and health are projected to be exceeded more frequently at higher global warming levels (*high confidence*).
{9.3, 9.5, 11.3, 11.9, Cross-Chapter Box 11.1, 12.3, 12.4, 12.5, Cross-Chapter Box 12.1, Atlas.4, Atlas.5, Atlas.6, Atlas.7, Atlas.8, Atlas.9, Atlas.10, Atlas.11, TS.4.3} (Table SPM.1, Figure SPM.9)

C.2.2 At 1.5°C global warming, heavy precipitation and associated flooding are projected to intensify and be more frequent in most regions in Africa and Asia (*high confidence*), North America (*medium* to *high confidence*)[40] and Europe (*medium confidence*). Also, more frequent and/or severe agricultural and ecological droughts are projected in a few regions in all inhabited continents except Asia compared to 1850–1900 (*medium confidence*); increases in meteorological droughts are also projected in a few regions (*medium confidence*). A small number of regions are projected to experience increases or decreases in mean precipitation (*medium confidence*).
{11.4, 11.5, 11.6, 11.9, Atlas.4, Atlas.5, Atlas.7, Atlas.8, Atlas.9, Atlas.10, Atlas.11, TS.4.3} (Table SPM.1)

C.2.3 At 2°C global warming and above, the level of confidence in and the magnitude of the change in droughts and heavy and mean precipitation increase compared to those at 1.5°C. Heavy precipitation and associated flooding events are projected to become more intense and frequent in the Pacific Islands and across many regions of North America and Europe (*medium* to *high confidence*).[40] These changes are also seen in some regions in Australasia and Central and South America (*medium confidence*). Several regions in Africa, South America and Europe are projected to experience an increase in frequency and/or severity of agricultural and ecological droughts with *medium* to *high confidence*;[40] increases are also projected in Australasia, Central and North America, and the Caribbean with *medium confidence*. A small number of regions in Africa, Australasia, Europe and North America are also projected to be affected by increases in hydrological droughts, and several regions are projected to be affected by increases or decreases in meteorological droughts, with more regions displaying an increase (*medium confidence*). Mean precipitation is projected to increase in all polar, northern European and northern North American regions, most Asian regions and two regions of South America (*high confidence*).
{11.4, 11.6, 11.9, Cross-Chapter Box 11.1, 12.4, 12.5, Cross-Chapter Box 12.1, Atlas.5, Atlas.7, Atlas.8, Atlas.9, Atlas.11, TS.4.3} (Table SPM.1, Figure SPM.5, Figure SPM.6, Figure SPM.9)

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[38] Based on 2500 year reconstructions, eruptions more negative than –1 W m^{-2} occur on average twice per century.

[39] Regions here refer to the AR6 WGI reference regions used in this Report to summarize information in sub-continental and oceanic regions. Changes are compared to averages over the last 20–40 years unless otherwise specified. {1.4, 12.4, Atlas.1}.

[40] The specific level of confidence or likelihood depends on the region considered. Details can be found in the Technical Summary and the underlying Report.

C.2.4 More CIDs across more regions are projected to change at 2°C and above compared to 1.5°C global warming (*high confidence*). Region-specific changes include intensification of tropical cyclones and/or extratropical storms (*medium confidence*), increases in river floods (*medium* to *high confidence*),[40] reductions in mean precipitation and increases in aridity (*medium* to *high confidence*),[40] and increases in fire weather (*medium* to *high confidence*).[40] There is *low confidence* in most regions in potential future changes in other CIDs, such as hail, ice storms, severe storms, dust storms, heavy snowfall and landslides.
{11.7, 11.9, Cross-Chapter Box 11.1, 12.4, 12.5, Cross-Chapter Box 12.1, Atlas.4, Atlas.6, Atlas.7, Atlas.8, Atlas.10, TS.4.3.1, TS.4.3.2, TS.5} (Table SPM.1, Figure SPM.9)

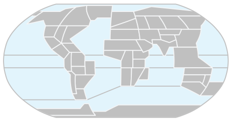
C.2.5 It is *very likely* to *virtually certain*[40] that regional mean relative sea level rise will continue throughout the 21st century, except in a few regions with substantial geologic land uplift rates. Approximately two-thirds of the global coastline has a projected regional relative sea level rise within ±20% of the global mean increase (*medium confidence*). Due to relative sea level rise, extreme sea level events that occurred once per century in the recent past are projected to occur at least annually at more than half of all tide gauge locations by 2100 (*high confidence*). Relative sea level rise contributes to increases in the frequency and severity of coastal flooding in low-lying areas and to coastal erosion along most sandy coasts (*high confidence*).
{9.6, 12.4, 12.5, Cross-Chapter Box 12.1, Box TS.4, TS.4.3} (Figure SPM.9)

C.2.6 Cities intensify human-induced warming locally, and further urbanization together with more frequent hot extremes will increase the severity of heatwaves (*very high confidence*). Urbanization also increases mean and heavy precipitation over and/or downwind of cities (*medium confidence*) and resulting runoff intensity (*high confidence*). In coastal cities, the combination of more frequent extreme sea level events (due to sea level rise and storm surge) and extreme rainfall/riverflow events will make flooding more probable (*high confidence*).
{8.2, Box 10.3, 11.3, 12.4, Box TS.14}

C.2.7 Many regions are projected to experience an increase in the probability of compound events with higher global warming (*high confidence*). In particular, concurrent heatwaves and droughts are *likely* to become more frequent. Concurrent extremes at multiple locations, including in crop-producing areas, become more frequent at 2°C and above compared to 1.5°C global warming (*high confidence*).
{11.8, Box 11.3, Box 11.4, 12.3, 12.4, Cross-Chapter Box 12.1, TS.4.3} (Table SPM.1)

Multiple climatic impact-drivers are projected to change in all regions of the world

Climatic impact-drivers (CIDs) are physical climate system conditions (e.g., means, events, extremes) that affect an element of society or ecosystems. Depending on system tolerance, CIDs and their changes can be detrimental, beneficial, neutral, or a mixture of each across interacting system elements and regions. The CIDs are grouped into seven types, which are summarized under the icons in the figure. All regions are projected to experience changes in at least 5 CIDs. Almost all (96%) are projected to experience changes in at least 10 CIDs and half in at least 15 CIDs. For many CID changes, there is wide geographical variation, and so each region is projected to experience a specific set of CID changes. Each bar in the chart represents a specific geographical set of changes that can be explored in the WGI Interactive Atlas.



interactive-atlas.ipcc.ch

Number of land & coastal regions (a) and **open-ocean regions** (b) where each **climatic impact-driver** (CID) is projected to **increase** or **decrease** with ***high** confidence* (dark shade) or ***medium** confidence* (light shade)

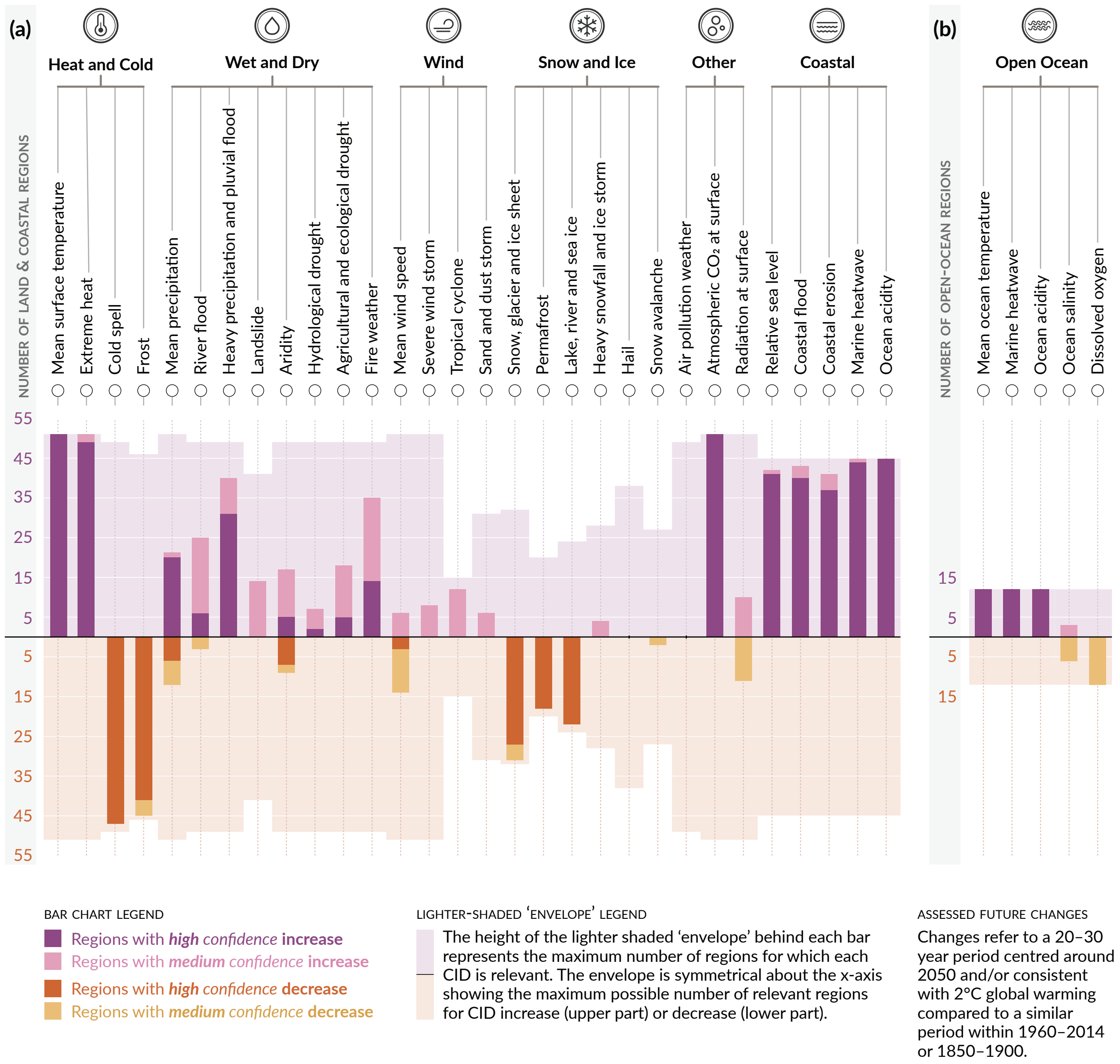


Figure SPM.9 | Synthesis of the number of AR6 WGI reference regions where climatic impact-drivers are projected to change

A total of 35 climatic impact-drivers (CIDs) grouped into seven types are shown: heat and cold; wet and dry; wind; snow and ice; coastal; open ocean; and other. For each CID, the bar in the graph below displays the number of AR6 WGI reference regions where it is projected to change. The **colours** represent the direction of change and the level of confidence in the change: purple indicates an increase while brown indicates a decrease; darker and lighter shades refer to *high* and *medium confidence*, respectively. Lighter background colours represent the maximum number of regions for which each CID is broadly relevant.

Panel (a) shows the 30 CIDs relevant to the **land and coastal regions**, while **panel (b)** shows the five CIDs relevant to the **open-ocean regions**. Marine heatwaves and ocean acidity are assessed for coastal ocean regions in panel (a) and for open-ocean regions in panel (b). Changes refer to a 20–30-year period centred around 2050 and/or consistent with 2°C global warming compared to a similar period within 1960–2014, except for hydrological drought and agricultural and ecological drought, which is compared to 1850–1900. Definitions of the regions are provided in Sections 12.4 and Atlas.1 and the Interactive Atlas (see https://interactive-atlas.ipcc.ch/).

{11.9, 12.2, 12.4, Atlas.1, Table TS.5, Figures TS.22 and TS.25} (Table SPM.1)

C.3 Low-likelihood outcomes, such as ice-sheet collapse, abrupt ocean circulation changes, some compound extreme events, and warming substantially larger than the assessed *very likely* range of future warming, cannot be ruled out and are part of risk assessment.
{1.4, Cross-Chapter Box 1.3, 4.3, 4.4, 4.8, Cross-Chapter Box 4.1, 8.6, 9.2, Box 9.4, 11.8, Box 11.2, Cross-Chapter Box 12.1} (Table SPM.1)

C.3.1 If global warming exceeds the assessed *very likely* range for a given GHG emissions scenario, including low GHG emissions scenarios, global and regional changes in many aspects of the climate system, such as regional precipitation and other CIDs, would also exceed their assessed *very likely* ranges (*high confidence*). Such low-likelihood, high-warming outcomes are associated with potentially very large impacts, such as through more intense and more frequent heatwaves and heavy precipitation, and high risks for human and ecological systems, particularly for high GHG emissions scenarios.
{Cross-Chapter Box 1.3, 4.3, 4.4, 4.8, Box 9.4, Box 11.2, Cross-Chapter Box 12.1, TS.1.4, Box TS.3, Box TS.4} (Table SPM.1)

C.3.2 Low-likelihood, high-impact outcomes[34] could occur at global and regional scales even for global warming within the *very likely* range for a given GHG emissions scenario. The probability of low-likelihood, high-impact outcomes increases with higher global warming levels (*high confidence*). Abrupt responses and tipping points of the climate system, such as strongly increased Antarctic ice-sheet melt and forest dieback, cannot be ruled out (*high confidence*).
{1.4, 4.3, 4.4, 4.8, 5.4, 8.6, Box 9.4, Cross-Chapter Box 12.1, TS.1.4, TS.2.5, Box TS.3, Box TS.4, Box TS.9} (Table SPM.1)

C.3.3 If global warming increases, some compound extreme events[18] with low likelihood in past and current climate will become more frequent, and there will be a higher likelihood that events with increased intensities, durations and/or spatial extents unprecedented in the observational record will occur (*high confidence*).
{11.8, Box 11.2, Cross-Chapter Box 12.1, Box TS.3, Box TS.9}

C.3.4 The Atlantic Meridional Overturning Circulation is *very likely* to weaken over the 21st century for all emissions scenarios. While there is *high confidence* in the 21st century decline, there is only *low confidence* in the magnitude of the trend. There is *medium confidence* that there will not be an abrupt collapse before 2100. If such a collapse were to occur, it would *very likely* cause abrupt shifts in regional weather patterns and water cycle, such as a southward shift in the tropical rain belt, weakening of the African and Asian monsoons and strengthening of Southern Hemisphere monsoons, and drying in Europe.
{4.3, 8.6, 9.2, TS2.4, Box TS.3}

C.3.5 Unpredictable and rare natural events not related to human influence on climate may lead to low-likelihood, high-impact outcomes. For example, a sequence of large explosive volcanic eruptions within decades has occurred in the past, causing substantial global and regional climate perturbations over several decades. Such events cannot be ruled out in the future, but due to their inherent unpredictability they are not included in the illustrative set of scenarios referred to in this Report
{2.2, Cross-Chapter Box 4.1, Box TS.3} (Box SPM.1)

D. Limiting Future Climate Change

Since AR5, estimates of remaining carbon budgets have been improved by a new methodology first presented in SR1.5, updated evidence, and the integration of results from multiple lines of evidence. A comprehensive range of possible future air pollution controls in scenarios is used to consistently assess the effects of various assumptions on projections of climate and air pollution. A novel development is the ability to ascertain when climate responses to emissions reductions would become discernible above natural climate variability, including internal variability and responses to natural drivers.

D.1 From a physical science perspective, limiting human-induced global warming to a specific level requires limiting cumulative CO_2 emissions, reaching at least net zero CO_2 emissions, along with strong reductions in other greenhouse gas emissions. Strong, rapid and sustained reductions in CH_4 emissions would also limit the warming effect resulting from declining aerosol pollution and would improve air quality.
{3.3, 4.6, 5.1, 5.2, 5.4, 5.5, 5.6, Box 5.2, Cross-Chapter Box 5.1, 6.7, 7.6, 9.6} (Figure SPM.10, Table SPM.2)

D.1.1 This Report reaffirms with *high confidence* the AR5 finding that there is a near-linear relationship between cumulative anthropogenic CO_2 emissions and the global warming they cause. Each 1000 $GtCO_2$ of cumulative CO_2 emissions is assessed to *likely* cause a 0.27°C to 0.63°C increase in global surface temperature with a best estimate of 0.45°C.[41] This is a narrower range compared to AR5 and SR1.5. This quantity is referred to as the transient climate response to cumulative CO_2 emissions (TCRE). This relationship implies that reaching net zero anthropogenic CO_2 emissions[42] is a requirement to stabilize human-induced global temperature increase at any level, but that limiting global temperature increase to a specific level would imply limiting cumulative CO_2 emissions to within a carbon budget.[43] {5.4, 5.5, TS.1.3, TS.3.3, Box TS.5} (Figure SPM.10)

Every tonne of CO_2 emissions adds to global warming

Global surface temperature increase since 1850–1900 (°C) as a function of cumulative CO_2 emissions ($GtCO_2$)

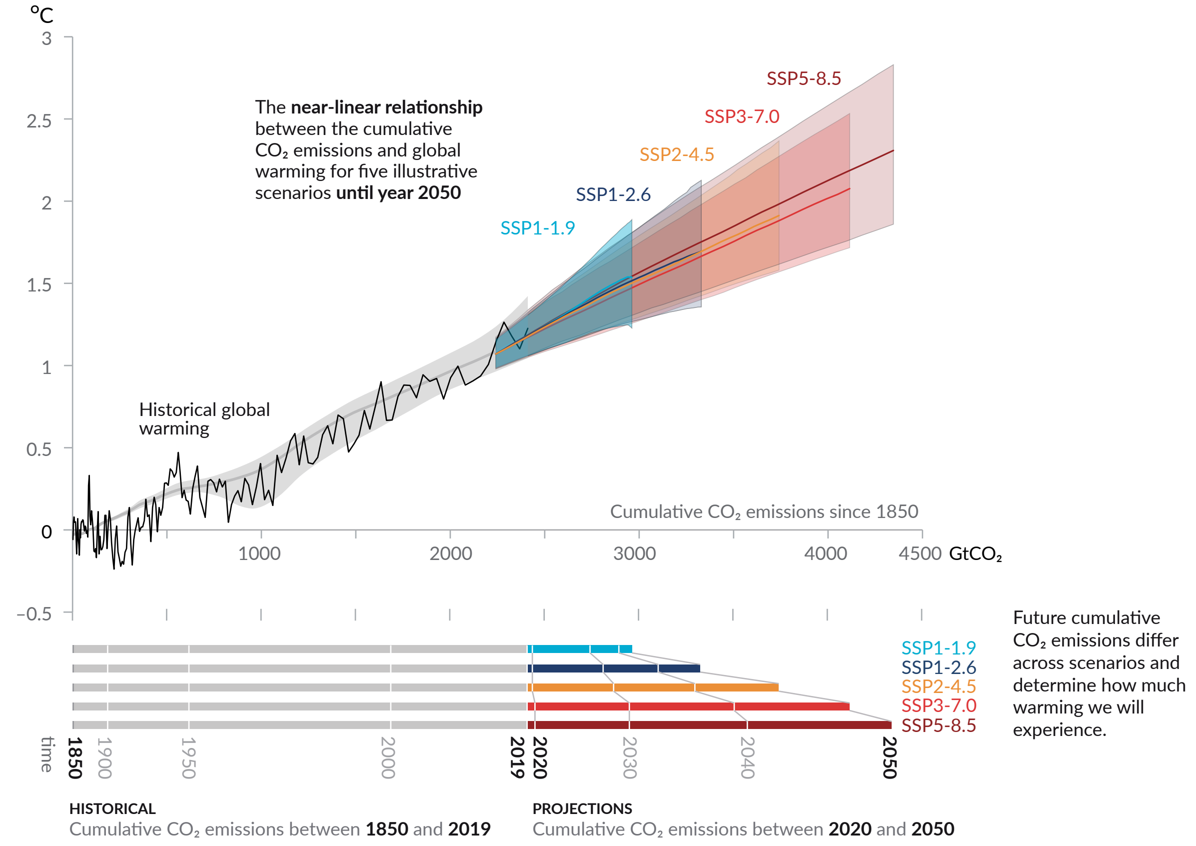


Figure SPM.10 | Near-linear relationship between cumulative CO_2 emissions and the increase in global surface temperature

Top panel: Historical data (thin black line) shows observed global surface temperature increase in °C since 1850–1900 as a function of historical cumulative carbon dioxide (CO_2) emissions in $GtCO_2$ from 1850 to 2019. The grey range with its central line shows a corresponding estimate of the historical human-caused surface warming (see Figure SPM.2). Coloured areas show the assessed *very likely* range of global surface temperature projections, and thick coloured central lines show the median estimate as a function of cumulative CO_2 emissions from 2020 until year 2050 for the set of illustrative scenarios (SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5; see Figure SPM.4). Projections use the cumulative CO_2 emissions of each respective scenario, and the projected global warming includes the contribution from all anthropogenic forcers. The relationship is illustrated over the domain of cumulative CO_2 emissions for which there is *high confidence* that the transient climate response to cumulative CO_2 emissions (TCRE) remains constant, and for the time period from 1850 to 2050 over which global CO_2 emissions remain net positive under all illustrative scenarios, as there is *limited evidence* supporting the quantitative application of TCRE to estimate temperature evolution under net negative CO_2 emissions.

Bottom panel: Historical and projected cumulative CO_2 emissions in $GtCO_2$ for the respective scenarios.

{Section 5.5, Figure 5.31, Figure TS.18}

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[41] In the literature, units of °C per 1000 PgC (petagrams of carbon) are used, and the AR6 reports the TCRE *likely* range as 1.0°C to 2.3°C per 1000 PgC in the underlying report, with a best estimate of 1.65°C.

[42] The condition in which anthropogenic carbon dioxide (CO_2) emissions are balanced by anthropogenic CO_2 removals over a specified period (Glossary).

[43] The term 'carbon budget' refers to the maximum amount of cumulative net global anthropogenic CO_2 emissions that would result in limiting global warming to a given level with a given probability, taking into account the effect of other anthropogenic climate forcers. This is referred to as the total carbon budget when expressed starting from the pre-industrial period, and as the remaining carbon budget when expressed from a recent specified date (Glossary). Historical cumulative CO_2 emissions determine to a large degree warming to date, while future emissions cause future additional warming. The remaining carbon budget indicates how much CO_2 could still be emitted while keeping warming below a specific temperature level.

D.1.2 Over the period 1850–2019, a total of 2390 ± 240 (*likely* range) $GtCO_2$ of anthropogenic CO_2 was emitted. Remaining carbon budgets have been estimated for several global temperature limits and various levels of probability, based on the estimated value of TCRE and its uncertainty, estimates of historical warming, variations in projected warming from non-CO_2 emissions, climate system feedbacks such as emissions from thawing permafrost, and the global surface temperature change after global anthropogenic CO_2 emissions reach net zero.
{5.1, 5.5, Box 5.2, TS.3.3} (Table SPM.2)

Table SPM.2 | Estimates of historical carbon dioxide (CO_2) emissions and remaining carbon budgets. Estimated remaining carbon budgets are calculated from the beginning of 2020 and extend until global net zero CO_2 emissions are reached. They refer to CO_2 emissions, while accounting for the global warming effect of non-CO_2 emissions. Global warming in this table refers to human-induced global surface temperature increase, which excludes the impact of natural variability on global temperatures in individual years.
{Table 3.1, 5.5.1, 5.5.2, Box 5.2, Table 5.1, Table 5.7, Table 5.8, Table TS.3}

Global Warming Between 1850–1900 and 2010–2019 (°C)		Historical Cumulative CO_2 Emissions from 1850 to 2019 ($GtCO_2$)					
1.07 (0.8–1.3; likely range)		2390 (± 240; likely range)					
Approximate global warming relative to 1850–1900 until temperature limit (°C)[a]	Additional global warming relative to 2010–2019 until temperature limit (°C)	Estimated remaining carbon budgets from the beginning of 2020 ($GtCO_2$) *Likelihood of limiting global warming to temperature limit*[b]					Variations in reductions in non-CO_2 emissions[c]
		17%	*33%*	*50%*	*67%*	*83%*	
1.5	0.43	900	650	500	400	300	Higher or lower reductions in accompanying non-CO_2 emissions can increase or decrease the values on the left by 220 $GtCO_2$ or more
1.7	0.63	1450	1050	850	700	550	
2.0	0.93	2300	1700	1350	1150	900	

[a] Values at each 0.1°C increment of warming are available in Tables TS.3 and 5.8.

[b] This likelihood is based on the uncertainty in transient climate response to cumulative CO_2 emissions (TCRE) and additional Earth system feedbacks and provides the probability that global warming will not exceed the temperature levels provided in the two left columns. Uncertainties related to historical warming (±550 $GtCO_2$) and non-CO_2 forcing and response (±220 $GtCO_2$) are partially addressed by the assessed uncertainty in TCRE, but uncertainties in recent emissions since 2015 (±20 $GtCO_2$) and the climate response after net zero CO_2 emissions are reached (±420 $GtCO_2$) are separate.

[c] Remaining carbon budget estimates consider the warming from non-CO_2 drivers as implied by the scenarios assessed in SR1.5. The Working Group III Contribution to AR6 will assess mitigation of non-CO_2 emissions.

D.1.3 Several factors that determine estimates of the remaining carbon budget have been re-assessed, and updates to these factors since SR1.5 are small. When adjusted for emissions since previous reports, estimates of remaining carbon budgets are therefore of similar magnitude compared to SR1.5 but larger compared to AR5 due to methodological improvements.[44]
{5.5, Box 5.2, TS.3.3} (Table SPM.2)

D.1.4 Anthropogenic CO_2 removal (CDR) has the potential to remove CO_2 from the atmosphere and durably store it in reservoirs (*high confidence*). CDR aims to compensate for residual emissions to reach net zero CO_2 or net zero GHG emissions or, if implemented at a scale where anthropogenic removals exceed anthropogenic emissions, to lower surface temperature. CDR methods can have potentially wide-ranging effects on biogeochemical cycles and climate, which can either weaken or strengthen the potential of these methods to remove CO_2 and reduce warming, and can also influence water availability and quality, food production and biodiversity[45] (*high confidence*).
{5.6, Cross-Chapter Box 5.1, TS.3.3}

D.1.5 Anthropogenic CO_2 removal (CDR) leading to global net negative emissions would lower the atmospheric CO_2 concentration and reverse surface ocean acidification (*high confidence*). Anthropogenic CO_2 removals and emissions are partially

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[44] Compared to AR5, and when taking into account emissions since AR5, estimates in AR6 are about 300–350 $GtCO_2$ larger for the remaining carbon budget consistent with limiting warming to 1.5°C; for 2°C, the difference is about 400–500 $GtCO_2$.

[45] Potential negative and positive effects of CDR for biodiversity, water and food production are methods-specific and are often highly dependent on local context, management, prior land use, and scale. IPCC Working Groups II and III assess the CDR potential and ecological and socio-economic effects of CDR methods in their AR6 contributions.

compensated by CO_2 release and uptake respectively, from or to land and ocean carbon pools (*very high confidence*). CDR would lower atmospheric CO_2 by an amount approximately equal to the increase from an anthropogenic emission of the same magnitude (*high confidence*). The atmospheric CO_2 decrease from anthropogenic CO_2 removals could be up to 10% less than the atmospheric CO_2 increase from an equal amount of CO_2 emissions, depending on the total amount of CDR (*medium confidence*).
{5.3, 5.6, TS.3.3}

D.1.6 If global net negative CO_2 emissions were to be achieved and be sustained, the global CO_2-induced surface temperature increase would be gradually reversed but other climate changes would continue in their current direction for decades to millennia (*high confidence*). For instance, it would take several centuries to millennia for global mean sea level to reverse course even under large net negative CO_2 emissions (*high confidence*).
{4.6, 9.6, TS.3.3}

D.1.7 In the five illustrative scenarios, simultaneous changes in CH_4, aerosol and ozone precursor emissions, which also contribute to air pollution, lead to a net global surface warming in the near and long term (*high confidence*). In the long term, this net warming is lower in scenarios assuming air pollution controls combined with strong and sustained CH_4 emissions reductions (*high confidence*). In the low and very low GHG emissions scenarios, assumed reductions in anthropogenic aerosol emissions lead to a net warming, while reductions in CH_4 and other ozone precursor emissions lead to a net cooling. Because of the short lifetime of both CH_4 and aerosols, these climate effects partially counterbalance each other, and reductions in CH_4 emissions also contribute to improved air quality by reducing global surface ozone (*high confidence*).
{6.7, Box TS.7} (Figure SPM.2, Box SPM.1)

D.1.8 Achieving global net zero CO_2 emissions, with anthropogenic CO_2 emissions balanced by anthropogenic removals of CO_2, is a requirement for stabilizing CO_2-induced global surface temperature increase. This is different from achieving net zero GHG emissions, where metric-weighted anthropogenic GHG emissions equal metric-weighted anthropogenic GHG removals. For a given GHG emissions pathway, the pathways of individual GHGs determine the resulting climate response,[46] whereas the choice of emissions metric[47] used to calculate aggregated emissions and removals of different GHGs affects what point in time the aggregated GHGs are calculated to be net zero. Emissions pathways that reach and sustain net zero GHG emissions defined by the 100-year global warming potential are projected to result in a decline in surface temperature after an earlier peak (*high confidence*).
{4.6, 7.6, Box 7.3, TS.3.3}

D.2 Scenarios with very low or low GHG emissions (SSP1-1.9 and SSP1-2.6) lead within years to discernible effects on greenhouse gas and aerosol concentrations and air quality, relative to high and very high GHG emissions scenarios (SSP3-7.0 or SSP5-8.5). Under these contrasting scenarios, discernible differences in trends of global surface temperature would begin to emerge from natural variability within around 20 years, and over longer time periods for many other climatic impact-drivers (*high confidence*).
{4.6, 6.6, 6.7, Cross-Chapter Box 6.1, 9.6, 11.2, 11.4, 11.5, 11.6, Cross-Chapter Box 11.1, 12.4, 12.5} (Figure SPM.8, Figure SPM.10)

D.2.1 Emissions reductions in 2020 associated with measures to reduce the spread of COVID-19 led to temporary but detectable effects on air pollution (*high confidence*) and an associated small, temporary increase in total radiative forcing, primarily due to reductions in cooling caused by aerosols arising from human activities (*medium confidence*). Global and regional climate responses to this temporary forcing are, however, undetectable above natural variability (*high confidence*). Atmospheric CO_2 concentrations continued to rise in 2020, with no detectable decrease in the observed CO_2 growth rate (*medium confidence*).[48]
{Cross-Chapter Box 6.1, TS.3.3}

D.2.2 Reductions in GHG emissions also lead to air quality improvements. However, in the near term,[49] even in scenarios with strong reduction of GHGs, as in the low and very low GHG emissions scenarios (SSP1-2.6 and SSP1-1.9), these improvements

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[46] A general term for how the climate system responds to a radiative forcing (Glossary).

[47] The choice of emissions metric depends on the purposes for which gases or forcing agents are being compared. This Report contains updated emissions metric values and assesses new approaches to aggregating gases.

[48] For other GHGs, there was insufficient literature available at the time of the assessment to assess detectable changes in their atmospheric growth rate during 2020.

[49] Near term: 2021–2040.

are not sufficient in many polluted regions to achieve air quality guidelines specified by the World Health Organization (*high confidence*). Scenarios with targeted reductions of air pollutant emissions lead to more rapid improvements in air quality within years compared to reductions in GHG emissions only, but from 2040, further improvements are projected in scenarios that combine efforts to reduce air pollutants as well as GHG emissions, with the magnitude of the benefit varying between regions (*high confidence*).
{6.6, 6.7, Box TS.7}.

D.2.3 Scenarios with very low or low GHG emissions (SSP1-1.9 and SSP1-2.6) would have rapid and sustained effects to limit human-caused climate change, compared with scenarios with high or very high GHG emissions (SSP3-7.0 or SSP5-8.5), but early responses of the climate system can be masked by natural variability. For global surface temperature, differences in 20-year trends would *likely* emerge during the near term under a very low GHG emissions scenario (SSP1-1.9), relative to a high or very high GHG emissions scenario (SSP3-7.0 or SSP5-8.5). The response of many other climate variables would emerge from natural variability at different times later in the 21st century (*high confidence*).
{4.6, Cross-Section Box TS.1} (Figure SPM.8, Figure SPM.10)

D.2.4 Scenarios with very low and low GHG emissions (SSP1-1.9 and SSP1-2.6) would lead to substantially smaller changes in a range of CIDs[36] beyond 2040 than under high and very high GHG emissions scenarios (SSP3-7.0 and SSP5-8.5). By the end of the century, scenarios with very low and low GHG emissions would strongly limit the change of several CIDs, such as the increases in the frequency of extreme sea level events, heavy precipitation and pluvial flooding, and exceedance of dangerous heat thresholds, while limiting the number of regions where such exceedances occur, relative to higher GHG emissions scenarios (*high confidence*). Changes would also be smaller in very low compared to low GHG emissions scenarios, as well as for intermediate (SSP2-4.5) compared to high or very high GHG emissions scenarios (*high confidence*).
{9.6, 11.2, 11.3, 11.4, 11.5, 11.6, 11.9, Cross-Chapter Box 11.1, 12.4, 12.5, TS.4.3}

נספח 12

העתק ממסמך העמדה של המשיב 5

עמ' 532

נספח 12

מדינת ישראל
המשרד להגנת הסביבה
לשכת המנכ"לית

המשרד להגנת הסביבה
الوزارة لحماية البيئة
Israel Ministry of Environmental Protection

ג׳ תשרי תשפ״ב
9 ספטמבר 2021

לכבוד,
מר אודי אדירי
<u>מנכ״ל משרד האנרגיה</u>

הנדון : **<u>המלצות הוועדה לבחינת מדיניות הממשלה בנושא משק הגז</u>**

<u>בעקבות החלטת ממשלה מס׳ 465 מיום 25.10.2020</u>

<u>עמדת המשרד להגנת הסביבה</u>

1. רקע

בימים אלו מסכמת ועדת אדירי 2 את המלצותיה, אשר עוסקות בעדכון המדיניות הקיימת לפיתוח משק הגז בישראל. לאור התחזיות העולמיות של ירידה בביקוש לגז, ובעקבות מעבר עולמי לכלכלה דלת פחמן על רקע מאמצי ההתמודדות עם משבר האקלים, מבקש משרד האנרגיה להאיץ את פיתוח מאגרי הגז במים הכלכליים והטריטוריאליים של ישראל.

הסוגיות המרכזיות אשר נדונו בוועדה הן:

א. סיכונים כלכליים לפיתוח מאגרי גז לנוכח הירידה הצפויה בביקושי הגז העולמיים כבר במהלך העשור הנוכחי. סיכונים אלו יכולים לפגוע בייתכנות הכלכלית לפיתוח מאגרי גז חדשים ובעקבות כך לירידה בתמלוגים לקופת המדינה.

ב. שינויים באומדן הביקוש לגז למשק הישראלי בעקבות עלייה בשיעור האנרגיות המתחדשות במשק החשמל ויישום היעדים להפחתת פליטות גזי חממה בתחומי התחבורה והתעשייה.

ג. הקטנת הסיכונים ליזמים המבקשים לפתח את משק הגז באמצעות כלים כלכליים ורגולטורים שונים לתימרוץ פיתוח מאגרי גז קיימים וחדשים.

עיקרי האתגרים הסביבתיים והכלכליים הצפויים מפיתוח משק הגז:

א. העלאת פליטות גזי החממה של ישראל, בדגש על פליטות גז מתאן אשר הוא גז חממה המזיק פי 28 מפחמן דו חמצני. על-פי דוח ה-IPCC שפורסם באוגוסט 2021, גז מתאן לבדו אחראי להתחממות של כ-0.5°C (בהשוואה לפחמן דו-חמצני האחראי לעלייה של כ-0.8°C).

ב. הקמה והרחבה של תשתיות פוסיליות כחלק מפיתוח משק הגז מסכנת ומייקרת את יכולת המשק ליישם את היעדים למעבר לכלכלה דלת פחמן. הקצאת משאבים ציבוריים להמשך פיתוח ומתן סובסידיות לדלקים פוסיליים, כמוצע על ידי הועדה, בהכרח תבוא על חשבון משאבים לפיתוח אנרגיות מתחדשות. הדבר יוביל לקצב חדירה איטי של אנרגיות מתחדשות, ולאי עמידה ביעדים עליהם החליטה הממשלה.

ג. אי ודאות באשר לייתכנות הכלכלית לפיתוח משק הגז ולתועלות הכלכליות למשק לעומת הסיכונים המשקיים ממדיניות זו (לא ברורות כל ההנחות שנלקחו לבחינת התועלת הכלכלית וכן לא נכלל ניתוח כלכלי מלא של כל העלויות למשק הישראלי מפיתוח המאגרים, כגון, המחיר של אי מציאת גז, עלות הגז שצפויה לרדת, העלות הכלכלית של מחסור ארוך טווח בעתודות הגז, עלות ההכרה בחיפושי הוצאות הגז, עלות הטעות של ייצוא עודף ועוד. לא נלקחו עליות נוספות בחשבון כגון השקעה בתשתיות נלוות, השקעה בתשתיות לייצוא, הכרה בכל העלויות החיצוניות, אובדני מתאן, הקלות מס נוספות שמקטינות את הכנסות המדינה, האמצעים הביטחוניים הנדרשים להגנה על האסדות והתשתיות הנלוות, עלות הסיכון הסביבתי ועוד, כך שבפועל התועלת הכלכלית נמוכה יותר מכפי שהוצגה).

ד. עליה בהיקף ובחומרה של סיכונים סביבתיים לים, לאוויר וליבשה כתוצאה מפיתוח שדות גז והתפעול השוטף של תשתיות הגז ותשתיות תומכות בים וביבשה.

המשרד להגנת הסביבה מבקש לקבל את העבודה הכלכלית המלאה והמעודכנת שהוכנה עבור הועדה על מנת להשלים את התייחסותו להיבטים הכלכליים.

2. עיקרי המלצות משרד האנרגיה

2.1 הסרת מגבלות וחסמים רגולטורים על יצוא גז, כמפורט להלן:

- <u>הפחתת הכמות המשוריינת לאספקת גז למשק הישראלי מתחת לתחזית הביקושים</u> – תחזיות הביקושים המשקיות לגז שחישב משרד האנרגיה עד לשנת 2045 נאמדות ב- BCM 405-531. התרחיש המרכזי שגובש מגיע לצריכת גז מצטברת של BCM 482 עד לשנת 2045, בין השאר על בסיס הנחה של 30% אנרגיות מתחדשות בלבד במשק החשמל, קצב חדירה גבוה של רכבים חשמליים, סגירת היחידות הפחמיות אורות רבין 1-4 והסבת יתר היחידות הפחמיות לגז עד לשנת 2026. על התרחיש הנבחר קיים פקטור של 0.5 משנת 2031, כך שבפועל הקף הגז שישמר למשק המקומי הוא 316 ולא BCM 482.

- <u>ביטול החלטת ועדת אדירי 1 לחיוב אספקת גז למשק הישראלי ממאגרים חדשים</u> – המשמעות של החלטה זו היא כי ניתן יהיה לייצא את כל הגז ממאגרים שעדיין לא פותחו, כלומר שאינם המאגרים תמר, לוויתן וכריש-תנין.

- <u>הפחתת חובת אספקת גז למשק המקומי מ-3 המאגרים הקיימים</u> - על כל BCM 1 נוסף מעבר ל- BCM 50 ועד ל- BCM 200, תופחת חובת האספקה למשק המקומי מ-50% ל-35%. על כל BCM 1 נוסף מעבר ל- BCM 200 תחול חובת אספקה למשק המקומי בשיעור של 40% לעומת הדרישה הנוכחית של 55%.

- <u>דחייה בשנתיים של חובת החיבור של מאגרי גז חדשים למשק המקומי</u> – הקלה זו תחול על מאגרים בינוניים (בהיקף BCM 50-200) אשר יתחילו בהפקה מסחרית של גז מחצבים לכל

המאוחר עד ליום ה- 1.1.2031. המאגרים יחויבו להתחבר למשק המקומי עד ליום 31.12.2035. בנוסף, מוצע לקבוע כי תתאפשר דחייה נוספת בהתאם לשיקול דעתו של הממונה על ענייני הנפט במשרד האנרגיה.

2.2 גיבוש כלים כלכליים לסיוע ולתימרוץ פיתוח מאגרי גז חדשים, כפורט להלן:

- הרחבת הקריטריונים להוצאה מוכרת ליזמים במהלך חיפוש ופיתוח מאגרי גז על-ידי קידום תיקון ה-Ring Fence. תיקון זה מתייחס להכרה בהוצאות חיפוש וקידוח מקדימים אשר נמצאו כמאגרים לא כלכליים. המשמעות של תיקון זה היא **דחיית התמלוגים** לאוצר המדינה מהכנסות על מכירת הגז.
- הגדלת המקדם בהכרה בהוצאות חיפושי הגז אשר משמעותה **דחיית התמלוגים** לאוצר המדינה.

3. עמדת המשרד להגנת הסביבה

המשרד להגנת הסביבה מתנגד למתווה המוצע על ידי משרד האנרגיה מאחר ומתווה זה יוביל לפיתוח מסוכן של מאגרים המכילים גז ונפט, תוך סיכון יכולתה של ישראל להיגמל מהתלות בדלקים מזהמים ולעבור לכלכלה דלת פחמן ותחרותית כמו שאר מדינות ה-OECD. עמדת המשרד היא שמדיניות פיתוח משק הגז חייבת לעמוד בהלימה למחויבות ולאסטרטגיה של ישראל להפסקת התלות בדלקים פוסיליים ולמעבר לכלכלה דלת פחמן ומשגשגת. מחויבות זו קיבלה משנה תוקף לאחרונה עם החלטת ממשלה מס' 171 מיום 25 ליולי 2021.

מאז כינונה של הממשלה החדשה, ישראל הביעה את מחויבותה לקחת חלק במאמץ העולמי להתמודדות עם משבר האקלים, ואף נדרשה להעמיק את היעדים להפחתת פליטות. לכן, כל הסרה של רגולציה ומתן תמריצים כלכליים לדלקים פוסיליים, עומדים בניגוד למחויבות זו ובניגוד לקונצנזוס המדעי לפיו הפסקת הפיתוח של מאגרי דלקים פוסיליים היא הכרחית לבלימת שינויי האקלים.

מחויבותה של ישראל להפחתת פליטות אינה יכולה להתמצות בהפחתת פליטות בשטחה, ועליה לקחת חלק במאמץ העולמי להפסקת השימוש בדלקים פוסיליים, שכן משבר האקלים הוא משבר גלובלי. לכן, לא מתקבל על הדעת שבצד המאמץ להפחתת פליטות והפסקת השימוש בדלקים פוסיליים בישראל, חברות הפועלות בישראל, בתמיכת ממשלת ישראל, דווקא יאיצו את הפקת הגז לצרכי ייצוא.

התועלת הכלכלית הישירה בטווח הקצר, מחתימה על עסקאות למכירת גז לאירופה, ברורה. עם זאת, היא אינה לוקחת בחשבון את הסיכונים הסביבתיים והכלכליים כתוצאה מפיתוח תעשיה מזהמת בתחומי ישראל, כמו גם את ההיבט המוסרי והערכי הכרוך בכך. היום כבר ברור שהמשך תמיכה ותמרוץ של תעשיית הדלקים הפוסיליים, גם אם מטרתה לייצוא ושריפתם לא תיכלל

בחישוב פליטות גזי החממה של ישראל, אינה השקעה נבונה בשוק גלובלי המשתנה בקצב מהיר, ואינה ראויה בהסתכלות מפוקחת על דחיפות המאבק במשבר האקלים.

כאמור, מעבר לכך שפיתוח מאגרי גז יחריף את משבר האקלים, לפיתוח מאגרי גז השפעות וסיכונים סביבתיים וכלכליים משמעותיים למרחב הימי, לאוויר וליבשה, לרבות סיכונים ישירים ועקיפים ממכלול רחב של תשתיות גז, פעולות להפקה וטיפול בגז ופעולות לשינוע הגז. בפרט, עולה רמת הסיכונים מאירועים בלתי שגרתיים, לרבות:

- דליפות של הידרוקרבונים נוזליים הנמצאים במאגר ביחד עם גז המתאן, תוך סיכון חמור למערכות אקולוגיות ימיות אשר הינן רגישות מאוד, סיכון לשטחי דיג ולתיירות חופית וימית, ואף עליה בסיכון למתקני ההתפלה;
- פליטות תפעוליות של מזהמים וגזי חממה מפעולות ההפקה והטיפול בגז, בין אם בהזרמות ישירות לים או בפליטות לאוויר, וכן חשש לתקלות בטיפול בחומרים מסוכנים;
- תפיסת שטחים בים וביבשה על ידי אסדות נוספות, צנרת תת ימית ופעולות לתחזוקתה, מתקני הנזלה, מתקני הפחתת לחץ ותשתיות נוספות אשר יפגעו במערכות אקולוגיות ימיות ויבשתיות רגישות וייחודיות.

לצורך שמירה על המרחב הימי, היבשתי ויישום היעדים הלאומיים למעבר למשק דל פחמן, על ישראל להפסיק בהדרגה את השימוש בדלקים פוסיליים מזהמים כגון גז, פחם ונפט ולעבור לשימוש באנרגיות מתחדשות. בנוסף, ישנו חשש משמעותי ומבוסס שהתועלת הכלכלית התיאורטית, קצרת הטווח, ממימוש פוטנציאל הגז במרחב הימי של ישראל עלולה להתגמד לעומת העלויות הכלכליות כתוצאה מהעלייה הצפויה בפליטות גזי החממה של ישראל, הסיכונים המשמעותיים לסביבה הימית והיבשתית, כמו גם אובדן הזדמנויות שכלכלה ללא דלקים פוסיליים מציבה למשק, לחברה ולסביבה. כל אלה לא נבחנו על-ידי הוועדה.

לעמדת המשרד להגנת הסביבה, במתווה המדיניות למשק הגז יש לכלול את הרכיבים הבאים:

א. <u>קביעת יעדים למעבר למשק מבוסס אנרגיות מתחדשות ושימוש בתמלוגי הגז לקידומם</u>

- בהתאם להחלטת ממשלה מס' 171, ולאור המלצת משרד האנרגיה לשריין BCM 316 למשק המקומי, יש לקבוע יעדים לאנרגיה מתחדשת – יעד לשנת 2050 ויעדי ביניים מחייבים לשנים 2030, 2035, 2040 ו-2045. המלצת משרד האנרגיה לשריין BCM 316 בלבד למשק המקומי תוכל להתבצע רק אם ישראל תעבור ליצור חשמל מבוסס אנרגיות מתחדשות, בהיקף של 95% עד שנת 2050.
- יש לגבש קריטריונים לשימוש בתמלוגי הגז לטובת תמיכה מתמשכת, ארוכת טווח בתעשייה הישראלית לצורך השקעות בטכנולוגיות יעילות ונקיות אשר מאפשרות את הפסקת השימוש בדלקים פוסיליים, וכן לטיפול ולמניעה של סיכונים וזיהומים סביבתיים שמקורם בפעילות של דלקים פוסיליים.

ב. <u>מניעת פיתוח תשתיות של גז וקונדנסט</u>

יש להימנע מפיתוח נוסף של תשתיות נוספות מזהמות כגון אסדות, צנרות ומתקני הפחתת לחץ. למען הסר ספק, אין שום הצדקה להקמת מתקן הנזלה נוסף בשטחי ישראל. מאחר וכל מאגר גז מכיל גם נוזלים הידרוקרבוניים כגון קונדנסט ונפט, יגבר הלחץ לשמירה ולפיתוח תשתיות לקליטה ולטיפול בנוזלים אלו בישראל בניגוד לאינטרס הלאומי למעבר לכלכלה שאינה תלויה בדלקים אלו.

ג. <u>בחינה מעמיקה של הכנסות המדינה החזויות לאור הסיכונים</u>

- נדרשת בחינה מעמיקה של הכנסות המדינה מפיתוח משק הגז מאחר וכבר היום שלושת המאגרים הקיימים מספיקים לצרכי האנרגיה של ישראל וקיימת אי ודאות לגבי הכנסות המדינה בפועל. זאת גם לאור תחזיות העבר להכנסות גבוהות למדינה, כאשר בפועל ההכנסות לקרן לאזרחי ישראל נמוכות מהתחזיות והקרן טרם החלה לפעול. לכן, יש לייצר ניהול סיכונים בראייה כלכלית מפוקחת ולהימנע מהשקעות עם סיכון כלכלי וסביבתי בסבסוד מדינה, ולהימנע מפיתוח שדות שלא יחזירו את ההשקעה הכלכלית בהם בגלל הירידה בביקושים העולמיים.

- יש להימנע מלהתערב בכוחות השוק הגלובאלי העובר לכלכלה נטולת פליטות, באמצעות מימון של יזמי הגז על ידי המדינה, לדוגמא דרך הקלות מס. כיום, משרד האנרגיה מסבסד בהיקפים של מאות מיליוני שקלים את תשתיות הגז במקום את תשתיות האנרגיות המתחדשות. במאי 2021 פרסם ה-IEA, הגוף הבינלאומי המוביל בתחום האנרגיה, המלצה להפסיק בתוך שנה את ההשקעה בפרויקטים פוסיליים חדשים.[1]

ד. <u>הגנה על הסביבה הימית ומניעת אסונות</u>

- יש לעצור לחלוטין כל פעילות הכרוכה בפיתוח מאגרי נפט או מאגרי גז חדשים, בים וביבשה. יש לעצור את הליכי המכרז המתוכננים לפתיחת שטחי חיפוש נוספים, ואין להעניק רישיונות נוספים על אלו שכבר ניתנו. מבין שטחי החיפוש שכבר הוענקו, יש להבטיח שתהיה הקפדה יתרה על מניעת פגיעה בסביבה הימית תוך נקיטה בעקרון הזהירות המונעת, ובמידה ולא נוצלו, אין להאריך את הרישיון. על פי משרד האנרגיה, המאגרים הקיימים משרתים את הצרכים של מדינת ישראל. כל פיתוח נוסף, גם ליצוא, כרוך בסיכונים כלכליים וסביבתיים משמעותיים ויבוא על חשבון המעבר של ישראל למשק מבוסס אנרגיות מתחדשות.

- יש לקבוע במאגרים קיימים או שמצויים בשלבי פיתוח מתקדם חובה לפינוי תשתיות הפקת הגז (ראשי קידוח, צנרת הולכה, אסדות) ושיקום הסביבה הימית בתום השימוש,

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[1] https://iea.blob.core.windows.net/assets/beceb956-0dcf-4d73-89fe-1310e3046d68/NetZeroby2050-ARoadmapfortheGlobalEnergySector_CORR.pdf

על-ידי חילוט ערבויות, קנסות, קרן ייעודית או כל מנגנון מחייב אחר, כתנאי לקבלת הרישיונות.

- יש להכריז על לפחות 30% שמורות טבע ימיות במים הטריטוריאליים ובמים הכלכליים, תוך מתן עדיפות לאזורים ימיים רגישים, בכדי להגן על בתי הגידול הייחודיים מפני פגיעות כתוצאה מהולכת קווי גז, אסדות ותשתיות נוספות.
- יש להכיר באזורים ימיים ויבשתיים אשר הוגדרו כרגישים אקולוגית כאזורים ימיים מוגנים – Marine Protected Areas.
- יש לקבוע אזורי חיץ מספקים בין בתי גידול ייחודיים, שמורות ימיות, או אזורים ימיים מוגנים לבין שטחי קידוח, חיפוש או הפקה של גז, זאת בהתאם להערכה של טווח ההשפעה ותוך שמירה על עקרון הזהירות המונעת. ערכי הטבע המצויים בים העמוק מתחדשים בקצב איטי מאוד וכל פגיעה בהם עשויה, בסבירות גבוהה, להיות בלתי הפיכה.
- יש להקצות תקציבים מתאימים, לדוגמא באמצעות שימוש בתמלוגי הגז, להעמקת יכולות ההגנה והניטור על הסביבה הימית והמערכות האקולוגיות הימיות, ולמניעת אסונות מדליפות ותאונות כפי שהתרחש לאחרונה בחופי ישראל.

לאור כל האמור לעיל, המשרד מתנגד לטיוטת הדו״ח כפי שהופצה, מבקש לעדכנה בהתאם לעמדה המפורטת לעיל ומבקש לקבל את העבודה הכלכלית המלאה העומדת ביסוד ההמלצות.

בברכה,

גלית כהן

מנכ״לית המשרד להגנת הסביבה

העתקים:
תמר זנדברג, השרה להגנת הסביבה;
שולי נזר, סמנכ״לית בכירה, תעשיות;
אלון זס״ק, סמנכ״ל בכיר למשאבי טבע;
יובל לסטר, מ״מ סמנכ״ל בכיר לתכנון מדיניות ואסטרטגיה;
ד״ר צור גלין, ראש אגף איכות אוויר ושינויי אקלים;
ד״ר גיל פרואקטור, ראש תחום אנרגיה ואקלים;
ד״ר רותי קירו, ממונה איכות אוויר ושינוי אקלים;
רני עמיר, מנהל היחידה הארצית להגנת הסביבה הימית;
אילה גלדמן, ראש אגף תכנון סביבתי;
עו״ד יעל בן עמוס, לשכה משפטית;
פנינה קפלן, ממונה תכנון סביבתי;
תמר רביב, ראש אגף מגוון ביולוגי ושטחים פתוחים.

נספח 13

העתק מיעדי הפחתת הפליטות המעודכנים שהעבירה ישראל

עמ' 539

נספח 13

UPDATE OF ISRAEL'S NATIONALLY DETERMINED CONTRIBUTION UNDER THE PARIS AGREEMENT

Submitted July 2021

This submission is in response to paragraphs 24 and 25 of decision 1/CP.21 and in particular Israel's commitment to communicate or update its nationally determined contribution (NDC). Israel has included in this document accompanying information to facilitate clarity, transparency and understanding (ICTU) of its NDC in compliance with Decision 4/CMA.1.

Israel formally communicated its INDC under the Paris Agreement on 29 September 2015 which became its NDC upon ratification of the Paris Agreement on 22 November 2016.

Since then, Israel has undertaken steps to increase its ambition. Most noteworthy is Government Decision 171 passed on the 25th of July 2021 entitled "Transition to a Low Carbon Economy.”

Unlike Israel's original NDC, this new Decision includes an unconditional absolute greenhouse gas (GHG) emissions reduction goal for 2030 of 27% relative to 2015 and an unconditional absolute GHG emissions reduction goal for 2050 of 85% relative to 2015.

Whereas our INDC submitted in 2015 projected 2030 emissions would be 81.65 MtCO2e, under this update they are projected to be 58 MtCO2e by 2030.

This updated goal significantly improves upon Israel's first NDC which was presented as a per capita economy-wide unconditional GHG reduction. The previous target was 7.7 tCO2e by 2030 which corresponded to a total of 81.6 MtCO2e. The updated target presented in this NDC is 58 MtCO2e, which corresponds to a reduction of 23 MtCO2e or 29% in Israel' s total emissions.

We believe that this updated NDC is a marked improvement both in the process by which the 2030 and 2050 national and sectoral goals were determined; in the more ambitious mitigation goal and in the work carried out to increase preparedness and adaptation to Climate Change.

A multi stakeholder process, entitled **"Israel 2050: A Flourishing Economy in a Sustainable Environment",** took place over two years to determine 2050 low carbon goals from which 2030 goals and targets were derived, including recommendations for implementation. Some of these policies already exist and others will be the subject of future government decisions, ministerial policies or other tools as required.

The main provisions of the recently adopted Decision 171 which set out updated national GHG reduction goals are as follows:

- ✓ Revision of the existing national greenhouse gas emission reduction target for 2030 set by Government Decision 542 so that the annual amount of greenhouse gas emissions by 2030 will be reduced by at least 27% from the annual amount measured in 2015 (79 MtCO2e). The annual amount of greenhouse gas emissions in 2030 will be about 58 MtCO2e.
- ✓ Approval of a national reduction target for greenhouse gas emissions by 2050, of at least 85% of the annual amount measured in 2015. Accordingly, the annual amount of greenhouse gas emissions in 2050 will be about 12 MtCO2e.
- ✓ Recognition of the desirability of a net-zero emissions goal by 2050 and a global target to limit temperature increase to 1.5 degrees Celsius. Therefore the 2050 target of 85% GHG emissions reduction will be periodically revisited.

The following sectoral targets were set:

- ✓ **Transport**
  - o As of 2026, all new municipal buses purchased will be clean vehicles as defined in section 77A of the Transport Ordinance [New Version].
  - o Limit the increase in greenhouse gas emissions from transportation by 2030, so that the total increase in emissions will be only 3.3% compared to emissions measured in 2015, which were 17.6 MtCO2e.
  - o Limit the amount of greenhouse gas emissions from new vehicles, weighing up to 3.5 tonnes, registered from 2030, to an amount equal to 5% of the average greenhouse gas emissions for a new vehicle, weighing up to 3.5 tonnes, registered in 2020. This target will be reexamined in 2025, and will be updated as necessary, having regard to technological developments, the extent of the penetration of electric vehicles in Israel and globally, electricity infrastructure and the deployment of charging stations in Israel.
  - o Reduction of greenhouse gas emissions from transport by 2050 by at least 96% compared to emissions measured in 2015.
- ✓ **Waste**
  - o Reduction of greenhouse gas emissions from solid waste by 2030 by at least 47% compared to emissions measured in 2015, which were 5.5MtCO2e.
  - o A 71% reduction in the amount of municipal waste landfilled by 2030 compared to the amount of municipal waste landfilled in 2018, which was about 4.5 million tonnes.
  - o Reduction of GHG emissions from municipal waste by 2050 by at least 92% compared to emissions measured in 2015.

- ✓ **Electricity Generation**
  - Reduction of greenhouse gas emissions from electricity generation by 2030 by 30% compared to emissions measured in 2015, which were 37.6 MtCO2e, taking into account the renewable energy targets set in Government Decision No. 465 (see below).
  - Reduction of greenhouse gas emissions from electricity generation by 2050 by at least 85% compared to emissions measured in 2015.
- ✓ **Energy Intensity**
  - To set a new energy intensity target so that by 2030 the energy intensity of GDP will be 122 MWh per NIS 1 million.
- ✓ **Industry**
  - Reduction of greenhouse gas emissions from industry by 2030 by at least 30% relative to emissions in 2015, which were 12 MtCO2e.
  - Reduction of industrial greenhouse gas emissions by 2050 by at least 56% relative to emissions in 2015.
- ✓ **Climate Impacts of Goods and Services**
  - To establish a voluntary mechanism for reporting and publicizing information on the GHG emissions associated with products and services manufactured in and imported to Israel.

Mid-century, long-term low greenhouse gas emission development strategies

Government Decision 171 detailed above also includes targets for 2050 in furtherance of Article 4, paragraph 19, of the Paris Agreement, and paragraph 35 of decision 1/CP.21 and constitutes Israel's current low greenhouse gas emission development strategy. GHG reductions will be reduced from 79.4 MtCO2e emissions in 2019 to 58 MtCO2e in 2030 and 12 MtCO2e in 2050.

Fair and ambitious

Taking into consideration its national circumstances, Israel believes its target to be fair and ambitious reflecting genuine efforts to move forward in a sustainable manner to facilitate the transition to a low-carbon and climate-resilient economy. Further information can be found in section 6(a) of the ICTU table below.

Key sectoral approved decisions and strategies contributing to the NDC’s achievement:

Government Decision N^{o} 465 (approved on October 25, 2020) which formalized the decision undertaken by the Minister of Energy to phase-out coal-fired power generation no later than 2026 and determined targets for a renewable power generation share of 20% in 2025 and 30% in 2030.

Implementation of the Kigali Amendment to the Montreal Protocol. In November 2020, the Internal Affairs and Environment Committee of the Knesset amended the Hazardous Materials Regulations to set quotas on the import of HFC refrigerant gases, in line with Israel's targets under the Kigali Amendment, to take effect in July 2022.

National Waste Strategy: In February 2021, the Ministry of Environmental Protection published a new National Strategy for a Circular Economy in 2050 and a Sustainable Waste Sector in 2030. The strategy addresses treatment of Municipal Solid Waste (MSW) in a comprehensive manner and includes the following key abatement measures in relation to sources of GHG emissions.

- Transition from 80% of waste landfilling in 2020, to only 20% by 2030;
- Zero landfilling of untreated organic waste and paper and cardboard by 2030;
- All active landfills will be sealed, and methane collection and destruction/utilization systems will be installed, so that methane collection will amount to no less than 50% of total methane production in the landfill.

Implementation

The government intends to review the national GHG reduction goals and strategy every five years which will also include an independent review process.

More detailed information on implementation is included in Israel's Third National Communication and in Israel's Second Biennial Update Report to be submitted in the near future.

Monitoring Reporting and Verification

In April 2016, the Israeli government set out in its National Greenhouse Gas Emissions Reduction Plan (Resolution 1403) the establishment of a national system for monitoring, reporting and verification, relating to the implementation of the program and national targets for reducing greenhouse gas emissions. Further information can be found in the table below.

Research and Development

Israel continues to be one of the largest investors in Research and Development per capita among OECD countries. A portion of that investment goes to Clean Tech and to climate technologies specifically in areas in which Israel has a relative advantage such as water use, agritech, and adaptation to arid and semi-arid conditions.

Adaptation to Climate Change

Israel has also been focusing on formulating adaptation policies, based on the increasingly severe climate predictions and trends for Israel and the region. The government adopted a government decision in 2018 for Adaptation to Climate Change and established the National Adaptation to Climate Change Committee (NACCC). The role of the NACCC is to mainstream adaptation efforts in all government bodies and relevant organizations, to coordinate cross sector adaptation activities and projects, to mainstream adaptation and to develop and distribute climate knowledge.

In 2019, The Israel Meteorological Service published the "Climate change in Israel – historical trends and future predictions of temperature and precipitation Report". This report presents the first comprehensive analysis of temperature and precipitation trends for Israel, based on data for various areas in Israel, and an analysis of projected climate models for the coming decades.

The Adaptation Committee submitted its first National Adaptation Report in May 2021 including recommendations to recognize Climate Change as a national security threat; outlining steps to be taken at the national and particularly at the local level for which a budget of 2.5 billion NIS over 5 years is proposed. It is intended that this Report will form the basis of a future government decision.

In the interim, the Water Authority, for example, is already incorporating data on the trends and projection into its master plans, thus maintaining Israel's ability to develop new desalination plants and to provide water supply both in Israel and for neighboring countries as well as continuing to develop innovation wastewater treatment and water recycling technologies. Enhancing the resilience of the public health system will be another area of focus

Tel Aviv – Yafo was the first city to publish its Adaptation to Climate Change Plan in 2020, in line with the C-40 covenant. 15 local authorities are currently developing their adaptation plans and In the next few years, it is expected that many more local authorities will follow suit. In recognition of the importance of the local government's role in adaptation efforts and in order to mainstream adaptation efforts, the NACCC developed Adaptation Guidelines for local government to be adopted by all local authorities.

Information to facilitate clarity, transparency and understanding

In line with Article 4, paragraph 8 of the Paris Agreement and Decision 4/CMA.1 Israel submits the following ICTU.

<table>
<tr><th colspan="3">Information to facilitate clarity, transparency and understanding of nationally determined contributions, referred to in decision 1/CP.21, paragraph 28</th></tr>
<tr><td>1.</td><td>Quantifiable information on the reference point (including, as appropriate, a base year):</td><td></td></tr>
<tr><td>(a)</td><td>Reference year(s), base year(s), reference period(s) or other starting point(s);</td><td>The reference year for all GHG emissions is 2015.</td></tr>
<tr><td>(b)</td><td>Quantifiable information on the reference indicators, their values in the reference year(s), base year(s), reference period(s) or other starting point(s), and, as applicable, in the target year;</td><td>Reference indicator: Net greenhouse gas (GHG) emissions in MtCO2e.
In 2015, Israel’s net GHG emissions were 79 MtCO2e. Achieving the targets will reduce emissions to approximately 58 MtCO2e by 2030 and approximately 12 MtCO2e by 2050.
Values in the reference year for the sectorial emission reduction targets are as follows:
<table>
<tr><th>Sector</th><th>GHG emissions (MtCO2e) in 2015</th><th>GHG emissions (MtCO2e) in 2030</th><th>GHG emissions (MtCO2e) in 2050</th></tr>
<tr><td>Electricity generation</td><td>37.6</td><td>26.3</td><td>5.6</td></tr>
<tr><td>Transport</td><td>17.6</td><td>17</td><td>0.7</td></tr>
<tr><td>Industry</td><td>12</td><td>8.4</td><td>5.3</td></tr>
<tr><td>Waste</td><td>5.5</td><td>2.9</td><td>0.4</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><td></td><td></td><td><table><tr><td>Other</td><td>6.3</td><td>N\A</td><td>N\A</td></tr></table></td></tr>
<tr><td>(c)</td><td>For strategies, plans and actions referred to in Article 4, paragraph 6, of the Paris Agreement, or polices and measures as components of nationally determined contributions where paragraph 1(b) above is not applicable, Parties to provide other relevant information;</td><td>Not applicable.</td></tr>
<tr><td>(d)</td><td>Target relative to the reference indicator, expressed numerically, for example in percentage or amount of reduction;</td><td>Israel will achieve an economy-wide net reduction in GHG emissions of 27% by 2030 relative to 2015 emission levels.
Israel will achieve an economy-wide net reduction in GHG emissions of 85% by 2050 relative to 2015 emission levels.

In addition, sectorial emissions reduction targets – relative to the annual amount measured in 2015 in each corresponding sector – have been approved:
<table>
<tr><td>Sector</td><td>2030</td><td>2050</td></tr>
<tr><td>Electricity generation</td><td>30%</td><td>85%</td></tr>
<tr><td>Transport</td><td>3.3% increase</td><td>96%</td></tr>
<tr><td>Industry</td><td>30%</td><td>56%</td></tr>
<tr><td>Waste</td><td>47%</td><td>92%</td></tr>
</table>
Israel has further committed to a complete phase out of coal-fired power generation by 2026, and to increase the share of renewable power generation to 20% in 2025 and 30% in 2030.</td></tr>
</table>

(e)	Information on sources of data used in quantifying the reference point(s);	Data used in quantifying the reference points will be based on the 2008-2030 Israeli GHG Inventory submitted to the UNFCCC in 2032.
(f)	Information on the circumstances under which the Party may update the values of the reference indicators.	Where necessary, the Israeli GHG inventory may be revised to incorporate methodological improvements, changes to international reporting guidelines and new data.
2.	**Time frames and/or periods for implementation:**	
(a)	Time frame and/or period for implementation, including start and end date, consistent with any further relevant decision adopted by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement (CMA);	NDC time frame: January 2021 - 31 December 2030 Long-term low-emission development strategy timeframe: January 2021 – 31 December 2050
(b)	Whether it is a single-year or multi-year target, as applicable.	Single-year target in 2030 and in 2050.
3.	**Scope and coverage:**	
(a)	General description of the target;	Israel's target is economy-wide to achieve a 27% reduction in net GHG emissions by 2030 relative to 2015, to a level of no more than 58 MtCO2e. In addition, Israel aims to achieve an 85% reduction in net GHG emissions by 2050, relative to 2015, to a level of no more than 12 MtCO2e. In order to achieve its economy-wide target, Israel has also approved sectorial targets for 2030 and 2050 (see above clause 1.d)

(b)	Sectors, gases, categories and pools covered by the nationally determined contribution, including, as applicable, consistent with Intergovernmental Panel on Climate Change (IPCC) guidelines;	**Sectors covered:** • Energy (Fuel combustion) in: energy industries (electricity generation), manufacturing industries, construction, transport, other sectors (residential, commercial, institutional, agriculture) • Industrial Processes • Agriculture • Waste and Wastewater • Land-use Change and Forestry **Greenhouse gases covered:** Carbon Dioxide (CO2), Methane (CH4), Nitrous Oxide (N2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), Sulphur Hexafluoride (SF6). **Categories covered:** Category 1.B. “Fugitive emissions from fuels” is currently not covered by Israel’s NDC. However, this category is to be included in Israel’s National GHG Inventory in the future (see below, section 3(c). Initial estimates are that fugitive emissions constitute between 0.1% to 0.8% of Israel’s total GHG emissions . LULUCF pools are negligible in Israel. The sectors, gases, categories and pools covered by Israel's NDC are based on the revised 1996 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories, the 2006 IPCC Guidelines for National GHG Inventories and the Global Warming Potential (GWP) values from the IPCC Second Assessment Report (1995).

(c)	How the Party has taken into consideration paragraph 31(c) and (d) of decision 1/CP.21;	Category 1.B. “Fugitive emissions from fuels” have not been included in past Israel’s Inventories but will be included in future inventories, starting with the report for the 2020 inventory year. Previous figures will be revised to include this category as well. Otherwise, all relevant categories of anthropogenic emissions or removals are included and will continue to be included.
(d)	Mitigation co-benefits resulting from Parties’ adaptation actions and/or economic diversification plans, including description of specific projects, measures and initiatives of Parties’ adaptation actions and/or economic diversification plans	Not applicable.
4.	**Planning process**	
(a)	Information on the planning processes that the Party undertook to prepare its nationally determined contribution and, if available, on the Party’s implementation plans, including, as appropriate:	**NDC update and Long-Term Low-Emission Development Strategy** In early 2019, in cooperation with the Israel Democracy Institute and the OECD, the Israeli government initiated a broad and collaborative multi-sector process for formulating Israel’s Long-Term Low-GHG Emission Development Strategy to transition to a prosperous and low-carbon economy by 2050. Five sectoral working groups (power generation, transport, industry, waste, and cities and buildings) were established, as well as a macroeconomic team and a social impacts team, consisting of a broad range of relevant stakeholders.
i.	Domestic institutional arrangements, public participation and engagement with local communities and indigenous peoples, in a gender-responsive manner;	A public consultation process was launched once the sectorial teams were established in the beginning of 2019. This consultation process enabled a wide participation of the public in the on-going work of the sectorial teams. It resulted in the integration of insights and comments by the public within the

		work of the sectorial teams, and ultimately it facilitated a more holistic and inclusive strategy for a low-carbon transition. **Inter-ministerial Steering Committee for GHG Emissions Reductions** The decision-making process going forward is supported by an Inter-ministerial Steering Committee for GHG Emissions Reductions, which consists of representatives from all relevant government ministries and other relevant stakeholders. The Steering Committee submits an annual report to the government evaluating the effectiveness of government measures to reduce emissions, the progress towards meeting national GHG emission reduction targets and supporting targets and recommends additional measures as needed. **Monitoring, Reporting and Verification of GHG emission reductions** In April 2016, the Israeli government set out in its National Greenhouse Gas Emissions Reduction Plan (Resolution 1403) the establishment of a national system for monitoring, reporting and verification, relating to the implementation of the program and national targets for reducing greenhouse gas emissions. To date, Israel monitors emission reduction on both a national and a policy level in accordance with the national Monitoring, Reporting and Verification (MRV) system. The MRV system was implemented in 2016 by the Ministry of Environmental Protection in cooperation with other government ministries and relevant statutory bodies. It operates on the basis of guiding principles of the UN Climate Convention and on the basis of methodologies developed in accordance with the characteristics of the Israeli economy. It is managed by the Ministry of Environmental Protection, on behalf of the Steering Committee.
ii.	Contextual matters, including, inter alia, as appropriate:	
a.	National circumstances, such as geography, climate, economy, sustainable development and poverty eradication;	National circumstances are described in detail in Israel's National Communication submitted in 2018 and additional information is detailed in the Biennial Update Report that will be submitted shortly.

		Sustainable development and poverty eradication: Israel is committed to the implementation of Agenda 2030 and the Sustainable Development Goals as detailed in its Voluntary National Review submitted to the UN in July 2019.
b.	Best practices and experience related to the preparation of the nationally determined contribution;	The establishment of sectorial working groups consisting of representatives of relevant ministries, local authorities, public representatives, NGOs, academia and others as described in section 4(a) above ensured broad public involvement and commitment, while the involvement of public policy think tanks and the OECD further contributed to the acceptability of the results. Within this context, establishing Israel's Long-Term Low-Emission Development Strategy further informed the process to revise Israel's 2030 NDC targets. (See above clause 4.a.)
c.	Other contextual aspirations and priorities acknowledged when joining the Paris Agreement;	Not applicable
(b)	Specific information applicable to Parties, including regional economic integration organizations and their member States, that have reached an agreement to act jointly under Article 4, paragraph 2, of the Paris Agreement, including the Parties that agreed to act jointly and the terms of the agreement, in accordance with Article 4, paragraphs 16–18, of the Paris Agreement;	Not applicable
(c)	How the Party's preparation of its nationally determined contribution has been informed by the outcomes of the global stocktake, in accordance with	Israel participated actively in the Talanoa Dialogues and looks forward to participating in the Global Stocktake in 2023.

	Article 4, paragraph 9, of the Paris Agreement;	
(d)	Each Party with a nationally determined contribution under Article 4 of the Paris Agreement that consists of adaptation action and/or economic diversification plans resulting in mitigation co-benefits consistent with Article 4, paragraph 7, of the Paris Agreement to submit information on:	
i.	How the economic and social consequences of response measures have been considered in developing the nationally determined contribution;	Not applicable
ii.	Specific projects, measures and activities to be implemented to contribute to mitigation co-benefits, including information on adaptation plans that also yield mitigation co-benefits, which may cover, but are not limited to, key sectors, such as energy, resources, water resources, coastal resources, human settlements and urban planning, agriculture and forestry; and economic diversification actions, which may cover, but are not limited to, sectors such as manufacturing and industry, energy and mining, transport and communication, construction, tourism, real estate, agriculture and fisheries	Not applicable
5	**Assumptions and methodological approaches, including those for estimating and accounting for anthropogenic greenhouse gas emissions and, as appropriate, removals:**	
(a)	Assumptions and methodological approaches used for accounting for anthropogenic greenhouse gas emissions and removals corresponding to the Party's nationally determined contribution, consistent with decision 1/CP.21,	In accordance with the modalities, procedures and guidelines outlined in Decisions 4/CMA.1 and 18/CMA.1 of the Paris Rulebook, Israel will publish and submit to the UNFCCC, an annual National Inventory Report and Biennial Transparency Report by 31 December 2024 at the latest, and biennially thereafter.

	paragraph 31, and accounting guidance adopted by the CMA;	The National Inventory Report will account for Israel anthropogenic GHG emissions and removals and the Biennial Transparency Report will report on progress towards the Israel's NDC. Israel will compare achieved net GHG emission reductions with its NDC target for 2030. Israel will comply with future UNFCCC reporting guidelines on tracking, and reporting on progress. For current IPCC methodologies and metrics used, see section 5(d). Final accounting towards the target will take place in 2032. It will be based on the 2008-2030 Israel GHG Inventory, by comparing 2030 net GHG emissions to the 2015 reference year.
(b)	Assumptions and methodological approaches used for accounting for the implementation of policies and measures or strategies in the nationally determined contribution;	For domestic MRV and UNFCCC reporting see section 4(a)(i) above. Israel has established a market-wide and sector specific GHG emissions modelling framework which enables to forecast emissions throughout to 2050 given different scenarios, abatement measures and assumptions. In addition, Israel has an MRV system which produces the following annual information and results: → Policy Measure Impacts: Within the MRV system framework, both achieved (ex-post) and expected (ex-ante) emission reductions are monitored for key policy measures. The expected reductions are calculated for each of the target years (2020, 2025 and 2030), for two levels of implementation: • Implementation of the policy measure to the extent that it has already approved (but not necessarily fully implemented) • Implementation in accordance with approved sectorial targets.

		→ Abatement Scenario Emissions: Abatement scenario emissions are forecasted for each of the target years and each of the abovementioned three levels of implementation. The MRV system facilitates the following: • Measurement of national progress towards achieving mitigation goals. • Measurement of the effectiveness of specific government GHG reduction policies and actions. • Revision and expansion of the policy actions to maximize the achieved economic and environmental benefits. • Fulfillment of reporting obligations to the UN on mitigation actions by Israel and their effects. • Transparency of information on Israel's progress towards its reduction goals The monitoring is conducted on the basis of approved government methodologies, which define the calculation methodology, the parameters to be monitored, and the requisite QA/ QC procedures. The methodologies also define the manner in which overlapping effects between different government measures are accounted for in order to avoid double counting. The current methodologies under approval within the MRV system framework are: ○ Monitoring fuel consumption and emission reductions in power generation ○ Monitoring energy efficiency and electricity consumption ○ Monitoring energy efficiency in buildings ○ Monitoring grant programs and support for energy efficiency and reduction of greenhouse gas emissions projects ○ Monitoring fuel consumption and emission reductions in the transport sector ○ Monitoring fuel consumption and emission reductions in industry and buildings sectors ○ Monitoring emissions reduction from the prevention of solid waste landfilling and emissions from the waste sector ○ Monitoring national targets for reduction of GHG emissions from fluorinated gases ○ Updating emission forecasts from agriculture, land use, wastewater and industrial process emissions

(c)	If applicable, information on how the Party will take into account existing methods and guidance under the Convention to account for anthropogenic emissions and removals, in accordance with Article 4, paragraph 14, of the Paris Agreement, as appropriate;	See section 5(d) below
(d)	IPCC methodologies and metrics used for estimating anthropogenic greenhouse gas emissions and removals;	**IPCC methodologies:** The revised 1996 IPCC Guidelines for National GHG Inventories were applied for the calculation of GHGs in all sectors, except agriculture and waste. Agriculture (category 4) is calculated according to the 2006 IPCC Guidelines for National GHG Inventories as of the 2011 Inventory year. Waste (category 6) was recalculated in 2012, for all inventory years according to the 2006 IPCC Guidelines. Additional Guidance: In addition to the IPCC Guidelines for National GHG Inventories, the 'Good Practice Guidance and Uncertainty Management in National GHG Inventories' guidelines were used for preparation of the inventories. Tier Levels : The tier level applied in the national GHG inventory varies from sector to sector due to the varying availability of data and information: • Module 1-Energy: In principle, Tier 1 was applied, with notable exceptions being the application of Tier 2 using information that is unique to Israel such as calorific values of primary energy sources (coal, natural gas, shale oil). Tier 3 was applied for emissions of SOx, NOx, and CO from vehicles, as well as emissions of SOx and NOx from electricity generation.

		• Module 2-Industrial Processes: In principle, Tier 1 was applied. For some sources emission factors specific to Israeli industry were used and therefore Tier 3 was applied. Regarding emissions of fluorinated gases, a methodology was adapted specifically to Israel and therefore Tier 3 was applied. • Module 3-Solvent and Other Product Use: There is no calculation of emissions from sources as such and therefore no tier level was applied yet. • Module 4- Agriculture: In principle, Tier 1 was applied, taking into account the specific processes in Israel’s agriculture sector and appropriate emission factors.For some sub sectors Tier 2 was applied. • Module 5- Land Use Change and Forestry: Israel uses the Tier 1 approach for estimating removals in forest land areas. There is no forest inventory in place as the forest land in Israel is negligible. However, data on forest land and on the mass of trees harvested do exist and are periodically updated. • Module 6- Waste: Tier 2 is applied to waste and Tier 1 to wastewater. **Metrics:** Global Warming Potential (GWP) values for a 100-year time horizon from the IPCC Second Assessment Report (1995).
(e)	Sector-, category- or activity-specific assumptions, methodologies and approaches consistent with IPCC guidance, as appropriate, including, as applicable:	
i.	Approach to addressing emissions and subsequent removals from natural disturbances on managed lands;	Not applicable
ii.	Approach used to account for emissions and removals from harvested wood products;	Not applicable
iii.	Approach used to address the effects of age-class structure in forests;	The effects of age-class structure are not currently taken into account in Israel's GHG Inventory.
(f)	Other assumptions and methodological approaches used for understanding the nationally determined contribution and, if applicable, estimating corresponding emissions and removals, including:	

i.	How the reference indicators, baseline(s) and/or reference level(s), including, where applicable, sector-, category- or activity-specific reference levels, are constructed, including, for example, key parameters, assumptions, definitions, methodologies, data sources and models used	Final reference year and target year emissions will be based on the 2015-2030 GHG Inventory to be submitted to the UNFCCC in 2032 for the 2030 target year. Emissions estimates in Israel's GHG Inventory are made using methodologies outlined in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories and subsequent IPCC guidelines (see section 5(d)). The Inventory is revised annually and undergoes extensive review processes.
ii.	For Parties with nationally determined contributions that contain non-greenhouse-gas components, information on assumptions and methodological approaches used in relation to those components, as applicable;	Not applicable
iii.	For climate forcers included in nationally determined contributions not covered by IPCC guidelines, information on how the climate forcers are estimated;	Not applicable
iv.	Further technical information, as necessary;	Not applicable
(g)	The intention to use voluntary cooperation under Article 6 of the Paris Agreement, if applicable.	Israel is planning to achieve its NDC mitigation objectives through domestic means but is following Article 6 negotiations so that this option remains open should it be relevant in the future.
6	**How the Party considers that its nationally determined contribution is fair and ambitious in the light of its national circumstances:**	
(a)	How the Party considers that its nationally determined contribution is fair and ambitious in the light of its national circumstances;	Taking into consideration its national circumstances, Israel believes its target to be fair and ambitious reflecting genuine efforts to move forward in a sustainable manner to facilitate the transition to a low-carbon and climate-resilient economy.

		Israel is a small and densely populated country characterized by an expanding population and economic growth, facing land and water scarcity. Arid zones comprise over 45% of the area of the country while there is an exceptionally high degree of biological diversity that must be protected. Electricity generation has been largely based on domestic and imported fossil fuels as Israel has no access to a number of widely used low-carbon sources of energy such as nuclear, hydro-electric and geothermal power. The country is an energy island, without grid interconnectivity. There is limited surface area available for large-scale energy installations. The few available areas are subject to competing uses such as industrial development and housing, bio-diversity preservation, habitat conservation, agriculture and defense. Electricity generation from renewable energy (mostly solar PV) amounted to 6.1% of the total electricity generation in 2020. For many years, there has been significant use of solar heaters for water heating and greenhouse gas emissions associated with water heating are substantially lower than the global average. An additional factor limiting Israel's abatement potential is its small share of heavy industry sector with relatively low emissions reduction potential. Israel attains extremely high levels of water reuse (85%). However, to meet increasing water demand several desalination plants have been constructed. These installations are comparatively energy efficient and currently account for 5% of energy consumption. Water scarcity may necessitate the construction of additional plants in the future.
(b)	Fairness considerations, including reflecting on equity;	See above, section 6(a)
(c)	How the Party has addressed Article 4, paragraph 3, of the Paris Agreement;	Israel’s first NDC formulated a per capita GHG emissions target that did not entail a reduction in absolute emissions .

		Considering the previous target set in 2015 and revised population growth forecasts, the expected annual GHG emissions in 2030 would have been around more than 85 MtCO2e. The current target of 58 MtCO2e is significantly more ambitious.
(d)	How the Party has addressed Article 4, paragraph 4, of the Paris Agreement;	Israel's NDC is an economy-wide absolute emissions reduction target in compliance with Article 4.4 of the Paris Agreement. Sectorial targets were defined as well in order to facilitate successful implementation of the economy-wide target. See above, section 1(d).
(e)	How the Party has addressed Article 4, paragraph 6, of the Paris Agreement.	Not applicable
7	**How the nationally determined contribution contributes towards achieving the objective of the Convention as set out in its Article 2:**	
(a)	How the nationally determined contribution contributes towards achieving the objective of the Convention as set out in its Article 2;	This NDC represents Israel's contribution to achieving the objective of Article 2 of the Convention and reflects Israel's highest ambition at this time to stabilize GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.
(b)	How the nationally determined contribution contributes towards Article 2, paragraph 1(a), and Article 4, paragraph 1, of the Paris Agreement.	Israel has outlined its specific circumstances (a growing population, limited land use area, and limitations on the forms of suitable renewable energies, among others). Through its multisectoral consultation process, Israel has determined a mid-century long-term low carbon strategy which was formalized and approved by the government. Thus, Israel aims to support the collective effort to reach global peaking of GHG emissions as soon as possible (which is expected to occur in Israel by mid-decade), as set out in Article 4.1 of the Paris Agreement.

נספח 14

העתק מן העבודות שבוצעו לטובת כימות מתאן

עמ' 560

נספח 14

מדינת ישראל
משרד האנרגיה

לשכת מדען ראשי

1/26/2021

תרומת פליטות לא מוקדיות של מתאן לאפקט החממה/ ד״ר עינת מגל

רקע:

העבודה מרכזת מידע ממקורות שונים לגבי הפליטות הלא מוקדיות (Fugitive emissions) של גז טבעי (המורכב בעיקר ממתאן), במטרה להעריך את התרומה של מקור זה בישראל לאפקט החממה. הפליטות הלא מוקדיות הללו, הינן הפסדים בלתי מכוונים של גז טבעי ממערכות הייצור, ההולכה וההובלה של הגז. הפסדים אלה, הגם שהם נמוכים יחסית יכולים להיות בעלי השפעה גדולה על אפקט החממה, לאור העובדה כי אפקט החימום הגלובאלי של המתאן באטמוספירה, גדול מזה של הפחמן הדו חמצני בעשרות מונים. ניתן להעריך מרכיב זה על ידי הערכה מדוקדקת של הפליטות הפוטנציאליות בכל מרכיב של מערכת הגז הטבעי, או על ידי שימוש במקדמי פליטת מתאן גלובאליים שמפרסם הפאנל הבין-ממשלתי לשינוי האקלים של האו״ם (IPCC). אולם, גם המדריכים של ה-IPCC מצהירים כי ישנה עדיפות גדולה לשימוש בערכים מחושבים מקומיים, על פני הערכים הגלובאליים. זאת, מאחר שהערכים הגלובאליים מבוססים על נתוני פליטות בינלאומיים, שהם תוצר של קשת רחבה של טכנולוגיות ייצור גז טבעי, ותשתיות המייצגות את הממוצע העולמי. להלן מובאים ערכי הפליטה על פי ההערכות לתשתיות בישראל יחד עם השוואה למקדמים הבינלאומיים.

הערכת הפליטות הלא מוקדיות של גז טבעי בישראל

שרשרת האספקה של גז טבעי כוללת את שלושה המקטעים: **הפקה ועיבוד** (production & processing), **הולכה ואחסון** (transmission & storage), **וחלוקה** (distribution), אשר לכל אחד מהם מקורות מידע שונים.

להלן פירוט היקף הפליטות הלא מוקדיות משלושת המקטעים בישראל:

1. ***מקטע ההפקה והעיבוד-*** נכון להיום, חברת נובל (שברון) הינה הגורם היחיד אשר מפיק ומטפל בגז טבעי בישראל. החברה מדווחת באופן סדיר למרשם הפליטות הלאומיות (המפל״ס) של המשרד להגנת הסביבה (https://www.gov.il/he/departments/publications/reports/full_data), ובשנת 2019 החברה דיווחה על פליטות בשיעור של 1.07 קילו טון מתאן.

   היקף פליטות המתאן ממקטע זה נבחן בהשוואה לעולם באיור 1, בו סוכמו נתונים שנאספו ממאגר המידע של האו״ם[1] וההשוואה נערכה בערכים של שווי ערך פחמן דו חמצני (פירוט לגבי

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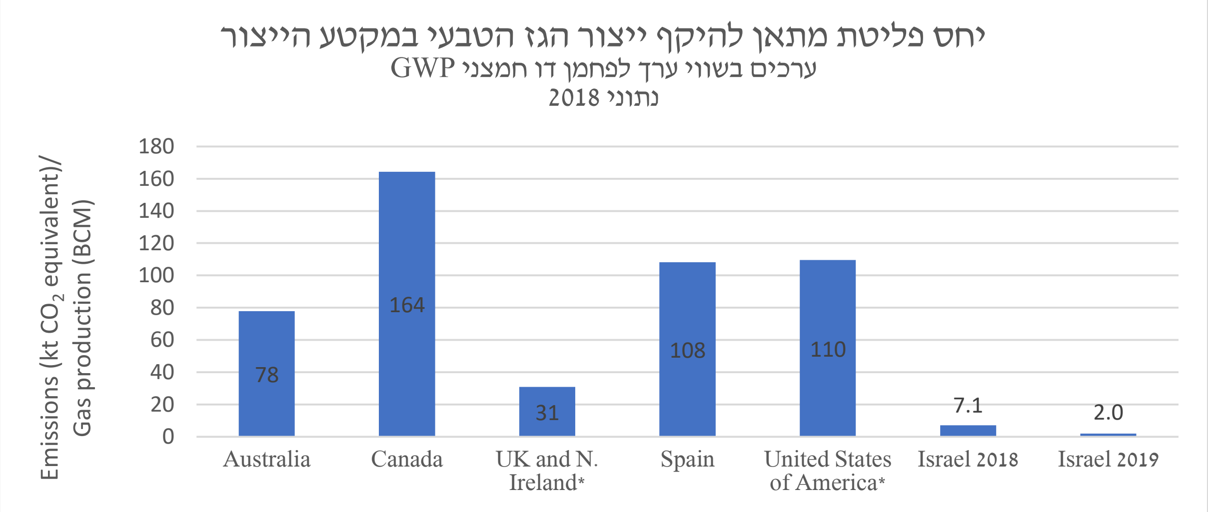
[1] https://di.unfccc.int/detailed_data_by_party

מקורות המידע ואופן החישוב ניתן בנספח 1 להלן). איור 1 מראה כי היקף הפליטות בישראל נמוך בצורה משמעותית בהשוואה לעולם. הדבר נובע משתי סיבות עיקריות. האחת, חלק גדול מן הגז הטבעי בארה״ב ובקנדה מיוצר בטכנולוגיה של שבירה הידראולית המביאה לפליטות מתאן משמעותית מאוד. השנייה, קשורה בכך שתעשיית הגז הטבעי בישראל צעירה מאוד ועל כן המערכות חדשות ונבנו בהתאם לתקינה סביבתית מודרנית ומחמירה, בעוד שבעולם קיימים קידוחים עתיקים מאוד, אשר בחלקם נוהגים לשחרר עודפי מתאן ישירות לאטמוספירה מבלי לשרוף אותם. חשוב לציין, כי היקף הפליטה הלא מוקדית של מתאן ממקטע זה עתיד לפחות עוד יותר, הודות לשדרוג שנערך במערכות הטיפול בגז הטבעי באסדת תמר במרץ 2019 ולא בא לידי ביטוי במלואו בנתוני 2019.



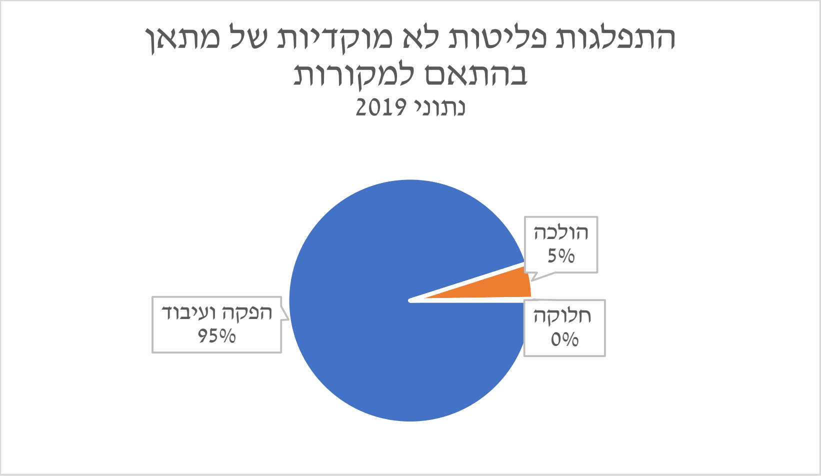
איור 1: *היקף הפליטות הלא מוקדיות של מתאן במקטע ההפקה והעיבוד במדינות שונות. הערכים מוצגים בשווי ערך פחמן דו חמצני ומנורמלים להיקף הייצור של הגז הטבעי המדינה. פירוט לגבי אופן החישוב ניתן בנספח 1 ו-2.*

2. **מקטע ההולכה**- חברת נתג״ז אשר מחזיקה במקטע ההולכה הגישה דוח שהוכן על ידי חברת Wood אשר העריך את פליטות המתאן בשנת 2019 ל- 77,575 מ״ק (פירוט נוסף ניתן בנספח 2, חלק ג'). ערך זה הינו שווה ערך ל-0.053 קילו טון מתאן (בהנחה שצפיפות הגז הטבעי של מאגר תמר עומדת על $6.9*10^{-4}$ Ton/m^3). נתונים אלה מתבססים על היקף הדליפות החזוי עבור פעולות התחזוקה השוטפות של החברה בהתאם לפרוטוקול התחזוקה השוטפת של מתקניה. מדובר בכמויות מזעריות בסדר גודל של אחד למיליון מכלל הגז הטבעי שהחברה מוליכה שלא ניתן למדוד אותם באופן ישיר. ערכים אלה נמוכים בשני סדרי גודל (חלקי 100), ביחס לאילו שהתקבלו בהתאם למקדמי פליטה גנריים/עולמיים (נספח 2 מתאר את החישוב). גם כאן ניתן ליחס את הפער לעובדה שהצנרת בישראל נבנתה לפני כעשור בלבד. לשם השוואה באותן השנים

בארה"ב נסללו רק 10% מצינורות הגז[2]. צנרת חדשה זו נבנתה בהתאם לתקנים סביבתיים מחמירים שאינם מאפשרים פליטות לא מוקדיות משמעותיות, ועל כן היקף הפליטות בישראל קטן מאוד בהשוואה למקדמים גלובאליים.

3. **מקטע החלוקה**- עיקר הגז הטבעי נצרך בישראל מרשת ההולכה, ורשת החלוקה בישראל סיפקה בשנת 2019 בסך הכל כ-0.57 BCM (רשת החלוקה ו-CNG). על פי הערכות משרד האנרגיה המפורטות בנספח 3, היקף הפליטות הלא מוקדיות ממקטע זה עומד על 1,560 מ"ק בשנה שהם 0.0011 קילו טון מתאן. גם במקטע זה שימוש במקדמים בינלאומיים מביא לקבלת ערך גבוה ולא ריאלי של 0.627 קילו טון מתאן (בהתבסס על מקדם של $1.1*10^{-3}$ giga gr/BCM, IPCC 2006, טבלה 4.2.4, סעיף gas distribution), שאינם מתאימים לישראל בה תשתית ההולכה קצרה וחדשה מאוד והרבה פחות מסועפת בהשוואה לעולם.

לסיכום- סך הפליטות הלא מוקדיות של מתאן ממערכות הגז הטבעי בישראל עמד על 1.12 קילו טון מתאן בלבד לשנת 2019. מדובר ב- 0.0016 מתוך 11.25 BCM שיוצרו בשנה זו, כלומר כ- 0.014% מכלל הגז הטבעי שיוצר בישראל באותה השנה. זאת, בניגוד לממוצע בקידוחי הגז הטבעי הימיים בארה"ב אשר הוערכה ע"י י. אראל[3] ב-0.5%. מקור הפליטה העיקרי בישראל, בדומה לעולם, הינו תהליך ההפקה והעיבוד של הגז הטבעי האחראי ל-95% מן הפליטות (איור 2), אולם ערך זה עתיד לרדת בשנת 2020 הודות לשיפורים באסדת תמר.



איור 2: התפלגות הפליטות הלא מוקדיות של מתאן ממערכת הגז הטבעי בשנת 2019

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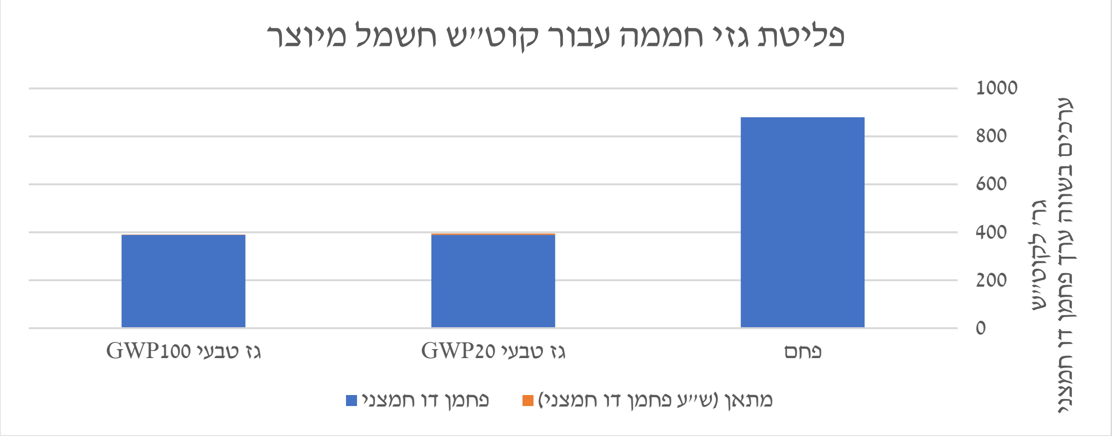
[2] https://www.bts.gov/content/us-oil-and-gas-pipeline-mileage

[3] השלכות פעילות חיפוש והפקה של נפט וגז טבעי בים על פליטות גזי חממה (מתאן) – התייחסות יוסף אראל, 2016, ראשונית

הערכת היקף פליטות גזי חממה בייצור חשמל מגז טבעי ופחם

היקף פליטות גזי החממה בייצור חשמל מגז טבעי ופחם הוערך בהתאם לשיטה של אראל 2016[4], בהתבסס על אובדן של 0.014% של המתאן לאורך כל שרשרת הייצור של הגז הטבעי. היקף פליטת הפחמן הדו חמצני בייצור חשמל הוערך ל-388 ו-879 גר׳ לקוט״ש בייצור מגז טבעי (מחז״ם) ופחם בהתאם לדוח הסביבתי של חברת החשמל לשנת 2019. כעת ניתן לתקן ערך זה ולהתחשב בכמות הפליטות הלא מוקדיות של המתאן לפני הגעתו לתחנת הכח. הדבר נעשה על ידי הגדלת הפליטת הפחמן דו חמצני לקוט״ש ב-0.014% שאבדו בדרך והכפלת ערך זה באפקט החממה של מתאן שהוא גבוה מזה של הפחמן הדו חמצני. החישוב נעשה פעמיים עבור מקדם חימום גבוה המייצג את האפקט על פני 20 שנה בשיעור של 86 ונמוך בשיעור של 25 עבור מקדם חימום נמוך המתאים לתקופת זמן של 100 שנה (GWP20 ו-GWP100, בהתאמה). תוספת גזי החממה שמקורם בפליטות לא מוקדיות של מתאן העלתה את היקף פליטות גזי החממה בייצור חשמל מגז טבעי בישראל בסך של 0.4% ו-1.2% בלבד (0.014% כפול 25 ו-86 בהתאמה). לשם השוואה, אראל העריך את פליטות המתאן הלא מוקדיות מקידוחים ימיים בארה״ב ב-0.5%. בהתאם לכך הוא הראה כי מרכיב זה העלה את היקף פליטת גזי החממה בייצור חשמל בארה״ב בשיעור של 11.5% ו-43%, בהתאם למקדם החימום הגלובאלי שנבחר. אולם עדיין מדובר בהפחתה משמעות מאוד. יוער כי מבחינה מתודולוגית ראוי לכלול גם בייצור חשמל מפחם את תרומת גזי החממה של פליטות מתאן לא מוקדיות מתהליך הכרייה. בשל החוסר בנתונים, מרכיב זה לא נכלל באיור 3, אבל בהתאם להערכות גלובאלית היקף הפליטות ממרכיב זה עומד על כ-40% בהשוואה לגז טבעי.

לסיכום, המעבר מייצור חשמל מפחם לגז טבעי הפחית את היקף פליטות הפחמן הדו חמצני בישראל בעשרות אחוזים, והתוספת של גזי החממה הנובעים מן הפליטות הלא מוקדיות של המתאן זניחה.



איור 3: פליטות גזי חממה פר קוט״ש מיוצר ע״י פחם וגז טבעי

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[4] יוסף אראל, 2016, השלכות פעילות חיפוש והפקה של נפט וגז טבעי בים על פליטות גזי חממה (מתאן) – התייחסות ראשונית

לסיכום:

- היקף הפליטות הלא מוקדיות של מתאן בישראל ממערכות הגז הטבעי בשנת 2019 עמד על 1.12 קילו טון מתאן בלבד. מדובר בפליטות נמוכות ביותר בשיעור של 0.014% מכלל ייצור הגז הטבעי בישראל. לשם השוואה בארה"ב היקף הפליטות הלא מוקדיות מקידוחי הגז הטבעי הימיים הוערך ב0.5%.
- עיקר הפליטות הן ממקטע הייצור, האחראי על רוב פליטות המתאן. מקטע זה עתיד לרדת מעט בשל השיפורים באסדת תמר אשר לא באו לידי ביטוי ברבעון הראשון של 2019.
- המעבר מייצור חשמל מפחם לגז טבעי הפחית בצורה משמעותית את היקף פליטות גזי החממה וההשפעה של הפליטות הלא מוקדיות של מתאן זניחה והינה בשיעור של פחות מחצי אחוז עד אחוז וקצת, בהתאם לבחירה במקדמי החימום הגלובאליים.

נספח 1: חישוב הפליטות הלא מוקדיות של מתאן ממקטע הייצור של הגז הטבעי

מקורות המידע:

1. נתוני הפליטות הלא מוקדיות במדינות שונות נלקחו מן האתר הרשמי של האו"ם https://di.unfccc.int/detailed_data_by_party
2. נתוני ייצור גז טבעי במדינות השונות נלקחו מן האתר https://yearbook.enerdata.net/
3. נתוני פליטות המתאן בישראל נלקחו מן המפל"ס עבור נובל אנרג'י מדיטרניאן בע"מ עבור אסדת מרי בי ואסדת תמר

אופן החישוב:

בישראל: היקף פליטות המתאן היה בשנת 2018 כ-3.5 קילו טון וב-2019 כ-1.07 קילו טון מתאן (אסדות מארי B, ותמר). בהתאם להנחיות של ה-IPCC הערכים המופיעים באתר של האו"ם בשווי ערך קילו-טון אקוויולנטי פחמן דו חמצני. הלמ"ס מחשב זאת עבור 100 שנה ועל כן מכפילים ב-21 והערך בטבלה הינו- בקירוב 74 ו-22 קילו טון אקויולנטי של פחמן דו חמצני לשנים 2018, 2019 בהתאמה.

לגבי מדינות העולם: נלקחו הערכים של פליטות המתאן עבור ייצור, טיפול, נישוב ושריפה בלפיד וכן ערכים נוספים שלא ניתן להם ציון ספציפי. החישוב נערך רק עבור מדינות אשר הנתונים באתר היו שלמים.

להלן טבלת החישוב:

Units	Category	Australia	Canada	UK&N. Ireland*	Spain	United States of America*	Israel 2018	Israel 2019
kt CO_2 equivalent	1.B.2.b.ii Production	5372	2312	IE	5	80942		
kt CO_2 equivalent	1.B.2.b.iii Processing	1277	290	60	0	12196		
kt CO_2 equivalent	1.B.2.b.vi Other	360	7333	0	0	1362		
kt CO_2 equivalent	1.B.2.c.i Venting	1725	20735	797	2	מידע חסר		
kt CO_2 equivalent	1.B.2.c.ii Flaring	432	557	415	1	מידע חסר		
kt CO_2 equivalent	Total	9167	31227	1271	8	94500	74	22.4
BCM	Gas Production	118	190	41	0	863	10	11.25
Ratio Methane emission/gas production		78	164	31	108	110	7	

הנתונים לגבי ארצות הברית גבוהים מאוד, בעיקר לאור העובדה שחסר מידע לגבי הנישוב והשריפה בלפידים. בספרד היקף ייצור הגז הטבעי קטן ועל כן יתכן שהערך לא מייצג ונובע משגיאה של חלוקת מספרים קטנים ולא מדויקים.

נספח 2: חישוב היקף הפליטה ממקטע ההובלה והאגירה ע״פ מקדמים גנריים בינלאומיים

החישוב נערך ע״י רואי עבודי מן הלמ״ס

2. א. חישוב לפי כמות גז של BCM 11.253 ע"פ המקדמים העולמיים של ה-IPCC

הערכים נלקחו מן המדריך IPCC 2006 table 4.2.4 page 4.49
(V2_4_Ch4_Fugitive_Emissions.pdf

1. בשתי השורות הראשונות בטבלה להלן מצוינים המקדמים העולמיים לחישוב פליטות בלתי מוקדיות בהתאם לנפח הגז המיוצר. קיימים שלושה מקדמים נמוך, גבוה ובינוני
2. בשתי השורות הבאות (4&3) מחושב הערך עבור נפח גז טבעי של BCM 11.3 (נתוני 2019)
3. השורה החמישית כוללת סיכום של הפליטות מנישוב ושריפה בלפיד

IPCC source	**Emissions source**	**EF- UNIT**	**EF - low**	**EF - high**	**EF - average or other**
1.B.2.b.iv	Fugitives	Gg per 10^6 m³ of marketable gas	6.60E-05	4.80E-04	2.73E-04
1.B.2.b.iv	Venting	Gg per 10^6 m³ of marketable gas	4.40E-05	3.20E-04	1.82E-04
	Fugitives	Gg(1000Ton)	0.74	5.40	3.07
	Venting	Gg(1000Ton)	0.50	3.60	2.05
	Total	Gg(1000Ton)	**1.24**	**9.00**	**5.12**

2. ב. חישוב לפי אורך הצנרת (הנחיות IPCC) (700 ק"מ)

הערכים נלקחו מן המדריך GPG 2000 table 2.1.6 page 4.49 (2_Energy GPG 2000.pdf)

1. בשתי השורות הראשונות בטבלה להלן מצוינים המקדמים העולמיים לחישוב פליטות בלתי מוקדיות בהתאם לאורך צנרת ההולכה. קיימים שלושה מקדמים נמוך, גבוה ובינוני
1. בשתי השורות הבאות (4&3) מחושב הערך עבור צנרת הולכה של 700 ק״מ
2. השורה החמישית כוללת סיכום של הפליטות מנישוב ושריפה בלפיד

IPCC source	**Emissions source**	**EF- UNIT**	**EF - low**	**EF - high**	**EF - average or other**
1.B.2.b.iv	Fugitives	Gg per year and per km of transmission pipeline	2.10E-03	2.90E-03	2.50E-03
1.B.2.b.iv	Venting	Gg per year and per km of transmission pipeline	8.00E-04	1.20E-03	1.00E-03
	Fugitives	Gg(1000Ton)	1.47	2.03	1.75
	Venting	Gg(1000Ton)	0.56	0.84	0.70
	Total	Gg(1000Ton)	**2.03**	**2.87**	**2.45**

2.ג. נתוני חברת נתג"ז

הדו״ח של חברת Wood שהגישה נתג״ז כולל הערכה של הפליטות הלא מוקדיות בהתבסס על סכימה של פליטות הגז הטבעי הצפויות בכל הפעולות הנדרשות על פי לפרוטוקול התחזוקה של מתקני הPRMS, בבדיקת הצינורות (in line inspections), בדיקות קבלה למתקני PRMS וצינורות חדשים (Commissioning activities associated with new gas pipeline and PRMS's), ודליפות נוספות מתהליכי תחזוקה של המערכות. הטבלה להלן מפרטת את הפליטות בכל אחד ממרכיבי התחזוקה הנ״ל. ניתן לראות כי התחזוקה השוטפת של מתקני PRMS היא הגורם הגדול ביותר לפליטות מתאן, ואחריו פעולות הקבלה של מתקנים חדשים.

טבלת פליטות מתאן מפעולות התחזוקה במתקני נתג״ז

-	Planned PRMS Maintenance.	**40,794 m^3**
-	Pipeline Inspections	**3,320 m^3**
-	Commissioning activities	**21,389 m^3**
-	Spurious Gas Emissions	**11,357 m^3**
	Total Annual Release =	**77,575m^3**

היקף הפליטות הלא מוקדיות עומד על 77575 מ״ק בשנת 2019. בהנחה שמדובר ב-100% מתאן שצפיפותו $6.84*10^{-4}$ טון למ״ק מקבלים דליפות מתאן לא מוקדיות בשיעור של 53 טון שהם 0.053 אלפי טון מתאן ביחידות בטבלאות מעלה

נספח 3: היקף הפליטה הלא מוקדיות של מתאן ממקטע החלוקה בישראל

מערכת החלוקה נכון לסוף שנת 2020 מורכבת מ-125 תחנות ו-12 תחנות הפחתת לחץ אזוריות (PRMS). היקף הפליטות הלא מוקדיות של הגז הטבעי ממקטע זה מבוסס על ההנחה כי לא קיימות דליפות מהותיות מקווי הגז במערכת החלוקה בשיגרה וכי הגז נפלט במסגרת פעולות תפעול בתחנות ובפעולות הגזה של הקווים כדליפות חד פעמיות.

א. פירוט הדליפות מן התחנות

ההערכה היא כי בכל פעולת תחזוקה בתחנות נפלט רבע מנפח התחנה ובתחנות הPRMS האזוריות פעולות התחזוקה נעשות בשני לחצי עבודה שונים ובסך הכל נפלט פי 3.75 מנפח התחנה.

להלן פירוט של נפח התחנות באזורי החלוקה השונים, מספר אירועי התחזוקה וסך הפליטות הלא מוקדיות

אזור חלוקה	נפח גז טבעי בתחנה (ליטר)	מספר תחנות	החלק היחסי של פליטות גז טבעי מן התחנה	היקף פליטות פר אירוע תחזוקה		מספר אירועי תחזוקה בשנה	סה״כ פליטות בשנה
				ליטר	מ״ק בתנאים סטנדרטיים		מ״ק בתנאים סטנדרטיים
א׳	40	59	0.25	590	0.59	1	0.59
א׳	70	23	0.25	403	0.40	2	0.81
PRMS כללי	3200	12	3.75	144,000	144.00	2	288.00
ב, ג	300	18	3.75	20,250	20.25	1	20.25
ד׳	300	13	0.25	975	0.98	1	0.98
סה״כ					166.22		310.62

ב. פירוט פליטות בפעולות הגזה

פליטות הגז הטבעי חושבו עבור קו מוגז ומנושב שקוטר הצינור הממוצע שלו ”2, הלחץ כ-7 בר, מהירות זרימה ממוצעת 10 מטר לשנייה, ומכאן הספיקה השעתית כ -500 מ״ק לשעה.

החישוב נערך עבור 10 אירועי הגזה בשנה, בהנחה שהזמן שלוקח למתאן להגיע לריכוז של 100% בצינור עומד על 15 דקות ובכל הזמן הזה נפלט גז טבעי. מדובר בהנחה מחמירה מאוד, מאחר שבפועל מטרת תהליך הנישוב וההגזה להגיע בסופו של דבר ל100% מתאן.
חישוב : 0.25 שעה* 500 מ״ק לשעה* 10 אירועי הגזה ונישוב בשנה= סה״כ 1250 מ״ק

ג. סה״כ פליטות שנתיות לשנת 2020 חד פעמיות וקבועות עומדות על כן על 1,560 מ״ק בתנאים סטנדרטים (1250+310 מ״ק בתנאים סטנדרטיים)

כימות פליטות מתאן משרשרת ההפקה והאספקה של גז מחצבים בישראל

ספטמבר 2022

הוכן על ידי :

עידן טננבאום ואילן אוחיון - חברת DHVMED, ד״ר רותי קירו - המשרד להגנת הסביבה

סיוע בהכנת הדו״ח:

ד״ר גיל פרואקטור, אלון סטמלר, אורי שלהב, שולי נזר, גיא לסט, ד״ר צור גלין - המשרד להגנת הסביבה

תוכן עניינים

קיצורים

AOT – Ashdod Onshore Terminal

API - American Petroleum Institute

BCM – Billion Cubic Meter

BOEM - Bureau of Ocean Energy Management

CNG - Compressed Natural Gas

EPA - Environmental Protection Agency

GWP - Global Warming Potential

IPCC - Intergovernmental Panel on Climate Change

LDAR – Leak Detection and Repair

LNG - Liquefied Natural Gas

OGI – Optical Gas Imaging

PRMS - Pressure Reduction and Metering Station

PRV – Pressure Release Valve

PSI - Pounds per Square Inch

1 תקציר

גז החממה מתאן הוא המרכיב העיקרי בגז המחצבים ונפלט לאטמוספירה באופן מוקדי ולא מוקדי לאורך תהליך הפקת הגז מהבאר עד צרכן הקצה. בדו״ח האחרון של הפאנל הבין ממשלתי לשינוי אקלים - ה IPCC, צוין כי מתאן לבדו, אשר הוא בעל פוטנציאל התחממות גלובלית גבוה מאוד, אחראי להתחממות של כ- 0.5 C°, בהשוואה לפחמן דו-חמצני האחראי לעלייה של כ- 0.8 C°, וכי נדרשת הפחתה מהירה בפליטות המתאן בכדי לעכב את קצב ההתחממות הגלובלית. לפיכך, קיימת חשיבות רבה בצמצום השימוש בגז והימנעות מהקמת תשתיות גז חדשות והרחבתן. פיתוח גז ותשתיותיו הנלוות מסכן ומייקר את יכולת המשק ליישם את היעדים למעבר לכלכלה דלת פחמן, בהתאם להצהרת ראש הממשלה בנובמבר 2021 ובהתאם לנתיב שמדינות העולם המפותחות פועלות להגיע לאיפוס נטו של פליטות בשנת 2050.

עבודה להערכת פליטות מתאן ממשק הגז בישראל בוצעה בעבר עבור המשרד להגנת הסביבה על ידי מוסד שמואל נאמן. מהעבודה עולה כי ישנה שונות גדולה באומדנים של פליטת מתאן ממערכות גז בעולם, וזו נאמדת במרבית המדינות בטווח שבין 0.5% ל-3% מכמות הגז המופקת. מטרת עבודה זו היא לדייק את כימות הפליטות השנתיות של מתאן מכלל שרשרת ההפקה והאספקה של גז מחצבים במדינת ישראל (באר - צרכן קצה) ופעולות נדרשות לשיפור כימות הפליטות, ע״י בחינת הגישות הנהוגות במצאי פליטות גזי חממה לאומיים של מדינות מובילות אחרות ובחירת מתודולוגיה לביצועה.

בהתאם לכך, כימות הפליטות מכל מקטע לאורך שרשרת ההפקה (מהבאר עד צרכן הקצה) בוצע בהתאם למתודולוגיה המפורטת במדריך של הפאנל הבין-ממשלתי לשינויי אקלים (IPCC), בדומה למדינות רבות. כאשר על פי מדריך ככלל ויש ממצאי ניטור ודיגום, העדיפות לכימות פליטות ניתנה להערכות חישוב פרטניות מאתרים ספציפיים כעדיפות ראשונה, שנייה שימוש במקדמי פליטה המותאמים ספציפית למדינה, ביתר המקרים שימוש במקדמי ברירת מחדל. בהסתמך על מתודולוגיה זו כימות הפליטות שבוצע בעבודה זו מסך המקטעים השונים עבור שנת 2020 בישראל, מוערך ב- 8,863 טון מתאן, כ- 0.3% מסך פליטות גזי החממה CO_2eq.

2 רקע

מתאן הוא גז חממה חשוב ובעל פוטנציאל גבוה להתחממות גלובלית (GWP) ומקדם ההתחממות שלו לאופק של 100 שנה הוא 29.8 ולאופק של 20 שנה הוא 82[1], לעומת פחמן דו חמצני שמקדם ההתחממות הגלובלית שלו הוא 1.

מתאן מהווה את המרכיב העיקרי בגז מחצבים, נפלט לאטמוספירה מכלל שרשרת ההפקה והאספקה של גז מחצבים, לרבות באופן לא-מוקדי כתוצאה מדליפות, נישובים ושריפה בלפידים במתקנים המשמשים להפקתו ולאספקתו לצרכני הקצה. בשנים האחרונות התפרסמו ידיעות ומאמרים רבים על כך שפליטות אלה הן למעשה גבוהות יותר מההערכות[2][3][4][5].

בדו״ח האחרון של הפאנל הבין-ממשלתי לשינויי אקלים (IPCC AR6)[6] צוין כי גז מתאן לבדו אחראי להתחממות של כ- 0.5 C° (בהשוואה לפחמן דו-חמצני האחראי לעלייה של כ- 0.8 C°) וכי נדרשת הפחתה מהירה בפליטות המתאן בכדי לעכב את קצב ההתחממות הגלובלית.

המשרד להגנת הסביבה, בהתאם למדיניות העולמית, רואה חשיבות רבה בצמצום השימוש בגז והימנעות מהקמת תשתיות גז חדשות כחלק מהמאמץ האסטרטגי אשר מוביל המשרד למעבר לישראל דלת פחמן ומשגשגת. הקמה והרחבה של תשתיות פוסיליות כחלק מפיתוח משק הגז מסכנת ומייקרת את יכולת המשק ליישם את היעדים למעבר לכלכלה דלת פחמן. זאת בנוסף לפעולות הרגולטוריות שהמשרד מיישם לצמצום והפחתה בפליטות ובזיהום ממערך הגז.

עבודה להערכת פליטות מתאן ממשק הגז בישראל בוצעה עבור המשרד להגנת הסביבה על ידי מוסד שמואל נאמן בשנת 2016[7]. מהעבודה עולה כי ישנה שונות גדולה באומדנים של פליטת מתאן ממערכות גז בעולם, וזו נאמדת במרבית המדינות בטווח שבין 0.5% ל-3% מכמות הגז המופקת.

השונות הרבה בהערכות נובעת, בין השאר, ממאפיינים שונים של מערכי ההפקה והשינוע של גז במדינות שונות, לדוגמא, אורך צנרת, לחצי עבודה, עומק הבארות, טכנולוגיות ורגולציה להפחתת

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[1] Intergovernmental Panel on Climate Change (IPCC) 2021, The Physical Science Basis, Working Group I Contribution to the Sixth Assessment Report: https://www.ipcc.ch/report/ar6/wg1/#FullReport

[2] https://science.sciencemag.org/content/361/6398/186.full

[3] https://www.pnas.org/content/109/17/6435#ref-1

[4] https://www.nytimes.com/2019/12/16/climate/methane-leak-satellite.html?auth=login-google

[5] https://www.nature.com/articles/d41586-018-05517-y#ref-CR1

[6] Intergovernmental Panel on Climate Change (IPCC) 2021, The Physical Science Basis, Working Group I Contribution to the Sixth Assessment Report: https://www.ipcc.ch/report/ar6/wg1/#FullReport

[7] מוסד שמואל נאמן למחקר מדיניות לאומית, מאי 2016 - פליטות מתאן ממגזר הנפט והגז הטבעי ושיטות מיטביות לכימות:
https://www.neaman.org.il/Files/Global%20Estimates%20Of%20Methane%20Emissions%20from%20Off-Shore%20Drilling%20Plants%20and%20Their%20Importance_20171122175809.456.pdf

הפליטות מאסדות ההפקה והטיפול והזמן שחלף מאז שהונחו התשתיות. לישראל מאפיינים שונים אשר משפיעים על אומדן הפליטות, לדוגמא הצנרת בישראל צעירה יחסית וקצרה לעומת תשתיות גז בים הצפוני או במפרץ מקסיקו.

בנוסף, מדריך ה-IPCC עודכן וכן באסדות הגז לוויתן ותמר בוצעו מדידות. מטרת העבודה הנוכחית היא להעריך באופן מדויק יותר את היקף הפליטות לאוויר של גז החממה מתאן לכל אורך שרשרת ההפקה והאספקה של גז מחצבים בישראל, ולהציג פעולות לשיפור הערכת הפליטות מהמקטעים השונים.

העבודה מתבססת על המדריך העדכני ביותר של IPCC משנת 2019 (שפורסם לאחר העבודה הקודמת), ובוחנת את הגישות הנהוגות במצאי פליטות גזי חממה לאומיים של מדינות מובילות אחרות. כמו כן, עבודה זו מתייחסת ומציגה אומדן פליטות ממקטעים ותתי-מקטעים נוספים בשרשרת כגון בארות נטושות, בארות פעילות ימיות וצנרת הולכה ימית, אחסון וייבוא LNG וצרכני קצה. העבודה מתבססת גם על מידע קיים עבור פליטות ממקטעי שרשרת ההפקה (אסדות הגז) המדווח במסגרת דוחות שנתיים ודיווחי מפל״ס אשר נבדק ומאושר ע״י המשרד להגנת הסביבה, המאפשר, בהתאם להמלצות העבודה הקודמת, לדייק את כימות הפליטות ממקטע זה.

3 מטרות

א. כימות הפליטות השנתיות של מתאן מכלל שרשרת ההפקה והאספקה של גז מחצבים במדינת ישראל (באר – צרכן קצה),

ב. פעולות לשיפור כימות הפליטות בישראל.

4 מתודולוגיה

לצורך קביעת שיטת ביצוע כימות פליטות המתאן מכלל שרשרת ההפקה והאספקה, בוצעה סקירה של שיטות כימות פליטות מקובלות, בהן נעשה שימוש בגופים ובמדינות שונות בעולם. לאור הסקירה, כפי שיפורט בעבודה, מצאנו כי השיטה המתאימה לביצוע כימות פליטות מתאן היא

בהתאם להנחיות הפאנל הבין-ממשלתי לשינוי אקלים IPCC אשר פרסם שורה של הנחיות לפיתוח מצאי פליטות עבור מדינות הכוללות שיטות חישוב מיטביות. המתודולוגיה של ה- IPCC כוללת: **(א)** חישוב לפי רמות (Tiers) דיוק שונות, כאשר העדיפות הגבוהה ביותר ניתנה להערכות חישוב פרטניות מאתרים ספציפיים, עבורם קיימים ממצאי ניטור בפועל (מדידות) - Tier 3, כעדיפות שנייה יישום Tier 2 הכוללת שימוש במקדמי פליטה המותאמים ספציפית למדינה. במקרים בהם אין הערכות חישוב פרטניות או שההערכות הפרטניות אינן שלמות ואינן מגובות בממצאי ניטור בפועל, נעשה שימוש במקדמי Tier 1 (הרמה הפשוטה ביותר) הכוללת שימוש במקדמי ברירת מחדל אוניברסליות לחישוב הפליטות עבור כל מקטע ותת-מקטע. **(ב)** חלוקה לפי מקטעי הפקה ואספקת הגז.

4.1 סקירת המדריך לכימות פליטות מהפאנל הבין-ממשלתי לשינויי אקלים (IPCC)

בוצעה בחינה של מתודולוגית כימות הפליטות במדריך העדכני ביותר של הפאנל הבין-ממשלתי לשינויי אקלים (IPCC), אשר המדריך של סוכנות הסביבה האירופית (EEA)[8], מפנה אליו לצורך הערכת פליטות מתאן. בשנת 2019 פורסם ע"י IPCC מדריך עדכני להכנת מצאי פליטות גזי חממה לאומיים (עדכון למדריך הקודם שפורסם בשנת 2006)[9]. כרך 2 במדריך עוסק במגזר האנרגיה, ובתוכו פרק 4 עוסק בפליטות לא-מוקדיות (Fugitive Emissions) ממגזר זה, לרבות ממערכות נפט וגז מחצבים.

המונח פליטות לא-מוקדיות במדריך כולל את כל הפליטות הנובעות מנישובים, מדליפות ומשריפת גז בלפיד, אך לא כולל פליטות משריפת דלקים (אלה מדווחות בקטגוריה נפרדת).

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[8] EEA report No 13/2019, EMEP/EEA Air Pollutant Emission Inventory Guidebook 2019, Technical guidance to prepare national emission inventories: https://www.eea.europa.eu/publications/emep-eea-guidebook-2019

[9] 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2 Energy, Chapter 4 – Fugitive Emissions: https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/2_Volume2/19R_V2_4_Ch04_Fugitive_Emissions.pdf

4.1.1 <u>מיפוי ואפיון מקורות הפליטה</u>

מיפוי ואפיון מקורות הפליטה הפוטנציאליים של מתאן לאוויר בכל מקטע ומקטע בוצעו בהתבסס על הפירוט במדריך של IPCC ובמצאי פליטות גזי החממה הלאומיים של המדינות האחרות שנסקרו. הטכנולוגיות והאמצעים השונים הקיימים בתעשיית הגז והנפט, ובהתאם לכך גם הפליטות, עשויות להשתנות מאוד בין מדינות שונות ולאורך זמן.

כאמור, המונח פליטות לא-מוקדיות במדריך IPCC כולל את כל הפליטות הנובעות מנישובים, מדליפות ומשריפה בלפיד, אך איננו כולל פליטות משריפת דלקים (אלה מדווחות בקטגוריה נפרדת):

נישובים (Venting) כוללים את כל השחרורים המכוונים של זרמי גז שונים לאטמוספירה (ללא שריפה או טיפול), לרבות פורקי לחץ ושחרור בזמן חירום. שחרורים אלה עשויים להתבצע באופן רציף או לא רציף;

שריפה בלפיד (Flaring) משמעה כל הבערה של גז ופחמימנים באמצעות לפיד או מתקן שריפה במטרה לסלקם, ולא למטרת ייצור של חום או אנרגיה מועילים. ההחלטה האם לנשב או לשרוף בלפיד תלויה בתכולת האנרגיה בזרם הגז המסולק ובתנאים הספציפיים באתר (למשל סוגיות הנוגעות לציבור, לסביבה ולבטיחות, ובדרישות הרגולציה);

דליפות (Leaking) מתרחשות בכל המקטעים של מערכות גז והן כוללות פליטות לא מכוונות (כלומר – שאינן כתוצאה מנישובים או משריפה בלפיד) מרכיבי ציוד כגון מדחסים, מגופים, מחברים אוגנים וכיוב'.

4.2 סקירת מצאי פליטות גזי חממה לאומיים של מדינות אחרות

סקירת שיטת כימות פליטות מתאן במדינות מפותחות אחרות, בהן תעשיית גז ונפט ענפה, לרבות אופן הערכת פליטות בכל מקטע משרשרת אספקת הגז. המדינות שנבחנו הן:

- מצאי פליטות גזי החממה של ארה"ב[10];
- מצאי פליטות גזי החממה של אוסטרליה[11];

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[10] USEPA, April 2021 - Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2019

[11] Australian Government, Department of Industry, Science, Energy and Resources, April 2021 – National Inventory Report 2019, The Australian Government Submission to the United Nations Framework Convention on Climate Change, Australian National Greenhouse Accounts: https://unfccc.int/documents/273478

- מצאי פליטות גזי החממה של בריטניה[12];
- מצאי פליטות גזי החממה של נורבגיה[13].

כל דוחות המצאי של המדינות הנ״ל פורסמו בחודש אפריל 2021 עבור השנים 1990-2019.

4.3 בחירת מתודולוגית ה- IPCC

המתודולוגיה של ה- IPCC כוללת:

4.3.1 חישוב לפי רמות (Tiers)

שיטות החישוב במדריך מחולקות ל- 3 רמות (Tiers) שונות של חישוב, כאשר ניתן ורצוי ליישם רמות חישוב שונות בעבור מקטעים ותתי-מקטעים שונים, ויתרה מכך, אף לכלול מדידות או תוצאות ניטור אמיתיות למקורות הפליטה המשמעותיים:

רמת Tier 1 היא הרמה הפשוטה ביותר והיא כוללת שימוש במקדמי ברירת מחדל לחישוב הפליטות עבור כל מקטע ותת-מקטע. לפי התיעדוף המפורט בהמשך, יש להשתמש בה אך ורק כמוצא אחרון למקרה שהמקטע אינו משמעותי, ורק אם המידע הנדרש לרמות החישוב הגבוהות יותר איננו זמין. רמת חישוב זו נתונה לאי דיוקים משמעותיים, והיא עלולה להוביל להערכות שגויות בסדר גודל אחד או יותר (למעלה ולמטה). לפחות אחד ממקדמי הפליטה בכל מקטע מתייחס לתפוקת הגז מכיוון שבחלק מהמדינות היא הנתון הסטטיסטי היחידי הזמין, אך יחד עם זאת, פליטות לא-מוקדיות עשויות להיות תלויות יותר בגורמים אחרים. בחלק מהמקטעים נתונים מספר מקדמי פליטה שונים כתלות בטכנולוגיה או באמצעים כאלה ואחרים, ולכן יש לבחון אילו מהם המתאימים ביותר לשימוש, ואף לשקול מקורות נוספים או שימוש חלקי בהם אם הם צפויים להשתנות משמעותית מהתנאים המתקיימים במדינה.

רמת Tier 2 כוללת שימוש במקדמי פליטה המותאמים ספציפית למדינה במקום שימוש במקדמי ברירת המחדל. יש להשתמש ברמת חישוב זו למקטעים משמעותיים כאשר לא ישים להשתמש

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[12] Peter Brown, Ricardo Energy & Environment, April 2021 - UK Greenhouse Gas Inventory, 1990 to 2019: Annual Report for Submission under the Framework Convention on Climate Change: https://uk-air.defra.gov.uk/assets/documents/reports/cat09/2105061125_ukghgi-90-19_Main_Issue_1.pdf

[13] Norwegian Environment Agency, April 2021 - Greenhouse Gas Emissions 1990-2019: National Inventory Report: https://www.miljodirektoratet.no/sharepoint/downloaditem?id=01FM3LD2QQ6HHS3WHQUJFISEZTTULJ47WJ

ברמת Tier 3. את ערכי מקדמי הפליטה המותאמים ספציפית למדינה מסוימת ניתן לפתח בהתבסס על מחקרים ומדידות, או באמצעות גזירה לאחור לאחר יישום רמת החישוב Tier 3.

רמת Tier 3 כוללת הערכה מדוקדקת של כלל מקורות הפליטה ברמת המתקן או האתר הספציפי. יש ליישם רמת חישוב זו לקטגוריות הפליטה המשמעותיות (key categories) כאשר המידע הנדרש על הפעילות והתשתיות זמינים או כאשר סביר להשיגם.

הערכות פליטות המבוססות על דיווחים של חברות גז ונפט נחשבות לרמות- Tier 2 או Tier 3, כתלות בגישה שננקטה על ידן בפועל, אך בכל מקרה יש לוודא שאין הערכות חסר או יתר בפליטות.

המדריך לא מפרט מקדמי פליטה עבור רמות חישוב Tier 2-3 מכיוון שמדובר במידע רב, ומכיוון שהמידע עובר עדכונים רצופים כך שיכלול תוצאות מדידה נוספות וכדי שישקף הטמעה של טכנולוגיות בקרה חדשות ודרישות רגולטוריות חדשות. עבור רמות חישוב אלה מפנה המדריך למקורות אחרים, כגון:

(1) מאגר מידע מקוון ומתעדכן של מקדמי פליטה (EFDB)[14]. מאגר זה משמש כספרייה מוכרת שבה משתמשים יכולים למצוא מקדמי פליטה ופרמטרים אחרים עם תיעוד רקע או הפניות טכניות שניתן להשתמש בהם להערכת פליטת גזי חממה;

(2) מסמך של מכון הנפט האמריקאי (API) משנת 2009 המקבץ מגוון רחב של שיטות לחישוב פליטות גזי חממה לתעשיית הנפט והגז[15] (בחודש נובמבר 2021 פורסמה ע״י API מהדורה עדכנית יותר של המסמך[16]) - ניכר כי רבים ממקדמי הפליטה של API משמשים במצאי פליטות גזי החממה של ארה״ב;

(3) מסמך הנחיות של מספר התאחדויות של תעשיית הנפט והגז משנת 2011 - שבו עקרונות לחישוב פליטות גזי חממה[17].

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[14] https://www.ipcc-nggip.iges.or.jp/EFDB/main.php

[15] American Petroleum Institute, August 2009 - Compendium of Greenhouse Gas Emissions Methodologies for the Oil and Natural Gas Industry: https://www.api.org/~/media/files/ehs/climate-change/2009_ghg_compendium.ashx

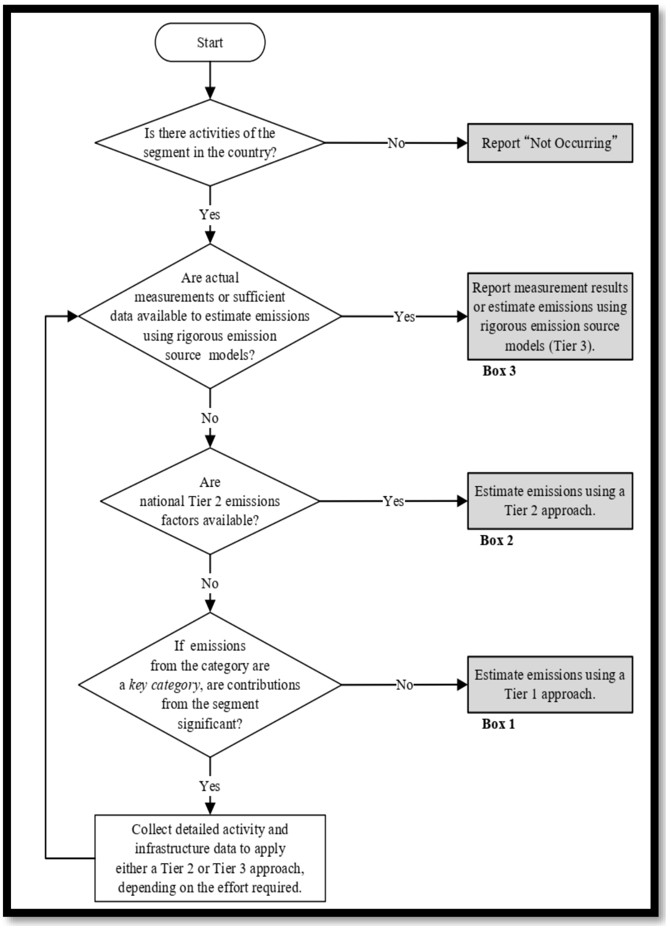
[16] American Petroleum Institute, November 2021 - Compendium of Greenhouse Gas Emissions Methodologies for the Natural Gas and Oil Industry: https://www.api.org/~/media/Files/Policy/ESG/GHG/2021-API-GHG-Compendium-110921.pdf

[17] International Petroleum Industry Environmental Conservation Association (IPIECA), American Petroleum Institute (API) & and International Association of Oil and Gas Producers (OGP), 2011 - Petroleum industry guidelines for reporting greenhouse gas emissions: https://www.api.org/~/media/Files/EHS/climate-change/GHG_industry-guidelines-IPIECA.pdf

4.3.2 תיעדוף רמות החישוב:

העיקרון הבסיסי לתיעדוף בין רמות החישוב השונות, מוצג איור 1 ומפורט להלן:

איור 1: קבלת החלטות על פי ה- IPCC בתיעדוף רמות החישוב[18]



- יש לבדוק האם המידע המפורט הנדרש ליישום Tier 3 זמין, אם כן, יש ליישם את Tier 3 (ללא קשר האם מדובר ב- key category והמקטע הוא משמעותי). אם המידע אינו זמין-
- יש לבדוק האם המידע המפורט הנדרש ליישום Tier 2 זמין, אם כן , יש ליישם את Tier 2. אם המידע אינו זמין-
- יש לבדוק האם מדובר ב- key category והמקטע הוא משמעותי, אם כן , יש לחזור אחורה ולאסוף את המידע הנדרש ליישום של Tier 3 או Tier 2. אם המקטע אינו משמעותי, כלומר הפליטות ממנו נחשבות כזניחות-
- יש ליישם את Tier 1.

בהתאם למתודולוגית ה- IPCC להערכה וכימות פליטות של גז מתאן מהמקטעים השונים, הבחירה בין רמות החישוב בכימות פליטות המתאן של ישראל בוצעה בהתאם לתיעדוף המפורט לעיל, קרי - העדיפות הגבוהה ביותר ניתנה להערכות חישוב פרטניות מאתרים ספציפיים, המגובות גם בממצאי ניטור בפועל (Tier 3); כעדיפות שנייה יישום Tier 2 אם רלוונטי; במקרים בהם אין

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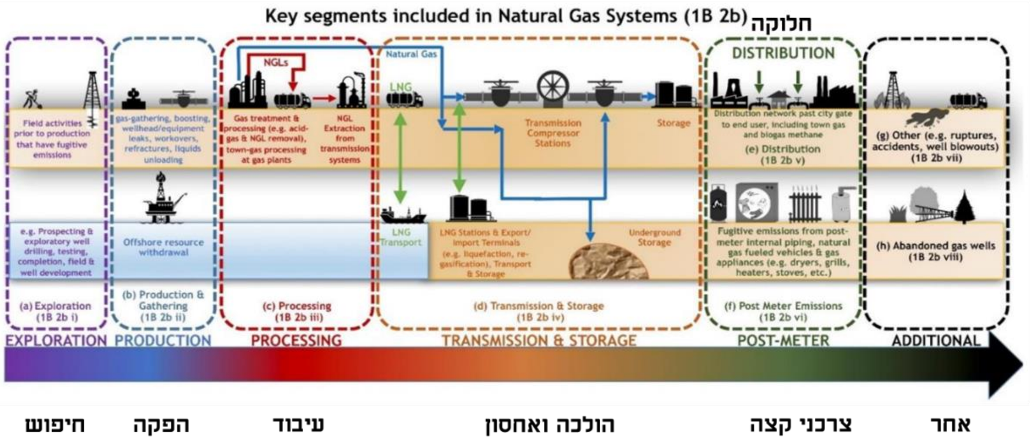
[18] Intergovernmental Panel on Climate Change (IPCC) 2021, The Physical Science Basis, Working Group

הערכות חישוב פרטניות או שההערכות הפרטניות אינן שלמות ואינן מגובות בממצאי ניטור בפועל, נעשה שימוש במקדמי Tier 1.

4.3.3 חלוקה למקטעי הפקה ואספקת הגז

המתודולוגיה המפורטת במדריך של הפאנל הבין-ממשלתי לשינויי אקלים (IPCC) מציגה חלוקה של שרשרת ההפקה והאספקה של גז מחצבים למקטעיה השונים. זאת בהתאם למתואר במדריך של IPCC, כפי שניתן לראות באיור 2.

איור 2 : מקטעים עיקריים על פי ה- IPCC, בשרשרת ההפקה והאספקה גז מחצבים[19]



מתודולוגית מדריך ה- IPCC, קובעת גם כי בעת הערכת הפליטות הלא-מוקדיות משרשרת הפקת ואספקת הגז יש ליישם חלוקה מפורטת יותר מהמתואר באיור 1, וזאת בכדי להתחשב טוב יותר בגורמים מקומיים המשפיעים על הפליטות, כגון : תנאי המאגר, תהליכי העיבוד והטיפול הנדרשים, תנאי התכנון והתפעול, גיל התשתיות, הדרישות הרגולטוריות ורמת הפיקוח הרגולטורי. תרומתו של כל אחד מהמקטעים לכלל הפליטות הלא-מוקדיות משתנה הן בהתאם להיקף הפעילות בו (למשל כמות הגז המופקת, הנצרכת, המיובאת והמיוצאת), והן בהתאם לטכנולוגיות ולאמצעים הקיימים בכל מקטע, העשויים להגדיל או להקטין את הפליטות.

בהתאם לכך, ההתייחסות לחלוקה למקטעים השונים משרשרת ההפקה והאספקה של גז המתאן למקטעים השונים בישראל, בוצעו בהתבסס על מקורות מידע המצויים בידי המשרד להגנ״ס, היתרי פליטה, דיווחי מפל״ס, דוחות שנתיים, מידע ודוחות המפורסמים ע״י משרד האנרגיה, רשות הגז

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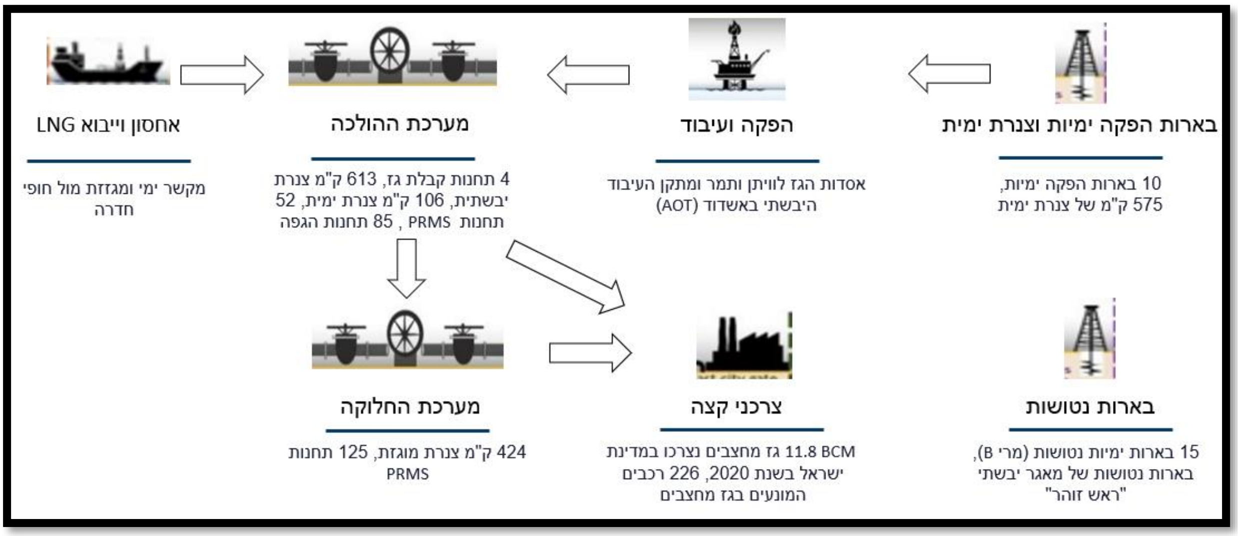
[19] Intergovernmental Panel on Climate Change (IPCC) 2021, The Physical Science Basis, Working Group 4

ונתג״ז. מקטעי שרשרת ההפקה והאספקה, ושיוך מרכיבים הרלוונטיים לכל מקטע מפורטים איור 3 וטבלה 1.

איור 3 : מקטעים במערכות גז מחצבים במדינת ישראל



טבלה 1 : חלוקה למקטעים ושיוך מרכיבים רלוונטיים בישראל

מקטע	מרכיבים רלוונטיים בישראל	הערות
חיפוש (Exploration)	פעילויות חיפוש והכנה להפקה מסחרית בים וביבשה	בחודש מאי 2022, הוחלט במשרד האנרגיה לצאת להליך תחרותי הרביעי לחיפושי גז במים הכלכליים של ישראל.
הפקה ואיסוף (Production and Gathering)	• בארות הפקה ימיות פעילות בשדות תמר ולוויתן ; • צנרת ימי בין הבארות הימיות לאסדות ההפקה הימיות ; • אסדות ההפקה הימיות תמר ולוויתן ; • צנרת ימית בין אסדות ההפקה הימיות לחוף.	לקראת סוף 2022 יכלול מקטע זה גם את אסדת כריש על בארותיה וצנרותיה הימיות.

מקטע	מרכיבים רלוונטיים בישראל	הערות
עיבוד (Processing)	מתקן הקבלה היבשתי באשדוד (AOT - Ashdod Onshore Terminal)	תהליכי עיבוד המבוצעים באסדות ההפקה בים, נכללים במסגרת אומדן זה תחת מקטע ההפקה.
הולכה ואחסון (Transmission and Storage)	• מערכת ההולכה הארצית בלחץ גבוה, לרבות תחנות קבלה, צנרת הולכה יבשתית וימית, תחנות PRMS ותחנות הגפה ; • המסוף לייבוא LNG מול חופי חדרה, לרבות המקשר הימי והאונייה המגזזת.	• בישראל קיימת חברה אחת ממשלתית (נתג״ז) האחראית על קווי ההולכה. • האונייה המגזזת משמשת לאחסון והגזת LNG כגיבוי, היא צפויה להפסיק את פעילותה בחודש אוקטובר 2022.
חלוקה (Distribution)	מערכת החלוקה בלחץ נמוך, לרבות קווי צנרת חלוקה יבשתיים ראשיים ומשניים, תחנות PRMS ומונים של צרכני קצה.	בישראל 6 בעלי רישיונות חלוקה אזוריים.
צרכני קצה (Post-Meter)	• מפעלי תעשייה, תחנות כוח, וצרכנים ביתיים הצורכים גז מחצבים ; • תדלוק רכבים המונעים בגז מחצבים.	
פליטות אחרות (Other)	כל אחד מהמקטעים	פליטות לא שגרתיות שאינן מחושבות במסגרת המקטעים האחרים, כגון התפרצות של בארות, התבקעות של צנרות או פגיעה בהן במהלך חפירות, תאונות ושחרורי לחץ בחירום.
בארות גז נטושות (Abandoned Gas Wells)	• הבארות הימיות של אסדת מרי-B ; • הבארות היבשתיות של מאגר ״ראש זוהר״ באזור ערד	

לאחר סקירת שיטות כימות פליטות המתאן במדינות אחרות, בחרנו להשתמש במתודולוגית של ה-IPCC, המתייחסת לכימות פליטות מתאן לפי מקטעי הפקה ואספקה בישראל, בהתבסס על מקדמי פליטה, הערכות הנדסיות ומדידות בפועל.

5 סקירת המקטעים בישראל, השיטות בעולם וכימות הפליטות

5.1 חיפוש (Exploration)

השלב הראשון במחזור החיים של מאגרי גז ונפט הוא שלב החיפוש. המטרה העיקרית של קידוחי החיפוש היא להוכיח שיש נפט ו/או גז במאגר, ולקבוע את טיבו ואת הרכבו במידה ונמצא גז. בהמשך מבוצעים גם קידוחים להערכת הפוטנציאל של השדה, ולבסוף פיתוח השדה והכנתו להפקה מסחרית.

חיפושי גז אינטנסיביים החלו בישראל מסוף שנות ה- 90 של המאה העשרים, בעיקר בים התיכון. בשנת 2012 נקדחו 7 קידוחי חיפוש בשטח הימי של ישראל, אך החל משנת 2013 נקדחו שלושה קידוחי חיפוש – 2 מהם בשנת 2013 וקידוח 1 נוסף בשנת 2019[20].

5.1.1 ***<u>כימות הפליטות ממקטע החיפוש - IPCC</u>***

לפי המדריך של IPCC מקטע החיפוש כולל פליטות לא מוקדיות (לרבות דליפות מרכיבי ציוד, נישובים ושריפה בלפיד) מפעילויות בשדות גז המתרחשות לפני ההפקה. במדריך מפורטים מקדמי פליטה ברמת חישוב Tier 1 עבור חיפושי גז ביבשה בלבד. המדריך לא מפרט מקדמי פליטה עבור חיפושי גז בים, מכיוון שהמידע אינו זמין. לרוב פליטות ממקטע החיפוש מתרחשות בשלב בו מבוצעים מבחני הפקה. במידה ומתגלה גז בשלב זה, הגז מנותב לשריפה בלפיד. ניתן להעריך כי הפליטות מפעילות חיפוש בים הינן זניחות.

5.1.2 ***<u>כימות הפליטות ממקטע החיפוש – מדינות אחרות</u>***

במצאי פליטות גזי החממה של בריטניה ושל נורבגיה, כמות הפליטות מפעילויות חיפוש מבוססת על דיווחי פליטות המתקבלים מהמפעילים לרשויות הרלוונטיות, לפי הנחייתם:

- **בבריטניה** – דיווחים למערכת לדיווח פליטות סביבתית – EEMS;

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[20] דו"ח הצוות המקצועי לבחינה תקופתית שנייה של מדיניות הממשלה בנושא משק הגז הטבעי, טיוטה להערות הציבור, יוני 2021: https://www.gov.il/BlobFolder/rfp/ng_210621/he/ng_report_2_draft.pdf

- **בנורבגיה** – דיווחים לסוכנות הסביבה הנורבגית. נישובים מקידוחי חיפוש מחושבים לפי מקדם פליטה אחיד ביחס לכמות הבארות שהושלמו. פליטות משריפה בלפיד מחושבות לפי מקדם פליטה של IPCC משנת 1997 ביחס לכמות הגז שנותבה לשריפה בלפיד.
- **ארה״ב** – במצאי פליטות גזי החממה של ארה״ב מפורטים מספר מקדמי פליטה לחישוב פליטות מנישובים ומשריפה בלפיד עבור מספר פעילויות כגון – אירועי בדיקת בארות שהושלמו, אירועי בדיקת בארות שלא הושלמו ועבור מספר הבארות שנקדחו. בנוסף, מפורטים מקדמי פליטה גם להשלמת בארות בטכנולוגיית סדיקה הידראולית שאינם רלוונטיים לישראל. המקדמים מבוססים על מידע המדווח מהמפעילים ל- EPA במסגרת התוכנית לדיווח על גזי חממה בארה״ב (GHGRP) ועל מסמך משנת 1992 של מכון הנפט האמריקאי (API).
- **אוסטרליה-** במצאי פליטות גזי החממה של אוסטרליה מפורטים מספר מקדמי פליטה: לשריפה בלפיד באירועי בדיקת בארות (לפי מקדם המבוסס על דיווחי מפעילים), לקידוחים (לפי מקדם של API) ולהשלמת בארות (לפי מחקר אוסטרלי, ועבור טכנולוגיית סדיקה הידראולית אומצו מקדמים מהמצאי של ארה״ב משנת 2016).

5.1.3 כימות הפליטות ממקטע החיפוש – מדינת ישראל

עד היום לא בוצעה הערכת פליטות פרטנית עבור פעילות החיפוש בישראל. כאמור, על פי מדריך ה – IPCC הפליטות ממקטע החיפוש הן זניחות.

5.2 הפקה ואיסוף (Production and Gathering)

פליטות לא מוקדיות במקטע ההפקה והאיסוף מתרחשות החל מראש הבאר ועד לכניסה למתקני עיבוד הגז, או עד לנקודת הכניסה למערכת ההולכה כאשר לא מבוצע עיבוד.

הפקת הגז בישראל מתבצעת כיום אך ורק בים (offshore) באמצעות אסדות ההפקה הימיות תמר ולוויתן, ובשנת 2020 הופקו בהן יחד 15.44 BCM גז מחצבים (8.2 BCM בתמר ו- 7.24 BCM בלוויתן)[21]. אסדת מרי-B הפסיקה את הפקת הגז בשנת 2019, והפקת הגז במתקן ה- FPSO העתידי כריש צפויה להתחיל בסוף שנת 2022.

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[21] משרד האנרגיה, רשות הגז הטבעי – סקירת ההתפתחויות במשק הגז הטבעי, סיכום לשנת 2020: https://www.gov.il/BlobFolder/reports/ng_2020/he/ng_2020.pdf

במערך ההפקה פועלות כיום 10 בארות הפקה ימיות: 6 בארות בשדה תמר ו- 4 בארות בשדה לוויתן[22]. למערך זה אמורות להתווסף בקרוב 3 בארות ההפקה הימיות של שדה כריש.

הזרם היוצא מהבארות (גז גולמי ונוזלים נוספים) מנוהל ומבוקר בשליטה מרחוק באמצעות מכלול מגופים המורכב על ראש כל באר (Christmas tree), מוזרם דרך רכזת (Manifold) הנמצאת במרכז השדה ומחוברת לצנרת ימית המוליכה אותו עד לאסדות ההפקה. אורכה הכולל של הצנרת הימית שבין שדות ההפקה לאסדות עומד כיום על כ- 540 ק״מ (שתי צנרות באורך של כ- 150 ק״מ כל אחת בין שדה תמר לבין אסדת תמר, ושתי צנרות באורך של כ- 120 ק״מ בין שדה לוויתן לבין אסדת לוויתן). לתת-מקטע צנרת זה תתווסף בקרוב הצנרת שבין בארות שדה כריש למתקן ה- FPSO כריש.

לאחר תהליכי הטיפול באסדות מוזרם הגז בצנרת ימית אל תחנות הקבלה היבשתיות. אורכה הכולל של הצנרת הימית שבין האסדות לתחנות הקבלה היבשתיות עומד כיום על כ- 50 ק״מ (כ- 40 ק״מ בין אסדת תמר לתחנת הקבלה באשדוד – AOT, וכ- 10 ק״מ בין אסדת לוויתן לתחנת הקבלה בדור). לתת-מקטע צנרת זה יתווספו בקרוב כ- 156 ק״מ שבין מתקן ה- FPSO העתידי כריש לתחנת הקבלה בדור (שתי צנרות באורך של כ- 78 ק״מ כל אחת).

האורך הכולל של תת-מקטעי הצנרת הימית המפורטים לעיל מסתכם כיום בכ- 575 ק״מ.

5.2.1 כימות הפליטות ממקטע ההפקה והאיסוף – IPCC

מדריך של IPCC מפנה למקדם פליטה יחיד ברמת חישוב Tier 1 המהווה את ברירת המחדל היחידה לחישוב פליטות מתאן עבור הפקת גז בים (Gas Production – Offshore) – העומד על 2.94 טון מתאן/מיליון מ״ק גז שהופק. לפי מקדם פליטה זה, הערכת הפליטות השנתיות עבור כלל כמות הגז שהופקה בישראל בשנת 2020 באסדות תמר ולוויתן יחד (15.44 BCM) – עומדת על 45,394 טון מתאן/שנה.

5.2.2 כימות הפליטות ממקטע ההפקה ואיסוף – מדינות אחרות

מצאי פליטות גזי החממה של בריטניה ושל נורבגיה, כמות הפליטות ממתקני ההפקה (בעיקר מתקני הפקה ימיים בים הצפוני) מבוססת על דיווחי פליטות שנתיים המתקבלים ממפעילי המתקנים לרשויות הרלוונטיות, לפי הנחייתם.

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[22] דו״ח הצוות המקצועי לבחינה תקופתית שנייה של מדיניות הממשלה בנושא משק הגז הטבעי, טיוטה להערות הציבור, יוני 2021: https://www.gov.il/BlobFolder/rfp/ng_210621/he/ng_report_2_draft.pdf

- **בבריטניה** – דיווחים למערכת לדיווח פליטות סביבתית – EEMS מהמתקנים הימיים שבהם מבוצעת כמעט כל הפקת הגז בבריטניה, ודיווחי PRTR (בדומה למפל״ס) מהמתקנים היבשתיים;

בנורבגיה – דיווחים לסוכנות הסביבה הנורבגית. הפליטות המדווחות מוערכות באופן פרטני ומותאם לכל אתר, לפי מקורות הפליטה הרלוונטיים עבורו בהתבסס על ממצאי ניטור ו/או חישובים. דליפות מרכיבי ציוד מכומתות על בסיס סריקה שנתית או דו-שנתית באמצעות מצלמה תרמית (OGI), בשילוב מקדמי פליטה לרכיבים דולפים ולא-דולפים (Leak/No-Leak).

לשם השוואה, להלן דיווח פליטות ממספר אסדות בנורווגיה המדווחת למערכת ה PRTR הנורווגית[23]. המחשת הפערים בכמות הפליטות לפי שיטות החישוב השונות, מוצגת בטבלה הערכה של הפליטות הצפויות מאסדות אלו, אילו הכימות היה מתבסס על שימוש במקדמי ה IPCC (Tier 1). לצורך השוואה מוצגות גם הפליטות של אסדות הגז תמר ולוויתן (פליטות עבור שנת 2020).

טבלה 2: דיווח פליטות מאסדות בנורווגיה

שם המתקן	מפעיל	כמות הפליטה המדווחת לשנת 2019 TON/Year	נפח ייצור BCM/Year	פליטה סגולית מדווחת TON/BCM	פליטה לפי מקדם IPCC TON/Year
Troll	EQUINOR ENERGY AS	472	35	14	102,172
Oseberg	EQUINOR ENERGY AS	401	14	28	42,036
Åsgard	EQUINOR ENERGY AS	1,586	13	124	37,611
Gullfaks	EQUINOR ENERGY AS	1,403	10	139	29,718
(2020)Tamar	Chevron	61	8	7	24,108
(2020)Leviatan	Chevron	309	7	43	21,286
Visund	EQUINOR ENERGY AS	115	6	19	17,787
Skarv	AKER BP ASA	259	6	43	17,555
מקדם פליטה (IPCC) הינו 2,940 TON/BCM					

אסדת Troll למשל ממחישה את ההבדל בין מקדם ה IPCC לבין דיווח פליטות במדינה, בהתאם לטבלה האסדה היא בעלת מקדם סגולי של 14 טון פליטת מתאן ל BCM לפי הדיווח הנורבגי ואילו הייתה מדווחת לפי מקדם ה- IPCC מקדם הפליטה הסגולי שלה היה 2,940 טון מתאן ל BCM. כלומר, הבדל הגבוה ביותר משני סדרי גודל, בדומה למצב בישראל.

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[23] https://www.norskeutslipp.no/en/Lists/Overview-facility/?SectorID=700

- **ארה״ב** – במצאי פליטות גזי החממה של ארה״ב מוערכות הפליטות באמצעות 3 סטים שונים של מקדמי פליטה, כאשר כל אחד מהם מיועד לאחד מ- 3 אזורים ימיים שונים בהם מופק גז בארה״ב[25,24]:
  - תחום המים הפדרליים במפרץ מקסיקו[26] - אזור בו מתבצעת מרבית ההפקה הימית של גז בארה״ב (כ- 70%). פליטות שמקורן בדליפות ובנישובים מחושבות באמצעות מקדמי פליטה ביחס למספר הקומפלקסים (אסדות הפקה ימיות) הגדולים והקטנים[27]. פליטות שמקורן בשריפה בלפיד מחושבות ביחס לכמות הגז שנותבה אליהם. מקדמי הפליטה מבוססים על דיווחי פליטות שנתיים ממפעילי האסדות ל- BOEM, לפי הנחיותיו. מתקני הפקה ימיים הנמצאים תחת אחריותו של BOEM מדווחים את אותן הפליטות השנתיות גם לתוכנית הפדרלית לדיווח על פליטות גזי חממה בארה״ב (GHGRP);
  - תחום המים שאינם פדרליים במפרץ מקסיקו (של המדינות אלבמה, לואיזיאנה וטקסס)[28] – כל הפליטות (דליפות, נישובים ולפידים) מחושבות באמצעות מקדמי פליטה ביחס לכמות הגז שהופקה. מקדמי הפליטה מבוססים על אותם הנתונים שדווחו בתחום המים הפדרליים במפרץ מקסיקו, לאחר נירמול לתפוקת הגז;
  - תחום המים של מדינת אלסקה- כל הפליטות (דליפות, נישובים ולפידים) מחושבות באמצעות מקדמי פליטה ביחס לכמות הגז שהופקה. מקדמי הפליטה מבוססים על דיווחי פליטות שהתקבלו ממפעילי האסדות באזור זה לתוכנית הפדרלית GHGRP, המחייבת בדיווח רק מתקנים הפולטים למעלה מ- 25,000 מיליון טון שווה ערך פד״ח (CO_2-eq) בשנה. מתקנים אלה משקפים פחות מ- 10% מכלל מתקני ההפקה הימית בארה״ב.
- **אוסטרליה-** הערכת הפליטות במצאי פליטות גזי החממה של אוסטרליה, מקורן בדליפות מאסדות הפקת גז ימיות (לא כולל נישובים או שריפה בלפיד) ומבוססת על שני מקדמי פליטה שנלקחו ממצאי פליטות גזי החממה של ארה״ב משנת 2016 , הנבדלים זה מזה לפי עומק המים בהן ממוקמות האסדות, מעל או מתחת ל- 200 מטרים עומק[29]. חשוב לציין כפי שמפורט לעיל,

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[24] Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2018: Updates for Offshore Production Emissions, April 2020: https://www.epa.gov/sites/default/files/2020-04/documents/2020_ghgi_update_-_offshore_production_final.pdf

[25] מתקני הפקה ימיים הנמצאים באזור האוקיינוס השקט מוגדרים כמתקני הפקת נפט, ולכן הפליטות מהן מדווחות בקטגוריה נפרדת

[26] תחום המים הפדרליים בארה״ב מוגדר כאזור שמחוץ למדף היבשת

[27] קומפלקס ״גדול״ מורכב מ- 6 בארות לפחות או שיש בו למעלה מ- 2 יחידות של ציוד הפקה, אחרת הוא מוגדר ״קטן״

[28] תחום המים שבאחריות המדינות הוא עד 3 מייל ימי מהחוף, ובחלק מהמדינות עד 9 או 12 מייל ימי מהחוף

[29] 656 feet, as described in: USEPA, April 2015 - Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2013: Revision to Offshore Platform Emissions Estimate:

כי ה- EPA כבר עדכן את המתודולוגיה הזו, ומקדמי פליטה אלה כבר אינם בשימוש כיום במצאי פליטות גזי החממה העדכני של ארה״ב (לפי ה- EPA עומק המים בו ממוקמות האסדות איננו מדד טוב לייצוג הפליטות). בנוסף לדליפות, כמות הפליטות שמקורן בנישובים מבוססת על הדיווחים המתקבלים במערכת האוסטרלית הלאומית לדיווח על גזי חממה ואנרגיה (NGERS), ופליטות שמקורן בשריפה בלפיד מחושבות באמצעות מקדם פליטה של ההתאחדות האוסטרלית להפקה וחיפושי נפט (APPEA).

5.2.3 כימות הפליטות ממקטע ההפקה והאיסוף – מדינת ישראל

בישראל – אסדות תמר ולוויתן מדווחות מדי שנה על כמויות המתאן הנפלטות מהן למפל״ס, בהתאם להנחיות הממונה לכימות פליטות מתאן. את הפליטות המדווחות למפל״ס ניתן לסווג כרמת חישוב Tier 3 מכיוון שהן מבוצעות באופן פרטני עבור כלל מקורות הפליטה באתרים ספציפיים. הנתונים המדווחים למפל״ס, לרבות אופן חישוב הפליטות מכל מקורות הפליטה הרלוונטיים באסדות, עוברים בקרת איכות ע״י המשרד להגנת הסביבה, ושיטות החישוב מתבססות בין היתר על ממצאי ניטור ותיקון דליפות מרכיבי ציוד (LDAR לקווי הקונדנסט, OGI לקווי הגז, בשילוב מקדמי פליטה לרכיבים דולפים ולא-דולפים Leak /No-Leak), על מדי ספיקה של הגז המנושב ושל הגז המנותב לשריפה ללפיד, יעילות השריפה בלפיד ועל תוצאות דיגום ארובות ושל הרכב הגז.דרישות אלו מוטמעות בהתרי הפליטה של האסדות.

בשנים קודמות כמות המתאן שנפלטה מאסדת תמר הייתה גבוהה יותר לעומת שנת 2020. בשנת 2018 דווח על פליטה של כ- 3,430 טון ובשנת 2019 דווח על פליטה של כ- 1,038 טון. הירידה עד לכמות שדווחה בשנת 2020 נובעת מהתקנה של מערכת השבת פליטות והפעלת הלפידים בחודש מרץ 2019 לפי דרישות היתר הפליטה לאוויר של האסדה. שנת 2020 הייתה שנת הדיווח הראשונה למפל״ס של אסדת לוויתן.

כמות המתאן שנפלטה לאוויר כפי שדווחה למפל״ס עבור שנת 2020 מאסדות ההפקה תמר ולוויתן יחד עומדת על כ- 370 טון מתאן/שנה (כ- 61 טון/שנה מתמר וכ- 309 טון/שנה מלוויתן), או כ- 359 טון מתאן/שנה ללא פליטות שמקורן בשריפת דלקים (לפי IPCC על פליטות משריפת דלקים יש לדווח כקטגוריה נפרדת).

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https://www.epa.gov/sites/default/files/2015-12/documents/revision-offshoreplatforms-emissions-estimate-4-10-2015.pdf

לצורך הבהרת הבדלים בין המקדם של ה IPCC לכימות הפליטות בישראל עבור מקטע הפקה זה, ושימוש במקדם הפליטה של ה IPCC, נבהיר כי מקדם של IPCC מבוסס על נתוני מנהל האנרגיה באוקיינוסים של ארה״ב (BOEM), כפי שהוטמעו במצאי גזי החממה של ארה״ב שפורסם בשנת 2018 (עבור השנים 1990-2016). במצאי גזי החממה העדכני של ארה״ב (החל מהמצאי שפורסם בשנת 2020) נערך שינוי מתודולוגי עבור מקטע ההפקה על בסיס מידע חדש ועדכני יותר[31,30]. ניכר כי מקדם ברירת המחדל אינו מתאים בכדי לשקף בצורה נכונה את הפליטות ממקטע זה בישראל, וזאת מהסיבות הבאות:

- אמצעי הפחתת הפליטות המותקנים באסדות תמר ולוויתן, כגון שריפה של גזים עודפים בלפידים הן בשגרה והן בחרום המביאה להפחתה של כ- 98% מהפליטות ביחס לשחרור גזים ללא שריפה, שימוש באוויר דחוס כגז מכשירים (instrument gas), קיום מערכות להשבת גזים, שימוש ברכיבי ציוד מועטי פליטות, בשילוב של שגרת ניטור פליטות מתאן מרכיבי הציוד (OGI), וביצוע מדידות שגרתיות של הפליטות, מאפשרות העדפה לכימות הפליטות לפי חלופת Tier 3.
- בשונה ממקטעים אחרים, מקדם הפליטה היחיד של IPCC עבור הפקה בים לא מתייחס לקיומן של תכניות לזיהוי ותיקון דליפות מרכיבי ציוד. דרישות הרגולציה המיושמות בישראל מחייבות צמצום דליפות מרכיבי ציוד באמצעות ניטור שוטף ותיקון של רכיבים דולפים (ביצוע LDAR לקווי הקונדנסט ו- OGI לקווי הגז). מנתונים שקיימים בידנו אודות הפחתות של פליטות מרכיבי ציוד בתעשיה, יישום שגרה לאורך זמן של תוכניות לזיהוי ותיקון דליפות מרכיבי ציוד (LDAR) וביצוע ניטור באמצעות OGI, מביא להפחתה מתמשכת של כ 85% בפליטות ממקור זה.
- מקדמי הפליטה בהם נעשה שימוש בעבר במצאי של ארה״ב, ושעליהם, כאמור, מבוסס המקדם של IPCC, מתייחסים במקור למספר האסדות (ק״ג מתאן/אסדה), אך במדריך של IPCC הם מנורמלים לתפוקת הגז (טון מתאן/מיליון מ״ק גז מופק). מכיוון שתפוקת הגז השנתית לאסדה ימית המוגדרת כמפיקה גז בארה״ב נמוכה יחסית לישראל[32], מתקבל מקדם פליטת מתאן גבוה כאשר הוא מנורמל לתפוקה.

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[30] תכתובת דוא״ל מיום 20/9/2021 עם Melissa Weitz מה- USEPA, החברה בצוות עורכי מצאי פליטות גזי החממה של ארה״ב ובצוות עורכי מדריך ה- IPCC.

[31] Tables 7 & 9 in: Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2018: Updates for Offshore Production Emissions, April 2020: https://www.epa.gov/sites/default/files/2020-04/documents/2020_ghgi_update_-_offshore_production_final.pdf

[32] תפוקות הגז במפרץ מקסיקו בשנת 2011 שעל בסיסה מחושב המקדם של IPCC: כ- 0.04 BCM/שנה לאסדה בממוצע, וכ- 1.65 BCM/שנה לאסדה שהפיקה את הכמות המרבית. הנתונים נלקחו מתוך:

- כפי שמצוין במדריך של IPCC עבור מקדמי Tier 1, פליטות לא-מוקדיות עשויות להיות תלויות יותר בגורמים אחרים מלבד תפוקת הגז (קיום/אי קיום מערכות להשבת גזים, שריפת גזים בלפידים מול שחרור גזים ללא שריפה, רמת תחזוקת רכיבי הציוד, סוג הרכיבים, כמות הרכיבים ועוד). עם זאת במדריך ה IPCC נתון מקדם פליטה אחד לפחות עבור כל מקטע המתייחס לתפוקת הגז, מכיוון שבחלק מהמדינות זהו הנתון הסטטיסטי היחידי הזמין;
- המקדם של IPCC לא מתחשב בדרישות הרגולציה המחמירות המיושמות באסדות ההפקה בישראל עבור מקורות הפליטה המשמעותיים. כאשר בוחנים את התפלגות פליטות המתאן ממקורות הפליטה השונים באסדות ימיות בארה״ב, שעליהן כאמור מבוסס המקדם של IPCC, עולה כי נישובים מתהליך ייבוש הגז באמצעות גליקול והפעלה פנאומטית של מכשירים באמצעות גז מחצבים דחוס, אחראיים לכ- 65-73% מהפליטות (בשנת 2011 שעליה מבוסס מקדם הפליטה)[33]. לפי IPCC, כ- 77% מכלל פליטות המתאן המחושבות לפי מקדם הפליטה מיוחסות לנישובים[34]. בישראל מיושמות דרישות רגולציה מחמירות עבור מקורות אלה, לרבות איסור על נישובים, השבת גזים עודפים מתהליך ייבוש הגז, שריפתם בלפיד במקרים של תקלה/חירום ושימוש באוויר דחוס להפעלת מכשירים במקום בגז מחצבים;

5.2.4 **בארות הפקה ימיות פעילות וצנרת ימית**

הפליטות המדווחות מאסדות ההפקה למפל״ס אינן כוללות דליפות אופציונליות מבארות ההפקה הימיות ומהצנרת הימית המוליכה בין הבארות לאסדות ובין האסדות לתחנות הקבלה היבשתיות בחוף.

5.2.4.1 התייחסות בעולם

במדריך של IPCC אין מקדמי פליטה או התייחסות ספציפית לבארות הפקה ימיות פעילות או לצנרת ימית. גם במצאי פליטות גזי החממה של ארה״ב, אוסטרליה ונורבגיה, וגם במסמך העדכני ביותר של API משנת 2021 המקבץ מגוון שיטות חישוב - אין התייחסות ספציפית להערכת פליטות מתאן מבארות הפקה ימיות פעילות או מצנרת ימית. לפי מצאי פליטות גזי החממה של בריטניה, פליטות

BOEM Data Center, Production Data Online Query for 2011: https://www.data.boem.gov/Production/ProductionData/Default.aspx

[33] Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2018: Updates for Offshore Production Emissions, April 2020: https://www.epa.gov/sites/default/files/2020-04/documents/2020_ghgi_update_-_offshore_production_final.pdf

[34] טבלה 4A.2.5 במדריך העדכני של IPCC

שמקורן בקרקעית הים אינן כלולות בהערכות המצאי, מתוך הנחה שפליטות אלה יתמוססו בעמודת המים ללא פליטה לאטמוספירה[35].

במסגרת בירור שנערך עם רגולטורים מארה״ב[36] לגבי דליפות פוטנציאליות מבארות ומצנרת תת ימית, הובהר כי לא ידוע על בדיקות שבוצעו לכימות דליפות מבארות הפקה ומצנרות תת ימיות (להבדיל מיבשתיות), ולכן מבחינתם כרגולטורים אין מהם דליפות שגרתיות שיש להעריך עבורן פליטות. יוצאים מן הכלל הם מקרים חריגים/קטסטרופליים שיידרשו בטיפול מידי. עם זאת לטובת עריכת אומדן פליטות שמרני, הערכת הפליטות מהציוד התת-ימי לאוויר בוצעה על בסיס הנחה שהפליטות המגיעות לאטמוספירה מהוות רק אחוזים בודדים ביחס למקדם פליטה יבשתי מקביל. עקרון זה מיושם הלכה למעשה גם במדריך של IPCC עבור פליטות מבארות ימיות נטושות (ראה סעיף 5.8 בהמשך).

במסגרת בירור נוסף בנושא זה עם חוקר מאוניברסיטת פרינסטון שעסק בין היתר במדידת דליפות מתאן מאסדות הפקה פעילות בים הצפוני[37], צוין כי למיטב ידיעתו עד היום לא נערכו מדידות לכימות פליטות מבארות או מצנרות תת ימיות, וכי להבנתו אין דליפות מצנרת תת ימית, למרות שאין כיום מידע אחר שיוכיח או יסתור זאת.

5.2.4.2 התייחסות בישראל

לפי התייחסות אגף סביבה במשרד האנרגיה והיחידה הארצית להגנת הסביבה הימית במשרד להגנ״ס לנושא זה[38], עולה כי כל הציוד התת ימי בישראל לרבות בשדות ההפקה ולכל אורך הצנרת עד לאסדות ההפקה מנוטר לפי תוכנית תחזוקה בתיאום, אישור ופיקוח של המחלקה ההנדסית של משרד האנרגיה ובהתאם לתקנים המקובלים בתעשייה. תכנית התחזוקה כוללת ביצוע סקר ויזואלי באמצעות ROV (Remote Operated Vehicle), בדיקת הגנה קתודית אחת לשלוש שנים, ובדיקה של פנים הצנרת באמצעות העברת מולוך (Pig) בהתאם לצורך. עד עתה לא נצפו דליפות גז מהציוד התת ימי.

בחודשים מרץ-אפריל 2021 התגלתה הופעה מקוטעת של בועות כתמי שמן בפני המים בקרבת אסדת לוויתן שמקורה בדליפה איטית מאוד מאוגן על הצינור. בעקבות הדליפה בוצעו בדיקות

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[35] Citation from the UK Greenhouse Gas Inventory, 1990 to 2019, Section 3.4, MS 18: "Emissions released at the seabed are not included in estimates; it is assumed that any such releases will dissolve in the water column without subsequent release to the atmosphere"

[36] פגישת MS TEAMS מיום 29/6/2021 עם נציגי ה- EPA (Melissa Weitz, Mark DeFigueiredo) ו- BOEM (Holli Ensz, Cholena Ran, Margaret Metcalf, Timothy McCune)

[37] תכתובת דוא״ל עם Stuart Riddick מתאריכים 12/6/2021 ו- 14/6/2021

[38] תכתובת דוא״ל מיום 19/8/2021 מערן ברוקוביץ', מרכז בכיר אגף סביבה, מינהל אוצרות טבע, משרד האנרגיה; תכתובת דוא״ל מיום 23/8/2021 מיבגני מלכין, ראש תחום משאבי אנרגיה בים, היחידה הארצית להגנת הסביבה הימית, המשרד להגנ״ס

שונות ע״י חיא״ל, חברת CSA, וכן בדיקות של קווים ואביזרים בתדירות גבוהה יותר. כיום התופעה פסקה וההנחה היא שמדובר בנוזלים ולא בגז.

5.2.4.3 הערכת פליטות

אף על פי שבכל המקורות הספרותיים שנסקרו לא נמצאה התייחסות פרטנית להערכת פליטות מבארות ימיות פעילות ומצנרת ימית, על מנת להתייחס אליהן כמקור פליטה פוטנציאלי במסגרת אומדן זה, הוערכו מהן פליטות מתאן לפי העקרון המתואר במדריך IPCC עבור בארות ימיות נטושות (ראה סעיף 5.8 בהמשך), וכפי שגם הוצע ע״י רגולטורים מארה״ב, באופן הבא:

- עבור בארות הפקה ימיות – נלקח מקדם פליטה המיועד לבארות הפקה יבשתיות מתוך מצאי גזי החממה של ארה״ב - העומד על 86.4 ק״ג מתאן/באר (בארות ללא סדיקה הידראולית). מבין המסמכים שנסקרו מקדם פליטה זה הוא היחיד שמתייחס לדליפה מהבאר עצמה בלבד (המקדם במדריך של IPCC המחשב את הפליטות ביחס לכמות הבארות היבשתיות כולל גם פליטות שמקורן בציוד הפקה נוסף הנמצא באתר הבאר היבשתית כגון מכשור פנאומטי, מייבשים ומפרידים);
- עבור צנרת ימית - נלקח מקדם פליטה המיועד לדליפות מצנרת איסוף ודחיסה (Gathering and boosting pipeline) יבשתית מתוך מצאי גזי החממה של ארה״ב - העומד על 295.6 ק״ג מתאן/מייל צנרת. מבין המסמכים שנסקרו מקדם פליטה זה הוא היחיד שמתייחס לדליפה מהצנרת עצמה בלבד (המקדם במדריך של IPCC המחשב את הפליטות ביחס לכמות הגז המופקת ונאספת במערכות האיסוף היבשתיות, כולל גם פליטות שמקורן בתחנות איסוף והעלאת לחץ כגון מדחסים, מכשור פנאומטי ומכלים);
- על מנת להתחשב בעובדה שהפליטה, במידה והיא אכן מתרחשת, היא תת ימית ולא ישירות לאטמוספירה, הוכפל כל אחד ממקדמי פליטה אלה במקדם הפחתה של 0.02, כפי שמתואר גם במדריך של IPCC עבור פליטת מתאן מבארות ימיות נטושות (ראה סעיף 5.8 בהמשך).

כמות הפליטה המוערכת לפי חישוב זה עבור 10 הבארות הימיות הפעילות כיום בישראל עומדת על כ- **0.02 טון מתאן/שנה**, ועבור הצנרת הימית באורך כולל של 575 ק״מ כ- **2.11 טון מתאן/שנה**.

בסה״כ, הערכת הפליטות הפוטנציאליות מבארות ההפקה הימיות הפעילות ומהצנרת הימית מסתכמת ב- **2.13 טון מתאן/שנה** בלבד.

5.3 עיבוד (Processing)

פליטות לא-מוקדיות במקטע העיבוד מתרחשות במתקנים לעיבוד גז מחצבים, שתפקידם להרחיק נוזלים ומרכיבים אחרים על מנת להביא את הגז לאיכות הנדרשת להזרמה למערכת ההולכה.

במתקן הקבלה היבשתי באשדוד (AOT - Ashdod Onshore Terminal) מבוצע המשך עיבוד הגז והקונדנסט המופקים באסדת תמר. בשנת 2020 עובדו ב- AOT כ- 8.2 BCM גז שהופק באסדת תמר[39]. הגז והקונדנסט המופקים באסדת לוויתן ושיופקו בעתיד במתקן ה- FPSO כריש עוברים את כל תהליכי העיבוד הנדרשים בים, ולכן הם אינם מצריכים את המשך עיבודם בחוף.

הגז המופק בישראל לא נחשב גז "חמוץ"[40] ולכן הוא לא עובר תהליך "המתקה" כחלק מתהליכי העיבוד.

5.3.1 כימות הפליטות ממקטע העיבוד - IPCC

לפי המדריך של IPCC, ניתן להעריך את הפליטות ממקטע העיבוד לפי מקדמי רמת החישוב Tier 1 ביחס לכמות הגז שהופקה או ביחס לכמות הגז שעובדה בפועל, אך ע"פ המדריך החישוב ביחס לכמות הגז שעובדה בפועל משקף בצורה טובה יותר את הפליטות, כפי שניתן לראות בטבלה 2. בנוסף, נציין כי מקדם הפליטה לעיבוד גז חמוץ אינו רלוונטי לישראל.

המדריך מבחין בין מקדמי הפליטה לפי ביצוע תכניות LDAR ולפי שימוש במדחסים, לרבות התייחסות לטכנולוגיית האיטום של המדחסים:

טבלה 2: מקדמי Tier 1 של IPCC לפליטת מתאן ממקטע העיבוד

ייעוד מקדם הפליטה	מקדם פליטת מתאן
תהליכי עיבוד שבהם לא מבוצע LDAR או מבוצע LDAR באופן מוגבל, **<u>או</u>** שפחות מ- 50% מהמדחסים הצנטריפוגליים הינם בעלי איטום יבש (dry seal)	1.83 טון/מיליון מ"ק גז מעובד
	1.65 טון/מיליון מ"ק גז מופק
תהליכי עיבוד שבהם מבוצעת תוכנית LDAR מקיפה, ובמרבית המדחסים הצנטריפוגליים קיים איטום יבש (dry seal)	0.75 טון/מיליון מ"ק גז מעובד
	0.57 טון/מיליון מ"ק גז מופק

במתקן AOT מבוצעת תוכנית LDAR שנתית לקווי הקונדנסט ובדיקה שנתית באמצעות OGI לקווי הגז. בנוסף, שלושת מדחסי הגז הגדולים (BGC – Booster Gas Compressors), שהם רכיבי הציוד

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[39] משרד האנרגיה, רשות הגז הטבעי – סקירת ההתפתחויות במשק הגז הטבעי, סיכום לשנת 2020: https://www.gov.il/BlobFolder/reports/ng_2020/he/ng_2020.pdf

[40] גז נחשב "חמוץ" (Sour) כאשר ריכוז ה- H_2S בו גבוה מ- 5.7 מ"ג/מק"ת (AP42, Chapter 5.3 – Natural Gas Processing). הפחתת ריכוזי ה- H_2S מתבצעת בתהליך הנקרא "המתקה".

בעלי קצבי הדליפה הגבוהים ביותר (המדריך אף מתייחס לטכנולוגיית האיטום שלהם לצורך הבחירה בין המקדמים), מושבתים ב- AOT[41]. לכן מבין מקדמי Tier 1 של IPCC למקטע זה, מקדם הפליטה המתאים ביותר עומד על 0.75 טון מתאן/מיליון מ״ק גז מעובד, וכמות הפליטות המתקבלת לפיו עבור כמות הגז שעובדה בשנת 2020 ב- AOT (8.2 BCM) עומדת על **6,150 טון מתאן/שנה**.

מקדם פליטה זה מבוסס על המידע המדווח מהמפעילים ל- EPA במסגרת התוכנית לדיווח על גזי חממה בארה״ב (GHGRP) ועל מידע ממסמך משנת 1996 של מכון אמריקאי למחקרי גז. מידע זה הוטמע במצאי גזי החממה של ארה״ב שפורסם בשנת 2018 (עבור השנים 1990-2016) לצורך הערכת הפליטות לשנת 2016. מעיון במקורות הפליטה מהם מורכב המקדם האמריקאי בשנת 2016, ניכר כי דליפות ממדחסים וגזי פליטה ממנועי מדחסים מהווים מקור משמעותי לפליטות מתאן במתקני עיבוד, אך אלה כאמור מושבתים ב- AOT.

5.3.2 ***כימות הפליטות ממקטע העיבוד - מדינות אחרות***

במצאי פליטות גזי החממה של בריטניה ושל נורבגיה, כמות הפליטות ממתקני עיבוד (טרמינלים יבשתיים לקבלת גז) מבוססת על דיווחי פליטות שנתיים המתקבלים ממפעילי המתקנים לרשויות הרלוונטיות, לפי הנחייתם:

- **בבריטניה -** דיווחים למערכת לדיווח פליטות סביבתית – EEMS, או דיווחי PRTR;
- **בנורבגיה** – דיווחים לסוכנות הסביבה הנורבגית. הפליטות המדווחות לסוכנות הסביבה הנורבגית מוערכות בהתבסס על ממצאי ניטור ו/או חישובים. דליפות מרכיבי ציוד מכומתות על בסיס סריקה שנתית או דו-שנתית באמצעות מצלמה תרמית (OGI), בשילוב מקדמי פליטה לרכיבים דולפים ולא-דולפים (Leak/No-Leak).
- **ארה״ב** - במצאי פליטות גזי החממה של ארה״ב מפורטים מספר מקדמי פליטה המיועדים למקורות פליטה שונים במתקני עיבוד. כאמור לעיל, המקדמים מבוססים על מידע המדווח מהמפעילים ל- EPA במסגרת התוכנית לדיווח על גזי חממה בארה״ב (GHGRP) ועל מידע ממסמך משנת 1996 של מכון אמריקאי למחקרי גז. למעט דליפות ממדחסים וגזי פליטה ממנועי מדחסים המחושבים ביחס לכמות המדחסים או ביחס להספק, שאר מקדמי הפליטה מחושבים ביחס למספר מתקני העיבוד (ק״ג מתאן/מתקן עיבוד).

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[41] המדחסים שכן פעילים ב- AOT הם מדחסי flash gas בהספק נמוך שאינם מיועדים לדחיסת גז מחצבים (המורכב כאמור בעיקר ממתאן), אלא לדחיסת פחמימנים קלים (כמעט ללא מתאן כלל) מתהליך ייצוב הקונדנסט

- **אוסטרליה** - במצאי פליטות גזי החממה של אוסטרליה הערכת הפליטות ממקטע העיבוד מבוצעת באמצעות נוסחת חישוב המבוססת על מחקר אוסטרלי, לפיה קיים יחס לא-לינארי הפוך בין כמות הפליטות לבין כמות הגז המעובדת (כלומר, פליטות גבוהות יותר ממתקנים בהם מעובדות כמויות גז נמוכות יותר).

5.3.3 כימות הפליטות ממקטע העיבוד – מדינת ישראל

בישראל - מתקן העיבוד AOT מדווח מדי שנה על כמויות המתאן הנפלטות ממנו למפל״ס. את הפליטות המדווחות למפל״ס ניתן לסווג כרמת חישוב Tier 3 מכיוון שהן מבוצעות באופן פרטני עבור כלל מקורות הפליטה באתר ספציפי. הנתונים המדווחים למפל״ס לרבות אופן חישוב הפליטות מכל מקורות הפליטה הרלוונטיים ב- AOT, שיטות החישוב מתבססות בין היתר על ממצאי ניטור ותיקון דליפות מרכיבי ציוד (LDAR לקווי הקונדנסט, OGI לקווי הגז, בשילוב מקדמי פליטה לרכיבים דולפים ולא-דולפים (Leak/No-Leak), על הערכות הנדסיות של כמויות הגז המנושבות בהתאם לגודלם הפיזי של יחידות הציוד ומקטעי הצנרת שבהם הופחת הלחץ באופן יזום בפועל, על מפרטי יצרן ועל תוצאות דיגום של הרכב הגז. יחד עם זאת, ראינו שניתן לשפר את דיוק החישובים על בסיס TIER-3 ובכוונת המשרד לדרוש ביצוע מדידות נוספות בחידוש היתר הפליטה למתקן.

כלל כמות המתאן שנפלטה לאוויר כפי שדווחה למפל״ס עבור שנת 2020 ממתקן AOT עומדת על 81.5 טון מתאן/שנה, או כ- 80 טון מתאן/שנה ללא פליטות שמקורן בשריפת דלקים (לפי IPCC על פליטות משריפת דלקים יש לדווח כקטגוריה נפרדת). יצוין, כי במתקן נעשו פעולות להפחתה במקור של פליטות מתאן, בין השאר, הסבה לשימוש בחנקן כ-purge במקום מתאן, והפסקת השימוש במתאן כגז מכשירים.

בדיווח למפל״ס עבור שנת 2019 כמות המתאן שנפלטה מ- AOT הייתה יותר מכפולה (196.7 טון/שנה בסה״כ), אך רוב הפער בין 2 הדיווחים (כ- 96 טון מתאן) נבע מנישוב יזום של כלל המתקן בעקבות מצב ביטחוני באזור הדרום בשנת 2019, וזאת בעקבות דרישה של הרשויות.

5.4 הולכה ואחסון (Transmission and Storage)

פליטות לא-מוקדיות מתרחשות במקטע ההולכה והאחסון ממערכות המשמשות להולכת הגז המעובד לשיווק (לצרכנים תעשייתיים גדולים כגון תחנות כוח ומפעלי כימיה, ולמערכות החלוקה), לרבות מערכות לאחסון הגז. הולכת הגז מתבצעת באמצעות צנרת רחבת קוטר הפועלת בלחץ גבוה לאורך מרחק רב, לעתים בשילוב תחנות דחיסה להעלאת הלחץ. בנוסף להולכת הגז, מקטע זה כולל גם תחנות לאחסון ומסופים לייבוא ולייצוא של LNG.

הגז המתקבל מהספקים בישראל מוזרם בלחץ גבוה (עד 80 בר) בצינורות רחבים המרכיבים את מערכת ההולכה הארצית, שהוקמה ומנוהלת על ידי חברת נתיבי הגז הטבעי לישראל (נתג״ז) ומשמשת כעורק ראשי לזרימת הגז. הגז מגיע לצמתים מרכזיים ברחבי הארץ שבהם פועלים מתקני מנייה והפחתת לחץ (PRMS) ומעבירים אותו לרשת החלוקה. חברת נתג״ז מוליכה את הגז לכל צרכני לחץ גבוה (מעל 16 בר), לצרכני לחץ נמוך (עד 16 בר) הצורכים מעל 2,000 מ״ק לשעה ו- 12 מיליון מ״ק לשנה, ולבעלי רישיונות חלוקה. מערכת ההולכה כוללת קווי צינורות להולכת גז ביבשה ובים, ואת המתקנים הקשורים אליהם, לרבות מתקני ה- PRMS ותחנות ההגפה[42].

מערכת ההולכה הארצית כוללת ארבעה מרכיבים עיקריים[43,44,45]:

1. 4 תחנות לקבלת גז מהספקים:
   - באשדוד - תחנה בה מתקבל הגז המופק בשדה תמר ומעובד ב- AOT;
   - באשקלון - תחנה בה התקבל גז ממצרים בין השנים 2008 ל- 2012, וכיום משמשת לייצוא;
   - בדור - תחנה בה מתקבל הגז המופק בשדה לוויתן, ובעתיד גם בשדה כריש-תנין;
   - המסוף לייבוא LNG מול חופי חדרה - המשמש כגיבוי להשלמת פערי ביקוש בתקופות צריכת שיא או בעת תקלה במאגרי/מתקני הפקת הגז. האונייה המגזזת עצמה מוחכרת ע״י חברת החשמל לישראל והיא איננה נמצאת תחת אחריות חברת נתג״ז.

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[42] משרד האנרגיה, גז טבעי, מערכת ההולכה והחלוקה, רשת ההולכה הארצית: https://www.gov.il/he/departments/guides/distribution_area?chapterIndex=1

[43] אתר נתג״ז – מערכת ההולכה: https://www.ingl.co.il/%d7%a0%d7%aa%d7%95%d7%a0%d7%99-%d7%94%d7%9e%d7%a2%d7%a8%d7%9b%d7%aa/

[44] המכון הישראלי לאנרגיה ולסביבה, 2017, גז טבעי, הוצאת הוד-עמי, שרה עמיהוד

[45] מידע משהתקבל משלומי זעירא, סמנכ״ל תפעול בחברת נתג״ז, במהלך סיור עם נציגי המשרד להגנ״ס בתחנת PRMS נשר ב- 13/1/2022

2. צנרת הולכה יבשתית באורך כולל של 613 ק״מ המורכבת מ- 4 מקטעים (מרכזי, דרומי, צפוני ומזרחי), וצנרת הולכה ימית באורך כולל של 106 ק״מ (98 ק״מ בין אשדוד לחוף דור, ו- 8 ק״מ בין מסוף ה- LNG לקו צנרת ההולכה הימי בחדרה);
3. 52 תחנות PRMS (Pressure Reduction and Metering Station) למנייה והפחתת לחץ. מטרת תחנות ה- PRMS היא להבטיח את אספקת הגז ללקוח באיכות, בלחץ ובטמפרטורה הנדרשים לו, והן מורכבות ממערכת סינון, מערכת מנייה, מערכת חימום הגז והפחתת לחץ ומערכת חימום מים. שחרורי לחץ באופן יזום מבוצעים במהלך פעולות תחזוקה, וכל פריקות הלחץ שאינן יזומות דרך שסתומי הבטיחות (PSVs) ידועות ומחושבות לפי מדי הפרש לחצים המחוברים למערכת הבקרה. כיום לא נעשה שימוש בגז מחצבים להפעלה פנאומטית של מכשירים, למעט בתחנת ה- PRMS ברידינג. בתחנות מותקנים גלאי דליפות אקוסטיים;
4. 85 תחנות הגפה (Block Valve Station). תחנות ההגפה פזורות לאורך מקטעי המערכת במרווחים של כ- 10 ק״מ, ומשמשות לתפעול ולבקרת המערכת, לבידוד מקטעי צנרת בעת חירום, ומתן מענה בעת חירום באמצעות שחרור לחץ דרך שסתום ריקון. פריקת לחץ בתחנות ההגפה מבוצעת באופן יזום בלבד.

מערכת ההולכה הוקמה בשנת 2003 (וממשיכה להתפתח גם כיום) לפי התקן ההולנדי NEN 3650-1 ומתופעלת לפי תקן DVGW של ההתאחדות הגרמנית לגז ומים.

כל צנרת ההולכה מרותכת ומוטמנת בקרקע, נבדקת בלחץ של 150% מלחץ העבודה והריתוכים עצמם נבדקים במהלך שלב ההקמה, כך שלא אמורות להיות דליפות מהצנרת עצמה, אלא במקרי חבלה שעליהם יתקבל חיווי מידי במערכת הבקרה.

בשנת 2020 הוזרם דרך מערכת ההולכה גז בכמות של כ- BCM 16[46].

5.4.1 כימות הפליטות ממקטע ההולכה והאחסון - IPCC

לפי המדריך של IPCC, כפי שניתן לראות בטבלה 3, ניתן להעריך את הפליטות ממערכות הולכה לפי מקדמי רמת החישוב Tier 1 ביחס לכמות הגז שנצרכה או ביחס לאורך הצנרת, אך מצוין כי אורך הצנרת משקף בצורה טובה יותר את הפליטות. המדריך מבחין בין מקדמי פליטה המיועדים

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[46] משרד האנרגיה, רשות הגז הטבעי – סקירת ההתפתחויות במשק הגז הטבעי, סיכום לשנת 2020: https://www.gov.il/BlobFolder/reports/ng_2020/he/ng_2020.pdf

למערכות הולכה שונות לפי ביצוע תוכניות LDAR ולפי שימוש במדחסים לאורכן, לרבות התייחסות לטכנולוגיית האיטום של המדחסים. בנוסף, ישנם מקדמי פליטה למסופי ייבוא/ייצוא LNG ולאחסון LNG המעריכים את הפליטות ביחס למספר התחנות.

טבלה 3 : מקדמי Tier 1 של IPCC לפליטת מתאן ממקטע ההולכה והאחסון

ייעוד מקדם הפליטה	מקדם פליטת מתאן
מערכת הולכה שבהן לא מבוצע LDAR או מבוצע LDAR באופן מוגבל, **או** שפחות מ- 50% מהמדחסים הצנטריפוגליים הינם בעלי איטום יבש (dry seal)	3.36 טון/מיליון מ״ק גז נצרך
	4.1 טון/ק״מ צנרת
מערכת הולכה שבהן מבוצעת תוכנית LDAR מקיפה, **ו**במרבית המדחסים הצנטריפוגליים קיים איטום יבש (dry seal)	1.29 טון/מיליון מ״ק גז נצרך
	2.08 טון/ק״מ צנרת
ייבוא/ייצוא LNG	1,660 טון/תחנה
אחסון LNG	22 טון/תחנה

בישראל, כל תחנות ה- PRMS ותחנות ההגפה במערכת ההולכה עוברות בדיקה לאיתור דליפות אחת ל- 8-6 שבועות באמצעות התזת מי סבון על גבי כל האוגנים (פלאנג׳ים) והתבריגים[47]. שיטה זו לניטור דליפות באמצעות מי סבון מהווה שיטה חלופית מקובלת לשיטה 21 של ה- EPA לצורך זיהוי ראשוני של רכיבים דולפים[48]. כמו כן, לאורכה של מערכת ההולכה בישראל אין כיום כלל תחנות דחיסה. לכן מבין מקדמי Tier 1 של IPCC למערכות הולכה, מקדם הפליטה המתאים ביותר הוא זה העומד על 2.08 טון מתאן/ק״מ צנרת, וכמות הפליטות המתקבלת לפיו עבור אורך הצנרת בישראל (719 ק״מ בסה״כ) עומדת על **1,496 טון מתאן/שנה**.

מקדם פליטה זה מבוסס על המידע המדווח ממפעילי מערכות ההולכה ל- EPA במסגרת התוכנית לדיווח על גזי חממה בארה״ב (GHGRP) ועל מידע ממסמך משנת 1996 של מכון אמריקאי למחקרי גז. מידע זה הוטמע במצאי גזי החממה של ארה״ב שפורסם בשנת 2018 (עבור השנים 1990-2016)

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[47] מידע משהתקבל משלומי זעירא, סמנכ״ל תפעול בחברת נתג״ז, במהלך סיור עם נציגי המשרד להגנ״ס בתחנת PRMS נשר ב- 13/1/2022

[48] USEPA, November 1995, Protocol for Equipment Leak Emission Estimates: https://www.epa.gov/sites/default/files/2020-09/documents/protocol_for_equipment_leak_emission_estimates.pdf

לצורך הערכת הפליטות לשנת 2016. מעיון במקדמי הפליטה המפורטים עבור מקטע זה במצאי האמריקאי, ניכר כי חלק ממקורות הפליטה אינם רלוונטיים לישראל (למשל תחנות דחיסה, וונטים לייבוש גז), או רלוונטיים באופן חלקי בלבד (הפעלה פניאומטית עם גז מכשירים המבוצעת כיום בתחנת PRMS רידינג בלבד). מנגד, מקטע זה במצאי של ארה״ב אינו כולל את תחנות ה- PRMS בגבול שבין מערכות ההולכה והחלוקה (למעט תחנות PRMS למכירה ישירה לצרכנים גדולים) מכיוון שהן משויכות בארה״ב למערכת החלוקה, אך בישראל הן משויכות למערכת ההולכה[49].

ייבוא LNG - מכיוון שהאונייה המגזזת מול חופי חדרה משמשת כגיבוי להשלמת פערי ביקוש, נתייחס אליה גם כאמצעי לאחסון וגם כמסוף לייבוא LNG. לפיכך כמות הפליטות השנתית המתקבלת לפי רמת החישוב Tier 1 עומדת על **1,682 טון מתאן/שנה**. מקדמי הפליטה של IPCC מבוססים על מידע שדווח מהמפעילים ל- EPA במסגרת התוכנית לדיווח על גזי חממה בארה״ב (GHGRP) בשנים 2015-2016.

עבור רמות החישוב Tier 2 ו- Tier 3, מפנה IPCC למסמך של API משנת 2015[50] שבו מפורטים מקורות הפליטה השונים ושיטות חישוב שונות לפעילויות הכוללות LNG.

5.4.2 כימות הפליטות ממקטע ההולכה והאחסון – מדינות אחרות

- **בריטניה** - במצאי פליטות גזי החממה של בריטניה- הערכת הפליטות ממערכת ההולכה מבוצעת ע״י החברה המפעילה את מערכת ההולכה הבריטית בלחץ גבוה (National Grid Gas) בהתבסס על: (1) סקרים תקופתיים לאיתור פליטות לא-מוקדיות (ממערכת ההולכה, מתחנות הדחיסה וממסופי ה- LNG); ו- (2) תיעוד של פעולות נישוב מכוונות שבוצעו במערכת.
- **נורווגיה -** במצאי פליטות גזי החממה של נורבגיה- הערכת הפליטות ממקטע ההולכה מבוססת על מקדמי ברירת המחדל מהמדריך הקודם של IPCC שפורסם בשנת 2006, לפני העדכון שנערך בשנת 2019.

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[49] לפי הגדרת ״מערכת ההולכה״ בחוק משק הגז הטבעי, תשס״ב-2002: ״קווי צינורות להולכה של גז טבעי בלחץ גבוה, ביבשה ובמימי החופין, ומיתקני הגז הקשורים אליהם, לרבות מיתקנים להפחתת הלחץ ללחץ נמוך לצורך חיבור רשת חלוקה או מיתקן גז של אחר אליהם, והכל עד למונה כאמור בסעיף 37(א), לרבות המונה עצמו, למעט צינורות איסוף כאמור בסעיף 35(ב) לחוק הנפט״

[50] American Petroleum Institute (API), 2015 - Liquified Natural Gas (LNG) Operations: Consistent Methodology for Estimating Greenhouse Gas Emissions: https://www.api.org/~/media/Files/EHS/climate-change/api-lng-ghg-emissions-guidelines-05-2015.pdf

- **ארה״ב**- במצאי פליטות גזי החממה של ארה״ב- מפורטים מגוון מקדמי פליטה למקורות פליטה שונים במקטע ההולכה והאחסון. המקדמים מבוססים על מידע המדווח מהמפעילים ל- EPA במסגרת התוכנית לדיווח על גזי חממה בארה״ב (GHGRP), על מידע ממסמך משנת 1996 של מכון אמריקאי למחקרי גז ועל מחקר אמריקאי משנת 2015 הכולל בין היתר מדידות בפועל במערכת ההולכה בארה״ב.
- **אוסטרליה -** במצאי פליטות גזי החממה של אוסטרליה- מוערכות הפליטות ממקטע ההולכה על בסיס עבודה שבוצעה ע״י הרשות האוסטרלית האחראית על מערכת ההולכה, שבה נקבע כי איבודי הגז מהווים 0.005% מכלל כמות הגז העוברת דרך צנרת הולכה טיפוסית באוסטרליה. עבור מסופי LNG מאמץ המצאי האוסטרלי את מקדם הפליטה מהמצאי של ארה״ב לשנת 2016.

5.4.3 כימות הפליטות ממקטע ההולכה והאחסון – מדינת ישראל

בישראל - לאחרונה בוצעה למערכת ההולכה הערכת פליטות פרטנית בדו״ח של חברת Wood שהוכן עבור חברת נתג״ז[51]. לפי הדו״ח, כמות הגז הנפלטת לסביבה ממערכת ההולכה הארצית מוערכת ב- 77,575 מ״ק/שנה, שהיא כ- **53.5 טון מתאן/שנה**[52]. הפליטות מיוחסות לשחרור גז לאטמוספירה כתוצאה מ:

- פעולות תחזוקה מתוכננות במתקני PRMS (53% מהפליטות, כ- 28.1 טון/שנה);
- בדיקות של מקטעי צנרת ומתקני PRMS חדשים (28% מהפליטות, כ- 14.7 טון/שנה);
- דליפות קטנות ממחברים ומפעולות תחזוקה נוספות (15% מהפליטות, כ- 7.8 טון/שנה); ו-
- בדיקות פנימיות של צנרת (4% מהפליטות, כ- 2.3 טון/שנה).

הערכת הפליטות כתוצאה מדליפות מבוססת על קצב ידוע של דליפה ידועה אחת בלבד מקו צנרת ימי באזור פלמחים, כפי שנקבע ע״י נתג״ז.

כמות הפליטות המפורטת בדו״ח של חברת Wood מבוססות בעיקר על חישובי הערכות הנדסיות לפי תוכנית התחזוקה השנתית ופעולות ההגזה הצפויות של קווים ותחנות חדשות. בהתאם לכך, ניתן לסווג הערכות אלה כרמת חישוב Tier 2 מכיוון שהן מותאמות לישראל אך אינן מבוצעות מדי שנה.

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[51] Wood 2020, INGL Estimated Annual Gas Release to the Environment

[52] לפי צפיפות גז מחצבים של 0.0006894 ק״ג/ליטר: https://www.gov.il/he/Departments/Guides/natural_gas_conecting?chapterIndex=4

לפי משרד האנרגיה[53], הפער בין הערכות נתג״ז לבין ההערכות לפי מקדמי IPCC מיוחס לעובדה שהצנרת בישראל נבנתה לפני כעשור בלבד ובהתאם לתקנים סביבתיים מחמירים שאינם מאפשרים פליטות לא-מוקדיות משמעותיות.

יחד עם זאת בהסתמך על הבאים, ייתכן וכמות הפליטות ממערכת ההולכה הוערכה בחסר:

(1) הכמויות שהוערכו עבור דליפות מרכיבי ציוד לא בוצעו לפי מתודולוגיית הכימות המקובלת על המשרד להגנ״ס (כפי שהיא נדרשת ומבוצעת גם באתרי ההפקה והעיבוד) - לפיה יש להתבסס על ספירה של כלל רכיבי הציוד (הדולפים ושאינם דולפים), ולהפעיל מקדמי פליטה **גם** על רכיבי הציוד שלא זוהו כדולפים במסגרת ממצאי ניטור הדליפות (leak/No-leak).

(2) חסרה התייחסות לפליטות משימוש בגז מחצבים להפעלה פניאומטית של מכשירים בתחנת ה-PRMS ברידינג;

(3) חסרה הערכה של פליטות מנישוף לצורך הפחתת לחץ.

(4) פערי מדידה - לפי דו״ח מסכם לשנת 2020 של רשות הגז הטבעי[54], קיים פער של 0.06 BCM (**כ-41,364 טון מתאן**[55]) בין כמות הגז הכוללת שסופקה למשק הישראלי לבין הכמות שנצרכה, הנגרם בשל ״איבודים״ (המירכאות במקור) ופערי מנייה ומדידה בתהליכי הולכת וחלוקת הגז. לפי דו״חות הפרשי המדידה המפורסמים ע״י נתג״ז[56], ״פער המדידה״ (UFG – Unaccounted For Gas) הוא הפרש חיובי או שלילי בין כל מוני הכניסה למערכת לבין כל מוני היציאה ממנה, לאחר שההפסדים והגז לצריכה עצמית (תחזוקה והגזה) של נתג״ז מקוזזים מהחישוב. כלומר, פערי המדידה אמורים לנבוע אך ורק מדיוק המונים (±1% לפי הדו״חות). עם זאת, כמעט בכל החודשים (35 מתוך 36 חודשים) שעבורם פורסמו הפרשי המדידה עד עתה (ינואר-דצמבר בין השנים 2019-2021) - הפרש המדידה היה חיובי. מבחינה סטטיסטית, הציפייה היא שלאורך זמן ההפרשים יהיו מאוזנים, כך שבחלק גדול יותר מהחודשים יתקבל גם הפרש מדידה שלילי.

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[53] משרד האנרגיה ינואר 2021 - תרומת פליטות לא מוקדיות של מתאן לאפקט החממה / ד״ר עינת מגל: https://www.gov.il/BlobFolder/reports/methane_fugitive_emissions/he/methane_fugitive_emissions.pdf

[54] משרד האנרגיה, רשות הגז הטבעי – סקירת ההתפתחויות במשק הגז הטבעי, סיכום לשנת 2020: https://www.gov.il/BlobFolder/reports/ng_2020/he/ng_2020.pdf

[55] לפי צפיפות גז מחצבים של 0.0006894 ק״ג/ליטר: https://www.gov.il/he/Departments/Guides/natural_gas_conecting?chapterIndex=4

[56] אתר נתג״ז – צריכה בפועל, ביקושים והפרשי מדידה של גז טבעי: https://www.ingl.co.il/%d7%a0%d7%aa%d7%95%d7%a0%d7%99-%d7%94%d7%9e%d7%a2%d7%a8%d7%9b%d7%aa/%d7%9e%d7%a2%d7%a8%d7%9b%d7%aa-%d7%94%d7%94%d7%95%d7%9c%d7%9b%d7%94/

לפיכך, כימות הפליטות עבור מקטע זה בוצע לפי מקדמי Tier 1 של IPCC למערכות הולכה. כאמור, מקדם הפליטה המתאים ביותר הוא זה העומד על 2.08 טון מתאן/ק״מ צנרת, וכמות הפליטות המתקבלת לפיו עבור אורך הצנרת בישראל (719 ק״מ בסה״כ) עומדת על 1,496 טון מתאן/שנה.

מסוף לייבוא LNG

ככל הידוע, נכון להיום לא בוצעה הערכת פליטות פרטנית עבור האוניה המגזזת והמסוף לייבוא LNG מול חופי חדרה. הערכות חברת נתג״ז אינן כוללות התייחסות לכך מכיוון שהאונייה המגזזת אינה נמצאת תחת אחריותה אלא מוחכרת ע״י חברת החשמל לישראל, וחברת החשמל לישראל אינה מדווחת על פליטות מפעילות זו למפל״ס מכיוון שלא מדובר בסוג פעילות הנדרש בדיווח.

האונייה המגזזת צפויה להפסיק את פעילותה בשנת 2022 (לאחר תחילת אספקת הגז גם ממאגר כריש, שתייתר את הצורך בגיבוי ע״י האונייה), אך המקשר הימי עצמו (המסוף לייבוא) ימשיך לשמש תשתית חיונית למקרה הצורך בעתיד[57].

5.5 חלוקה (Distribution)

פליטות לא-מוקדיות מתרחשות במקטע זה ממערכות המשמשות לחלוקת הגז בלחץ נמוך (עד 16 בר) באמצעות קווי צנרת תת-קרקעיים ראשיים (mains) ומשניים (service) עד לצרכני הקצה. מקורות הפליטה כוללים דליפות מהצנרת, תחנות PRMS/PRS ומונים.

מערכת החלוקה בישראל מוזנת ע״י מערכת ההולכה ומספקת גז בלחץ נמוך לצרכנים תעשייתיים קטנים ולצרכנים ביתיים. המערכת מתוכננת, מוקמת ומתופעלת על ידי 6 בעלי רישיונות החלוקה והיא מצויה בבעלותם ובאחריותם, באזורים - חיפה והגליל, חדרה והעמקים, מרכז, נגב, דרום וירושלים. המערכת נבנתה על פי תקן ישראלי המבוסס על התקן האירופי EN-12007[58].

נכון לשנת 2020, אורך צנרת החלוקה בישראל עומד על כ- 554 ק״מ, מתוכם 424 ק״מ מוגזים, ומחוברים אליה 110 צרכנים תעשייתיים. למערכת החלוקה מחוברים גם צרכניים ביתיים בדימונה, ערד, באר שבע ואופקים, ובמהלך שלוש השנים הקרובות מתוכננות לחיבור עוד למעלה מ- 31 אלף יחידות דיור (מספר יחידות הדיור המחוברות כיום אינו ידוע). כמו כן, חלק ממפעלי התעשייה

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[57] משרד האנרגיה, רשות הגז הטבעי – סקירת ההתפתחויות במשק הגז הטבעי, סיכום לשנת 2020: https://www.gov.il/BlobFolder/reports/ng_2020/he/ng_2020.pdf

[58] משרד האנרגיה, גז טבעי, מערכת ההולכה והחלוקה, רשת החלוקה: https://www.gov.il/he/departments/guides/distribution_area?chapterIndex=2

צורכים גז מחצבים דחוס (CNG) המשונע במשאיות. כמות הגז הכוללת שסופקה לצרכנים דרך מערכת החלוקה בשנת 2020 עמדה על 0.25 BCM בלבד[59].

במערכת החלוקה יש 125 תחנות PRMS/PRS[60] (כולל תחנות בצרכני הקצה), ובנוסף להן קיימות כ-100 תחנות הגפה של חברות החלוקה הכוללות ברזי וויסות ואמצעים להוספת ריחן (מולקולה בעלת ריח אך לא נחשבת כרעילה) לגז (THT).

5.5.1 כימות הפליטות ממקטע החלוקה - IPCC

לפי המדריך של IPCC, ניתן להעריך את הפליטות ממקטע החלוקה לפי מקדמי רמת החישוב Tier 1, וכפי שניתן לראות בטבלה 4, ביחס לכמות הגז שנצרכה או ביחס לאורך הצנרת, אך מצוין כי אורך הצנרת משקף בצורה טובה יותר את הפליטות. המדריך מבחין בין מקדמי פליטה המיועדים למערכות חלוקה שונות לפי חומרי המבנה של הצנרת (צנרת העשויה ברובה מפלסטיק או לא) ולפי ביצוע תוכניות LDAR. מקדמי הפליטה עבור אחסון גז לטווח קצר[61] ועבור חלוקה של גז עירוני[62] אינם רלוונטיים לישראל.

טבלה 4: מקדמי Tier 1 של IPCC לפליטת מתאן ממערכות חלוקה

ייעוד מקדם הפליטה	מקדם פליטת מתאן
מע' חלוקה שבהן פחות ממחצית מהצנרת עשויה מפלסטיק, **או** שמבוצע עבורן LDAR מוגבל או לא מבוצע LDAR כלל	2.92 טון/מיליון מ"ק גז נצרך
	1.17 טון/ק"מ צנרת
מע' חלוקה שבהן מרבית הצנרת עשויה מפלסטיק, **ו**שמבוצעת עבורן תוכנית LDAR	0.62 טון/מיליון מ"ק גז נצרך
	0.23 טון/ק"מ צנרת

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[59] משרד האנרגיה, רשות הגז הטבעי – סקירת ההתפתחויות במשק הגז הטבעי, סיכום לשנת 2020: https://www.gov.il/BlobFolder/reports/ng_2020/he/ng_2020.pdf

[60] משרד האנרגיה ינואר 2021 - תרומת פליטות לא מוקדיות של מתאן לאפקט החממה / ד"ר עינת מגל: https://www.gov.il/BlobFolder/reports/methane_fugitive_emissions/he/methane_fugitive_emissions.pdf

[61] Short term surface storage - a man-made above-ground storage facilities, for storage of medium-sized quantities of natural gas, help meet and balance rapid fluctuations in demand. Spherical and pipe storage tanks, and other types of low-pressure containers, are used for this purpose

[62] The composition of town gas differs from natural gas and therefore emissions are estimated for town gas using distinct emission factors

ככל הידוע במערכת החלוקה בישראל לא מבוצעת כיום תכנית LDAR, וחומרי המבנה אינם ידועים.

לכן מבין מקדמי Tier 1 של IPCC למקטע זה, מקדם הפליטה המתאים ביותר הוא זה העומד על 1.17 טון מתאן/ק״מ צנרת, וכמות הפליטות המתקבלת לפיו עבור אורך הצנרת המוגזת בישראל (424 ק״מ בסה״כ) עומדת על **496 טון מתאן/שנה**.

מקדם פליטה זה מבוסס על מידע ממסמך משנת 1996 של מכון אמריקאי למחקרי גז, כפי שהוטמע במצאי גזי החממה של ארה״ב שפורסם בשנת 2018 (עבור השנים 1990-2016) לצורך הערכת הפליטות לשנת 1992. כאמור לעיל, מקטע החלוקה במצאי האמריקאי כולל גם את תחנות ה-PRMS בגבול שבין מערכות ההולכה והחלוקה (תחנות PRMS בלחץ כניסה גבוה מ- 300 psi שהם כ- 20 bar), אך בישראל הן משויכות למערכת ההולכה.

5.5.2 כימות הפליטות ממקטע החלוקה – מדינות אחרות

- **בריטנה** - במצאי פליטות גזי החממה של בריטניה הערכת הפליטות ממערכת החלוקה מתבצעת כיום ע״י החברות הפרטיות המפעילות את 14 אזורי החלוקה השונים של גז בלחץ נמוך ובינוני בבריטניה, בהתבסס על מודל אחיד לחישוב דליפות (UK Gas Network Leakage Model). המודל פותח ע״י חברת British Gas שתפעלה בעבר את כל מערכת החלוקה בבריטניה. המודל עושה שימוש במקדמים ובהנחות שונות לגבי קצבי דליפה מקווים ומסוגי ציוד שונים, בהתבסס על מדידות וסקרים שנערכו בשנים 1992 ו- 2002, והוא עובר עדכונים שנתיים בהתאם לשינויים שבוצעו בתשתיות החלוקה בבריטניה.
- **נורבגיה -** במצאי פליטות גזי החממה של נורבגיה הערכת הפליטות ממקטע החלוקה מבוססת על מקדם ברירת מחדל יחיד מהמדריך הקודם של IPCC שפורסם בשנת 2006, לפני העדכון שנערך בשנת 2019.
- **ארה״ב**- במצאי פליטות גזי החממה של ארה״ב מפורטים מגוון מקדמי פליטה למקורות פליטה ולסוגי ציוד שונים במקטע החלוקה: (1) לדליפות מהצנרת בחלוקה לפי קווים ראשיים ומשניים ולפי חומרי המבנה; (2) לתחנות ה- PRMS בחלוקה לפי לחץ הגז בכניסה לתחנה; (3) למונים של צרכני הקצה בחלוקה לפי צרכנים ביתיים, מסחריים או תעשייתיים; (4) לתחזוקה שוטפת; ו- (5) לתקלות. המקדמים מבוססים על מידע ממסמך משנת 1996 של מכון אמריקאי למחקרי גז ועל מחקר אמריקאי משנת 2015 הכולל בין היתר מדידות בפועל במערכת החלוקה בארה״ב.

אוסטרליה - במצאי פליטות גזי החממה של אוסטרליה- הפליטות ממקטע החלוקה אינן נמדדות באופן ישיר, אך חייבות להתבסס על הערכות פערי המדידה בין מוני הכניסה ליציאה מהמערכת. החל משנת 2018 ועד עתה ההנחה היא ש- 37.3% מהפרשי המדידה במערכת החלוקה מיוחסים לדליפות (בשנים קודמות יוחסו אחוזים גבוהים יותר). פערי המדידה

במערכות החלוקה השונות באוסטרליה שונים מאוד זה מזה: החל מ- 0.2% בטזמניה ועד ל- 4.9% בדרום אוסטרליה[63].

5.5.3 כימות הפליטות ממקטע החלוקה – מדינת ישראל

בישראל, למערכת החלוקה בוצעה לאחרונה הערכת פליטות פרטנית בדו״ח של משרד האנרגיה[64]. לפי הדו״ח, היקף הפליטות הלא מוקדיות ממקטע החלוקה בישראל עומד על **1.1 טון מתאן/שנה** בלבד, על בסיס הנחה כי לא קיימות דליפות מהותיות מקווי הגז בשגרה, וכי מקור הגז הנפלט הוא בפעולות תחזוקה בתחנות ה- PRMS/PRS ובפעולות הגזה של קווים בלבד.

הפער בין הערכות משרד האנרגיה לבין ההערכות המתקבלות לפי IPCC מיוחס בדו״ח לעובדה שהתשתית בישראל קצרה, חדשה מאוד והרבה פחות מסועפת בהשוואה לעולם.

כמויות הפליטות המפורטות בדו״ח של משרד האנרגיה מבוססות בעיקר על חישובי הערכות הנדסיות לפי תוכנית התחזוקה השנתית ופעולות ההגזה הצפויות. בהתאם לכך, ניתן לסווג הערכות אלה כרמת חישוב Tier 2 מכיוון שהן מותאמות לישראל אך אינן מבוצעות מדי שנה. הערכות אלה אינן כוללות כלל התייחסות לדליפות מרכיבי ציוד, למרות שככל הידוע כיום לא מבוצעות כלל תוכניות LDAR.

לפיכך, כימות הפליטות עבור מקטע זה בוצע לפי מקדמי Tier 1 של IPCC למערכות חלוקה. כאמור, מקדם הפליטה המתאים ביותר הוא זה העומד 1.17 טון מתאן/ק״מ צנרת, וכמות הפליטות המתקבלת לפיו עבור אורך הצנרת המוגזת בישראל (424 ק״מ בסה״כ) עומדת על **496 טון מתאן/שנה**. ככל הידוע נכון להיום, הפרשי המדידה במערכת החלוקה בישראל אינם ידועים.

5.6 צרכני קצה (Post-Meter)

מקטע צרכני הקצה כולל פליטות המתרחשות: (1) לאחר מונה הגז של צרכני הקצה כתוצאה מדליפות מהצנרת הפנימית וממכשירים הפועלים על גז מחצבים (במפעלי תעשייה, בתחנות כוח ובמגזר הבייתי); ו- (2) מרכבים המונעים בגז מחצבים כתוצאה מתדלוק, ריקון צילינדרים

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[63] Australian Government, Department of Industry, Science, Energy and Resources – National Greenhouse Accounts Factors, October 2020: https://www.industry.gov.au/sites/default/files/2020-10/national-greenhouse-accounts-factors-2020.pdf

[64] משרד האנרגיה ינואר 2021 - תרומת פליטות לא מוקדיות של מתאן לאפקט החממה / ד״ר עינת מגל: https://www.gov.il/BlobFolder/reports/methane_fugitive_emissions/he/methane_fugitive_emissions.pdf

המשמשים לאחסון הגז בלחץ גבוה, בדיקות לחץ ושחרורי לחץ מכלי הרכב. פליטות כתוצאה מהתנעות והדממות של מכשירים ומתקני שריפת גז אינן כלולות.

5.6.1 כימות הפליטות ממקטע צרכני קצה - IPCC

לפי המדריך של IPCC, וכפי שניתן לראות בטבלה 5, ברמת החישוב Tier 1 למקטע זה מפורטים 3 מקדמי פליטה המתייחסים למקורות הפליטה השונים. להלן פירוט מקדמי הפליטה וכמות הפליטות המתקבלת לפיהם בישראל:

טבלה 5: מקדמי Tier 1 של IPCC לפליטת מתאן ממקטע צרכני הקצה והערכת הפליטות

ייעוד הפליטה	**מקדם פליטת מתאן**	**הערכת פליטות מתאן (טון/שנה)**	**הנחות חישוב**
רכבים המונעים בגז מחצבים	0.0003 טון/רכב	0.1	226 רכבים בישראל[65]
מכשירים הפועלים על גז מחצבים במגזר המסחרי והביתי	0.004 טון/מכשיר	28	כ- 7,000 צרכני קצה במגזר המסחרי והביתי[66]. בכל אחד מכשיר אחד הפועל על גז מחצבים (הנחיית IPCC למדינות חמות)
דליפות מצנרת פנימית במפעלי תעשייה ובתחנות כוח	0.4 טון/מיליון מ״ק גז נצרך	4,720	בשנת 2020 נצרכו 11.8 BCM גז במשק המקומי[67]
סה״כ -		**4,748**	

מקטע צרכני הקצה מופיע לראשונה רק במדריך העדכני של IPCC משנת 2019, בעוד במדריך הקודם משנת 2006 השלב האחרון בשרשרת הוא נקודת המכירה האחרונה לצרכן. סביר להניח שזו הסיבה לכך שההתייחסות למקטע זה במצאי הפליטות של מדינות אחרות היא חלקית או חסרה, כפי שמפורט להלן:

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[65] נתוני אגף תחבורה במשרד להגנ״ס נכון לחודש יולי 2021

[66] משרד האנרגיה, רשות הגז הטבעי, דו״ח השפעת רגולציה חדשה (RIA) תיקון חוק הגז (בטיחות ורישוי), התשמ״ט-1989 – מקטע ביתי: https://www.tazkirim.gov.il/sfc/servlet.shepherd/version/download/0683Y00000CDeF9QAL

[67] משרד האנרגיה, רשות הגז הטבעי – סקירת ההתפתחויות במשק הגז הטבעי, סיכום לשנת 2020: https://www.gov.il/BlobFolder/reports/ng_2020/he/ng_2020.pdf

5.6.2 כימות הפליטות ממקטע צרכני קצה – מדינות אחרות

- **בריטניה-** במצאי פליטות גזי החממה של בריטניה, פליטות המתרחשות בנקודה בה נצרך הגז מדווחות כיום תחת מקטע החלוקה ולא כמקטע נפרד. המצאי הבריטי מתייחס רק לפליטות שמקורן בשימוש בייתי ומסחרי בגז לצרכי חימום ובישול המתרחשות בטרם ההצתה, לפי מקדם פליטה בריטי ביחס לכמות הגז שנצרכה. המצאי הבריטי מניח שלא מתרחשות פליטות כתוצאה משימוש בגז כדלק בדוודים תעשייתיים, מכיוון שהם פועלים כמעט ברציפות ללא עצירות והתנעות, ומכיוון ששחרור גז שאינו נשרף מבוקר בקפידה במתקנים תעשייתיים מסיבות בטיחותיות. במצאי הבריטי אין כלל התייחסות לדליפות מהצנרת הפנים מפעלית, וגם לא לפליטות שמקורן בתדלוק רכבים המונעים בגז מחצבים.
- **נורבגיה -** במצאי פליטות גזי החממה של נורבגיה אין כלל התייחסות למקטע זה.
- **ארה"ב -** במצאי פליטות גזי החממה של ארה"ב אין כיום התייחסות נפרדת למקטע זה, אך מצוין כי ה- EPA שוקל לעדכן את המצאי עבורו החל מהשנה הבאה על מנת שיתאים למדריך העדכני של IPCC. בחודש ספטמבר 2021 פורסם מסמך המתאר את שיקולי ה- EPA לגבי הכללת המקטע במצאי של ארה"ב[68].
- **אוסטרליה-** במצאי פליטות גזי החממה של אוסטרליה מוערכות פליטות ממכשירים ביתיים ומסחריים הפועלים על גז מחצבים לפי מקדמי פליטה שפותחו עבור סוגי מכשירים שונים בהתבסס על מדידות. דליפות מהצנרת הפנימית במפעלים ובתחנות כוח ופליטות מרכבים המונעים בגז מחצבים מחושבות לפי מקדמי Tier 1 של IPCC משנת 2019.

5.6.3 כימות הפליטות ממקטע צרכני הקצה – מדינת ישראל

בישראל, למקטע צרכני הקצה אין כיום הערכת פליטות פרטנית ברמת חישוב גבוהה יותר (Tier 2, Tier 3). פליטות כתוצאה משימוש בגז מחצבים כדלק במפעלים ובתחנות הכוח המדווחים למפל"ס מחושבות באמצעות מחשבון שריפת דלקים המבוסס על מקדמי פליטת מתאן מתוך מדריך קודם של IPCC[69]. מקדמים אלה מחשבים למעשה רק את פרקציית הגז שאיננה נשרפת במלואה במתקן השריפה. נוהל LDAR הנוכחי[70] של המשרד להגנ"ס אינו מבוצע בפועל על צנרת גז המחצבים

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[68] USEPA, September 2021 - Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2020: Updates Under Consideration for Post-Meter Emissions: https://www.epa.gov/system/files/documents/2021-09/2022-ghgi-update-post-meter_sept-2021.pdf

[69] גרסת מדריך IPCC שפורסמה בשנת 2006, אך המקדמים לפליטת מתאן משריפת דלקים לא עברו עדכון בגרסת 2019

[70] המשרד להגנ"ס, אגף איכות אוויר ושינוי אקלים, 2008 - נוהל ביצוע תוכנית לאיתור וטיפול בדליפות מרכיבי ציוד (LDAR):

הפנימית במפעלים ובתחנות כוח, ולכן בנתונים המדווחים למפל״ס אין כרגע התייחסות לדליפות אפשריות מהצנרת הפנים מפעלית שבין המונים למתקני השריפה. פליטות מצריכת גז במגזר המסחרי והבייתי או מרכבים המונעים בגז מחצבים אינן מדווחות.

כימות הפליטות עבור מקטע זה בוצע לפי מקדמי Tier 1 של IPCC לצרכני קצה וכמות הפליטות המתקבלת עומדת על **4,748 טון מתאן/שנה**.

5.7 פליטות אחרות (Other)

פליטות אחרות ממערכות גז מחצבים הן כאלה שאינן מחושבות במסגרת המקטעים האחרים, והן עשויות לכלול התפרצות של בארות, התבקעות של צנרות או פגיעה בהן במהלך חפירות, תאונות ושחרורי לחץ בחירום.

5.7.1 כימות פליטות אחרות - IPCC

לפי המדריך של IPCC, למקרים אלה לא מפורטים מקדמי Tier 1 מכיוון שהערכת הפליטות מהם צריכה להתבצע לגופו של מקרה, לעתים תוך שילוב מקדמי פליטה והערכות הנדסיות.

5.7.2 כימות פליטות אחרות – מדינות אחרות

- **בריטניה ונורבגיה -** במצאי פליטות גזי החממה של בריטניה ושל נורבגיה אין התייחסות לפליטות אחרות כמקטע נפרד. יחד עם זאת, במצאי הבריטי מצוין כי כיום אין מידע זמין להערכת פליטות מהתפרצויות של בארות גז ונפט, למעט הערכות שבוצעו עבור ההתפרצות שהתרחשה באסדת Elgin בשנת 2012, ומבוססות על תצפיות של קצב זרימת המתאן במשך 5 ימים לפי דגימות אוויר ואנליזות מטיסות מחקר.
- **ארה״ב -** במצאי פליטות גזי החממה של ארה״ב אין כיום התייחסות נפרדת למקטע זה, אך מצוין כי בשנים האחרונות נערכו מספר מחקרים בנושא שבחלקם כומתו פליטות מאירועי התפרצות בארות, ושה- EPA שוקל לעדכן את המצאי עבורו החל מהשנה הבאה.
- **אוסטרליה -** במצאי פליטות גזי החממה של אוסטרליה נכללות תחת מקטע זה פליטות מבארות גז נטושות (ראה סעיף 5.8 בהמשך) ומצרכני קצה (ראה סעיף 5.6 לעיל).

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https://www.gov.il/he/departments/policies/procedures_and_guidelines_for_treating_nonpoint_emissions

5.7.3 כימות פליטות אחרות – מדינת ישראל

בישראל, ככל הידוע כיום אין פליטות מסוג זה ולכן בשלב זה אין הערכת פליטות.

5.8 בארות גז נטושות (Abandoned Gas Wells)

נטישה של שדה נפט או גז כרוכה על פי רוב באטימה של בארות מפיקות, בניקוי וסילוק מתקנים ובהשבת סביבת הפיתוח לקדמותה.

בישראל, אסדת מרי-B הפסיקה את הפקת הגז בשנת 2019, וכיום **15 בארותיה הימיות אינן פעילות**. לפי ההערכות אטימת בארות אלה צפויה להסתיים במהלך שנת 2022.

יש לציין גם את מאגר הגז היבשתי ״ראש זוהר״ באזור ערד שסיפק בעבר גז לשכונות מסוימות בערד ובדימונה והידלדל באופן משמעותי[71]. מספר בארותיו הנטושות וסטטוס אטימתן אינו ידוע.

5.8.1 כימות הפליטות מבארות נטושות - IPCC

לפי המדריך של IPCC, וכפי שניתן לראות בטבלה 6, המידע הקיים לגבי בארות נטושות איננו מאפשר להבחין בין פליטות מבארות נפט או גז נטושות, ולכן עבור בארות גז נטושות מפנה המדריך לסעיף העוסק בבארות נפט נטושות. במדריך נתונים 6 מקדמי פליטה שונים ברמת חישוב Tier 1 עבור בארות נטושות – בחלוקה ליבשתיות ולימיות, ובחלוקה נוספת לכאלה שנאטמו, שלא נאטמו ושלא ידוע (שנאטמו או שלא).

המקדמים לבארות הימיות הנטושות מבוססים על מקדמי פליטה המיועדים לבארות יבשתיות לאחר הכפלה במקדם הפחתה של 0.02, המשקף את העובדה שרוב המתאן הנפלט בקרקעית הים (כ- 98%) מומס במי הים, ולכן אינו מגיע לאטמוספירה.

טבלה 6: מקדמי Tier 1 של IPCC לפליטת מתאן מבארות נטושות

ייעוד מקדם הפליטה	מקדם פליטת מתאן (טון/באר)
בארות יבשתיות נטושות שנאטמו	2.5E-05
בארות יבשתיות נטושות שלא נאטמו	8.8E-02

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[71] משרד האנרגיה, רשות הגז הטבעי, דו״ח השפעת רגולציה חדשה (RIA) תיקון חוק הגז (בטיחות ורישוי), התשמ״ט-1989 – מקטע ביתי: https://www.tazkirim.gov.il/sfc/servlet.shepherd/version/download/0683Y00000CDeF9QAL

ייעוד מקדם הפליטה	מקדם פליטת מתאן (טון/באר)
כל הבארות היבשתיות הנטושות (שנאטמו או לא)	1.2E-02
בארות ימיות נטושות שנאטמו	3.5E-07
בארות ימיות נטושות שלא נאטמו	1.8E-03
כל הבארות הימיות הנטושות (שנאטמו או לא)	2.4E-04

בהנחה שאטימת בארות מרי-B טרם הושלמה במלואה, מקדם הפליטה המתאים ביותר הוא זה העומד על 2.4E-04 טון מתאן/באר, וכמות הפליטות המתקבלת לפיו עבור 15 בארות עומדת על כ-**0.004 טון מתאן/שנה**.

לגבי הבארות היבשתיות הנטושות של מאגר "ראש זוהר" – בשלב זה המידע חסר אך הן לא צפויות להוות מקור פליטה משמעותי ביחס לכלל השרשרת.

גם מקטע זה (בדומה למקטע צרכני הקצה) מופיע לראשונה רק במדריך העדכני של IPCC משנת 2019, ולכן גם כאן סביר להניח שזו הסיבה לכך שההתייחסות אליו במצאי הפליטות של מדינות אחרות היא חלקית או חסרה, כפי שמפורט להלן:

5.8.2 כימות הפליטות מבארות נטושות - מדינות אחרות

- **בריטניה ונורבגיה -** במצאי פליטות גזי החממה של בריטניה ושל נורבגיה אין כלל התייחסות לבארות נטושות.
- **ארה"ב-** במצאי פליטות גזי החממה של ארה"ב אין התייחסות ספציפית לבארות ימיות נטושות, אלא ליבשתיות בלבד.
- **אוסטרליה -** במצאי פליטות גזי החממה של אוסטרליה מחושבות הפליטות לפי מקדמי Tier 1 של IPCC.

5.8.3 כימות הפליטות מבארות נטושות - ישראל

בישראל , ככל הידוע כיום לא בוצעה הערכת פליטות פרטנית לבארות הנטושות.

6 סיכום הערכת הפליטות ופעולות לשיפור האומדן

טבלה 7 מסכמת את הערכת פליטות המתאן מהמקטעים השונים בהתאם לתיעדוף רמות החישוב של IPCC, קרי – העדיפות הגבוהה ביותר להערכות חישוב פרטניות מאתרים ספציפיים (Tier 3) המגובות בממצאי ניטור ומדידה בפועל (הפקה, עיבוד); כעדיפות שנייה יישום Tier 2 אם רלוונטי; במקרים בהם אין הערכות חישוב פרטניות (אחסון וייבוא LNG, צרכני קצה, בארות נטושות) או שההערכות הפרטניות אינן שלמות ואינן מגובות בממצאי ניטור בפועל (הולכה, חלוקה) נעשה שימוש במקדמי Tier 1.

טבלה 7 : סיכום הערכת פליטות מתאן במקטעים השונים (טון/שנה)

מקטע	מקדמי Tier 1 של IPCC -כל הטווח	מקדם Tier 1 של IPCC - מתאים	הערכות פרטניות מקומיות קיימות	כימות הפליטות באומדן זה	רמת חישוב (Tier)	הערות
חיפוש	-	-	-	-	-	
הפקה (אסדות)	45,394	45,394	359	359	**Tier 3**	דיווחי מפל״ס לשנת 2020 מאסדות תמר ולוויתן (ללא שריפת דלקים).
בארות הפקה ימיות וצנרת ימית (חלק ממקטע ההפקה)	-	-	-	2	משולב	ללא התייחסות פרטנית בעולם, מוערך ע״פ המלצת רגולטורים מארה״ב והעקרון המתואר במדריך של IPCC
עיבוד (AOT)	6,150 – 15,006	6,150	80	*80	**Tier 3**	דיווחי מפל״ס לשנת 2020 ממתקן AOT (ללא שריפת דלקים). יחד עם זאת, ראינו שניתן לשפר את דיוק החישובים על בסיס TIER-3 ובכוונת המשרד לדרוש ביצוע מדידות נוספות בחידוש היתר הפליטה למתקן
מערכת ההולכה	1,496 – 53,760	1,496	53.5	1,496	Tier 1	בהערכה הפרטנית שבוצעה ע״י נתג״ז, אין כימות דליפות לפי מתודולוגיה המקובלת על המשרד עבור דליפות מהצנרת. באומדן זה נעשה שימוש במקדם המתאים לאורך צנרת.
אחסון וייבוא LNG (חלק ממקטע ההולכה)	1,682	1,682	-	1,682	Tier 1	המקשר הימי (נתג״ז) והמגזזת מול חופי חדרה (חח״י)
חלוקה	98 – 730	496	1.1	496	Tier 1	ההערכה הפרטנית המקומית (משרד האנרגיה) הקיימת מניחה כי אין דליפות
צרכני קצה	4,748	4,748	-	4,748	Tier 1	הרוב המוחלט מיוחס לדליפות מצנרת פנימית במפעלים ותחנות כוח
פליטות אחרות	-	-	-	-	-	אירועים לא שגרתיים שאינם כלולים במקטעים אחרים
בארות נטושות	0.00001 – 0.03	0.004	-	0.004	Tier 1	15 בארות מרי-B בלבד, לא כולל הבארות היבשתיות של מאגר ״ראש זוהר״
סה״כ פליטות מכלל המקטעים במדינת ישראל	**59,568 – 121,320**	**59,966**	**496**	**8,863**		

כימות הפליטות בעבודה זו מתייחס לכך, שעבור מקטע ההפקה והעיבוד נעשה שימוש ברמת החישוב Tier 3 בהתאם להנחיות ה IPCC. עבור יתר המקטעים רמת החישוב היתה נמוכה יותר, Tier 1. בהתאם לממצאי עבודה זו, סך הפליטות בישראל לשנת 2020 מוערכת ב- 8,863 טון מתאן, שהן כ- 0.3% מסך פליטות גזי החממה (CO_2eq) שדווחו בישראל בשנת 2020.

לאורך הדו״ח ניכר כי מקדמי Tier 1 של IPCC מובילים להערכת פליטות גבוהה יותר משמעותית ביחס להערכות הפרטניות (אם קיימות), בד״כ בכ- 2 סדרי גודל. הערכות הפליטות הגבוהות שחושבו לפי מקדמי Tier 1 מתבטאות גם בהיקף איבודי הגז לאורך המקטע (החלק היחסי של הפליטות מכלל כמות הגז המוזרמת). כפי שמצוין גם במדריך של IPCC, מקדמי Tier 1 עלולים להוביל בקלות לשגיאה של סדר גודל אחד או יותר, ולכן יש להשתמש בהם כמוצא אחרון.

להלן סיכום פעולות לשיפור האומדן לפי מקטעים:

(1) **חיפוש** - הטמעת דרישות תחת היתר הרעלים של מבצעי פעולות חיפוש שיתקיימו בעתיד, לביצוע מדידה ודיווח על כמויות המתאן הנפלטות במהלך פעולות חיפוש חדשים.

(2) **הפקה ועיבוד**

- הטמעת דרישות נוספות בחידוש היתר הפליטה של מתקן AOT לביצוע מדידות, שיפור ודיוק החישובים על בסיס Tier 3 ;
- שימוש במצלמה תרמית ע״י פקחי המשרד להגנ״ס במהלך סיורי פיקוח לצורך איתור דליפות מרכיבי ציוד, זיהוי נישובים מכוונים ואירועים בהם לא מופעלים לפידים ;

(3) **מערכת ההולכה**

- הטמעת דרישות תחת היתר הרעלים לביצוע ניטור דליפות מתחנות ההגפה ומתחנות ה-PRMS באמצעות שיטות מקובלות (למשל מצלמה תרמית, והערכות הנדסיות לכימות פליטות מארועים בלתי שגרתיים, שחרורי לחץ וכו׳. דרישות אלה יביאו לדיוק האומדן לרמת Tier 3 ;
- הטמעת דרישות תחת היתר הרעלים לביצוע בקרה וכיול של מכשירי המנייה והמדידה בתהליכי הולכת הגז, לצורך דיוק הפערים וקבלת תמונת מצב מדויקת על איבודים במערכת ;
- הטמעת דרישות תחת היתר הרעלים להוספת קו הצנרת הימית של מערכת ההולכה לתוכנית הניטור התקופתי המבוצע לתשתיות הימיות.

(4) **חלוקה** – הטמעת דרישות תחת היתר הרעלים לביצוע ניטור וכימות דליפות מרכיבי ציוד, או לחילופין לבצע סקרים מדגמיים תקופתיים לצורך קביעת קצבי פליטה המאפיינים את

המערכת המקומית על סמך מדידות בפועל והערכות הנדסיות לכימות פליטות מארועים בלתי שגרתיים, שחרורי לחץ וכו׳. דרישות אלה יביאו לדיוק האומדן לרמת Tier 3.

(5) **צרכני קצה** – הטמעת דרישות תחת היתרי פליטה עבור צרכני גז גדולים (תעשייה ותחנות כוח) לביצוע כימות פליטות מתחנות PRMS/PRS ומצנרת גז המחצבים הפנימית באמצעות OGI LDAR. דרישות אלה יביאו לדיוק האומדן לרמת Tier 3.

7 נספח 1 – הרגולציה הפדרלית בארה״ב לניטור ודיווח על פליטות גזי חממה ממערכות הולכה וחלוקה

לפי החלק העוסק בחובות הדיווח על גזי חממה ממערכות נפט וגז מחצבים ברגולציה הפדרלית בארה״ב[72], יש לדווח על פליטות של גזי חממה במידה והן גבוהות מ- 25,000 טון שווה ערך פד״ח (CO_2-e) לשנה ממקורות הפליטה הרלוונטיים למקטע:

<u>**מערכות הולכה:**</u>

<u>במערכת הולכה יבשתית שאינה כוללת דחיסה</u> [98.232(m) - onshore natural gas transmission pipeline], מקור הפליטות שעליהן יש לדווח הוא נישובים כתוצאה מהפחתת לחץ בצנרת בלבד (pipeline blowdown CO_2 and CH_4 emissions from blowdown vent stacks).

את הנישובים ניתן לחשב באמצעות אחת או יותר משתי שיטות המפורטות ברגולציה עצמה בסעיף 98.233(i) (הערכת נפח הגז המנושב כתוצאה מפעולות שונות, או מד ספיקה).

<u>במערכת הולכה הכוללת גם דחיסה</u> [98.232(e) - onshore natural gas transmission compression], יש לדווח בין היתר גם על דליפות מרכיבי ציוד.

כלומר, ניטור ודיווח על דליפות מרכיבי ציוד נדרש רק כאשר יש תחנות דחיסה.

עם זאת, **כן נדרש ניטור ודיווח על דליפות מרכיבי ציוד <u>המשויכים בארה״ב למקטע החלוקה, אך משויכים בישראל למערכת ההולכה</u>** – בתחנות ה- PRMS הנמצאות מעל לגובה פני הקרקע בגבול שבין מערכת ההולכה לחלוקה (ראה פירוט בטבלה 8 בהמשך תחת מערכות חלוקה).

<u>**מערכות חלוקה:**</u>

בטבלה 8 מפורטים מקורות הפליטה השונים במקטע החלוקה [סעיף 98.232(i) ברגולציה], אופן הערכת הפליטות הנדרש מהם [סעיפים 98.233(q), (r), (z) ברגולציה] ושיטות הניטור הנדרשות [סעיפים 98.234(a)(1-5) ברגולציה]:

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[72] Code of Federal Regulations Title 40 (40 CFR), Chapter I, Subchapter C, Part 98 (Mandatory Greenhouse Gas Reporting), Subpart W (Petroleum and Natural Gas Systems): https://www.ecfr.gov/cgi-bin/text-idx?node=sp40.23.98.w&rgn=div6#se40.23.98_1234

טבלה 8: מקורות פליטה, אופן הערכת הפליטות ושיטות הניטור הנדרשות במערכת החלוקה לפי הרגולציה הפדרלית בארה״ב

מקור פליטה במערכת החלוקה	אופן הערכת הפליטות ושיטות הניטור
1. דליפות מרכיבי ציוד כגון מחברים, מגופים, ברזי שליטה, PRV's, מדי ספיקה, וסתים וקווים פתוחים (open-ended lines) בתחנות PRMS הנמצאות מעל לגובה פני הקרקע בגבול שבין מערכת ההולכה לחלוקה (above grade transmission-distribution transfer stations[73])	**ניטור אחת לשנה** באמצעות אחת מהשיטות הבאות: א. מצלמה תרמית (OGI); ב. שיטה 21 (גלאי VOC); ג. מכשיר קרן לייזר אינפרא-אדום; ד. מכשיר אקוסטי לגילוי דליפות **כימות** הפליטות באמצעות נוסחת חישוב המפורטת ברגולציה עצמה – מקדמי פליטה לרכיבים שנמצאו דולפים בלבד
2. דליפות מרכיבי ציוד בחלק שמתחת לגובה פני הקרקע בתחנות ההשקה שבין מערכת ההולכה לחלוקה	אין חובה לבצע ניטור בפועל. הערכת פליטות באמצעות נוסחת חישוב המפורטת ברגולציה עצמה, המבוססת על ספירה של רכיבי ציוד והכפלתם במקדמי פליטה ובשעות הפעילות שלהם. מערכות צנרת שקוטרן שווה או קטן מ- ”0.5 מוחרגות
3. דליפות מרכיבי ציוד בחלק שמעל לגובה פני הקרקע של תחנות מדידה והפחתת לחץ, שאינן תחנות השקה	
4. דליפות מרכיבי ציוד בחלק שמתחת לגובה פני הקרקע של תחנות מדידה והפחתת לחץ	
5. דליפות מרכיבי ציוד בקווי חלוקה ראשיים (Distribution main)	
6. דליפות מרכיבי ציוד בקווי חלוקה משניים (Distribution services)	
7. מתקני שריפת דלקים	במידה ורלוונטי, יש להגיש נתונים המפורטים ברגולציה עצמה (לא מפורט במסגרת דו״ח זה)

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[73] Transmission-distribution (T-D) transfer station means a metering-regulating station where a local distribution company takes part or all of the natural gas from a transmission pipeline and puts it into a distribution pipeline

נספח 15

העתק מחוות דעת המומחה

עמ׳ 621

נספח 15

חוות דעת מומחה

שם המומחה: ד״ר אבי לובצ׳יק

נושא חוות הדעת: בחינת השפעת ההליך התחרותי הרביעי על פליטות גזי חממה בישראל

עיסוק נוכחי: מנכל ושותף מייסד חברת אופורטו-קרבון בע״מ

השכלה אקדמית: תואר ראשון במדעי הסביבה; תואר שני בגיאופיזיקה; תואר שלישי- גאופיזיקה- מודלים מתמטיים באנרגיה מתחדשת.

ניסיון תעסוקתי רלוונטי:

- 2014- יועץ מדעי (עמית ממשק) באגף תקציבים משרד האוצר. חבר בצוות בתוכנית הלאומית להפחתת פליטות.
- 2015-2019- מהנדס איכות סביבה וקיימות אינטל ישראל- אחראי על מצאי הפליטות ממערך הייצור של אינטל בישראל, דיווחי PRTR, עמידה ביעדי אקלים ותוכנית התייעלות אנרגטנית
- 2019-2022- סמנכ״ל פיתוח עסקי קפיטל נייצ׳ר- קרן העוסקת בהשקעות בסטארטפים בתחום הקיימות. סך השקעות של כ20 מ׳ דולר, הנפקה של 4 חברות בבורסה, חבר דירקטוריון של 9 חברות.
- 2022- כיום, מנכ״ל ושותף מייסד אופורטו-קרבון, חברה המתמחה ביצירת תעודות הפחתה והובלה של השווקים לכלכלה מאוזנת פחמן.

אני החתום מטה, ד״ר אבי לובציק, נותן בזאת, לבקשת גרינפיס ים תיכון בע״מ, חוות דעת בעניין השפעת פיתוח משק הגז בישראל על יעדי הפחתה של פליטות גזי חממה.

תאריך: **חתימה:**

__________21.6.23__________

מודל חיזוי 2023

בחינת השפעת ההליך התחרותי הרביעי על פליטות גזי חממה

ד"ר אבי לובצ'יק

עבור גרינפיס ישראל

תקציר מנהלים

7 במאי, 2023

מחקר זה מתבסס על מודל ההדמיה "מונטה קרלו", על מנת לחזות באופן המהימן ביותר, בהתבסס על הספרות המחקרית העדכנית, את שיעור פליטות גזי החממה העתידיות בישראל כתוצאה ממימושו של ההליך התחרותי הרביעי לקבלת רישיונות לחיפוש גז טבעי במימי ישראל ("**ההליך התחרותי הרביעי**"), מימוש אשר עתיד (בהערכה שמרנית) להרחיב את משק הגז של ישראל בהיקף משוער של כ- BCM500.

מספר מוסדות מחקר ומשרדי ממשלה שונים ניסו בעבר להעריך את שיעור פליטות גזי החממה ממאגרי הגז הקיימים במים הכלכליים של ישראל, אך הערכות אלו לא התבססו על מחקר ושימוש במודלים מתמטיים לכימות הפליטות, אלא על הערכות, שהתבררו כהערכות חסר שנעשו על בסיס מדידות חלקיות והערכות חלקיות אחרות. כמו כן, טרם ההחלטה על פרסום ההליך התחרותי הרביעי לא התבצעה בחינה של ההשפעה האקלימית של המהלך, בדמות כימות של תוספת פליטות גזי החממה הצפויה כתוצאה מפיתוח משק הגז הנובע מההליך התחרותי הרביעי.

לבחינה זו חשיבות מכרעת, בשל העובדה כי בהחלטת ממשלת ישראל מס. 171 "כלכלה דלת פחמן" מיולי 2021, הציבה הממשלה לעצמה יעדים לאומיים להפחתת פליטות גזי חממה בשיעורים ניכרים. יעדים אלו עוגנו בהתחייבויות של ישראל במסגרת הסכם פריז. לראשונה, ישראל התחייבה להפחתה אבסולוטית בפליטות בשיעור של 27% עד 2030 ו-85% עד 2050, בהשוואה לרמת הפליטות ב-2015.

המחקר הנוכחי מבקש לחדד את הסתירה המובנית שבין הרחבת משק הגז בהיקפים האמורים כתוצאה מההליך התחרותי הרביעי, לבין עמידה ביעדי הפחתת פליטות גזי חממה אליהם מחויבת ישראל במסגרת אמנה בינלאומית וכן בהתאם להחלטת הממשלה, כאמור לעיל.

הממצאים העיקריים העולים מהמחקר:

- הרחבת משק הגז בהיקף של BCM500 (בהתאם להערכות השמרניות עליהן מתבסס משרד האנרגיה) תביא לתוספת פליטות גזי חממה כוללת בסך של Mton CO2eq 806.01, שיתפרסו לאורך 30 שנה מתחילת פיתוח המאגר. בהתאם, תוספת הפליטות השנתית צפויה לעמוד על Mton CO2eq 26.86 מדי שנה.
- לשם המחשה, תוספת פליטות שנתית בהיקף שנתי של על Mton CO2eq 26.86 **מפיתוח מאגרי הגז החדשים בלבד**, שווה ערך ל35% מסך פליטות גזי החממה שנפלטו בישראל בשנת 2022; 46% מסך פליטות גזי החממה שעל ישראל יהיה להפחית בשנת 2030, ו220% מסך פליטות גזי החממה שעל ישראל יהיה להפחית בשנת 2050.
- לצורך עמידה ביעד הפחתת פליטות גזי החממה שנקבע לשנת 2030, נדרשת מדינת ישראל לקצב הפחתה ממוצע של כ-8% מדי שנה לאורך 8 השנים הקרובות, עד להגעה לסך פליטות של Mton CO2eq 57.87 בשנת 2030. במידה והרחבת משק הגז תחל בין השנים -2023 2030, לרבות שלב החיפושים, היא צפויה להגביר את הקצב השנתי של הפחתת פליטות גזי החממה הנדרש לעמידה ביעד ההפחתה, כך שתידרש הפחתה ממוצעת של כ-52% מדי שנה.
- בהנחה שמרנית ביותר לפיה ישראל תעמוד ביעדי ההפחתה לשנת 2030, לצורך עמידה ביעד שנקבע לשנת 2050, נדרש קצב הפחתה שנתי של כ-7.5% בממוצע לאורך 20 שנה, עד להגעה לסך פליטות של Mton CO2eq 11.96 בשנת 2050. במידה והרחבת משק הגז תתבצע בין

השנים 2030-2050, היא צפויה להגביר את הקצב השנתי של הפחתת פליטות גזי חממה הנדרשות לעמידה ביעד, כך שתידרש הפחתה ממוצעת של כ-197% מדי שנה.

- בשל ההיערכות המוקדמת הנדרשת לטובת צמצום פליטות גזי חממה, הרחבת משק הגז בהיקף האמור תפגע בצורה משמעותית ביכולת העמידה של ישראל ביעדי הפחתת הפליטות אליהם התחייבה.

יש לציין כי תוספת פליטות גזי החממה הצפויה מהרחבת משק הגז, והאחוז שלה מקצב ההפחתה השנתי הנדרש לטובת עמידה ביעדים, תלויה במועד המדויק בו יחל פיתוח והפקת הגז מהמאגר.

כמו כן, חשוב לציין כי מעבר לחישוב שבוצע במחקר הנוכחי, הרחבת משק הגז לטובת ייצוא כרוכה בהקמת תשתיות נלוות נוספות, לרבות הקמת מתקן הנזלה (LNG) וכן הקמת הצינור ומתקן הדחיסה הנדרשים לטובת הקמת המקטע הישראלי של צינור ה"איסט-מד", שמתוכנן לחבר בין מאגרי הגז בים התיכון לבין מדינות אירופה. מפאת היקף העבודה, הערכת פליטות גזי החממה הצפויות מתשתיות נלוות אלה לא נכללה במסגרת המודל. יש להניח כי במידה ויוקמו תשתיות אלו, הן יביאו לתוספת פליטות גזי חממה בשיעור משמעותי נוסף.

תוכן עניינים

1. הרקע למחקר

בחינה זו נערכה לבקשת ארגון גרינפיס ישראל, כדי להעריך את פליטות גזי החממה העתידיות בהתחשב בהרחבת משק הגז במים הכלכליים של ישראל, בהיקף משוער של כ-BCM 500. בעוד שמוסדות מחקר ומשרדי ממשלה שונים ניסו להעריך בעבר את פליטות גזי חממה ממאגרי הגז בים התיכון, הם לא פיתחו כלי מתמטי יעיל שלוקח בחשבון מספר רב של פרמטרים וסימולציות.

ביולי 2021, בהחלטה מס. 171 לגבי המעבר לכלכלה דלת פחמן, ממשלת ישראל הציבה לעצמה יעדים לאומיים להפחתת פליטות גזי חממה. יעדים אלו עוגנו בהתחייבויות של מדינת ישראל במסגרת הסכם פריז. לראשונה, ישראל התחייבה להפחתה אבסולוטית בפליטות בשיעור של 27% עד 2030 ו-85% עד 2050, בהשוואה לרמת הפליטות ב-2015 [7]. ראש הממשלה לשעבר נפתלי בנט הכריז בוועידת האקלים בגלזגו (2021) כי ישראל שואפת להגיע לנטו-אפס פליטות עד 2050. בנוסף, בשנת 2021 הצטרפה ישראל לאמנת המתאן (Global Methane Pledge), יוזמה משותפת של כ-120 מדינות שמטרתה להפחית את פליטות המתאן בלפחות 30% עד 2030 בהשוואה לרמות של 2020 [7].

על מנת לתמוך בהתחייבויות אלה, המחקר הנוכחי כולל סקירה של מחקרים שפורסמו בספרות המקצועית העדכנית אודות מדידות פליטות גזי חממה משרשרת הייצור של גז טבעי, לרבות מחקרים שנערכו בישראל ומתודולוגיות למודלים מרובי משתנים. המתודולוגיה שנבחרה למחקר זה, יחד עם המודל שנבחר, הפרמטרים שנבחרו לקלט, המשוואות של הדמיית מונטה-קרלו וניתוח רגישות, מוצגות. תוצאות המודל מוצגות, ומסקנה והמלצות מסופקות לסיום המחקר.

1.1 מוקד המחקר

מחקר זה מתמקד בניתוח של פליטות ממציאה וניצול של מאגר גז חדש בקיבולת של כ-BCM 500. יש לציין, כי הפליטות ממאגרי הגז הקיימים בישראל, דהיינו תמר, לויתן וכריש-תנין, לא נבחנו במסגרת המחקר. הפליטות מאותם מאגרים נכללו בתרחיש "עסקים כרגיל", המפורט בפרק המתודולוגיה.

2. בחינת הספרות המקצועית

2.1 רקע

בשנים האחרונות, מדינות רבות התחייבו להגיע לאיפוס נטו של פליטות גזי חממה עד ל-2050/60, וחלקן מיישמות אסטרטגיות מגוונות בהתמקדות בפליטות בעייתיות במיוחד. אחד התורמים העיקריים לפליטות גזי חממה הוא מגזר הפקת הנפט והגז, ולאור כך שהביקוש לגז טבעי עולה, חשוב להבין את השפעתו על האקלים. דליפות מתאן הינם המקור העיקרי לפליטות גזי חממה ממערכות לאספקת גז טבעי, אך קיימת אי ודאות לגבי שיעור הפליטות, השוני ביניהן ואילו גורמים עיקריים משפיעים עליהן. לפיכך, נעשים מאמצים רבים להגיע למדידה מדויקת של פליטות מתאן. עם זאת, באזורים רבים ברחבי העולם חסרים הידע והיכולות למדידה ישירה של פליטות מתאן. לאור זאת, רבים מסתמכים על מקדמי פליטה בפועל כדי להעריך את הפליטות שלהם.

ההפקה של גז טבעי גדלה בעשורים האחרונים ברחבי העולם. גם החששות באשר להשפעה הסביבתית של פליטות גזי חממה מבארות גז טבעי גוברות. מתאן, המרכיב העיקרי של הגז הטבעי, הוא גז חממה חזק ביותר, בשל היותו יעיל יותר ביכולתו ללכוד חום מאשר פחמן דו חמצני, בפרקי זמן קצרים. מספר מחקרים בחנו עד כה את פליטות המתאן וגזי חממה אחרים מבארות גז טבעי, עם תוצאות שונות בהתאם למתודולוגיה ולמיקום ביצוע המחקר. לדוגמה, מחקר שנערך בארצות הברית מצא כי סך פליטות גזי החממה מבארות גז טבעי השתנה מאוד בין בארות, והראה כי שיעור הפליטות תלוי בגורמים כגון גיל הבאר ותהליך הפקת הגז שנעשה בו שימוש [10, 5]. בסקירת ספרות זו, נבחן את מצב המחקרים אודות פליטות גזי חממה מבארות גז טבעי, כולל המתודולוגיות בהן נעשה שימוש, הגורמים המשפיעים על הפליטות והשלכות המדיניות של הממצאים [8].

2.2 היעדר מידע

למרות החשיבות ההולכת וגוברת של גז טבעי כדלק מעבר בתמהיל האנרגיה העולמי, הספרות המקצועית מצביעה על חוסר משמעותי במידע ובמדידות של פליטות גזי חממה הקשורים בהפקתו והובלתו. פער ידע זה מגביל את היכולת להעריך את ההשפעה הסביבתית של גז טבעי כמקור לאנרגיה, כמו גם את האפקטיביות של אסטרטגיות מיטיגציה להפחתת פליטות גזי חממה. מחקרים עדכניים מצביעים על כך שההערכות של פליטות גזי חממה מהפקת גז טבעי עשויות להיות בלתי מדויקות, וכי דרושות טכניקות מדידה טובות יותר [16]. הדבר מדגיש את הצורך במחקר נוסף כדי להשלים את פערי הידע ולפתח שיטות מדידה מדויקות יותר לבחינת ההשפעה הסביבתית של הפקת גז טבעי.

ממצאים מראים שבשנת 2015, פליטות לא-מוקדיות בארה"ב הוערכו כגבוהות ב-60% מההערכה המקורית של ה-EPA (הסוכנות האמריקאית להגנת הסביבה) בכ-13±2 Mt/שנה, ככל הנראה בשל שיטות מצאי פליטות קיימות שמעריכות בחסר את הפליטות המשתחררות בתנאי הפעלה חריגים, מה שמעיד על כך שהמקור העיקרי לאי דיוק טמון בפליטות לא מוקדיות מדליפות מציוד וכלי אחסון, בעוד מודלים המבוססים על מערכות הפאנל הבין-ממשלתי לשינוי אקלים (IPCC) מעריכים בחסר משמעותי את הפליטות הללו [14, 8]. בארקלי ואח'. (2019) [2] הראו כי הדיווחים של פליטות מתאן בדרום מערב פנסילבניה מהווים רק כ-20% מהפליטות הנמדדות. רוב הפליטות הלא מוקדיות התרחשו במקטע ההפקה והעיבוד, כאשר הובלה ואחסון הם הגורם השלישי לפליטות לא מוקדיות. מקיי ואח' (2021) [13] טוענים כי הפליטות ממקטע ההולכה בקנדה מוערכות בחסר של פקטור 1.5, נתון שתואם מחקרים קודמים. המקורות העיקריים לפליטת מתאן הם תהליכי שיקוע, בעירה לא מלאה במהלך שריפה מבוקרת בלפיד ופליטות לא מוקדיות. אחת הנקודות שעלו במהלך מחקר זה היא שיש אי דיוק משמעותי כתוצאה מהערכת חסר של ממצאי הרכיבים, ולכן מקורות רבים של

פליטות לא נספרים. קופר ואח'. (2021) [6] העריכו שב-2017 נפלטו בממוצע Mt 26.4 של מתאן בכל רשתות האספקה של גז טבעי המשמעותיות בעולם. בנוסף, הם מסיקים כי 58% מהמדינות שנסקרו נמצאות בסיכון גבוה לייצר פליטות לא מוקדיות, במיוחד במקטע ההפקה.

2.3 המקרה של ישראל

בדומה למדינות רבות בעולם, אין בישראל מדידות שיטתיות של פליטות מתאן מאתרי ההפקה של גז טבעי, דבר שמקשה על אומדן מדויק של הפליטות ממגזר זה. בהיעדר ניטור מקיף של כל שרשרת הייצור של הגז, ניתן להעריך דליפות ממאגרים באמצעות מקדמי פליטה שפותחו ממדידות במאגרי גז אחרים ומרכיבי ציוד שונים, בהתאם לדיווחים בספרות הטכנית.

בדו"ח של אדם טבע ודין שבחן את הפליטות ממאגר תמר בשנת 2016, נעשה שימוש במקדם פליטה מהספרות המקצועית להערכת דליפות מתאן ממאגרי גז, בטווח של 0.05-0.7% מהגז במאגר [15].

עבודה שנערכה בשנת 2021 על ידי משרד האנרגיה בישראל מצאה כי היקף פליטת המתאן הלא מוקדיות מגז טבעי בישראל בשנת 2019 הסתכם בשנת 2019 ב-1.19 קילו טון מתאן בלבד. ממצא זה מייצג את שיעור הפליטות הנמוך ביותר של 0.014% מהפקת הגז הטבעי בישראל [7].

דו"ח של המשרד להגנת הסביבה משנת 2022 בעניין סך הפליטות מכל מקטע לאורך שרשרת הייצור (מהבאר ועד לצרכן הסופי), נערך בהתאם למתודולוגיה המפורטת במדריך של הפאנל הבין-ממשלתי לשינויי אקלים (IPCC), בדומה למדינות רבות אחרות. כאשר ישנם ממצאי ניטור וחישוב זמינים, ניתנה עדיפות ראשונה לכימות פליטות בהתאם לאומדנים פרטיים מאתרים ספציפיים, ולאחר מכן שימוש במקדמי פליטה ספציפיים למדינות ספציפיות, וברוב המקרים נעשה שימוש במקדמי פליטה "ברירת מחדל". בהתבסס על מתודולוגיה זו, כימות הפליטות שבוצע בדו"ח למקטעים שונים בישראל לשנת 2020 נאמד בכ-8,638 טונות של מתאן[19], שלפי חישוב עומדים על אחוז אובדן של 0.08% לכל אורך שרשרת הערך.

במחקר נוסף, המבוסס על מקדם פליטה ממוצע של 0.2%, נטען כי בהפקה של BCM 240 לאורך 20 שנה, סך הדליפה הצפויה ממאגר תמר תהיה BCM 0.5. עם זאת, יש לציין כי תקלה משמעותית בלתי צפויה לאורך חיי המאגר עלולה להביא לפליטות גבוהות בהרבה [15].

לאורך השנים, התברר כי הפליטות והדליפות בפועל גבוהות ממה שהיה צפוי. דו"ח לב-און וחובריה דן בגישות מתודולוגיות למדידת דליפות מתאן ממערכות גז. בהיעדר נתונים פרטניים אודות מערכת הגז הישראלית (לרבות מאפייני המאגרים, הרכב הגז, המערכות, המתקנים ורכיבי הציוד במערכת, אורך הצינורות, ועוד), מוצע להשתמש במקדם פליטה גנרי של 2.26% מכמות הגז המופקת [11].

מיפוי ואפיון של מקורות הפליטה הפוטנציאליים של מתאן מתחלקים לחלקים שונים בהתבסס על הנחיות ה-IPCC וממצאי מצאי הפליטות של גזי חממה של מדינות אחרות שנסקרו. טכנולוגיות ושיטות עבודה שונות בתעשיית הנפט והגז, מביאות לכך שהפליטות עשויות להיות שונות מאוד בין מדינות ולאורך זמן. המונח "פליטות לא מוקדיות" לפי הנחיות ה-IPCC כולל את כל הפליטות מנישוב, דליפות ושריפה מבוקרת בלפיד, אך לא כולל פליטות משריפת דלקים (אלה מדווחות בקטגוריה נפרדת). נישוב כולל כל שחרור של זרמי גז בצורה מכוונת לאטמוספירה (ללא בעירה), וגם דליפות ושריפות מבוקרות בלפיד הם מקורות משמעותיים לפליטות.

הנחיות ה-IPCC מתארות שלושה נדבכים של שיטות חישוב, המאפשרים גמישות בבחירת רמת החישוב המתאימה עבור מקטעים ותתי-מקטעים שונים, לרבות הכללת מדידה ישירה או תוצאות ניטור בפועל ממקורות פליטה משמעותיים. המטרה של החישוב היא להעריך את כמות הפליטות ביחס לכמות הגז שמופק במתקן נתון.

1. רמת Tier 1 היא רמת החישוב הפשוטה ביותר, עושה שימוש במקדמי פליטה שהם ברירת המחדל להערכת פליטות עבור כל מקטע ותת-מקטע.
2. רמת Tier 2 עושה שימוש במקדמי פליטה ספציפיים למדינה במקום ערכי ברירת מחדל.
3. רמת Tier 3 כוללת בחינה מפורטת של כל מקורות הפליטה ברמת המתקן או האתר.

2.3.1 מערכת הגז הטבעי בישראל

מערכת ההפקה והעיבוד של גז טבעי בישראל כוללת את המקטעים הבאים:

1. אחסון וייבוא של גז טבעי נוזלי (LNG) (נמצא מול חופי חדרה).
2. 10 בארות הפקה ימיות.
3. תמר, לויתן, כריש-תנין ומתקן ההפקה היבשתי באשדוד.
4. מערכת החלוקה הכוללת 424 ק"מ של צינורות ו-125 תחנות PRMS (הפחתת לחץ וניטור).
5. מערכת ההולכה הכוללת 4 תחנות, 613 ק"מ של צנרת יבשתית, 106 ק"מ של צנרת ימית, 52 תחנות PRMS (הפחתת לחץ וניטור) ו-85 תחנות דחיסה.

2.3.2 מקטע ההפקה והעיבוד

הנחיות ה-IPCC לא מתייחסות לבארות הפקה ימיות, ולכן נהוג להשתמש במקדם הפליטה המיועד לבארות הפקה יבשתיים לבארות עצמן. עבור הצנרת הימית, נעשה שימוש במקדם הפליטה של הצנרת היבשתית שהוכפל ב-0.02, כמקובל בהנחיות ה-IPCC עבור בארות הפקה ימיות נטושות. פליטות המתאן המשוערות ממקטע ההפקה התת-ימי הן 2.13 טון לשנה מ-10 קידוחים ימיים ו-575 ק"מ של צנרת ימית. על פי דו"ח של רשות הגז הטבעי, הייתה הפחתה של 70% בפליטות המתאן בין השנים 2018 ל-2019, וירידה של 90% בין 2019 ל-2020 באסדת תמר. לדברי המחברים, ניתן ליחס את ההפחתה המשמעותית לשיפורים שנעשו בצנרת, והעובדה שהצנרת חדשה ועומדת בתקני בטיחות ואיכות גבוהים ביחס לצנרת ישנה יותר.

2.4 מסקנות

לסיכום, סקירת ספרות זו מדגישה את החשיבות של איסוף מדויק ובלתי תלוי של נתונים בבחינת פליטות גזי חממה מכל שרשרת ייצור הגז הטבעי. כפי שעולה מהמאמרים שנבדקו, חוקרים עושים יותר ויותר שימוש ברחפנים וחיישנים לאיסוף נתונים על מנת להפחית את הפוטנציאל להטיה ולניגוד אינטרסים. בהתבסס על התובנות שהושגו מהסקירה, המחקר הנוכחי מבקש לפתח מודל מקיף להערכת פליטות גזי חממה שרשרת הייצור של גז טבעי. באמצעות שימוש בנתונים ממקורות בלתי תלויים, אנו שואפים לייצר מודל המספק אומדן מדויק ומהימן יותר של פליטות, אשר יוכל להוות בסיס לקבלת החלטות מדיניות וכשיטת עבודה בתעשייה. הפרק הבא יספק הסבר מפורט על המתודולוגיה והתוצאות של המחקר.

3 מתודולוגיה

3.1 רקע

הדמיית מונטה קרלו היא טכניקה חישובית רבת עוצמה שניתן להשתמש בה כדי למדל ולנתח מערכות מורכבות. ההדמיה שימושית במיוחד בהתמודדות עם בעיות שקשה לפתור בצורה אנליטית או כאשר למערכת שממדלים יש מספר רב של משתנים עם השפעה הדדית. במקרה של פליטות גזי חממה מבארות גז טבעי, יש ריבוי של גורמים שיכולים להשפיע על סך הפליטות, וגורמים אלו יכולים להשתנות מאוד מבאר לבאר.

באמצעות הדמיית מונטה קרלו ניתן למדל את אותן מערכות מורכבות על ידי יצירת מספר רב של דגימות אקראיות מסדרה של פרמטרי קלט ולאחר מכן לעשות שימוש בדגימות אלו להעריך את הפלט של המערכת. ניתן לעשות שימוש בשיטה זו כדי לדמות מגוון רחב של תרחישים, והיא יכולה לספק תובנות חשובות לגבי התנהגות המערכת בתנאים שונים.

ישנן דוגמאות רבות של שימוש בהדמיית מונטה קרלו למידול של פליטות גזי חממה מבארות גז טבעי. לדוגמה, מחקר של Liang ואח', השתמש בהדמיית מונטה קרלו כדי להעריך את אי הוודאות בפליטות מתאן מהפקת פצלי גז בארצות הברית. המחקר מצא כי אי הוודאות בפליטות מתאן מאוד תלויה בהנחות שנעשו בהרצת המודל כלפי פרמטרים הקשורים לשלב השלמת הבאר, לגבי שיטות להשלמת הבאר להפקה (completion) ושיעור הדליפות מרכיבי הציוד [18].

מחקר של Zhang ואח' השתמש בהדמיית מונטה קרלו כדי להעריך את השפעתם של תרחישי מדיניות שונים על פליטות גזי חממה מהפקת גז טבעי בסין [17]. המחקר מצא כי המדיניות האפקטיבית ביותר להפחתת פליטות הייתה כזאת שמכוונות לפרקטיקות של השלמת הבאר ושיעורי הדליפות מרכיבי ציוד.

באופן כללי, הדמיית מונטה קרלו היא כלי בעל ערך למידול מערכות מורכבות כמו פליטות גזי חממה מבארות גז טבעי. היא מאפשרת יצירת מגוון רחב של תרחישים אפשריים ויכולה לספק תובנות באשר להתנהגות המערכת בתנאים שונים.

3.1.1 הטכנולוגיה הזמינה הטובה ביותר (BAT)

כאמור לעיל, מחקר זה בוחן מגוון רחב של פרמטרים על מנת להעריך את סך הפליטות ממאגר גז טבעי חדש. כדי להעריך את סך הפליטות אל מול תוצאות המודל, נבחרו מגוון פרמטרים עם פוטנציאל לגרום לפליטות על בסיס הקריטריונים של הטכנולוגיה הזמינה הטובה ביותר, עם ספקטרום של טווחי פליטה כפי שהוגדרו בספרות. לדוגמה, בעת הזנת ערך הפליטה של שריפה מבוקרת בלפיד למודל, ערכי הפליטה שהוזנו למודל תואמים את השריפה המבוקרת בלפיד המוגדרת כטכנולוגיה הזמינה הטובה ביותר (BAT) בהתאם לסקירת הספרות.

3.2 משוואות המודל

ההליך של הדמיית מונטה קרלו מורכב מהשלבים הבאים:

1. הגדרת פרמטרי הקלט והתפלגויות ההסתברות שלהם
2. יצירת מספר רב של דגימות אקראיות מהתפלגות הקלט
3. בחינה של המודל לכל קבוצה של ערכי קלט, תוך השגה של התפלגות ערכי פלט
4. ניתוח של התפלגות הפלט כדי להעריך את הממוצע, השונות ומאפיינים סטטיסטיים נוספים של המודל

מודל הדמיית מונטה קרלו המשמש במחקר זה מבוסס על המשוואות הבאות:

Probability density function (PDF):

$$P(x) \Longrightarrow probability - density - function \tag{1}$$

Cumulative distribution function (CDF):

$$F(x) = P(X \leq x) = \int_{-\infty}^{x} p(x)dx \tag{2}$$

Inverse transform sampling:

$$X = F^{-1}(U) \Rightarrow inverse - transform - sampling \tag{3}$$

Monte Carlo integration:

$$\int_{a}^{b} f(x)dx \approx \frac{b-a}{n} \sum_{i=1}^{n} f(X_i) \tag{4}$$

Monte Carlo simulation:

$$Y = g(X_1, X_2, \ldots, X_n) \Rightarrow \tag{5}$$

3.3 פרמטרי קלט למודל

- קצב הפקת גז טבעי: פרמטר זה משפיע על כמות הגז הטבעי המופק ומעובד, ולכן משפיע על פליטות המתאן והפחמן הדו חמצני. טווח של 1,000 עד 10,000 MCF (אלף פיט מעוקבים) ליום נבחר על סמך שיעורי הפקת גז טבעי טיפוסיים [12].
- מקדמי פליטת מתאן עבור השלמת הבאר, עבודות תחזוקה בבארות, רכיבים פנאומטיים, דליפות מרכיבי ציוד, שריפה מבוקרת בלפיד ונישוב: מקדמי פליטה אלה מייצגים את אחוז המתאן שנפלט בשלבים שונים של הפקה ועיבוד של גז טבעי. הטווחים נבחרו על סמך ערכי הספרות [12, 3]. מקדמי פליטת המתאן חיוניים להערכת כמות המתאן הנפלטת בשלבים שונים של הפקה ועיבוד גז טבעי. על ידי הכללת מקדמים אלה בהדמיית מונטה קרלו, המודל יכול לקחת בחשבון את השונות בין פליטות המתאן, ולספק אומדן מדויק של סך הפליטות. הטווחים שנבחרו התבססו על ערכי הספרות, מה שמבטיח שהסימולציה מבוססת על המחקר העדכני ביותר [1, 14].
- עצימות אנרגטית של עיבוד גז טבעי: פרמטר זה מייצג את כמות האנרגיה הנדרשת לעיבוד גז טבעי, ומשפיע על כמות פליטת הפחמן הדו חמצני מהעיבוד. טווח של 0.5 עד MJ/MCF2 נבחר על סמך ערכים מהספרות [4, 1, 12]. העצימות האנרגטית של עיבוד גז טבעי היא פרמטר חשוב, שכן היא משפיעה על כמות פליטת הפחמן הדו חמצני מהעיבוד. על ידי הכללת מקדם זה בסימולציה, המודל יכול להעריך את צריכת האנרגיה לעיבוד גז טבעי ואת הפליטות הנלוות, ולספק אומדן מקיף יותר של פליטות גזי חממה. הטווח שנבחר של עצימות האנרגיה מבוסס על ערכי הספרות, מה שמבטיח שהסימולציה מבוססת על המחקר העדכני ביותר [2, 14].
- פליטת פחמן דו חמצני משריפת גז טבעי: פרמטר זה מייצג את כמות הפחמן הדו חמצני הנפלטת במהלך שריפת הגז הטבעי, ובכך משפיעה על סך פליטות גזי החממה מההפקה והשימוש בגז טבעי. טווח שבין 50 עד 60 ק"ג CO_2/MCF נבחר על סמך ערכים המאפיינים פליטות משריפת גז טבעי [12].פליטות הפחמן הדו חמצני משריפת גז טבעי הן פרמטר קריטי, שכן הן גורם משמעותי בסך פליטת גזי החממה מהפקה ושימוש בגז טבעי. טווח הפליטות שנבחר מבוסס על ערכים אופייניים לפליטות משריפת גז טבעי, מה שמבטיח שהסימולציה רלוונטית לתרחישים מהעולם האמיתי. על ידי הכללת פרמטר זה בסימולציה, המודל יכול להעריך את ההשפעה של שריפת גז טבעי על פליטות גזי חממה, ולספק אומדן מדויק יותר של סך הפליטות מהפקה ושימוש בגז טבעי. הפליטות המוזכרות לעיל מיוחסות לפליטות בלתי מבוקרות במהלך שריפות בשלבי ההפקה והקידוח.

פרמטר	יחידה	מינימום	מקסימום	התפלגות
קצב הפקת גז טבעי	MCF/day	1,000	10,000	רגילה
מקדם פליטת מתאן להשלמת הבאר	%	0.5	2	אחידה
מקדם פליטת מתאן לתחזוקת באר	%	0.1	0.5	אחידה
מקדם פליטת מתאן לרכיבים פנאומטיים	%	0.1	1	לוג-נורמלית
מקדם פליטת מתאן לדליפות ציוד	%	0.2	2	לוג-נורמלית
מקדם פליטת מתאן לשריפה מבוקרת בלפיד	%	0.1	5	לוג-נורמלית
מקדם פליטת מתאן לנישוב	%	0.01	1	אחידה
עצימות אנרגטית של עיבוד גז טבע	MJ/MCF	0.5	2	רגילה
פליטות הפחמן הדו-חמצני משריפת גז טבעי	kg CO_2/MCF	50	60	אחידה

טבלה 1: פרמטרים עבור הדמיית מונטה-קרלו במחקר זה

במחקר הנוכחי, לכל אחד מהפרמטרים תוקצה פונקציית התפלגות (probability distribution) על פי ערכי המינימום והמקסימום בטבלה, והסימולציה תדגום באופן אקראי ערכים מהתפלגויות הללו כדי לייצר מגוון של ממצאים אפשריים לפליטות גזי חממה מבאר הגז הטבעי.

3.3.1 מיקוד המחקר

בישראל יש פליטות רבות ממקורות השייכים למשק הגז וממאגרים קיימים. פליטות אלו, ללא ספק, גבוהות בהרבה מהפליטות המדווחות בישראל. עם זאת, מחקר זה מתמקד בניתוח פליטות מפיתוח מאגר גז עתידי. לפיכך, פליטות ממאגרי הגז הקיימים בישראל, דהיינו תמר, לויתן וכריש-תנין, לא נבחנו במחקר זה. הפליטות מהמאגרים הקיימים נלקחו בחשבון בתרחיש העסקים כרגיל. יחד עם זאת, המודל בוחן את סך הפליטות ממאגר גז חדש לאורך כל שרשרת הערך, לרבות תהליכי החיפוש, קידוח, ההפקה וההובלה של הגז שיופק מהבאר.

יש לציין כי מעבר לחישוב שבוצע במחקר הנוכחי, הרחבת משק הגז לטובת ייצוא כרוכה בהקמת תשתיות נלוות נוספות, לרבות הקמת מתקן הנזלה (LNG) וכן הקמת הצינור ומתקן הדחיסה הנדרשים לטובת הקמת המקטע הישראלי של צינור ה"איסט-מד", שמתוכנן לחבר בין מאגרי הגז בים התיכון, לרבות מאגר לוויתן, לבין אירופה, דרך קפריסין, יוון ואיטליה. מפאת היקף העבודה, הערכת פליטות גזי החממה הצפויות מתשתיות נלוות אלה לא נכללה במסגרת המודל. עם זאת, ניתן להניח כי במידה ויוקמו תשתיות אלו, הן יביאו לתוספת פליטות גזי חממה בשיעור משמעותי נוסף.

4 תוצאות

4.1 סקירה כללית

במחקר זה, נבחנו פליטות גזי החממה העתידיות כתוצאה מהרחבת משק הגז הישראלי בהיקף של BCM500. נעשה שימוש בהדמיית מונטה קרלו על מנת לחזות פליטות גזי חממה על סמך משתני קלט כגון לחץ במאגר, טמפרטורה, צפיפות ולחץ מראש הבאר. הסימולציה סיפקה לנו מידע רב ערך לגבי פליטות גזי החממה הפוטנציאליות מפעילות מסוג זה. הניתוח הניב מספר תוצאות מפתח, וביניהן ממוצע פליטות גזי חממה **מתהליכי ההפקה** לאורך חיי המאגר, אשר עומד של 159.11 Mt CO_2eq, סטיית תקן של 45.92 Mt CO_2eq, שהם 5.2 Mton CO2 eq לשנה. בפרט ראוי לציין, מצאנו שממוצע פליטות גזי חממה מבאר גז טבעי חדש הוא 5.2 Mton CO_2eq /שנה. מדובר בתוספת פליטות של 6.9% ברמה הלאומית מדי שנה, מעבר לפליטות השנתיות הנוכחיות. בנוסף, על פי תוצאות המחקר, סך הפליטות ממאגר גז חדש בגדול של 500 BCM, עמוד על 2.7% (מהיקף הנפח) שמהווים סך פליטות של 13.5 BCM לאורך כל חיי המאגר.

4.2 תוצאות הסימולציה

תוצאות המודל מראות שלאורך חיים של 30 שנה סך פליטות גזי החממה מניצול מאגר של 500 BCM, עומד על **806.01 Mton CO_2 eq.**

סיכום והשוואה

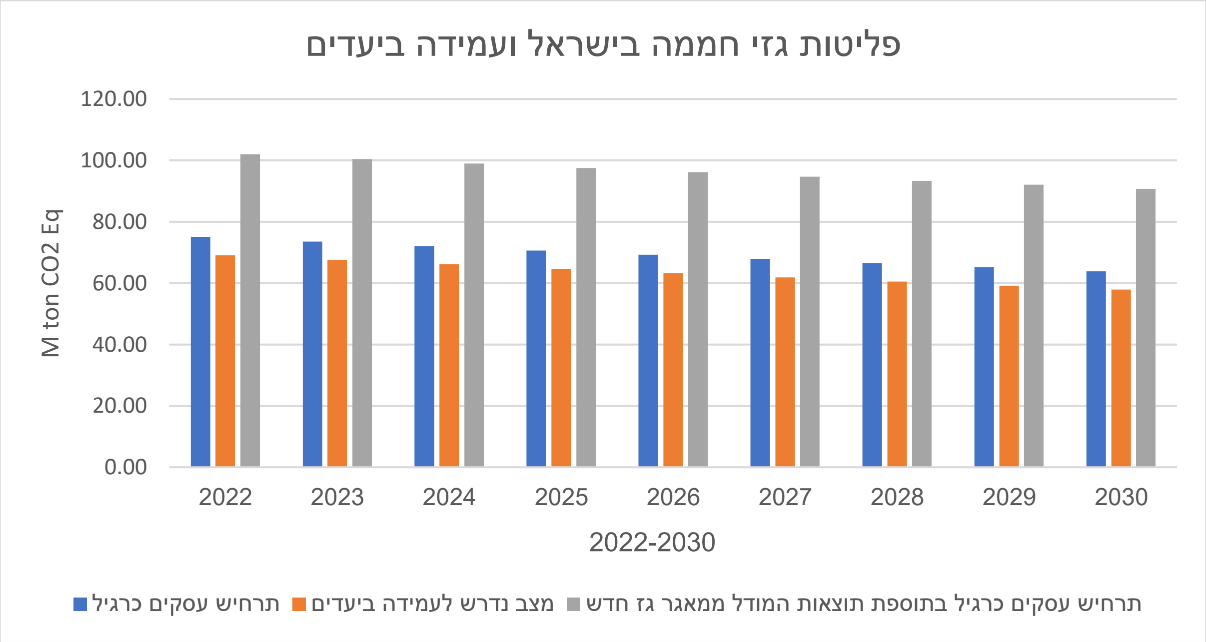
טבלה 2 משווה את סך פליטות גזי החממה בישראל עד לשנת 2030, בהתבסס על שני תרחישים: תרחיש עסקים כרגיל ותרחיש הכולל את תוצאות המודל, שמצא תוספת פליטות של 26 Mton CO_2eq/שנה. תרחיש עסקים כרגיל מייצג את סך הפליטה השנתית הצפויה בישראל בהתבסס על הפחתה שנתית ממוצעת של 2% (על סמך נתוני המשרד להגנת הסביבה מאפריל 2023) [9]. התרחיש המבוסס על תוצאות המודל מציג את הפליטה השנתית הצפויה בהתחשב בהרחבת משק הגז. הטבלה מציגה גם את הפחתת הפליטות הנדרשת על מנת לעמוד ביעד של 27% הפחתה עד 2030, הן בהשוואה לתרחיש עסקים כרגיל והן לסך הפליטה כפי שחושבה במודל. התוצאות מצביעות על כך שהמודל חוזה פליטות גזי חממה גבוהות יותר בהשוואה לתרחיש עסקים כרגיל, עם הבדל מרבי של 26Mton CO_2eq/שנה.

בהנחה שפיתוח משק הגז בהיקף של BCM500 היה מתחיל בשנת 2023, ועל מנת להגיע ליעד הפחתה של 27% עד שנת 2030, אליו ישראל מחויבת במסגרת הסכם פריז, נדרשת הפחתה של עד 48.64%בשנת 2023 בהשוואה להפחתה של 8.16% הנדרשת בהתבסס על תרחיש עסקים כרגיל. מדובר בעלייה של 600%. עד 2030, יש צורך בהפחתה של 56.79% כדי לעמוד ביעדי הממשלה, בהשוואה להפחתה של 9.39% הצפויה בהתבסס על תרחיש העסקים כרגיל. מדובר בעלייה של כמעט מעל 620% בהשוואה לתרחיש עסקים כרגיל.

שנה	תרחיש עסקים כרגיל[1] Mton CO_2 eq	מצב נדרש לעמידה ביעד[2] Mton CO_2 eq	הפחתה ממוצעת נדרשת לעמידה ביעדים[3] (%)	תרחיש עסקים כרגיל בתוספת תוצאות המודל ממאגר חדש[4] Mton CO_2 eq	הפחתה שנתית נדרשת לעמידה ביעד בתוספת מאגר חדש[5] (%)
2022	75.07	69.07	7.99%	101.94	-47.58%
2023	73.57	67.57	8.16%	100.44	-48.64%
2024	72.10	66.1	8.32%	98.97	-49.72%
2025	70.65	64.65	8.49%	97.52	-50.84%
2026	69.24	63.24	8.67%	96.11	-51.97%
2027	67.86	61.86	8.84%	94.73	-53.13%
2028	66.50	60.5	9.02%	93.37	-54.33%
2029	65.17	59.17	9.21%	92.04	-55.55%
2030	63.87	57.87	9.39%	90.74	-56.79%

טבלה 2: השוואה בין פליטות גזי חממה בתרחיש עסקים כרגיל ותוצאת המודל

1. תרחיש עסקים כרגיל: סך הפליטות הצפויות בישראל על בסיס שנתי עם ממוצע הפחתה שנתית של 2%.
2. מצב נדרש לעמידה ביעד: הפליטה הנדרשת בפועל ע"מ לעמוד ביעד הפחתה של 27% עד שנת 2030.
3. הפחתה נדרשת לעמידה ביעד: ההפחתה הנדרשת בפועל מדי שנה על מנת לעמוד ביעד של 27% הפחתה עד שנת 2030.
4. תרחיש עסקים כרגיל בתוספת תוצאות המודל: סך הפליטות הצפויות בישראל על בסיס שנתי בהתבסס על תוצאות המודל. מדובר בפליטה נוספת של 26 Mton CO_2eq/שנה בהתחשב בהרחבת משק הגז בהיקף של 500 BCM.
5. הפחתה נדרשת לעמידה ביעד לפי תוצאות המודל: ההפחתה הנדרשת בפועל מדי שנה (בהתחשב בפיתוח משק הגז בהיקף של BCM500) על מנת לעמוד ביעד של 27% הפחתה עד שנת 2030.



איור 3: פליטות גזי חממה ע"פ תרחיש עסקים כרגיל ותרחיש המודל

5 סיכום

המחקר הנוכחי הדגים את הפוטנציאל של שימוש בהדמיות מונטה קרלו כדי לחזות פליטות גזי חממה מהפקת גז טבעי. הממצאים מצביעים על כך שהרחבת משק הגז בהיקף של BCM 500 עשויה לייצר פליטות גזי חממה בשיעור של כ-26 מיליון טון CO_2 eq/לשנה, שהם ברי השוואה לכמעט 35% משיעור הפליטות בשנת 2023. המחקר מדגיש את הצורך במאמצים נוספים להפחתת פליטות גזי חממה מסקטור האנרגיה, ובין היתר שימוש בטכנולוגיות ומקורות אנרגיה נקיים יותר, כדי למתן את שינויי האקלים.

5.1 תכנית להפחתת פליטות

כפי שהוצג במחקר, ישנה חשיבות מירבית בהיערכות מוקדמת, על מנת להבטיח עמידה בהתחייבויות הבינלאומיות להפחתת פליטות. תהליך הפחתת פליטות גזי חממה הינו תהליך ממושך ומורכב הדורש תכנון, בקרה, תקצוב וביצוע פעולות בפועל - לא ניתן להפחית את פליטות גזי החממה ביום אחד. כך למשל, אם הממשלה מחליטה לצמצם את הפליטות מתחבורה באמצעות השקעה נרחבת בתחבורה ציבורית, על מדינת ישראל להיערך מראש ולתקצב פרויקטים להקמה של נתיבי תחבורה ציבורית, הרחבת השימוש ברכבת הקלה, עידוד השימוש בתחבורה ציבורית, ועוד. בדומה, יש לזכור כי לא ניתן יהיה להמשיך את ההפקה ממאגרי גז קיימים ועתידיים, ולקבל החלטה להפסיק את השימוש במשאבים הללו ביום אחד. על ישראל להיערך מראש להפחתה, לבנות תשתית חלופית לשימוש בדלקים מאובנים, ולהכין את התשתית הנדרשת לאגירת אנרגיה ושימוש באנרגיה מתחדשת. לאור האמור לעיל, לא ניתן יהיה לעמוד ביעדי הממשלה אם לא תתקבל ההחלטה על הפסקת הרחבת משק הגז בעת הנוכחית.

5.2 פליטות ממאגרי גז קיימים – לויתן, תמר, כריש-תנין

באשר למאגרי המידע הקיימים: מעבודה זו עולה כי פליטות גזי החממה של ישראל גבוהות בהרבה מאלה המדווחות היום למשרד להגנת הסביבה. בהתבסס על דיווחי החברות, אחוז הפליטות ממאגרי הגז עומד על 0.014%, בעוד במחקר זה מצאנו כי מקדם הפליטה עומד על 2.7%. הבדל משמעותי זה מודד את אחוז ההפחתה שתידרש בפועל בתרחיש העסקים כרגיל לבין אחוז ההפחתה שתידרש לאורך השנים כדי לעמוד ביעדי הממשלה. הסבר: בהנחה שמאגרי המידע הקיימים מציגים אחוז גבוה יותר מאלה המדווחים היום למשרד להגנת הסביבה, ההבדל בין סך הפליטות (קיימות + עתידות) יהיה אף גבוה יותר מאלה שהוצגו בפרק התוצאות.

5.3 פליטות גזי חממה בשנת 2050

מדינת ישראל התחייבה להפחית את פליטות גזי החממה ב85% עד שנת 2050 ביחס לשנת הבסיס 2015. במונחים מספריים, ישראל מחויבת להגיע לסך פליטות של כ-12 מיליון טון CO_2 eq, זאת ביחס ל78 מיליון טון CO_2 eq שנפלטו בשנת 2015. בנוסף, מדינת ישראל התחייבה להפחית את פליטות גזי החממה ב27% עד שנת 2030, ביחס לשנת הבסיס 2015, כלומר להגיע לסך פליטות של כ-57 מיליון טון CO_2 eq. במטרה לחשב את תוספת הפליטות הצפויה מהרחבת משק הגז בישראל בהיקף של BCM500, וכן להציג את ההפחתה הנדרשת על מנת לעמוד ביעדים, הונחו מספר הנחות:

1. מדינת ישראל תעמוד ביעדי ההפחתה לשנת 2030 אליהם התחייבה, וסך הפליטות בשנה זו יעמוד על כ-57 מיליון טון CO_2 eq.
2. ההפחתה הממוצעת תהיה שווה על בסיס שנתי.
3. בהתאם לממצאי המחקר, התוספת הצפויה מהרחבת משק הגז תעמוד על 26מיליון טון CO_2eq מדי שנה.

כפי שניתן לראות בטבלה 3, ההפחתה השנתית הממוצעת הנדרשת לעמידה ביעדי הממשלה היא 7.51%. מנגד, על מנת לעמוד ביעד הממשלתי בהתחשב בתוספת הנובעת מהרחבת משק הגז בהיקף של BCM500, נדרשת הפחתה שנתית ממוצעת של כ197%. משמעות הדבר היא כי מדינת ישראל תצטרך להפחית פליטות בהיקף של פי 26 על מנת לעמוד ביעדים שנקבעו לשנת 2050.

הפחתה שנתית נדרשת לעמידה ביעד בתוספת מאגר חדש (%)	**תרחיש עמידה ביעדי הפחתה בתוספת תוצאות המודל ממאגר חדש Mton CO_2 eq**	**הפחתה ממוצעת נדרשת לעמידה ביעד (%)**	**תרחיש עמידה ביעד הפחתה של 85% Mton CO_2 eq**	**שנה**	
	84.47		57.67	2030	נקודת ההתחלה
148.39%	82.18	3.97%	55.38	2031	
150.48%	79.89	4.14%	53.09	2032	
152.76%	77.60	4.32%	50.80	2033	
155.25%	75.31	4.51%	48.51	2034	
157.99%	73.02	4.14%	46.22	2035	
161.01%	70.72	4.96%	43.92	2036	
164.37%	68.43	5.22%	41.63	2037	
168.12%	66.14	5.50%	39.34	2038	
172.33%	63.85	5.82%	37.05	2039	
177.10%	61.56	6.18%	34.76	2040	
182.54%	59.27	6.59%	32.47	2041	
188.81%	56.98	7.06%	30.18	2042	
196.10%	54.69	7.59%	27.89	2043	
204.70%	52.40	8.22%	25.60	2044	
215.00%	50.11	8.95%	23.31	2045	
227.53%	47.81	9.83%	21.01	2046	
243.14%	45.52	10.90%	18.72	2047	
263.10%	43.23	12.24%	16.43	2048	
289.52%	40.94	13.94%	14.14	2049	
326.16%	38.65	16.20%	11.85	2050	יעדי הממשלה

טבלה 3: השוואה בין ההפחתה הנדרשת לעמידה ביעדים – ללא הרחבת משק הגז, ובתוספת BCM500.

5.4 סיכום והמלצות

בהתאם לממצאי המחקר, ישראל לא יכולה להרשות לעצמה להמשיך ולפתח את משק הגז כמקור אנרגיה. בעידן הנוכחי, בעוד שינוי האקלים עומדים לפתחנו, עלינו לפעול ולפתח מקורות אנרגיה מתחדשים כמו אנרגיית שמש, רוח ומים. ישראל היא אי אנרגטי שלא יכולה לקנות עודפי חשמל משכנותיה, כפי שעושות מדינות רבות, ולכן עליה לאמץ אנרגיות מתחדשות להחלפת דלקי מאובנים.

חשוב לציין שיש הרבה חברות מצליחות בישראל, חלקן בינלאומיות, בתחום זה. על מקבלי ההחלטות, ובפרט משרד האנרגיה והמשרד להגנת הסביבה, לתמוך ולקדם את השימוש בטכנולוגיות אלו, וכן לעודד סטרטאפים וחברות חדשות לסייע לישראל במעבר לאנרגיה מתחדשת נקייה ובריאה. חשוב לזכור שהרגולציה העולמית, במיוחד הרגולציה האירופית, לא תאפשר סחר, ובמקרים מסוימים תטיל מס פחמן על סחורות שלא עומדות ביעדים סביבתיים (לדוגמא רישום CBAM)[9].

לאור המחקר ותוצאותיו, ברור שישראל צועדת בכיוון ההפוך מהמגמה העולמית, דבר שעלול לפגוע במשק הישראלי ובעיקר בייצוא הישראלי.

רשימת מקורות

[1] Ram’on A Alvarez et al. “Assessment of methane emissions from the US oil and gas supply chain”. In: Science 361.6398 (2018), pp. 186–188.

[2] ZR Barkley et al. “Estimating methane emissions from underground coal and natural gas production in southwestern Pennsylvania”. In: Geophysical Research Letters 46.8 (2019), pp. 4531–4540.

[3] Clay S Bell et al. “Comparison of methane emission estimates from multiple measurement techniques at natural gas production pads”. In: Elementa: Science of the Anthropocene 5 (2017).

[4] Adam R Brandt, Garvin A Heath, and Daniel Cooley. “Methane leaks from natural gas systems follow extreme distributions”. In: Environmental science & technology 50.22 (2016), pp. 12512–12520.

[5] Adam R Brandt et al. “Methane leaks from North American natural gas systems”. In: Science 343.6172 (2014), pp. 733–735.

[6] Jasmin Cooper, Paul Balcombe, and Adam Hawkes. “The quantification of methane emissions and assessment of emissions data for the largest natural gas supply chains”. In: Journal of Cleaner Production 320 (2021), p. 128856.

[7] MOE Einat Magal. The contribution of fugitive methane emissions to the green house effect in Israel (2021).
https://www.gov.il/BlobFolder/reports/methane_fugitive_emissions/he/methane_fugitive_emissions.pdf.

[8] Environmental Protection Agency (EPA). “Inventory of US greenhouse gas emissions and sinks: 1990-2017”. In: (2019).

[9] Taxation European Union and Customs. Carbon Border Adjustment Mechanism (2023).https://www.gov.il/BlobFolder/reports/methane_fugitive_emissions/he/methane_fugitive_emissions.pdf.

[10] Robert W Howarth, R Santoro, and A Ingraffea. “Methane and the Green-House Foot print of Natural Gas from Shale Formations”. In: Department of Ecology and Evolutionary Biology, USA 9 (2010).

[11] Shmuel Neaman Institute. Methane emissions from the oil and gas sector The natural and best methods for quantification (2016).
https://www.neaman.org.il/Files/Global%20Estimates%20Of%20Methane%20Emissions%20from%20OffShore%20Drilling%20Plants%20and%20Their%20Importance_20171122175809.456.pdf

[12] Tegan N Lavoie et al. “Assessing the methane emissions from natural gas-fired power plants and oil refineries”. In: Environmental Science & Technology 51.6 (2017), pp. 3373–3381.

[13] Katlyn MacKay et al. “Methane emissions from upstream oil and gas production in Canada are underestimated”. In: Scientific reports 11.1 (2021), pp. 1–8.

[14] Jeffrey S Rutherford et al. “Closing the methane gap in US oil and natural gas production emissions inventories”. In: Nature communications 12.1 (2021), p. 4715.

[15] Adam Teva Vadin. Methane emissions from the Tamar and Levitan gas reservoirs. 2021.https://adamteva.org.il/wp-content/uploads/2022/05/%D7%A4%D7%9C%D7%99%D7%98%D7%95%D7%AA-%D7%9E%D7%AA%D7%90%D7%9F-%D7%9E%D7%AA%D7%9E%D7%A8-%D7%95%D7%9C%D7%95%D7%95%D7%99%D7%AA%D7%9F.pdf

[16] Aranya Venkatesh et al. “Uncertainty in life cycle greenhouse gas emissions from United States natural gas end-uses and its effects on policy”. In: Environmental science & technology 45.19 (2011), pp. 8182–8189.

[17] Jian-liang Ye et al. “The second natural gas hydrate production test in the South China Sea”. In: China Geology 3.2 (2020), pp. 197–209.

[18] Haoran Zhang et al. “Optimal design and operation for supply chain system of multistate natural gas under uncertainties of demand and purchase price”. In: Computers &Industrial Engineering 131 (2019), pp. 115–130.

[19] Ministry of Environment Protection. Quantification of methane emissions from the production and supply chain of natural gas in Israel (2022). https://www.gov.il/he/departments/publications/reports/quantification_methane_emissions_gas_production.

[20] Ministry of Environment Protection. Reducing greenhouse gas emissions in Israel-Annual follow-up report on the implementation of the plan and national goals. 2023. https://drive.google.com/drive/folders/1bsyl-nSQRMuso1apZd0-ef5VS7O2pEqX.

Model Script

```
import numpy as np
import matplotlib . pyplot as plt
from scipy . stats import norm
import pandas as pd
import json

import os

class GHGEmissionsSimulator :
def _get_file_path (self , filename ):
dirnname = os. path . dirname ( file )
return os. path . join ( dirnname , filename )


def __init__ (self , num_simulations , distributions_file = " data . json ",
methane_pct =0.965 , gas_density =0.712 , gwp = 84, years = 30):

self . num_simulations = num_simulations
self . mcf_to_bcm = 0.00002832
self . methane_pct = methane_pct
self . gas_density_mcf = gas_density / 0.0000353107
self .gwp = gwp
self . years = years
self . distribution = json . load ( open ( self . _get_file_path (
distributions_file )))
self . generate_distributions ()

def generate_distributions ( self ):
self . ng_production_dist = np. random . normal ( loc= self . distribution ["
ng_production_dist "][" mean "], scale = self . distribution [" ng_production_dist "
][" std"], size = self . num_simulations )
self . well_completion_dist = np. random . uniform (low= self . distribution ["
well_completion_dist "]["min"], high = self . distribution ["
well_completion_dist "]["max"], size = self . num_simulations )
self . well_workovers_dist = np. random . uniform (low= self . distribution ["
well_workovers_dist "]["min "], high = self . distribution [" well_workovers_dist
"]["max "], size = self . num_simulations )
self . pneumatic_devices_dist = np. random . lognormal ( mean = self . distribution
[" pneumatic_devices_dist "][" mean "], sigma = self . distribution ["
pneumatic_devices_dist "]["std"], size = self . num_simulations )
self . equipment_leaks_dist = np. random . lognormal ( mean = self . distribution ["
equipment_leaks_dist "][" mean "], sigma = self . distribution ["
equipment_leaks_dist "]["std"], size = self . num_simulations )
self . flaring_dist = np. random . lognormal ( mean = self . distribution ["
flaring_dist "][" mean "], sigma = self . distribution [" flaring_dist "]["std"],
size = self . num_simulations )
self . venting_dist = np. random . uniform (low= self . distribution ["
venting_dist "]["min "], high = self . distribution [" venting_dist "]["max"],
size = self . num_simulations )
self . ng_processing_dist = np. random . normal ( loc= self . distribution ["
ng_processing_dist "][" mean "], scale = self . distribution [" ng_processing_dist
"]["std "], size = self . num_simulations )
self . co2_emissions_dist = np. random . uniform ( low= self . distribution ["
co2_emissions_dist "]["min"], high = self . distribution [" co2_emissions_dist "
][" max"], size = self . num_simulations )

def calc_ghg_emissions (self , ng_production , well_completion , well_workovers ,
pneumatic_devices , equipment_leaks , flaring , venting
```

```
,
ng_processing , co2_emissions ):
methane_emissions = ( self . methane_pct * self . gas_density_mcf *
ng_production * ( well_completion + well_workovers +
pneumatic_devices +
equipment_leaks + flaring + venting ) /100)
co2_emissions = ng_production * co2_emissions
energy_use = ng_production * ng_processing
ghg_emissions = methane_emissions * self .gwp + co2_emissions +
energy_use * 0.06
return ghg_emissions

def run_simulation ( self ):
self . ghg_emissions = np. array ([ self . calc_ghg_emissions ( self .
ng_production_dist [i],
self .w
```

נספח 16

העתק ממסמך מפת הדרכים

עמ׳ 643

נספח 16

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מפת הדרכים למשק אנרגיה
דל פחמן עד שנת 2050

מפת הדרכים למשק אנרגיה דל פחמן עד שנת 2050

אפריל 2021 (עמדות הציבור הוטמעו באוקטובר 2021)

2

עבודה זו בוצעה ע"י צוות מומחים של משרד האנרגיה ולווה ע"י וועדת היגוי רב מגזרית לגיבוש יעדי משק האנרגיה לשנת 2050 וכללה את רשות החשמל, המשרד להגנת הסביבה, משרד האוצר, מנהל התכנון, משרד התחבורה, משרד הכלכלה, משרד הפנים, רשות המיסים, בנק ישראל, המועצה הלאומית לכלכלה, המכון הישראלי לאנרגיה וסביבה, המכון הישראלי לדמוקרטיה, התאחדות התעשיינים, מרכז השל לקיימות, חיים וסביבה, גרינפיס ישראל, החברה להגנת הטבע, תכנית שינוי כיוון 2020, מכללת ספיר, האוניברסיטה העברית ומכון אהרן למדיניות כלכלית.

עורכים ראשיים:

ד"ר חנית בן ארי (מרכזת וועדת ההיגוי ומנהלת הפרויקט), תכנון מדיניות ואסטרטגיה

ד"ר שחר דולב, מנהל פרויקטים מיוחדים ומודלים, המדען הראשי

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דבר השר

משבר האקלים שהולך ומחריף מכריח כלכלות רבות, בהן גם ישראל, להחיל מדיניות ארוכת טווח ואחראית. לאור השינויים הדרמטיים שעובר המשק העולמי והישראלי בניסיון להתמודד עם המשבר, ברור כי עלינו להקדים ולפעול כבר כעת. על כן, אני שמח להציג את מפת הדרכים למשק אנרגיה דל פחמן עד לשנת 2050. התוכנית היא המשך ישיר למדיניות שאני מוביל בשנים האחרונות במשק האנרגיה לצמצום זיהום האוויר ופליטות גזי החממה וזאת תוך שמירה על ביטחון האנרגיה ופיתוח המשק והכלכלה.

לפני כארבע שנים הנחיתי את אנשי משרדי לגבש תכנית למיגור זיהום האוויר במשק האנרגיה. התכנית כללה יעדים שאפתניים במיוחד, שרבים אף הגדירו כלא ישימים. אולם, המשרד בראשותי לא נרתע והפך חזון למציאות. ההישגים, שלא איחרו לבוא הם תוצאה של מהלכים חסרי תקדים בישראל לקידום אנרגיות מתחדשות, צמצום התלות בפחם עד כדי הפסקת השימוש בו בשנת 2025, קביעת יעד חדש לעצימות באנרגיה מתוך עדכון התכנית הלאומית להתייעלות באנרגיה, והעלאת יעד האנרגיות מתחדשות, בעיקר שמש, ל-30% בשנת 2030 - אחד מהיעדים השאפתניים ביותר בעולם לאנרגיה סולארית. בנוסף, משרד האנרגיה בראשותי מוביל את המאמץ לקביעת יעד למעבר המשק לתחבורה חשמלית ודלת פליטות.

לאחרונה, העולם כולו נושא עיניו לנעשה בישראל, פרויקט החיסונים המהיר והנרחב למיגור מגפת הקורונה, הוכיח שוב את היכולת של ישראל להתמודד עם משברים, להוביל ולפרוץ דרך. כך גם בתחום האנרגיה, היעדים שהוצבו בתכנית זו הם יעדים מאתגרים במשק משתנה בקצב מהיר, ובוודאי על רקע מאפייניה הייחודיים של ישראל. גם כאן ישראל מתכוונת להוכיח כי באמצעות מדיניות גמישה המאפשרת תעוזה ישראלית ושימוש בטכנולוגיות לא רק שנעמוד באתגרים, אלא שתרומתה הגדולה של ישראל תוכר גם בהפחתת הפליטות בגבולותיה, וגם בפיתוח פתרונות חדשניים שישמשו מדינות ברחבי העולם להאצת הצעדים להתמודדות עם משבר האקלים ויהוו בסיס חיוני וחשוב למעמדה של ישראל בעולם ולשיתוף פעולה בין ישראל לשכנותיה ולמדינות אחרות נוספות.

דבר המנכ"ל

כחלק ממאמצי ישראל ומדינות נוספות ברחבי העולם להתמודדות עם משבר האקלים, משרד האנרגיה קובע בפעם הראשונה תכנית אסטרטגית ארוכת טווח להפחתת פליטות במשק האנרגיה בשנת 2050.

קביעת יעדים ארוכי טווח מבוססת בראש ובראשונה על קביעת יעדים ותכנית פעולה לטווח הקצר והבינוני (עד עשור קדימה). ואכן, בשנים האחרונות פועל משרד האנרגיה לקידום השימוש באנרגיה נקייה ומופחתת פליטות, זאת בין היתר על ידי צמצום השימוש בפחם לייצור חשמל, המתבצע בקצב המהיר ביותר בעולם, עד כדי הפסקת השימוש בו בשנת 2025, העלאת יעד ייצור החשמל באנרגיה מתחדשת, רובה המכריע שמש, ל-30% בשנת 2030, וקביעת יעד חדש לעצימות באנרגיה מתוך עדכון התכנית הלאומית להתייעלות באנרגיה.

התכנית המובאת בפניכם כוללת יעדי הפחתת פליטות לשנת 2050 ומסמנת את מפת הדרכים, כיווני הפעולה העיקריים, אבני הדרך, האילוצים וצעדי המדיניות הנדרשים להשגת היעדים במגזרי החשמל, התחבורה והתעשייה לצד תכנון תשתיות ושיתופי פעולה אזוריים. התכנית גובשה בהובלתם של צוותים מקצועיים משרדיים, כללה ועדת היגוי רב מגזרית ונבחנה ע"י מודל טכנו-כלכלי ייחודי. הבסיס התאורטי של העבודה מסתמך על המגמות העולמיות, המאפיינים הייחודיים של ישראל וכמובן על עקרונות התכנון של משק האנרגיה הישראלי – אבטחת אנרגיה אמינה, בת השגה ונקייה.

התכנית האסטרטגית הנה פרי עבודה מאומצת ומקצועית של עובדות ועובדי המשרד, ובזכותן ובזכותם אני משוכנע שכפי שקרה בעבר- משק האנרגיה הישראלי יעמוד ביעדים ואפילו מעבר לכך.

תוכן העניינים

תקציר

אנרגיה היא המרכיב המרכזי בכל משק מפותח מודרני. הפעילות האנושית תלויה בשימוש בצורות ומקורות אנרגיה שונים לצורך ביצוע מגוון פעולות ועבודות ולפיכך, אין זה מפתיע שההתפתחות הכלכלית מתואמת עם רמות גבוהות יותר של צריכת אנרגיה. אנרגיה קשורה באופן ישיר כמעט לכל היבט בחיינו- תעשיה, תחבורה, מבנים ועוד, עד כי קיימת תלות באנרגיה לפעילותם השוטפת ולשגרת חיינו. מתוך כך, ניתן לראות לאורך ההיסטוריה כי עלייה באיכות החיים ובצמיחת המשקים השונים, מובילה לעלייה בצריכת האנרגיה, וכפועל יוצא לגידול בפליטות הנוצרות בתהליך הייצור שלה.

לאור משבר האקלים, התקדמות טכנולוגית והשינויים העולמיים באופיים של משקי אנרגיה, עולה הצורך לגבש, כבר היום, מדיניות ארוכת טווח אשר תכין את התשתית כבר היום ותוביל את משק האנרגיה הישראלי להתמודדות עם השינויים הצפויים תוך מתן מענה לצורך להפחית את פליטות גזי החממה הנובעים מסקטור מרכזי זה. מגמות גלובליות ומקומיות משנות את משקי האנרגיה בעולם. אל מול שינויים אלה ובעזרתם, יש לעצב יעדים ארוכי טווח התומכים בקיומו של משק בר קיימא המאופיין באמינות אספקה גבוהה, ביעילות ובמחיר הולם.

לצד מתן ביטוי למגמות עולמיות, תהליך קביעת יעדים בתחום האנרגיה צריך לקחת בחשבון את מאפייניו הייחודיים של המשק הישראלי. ישראל היא אי אנרגטי גאו-פוליטי, המאופיינת בצפיפות אוכלוסייה גבוהה יחסית, בקצב גידול אוכלוסייה גבוה, במיעוט שטחים פתוחים באזור המרכז, בעתודות גז טבעי גדולות, בפוטנציאל ייצור חשמל גבוה מאנרגיית השמש לעומת אפשרויות מוגבלות לייצור אנרגיה ממקורות מתחדשים אחרים.

קביעת יעדים שאפתניים ארוכי טווח בתחום מורכב וחיוני כל כך, מחייבת בחינה רחבה של המשק ומחויבות לעמידה ביעדי ביניים כבר בעשור הקרוב. מתוך כך נבחנו באופן מעמיק יעדי ביניים למשק וזאת לצד קביעת יעדים ארוכי טווח לשנת 2050. בשנתיים האחרונות, משרד האנרגיה הוביל תהליך לקביעת יעדי משק האנרגיה לשנת 2050. התהליך כלל צוות רב מגזרי בו השתתפו משרדי הממשלה הרלוונטיים לרבות אך לא רק, משרד הגנת הסביבה, משרד האוצר, מנהל התכנון, המועצה הלאומית לכלכלה, בנק ישראל, משרד התחבורה, משרד הכלכלה, רשות המיסים, כמו גם נציגי אקדמיה והמגזר השלישי.

תהליך זה התבצע בחלק מתהליך ממשלתי רחב לגיבוש חזון למעבר לכלכלה משגשגת ודלת פחמן בישראל, אשר בסיומו התקבלה החלטת ממשלה 171 "מעבר לכלכלה דלת פחמן" הקובעת יעדי הפחתת פליטות לכלל הסקטורים ולמשק הישראלי. העבודה שלפניכם מראה כי משק האנרגיה הישראלי, בתנאים מסוימים, יכול להפחית בין 75-85% מפליטות גזי החממה עד לשנת 2050, כאשר הפחתה של 81% הינו התרחיש האופטימאלי כלכלית. עם זאת, נכון היה לקבע את היעד ברף השאפתני ביותר שניתן ועל כן

קבע משרד האנרגיה כי היעד יעמוד על הערך המקסימלי – הפחתה של 85% בפליטות גזי החממה ביחס לשנת 2050. יעד זה, כמו גם יעד נוסף של 1.3% התייעלות שנתית בעצימות האנרגיה עוגנו בהחלטת הממשלה "מעבר לכלכלה דלת פחמן".

בשנים האחרונות, אנחנו רואים כי במשקים רבים, ביניהם גם משק האנרגיה הישראלי, נעשים מאמצים להפריד בין מגמת עלייה באיכות חיים לבין מגמת עלייה בצריכת אנרגיה ולפעול כך שבמקביל להתפתחות המשק, ייצור האנרגיה יהיה דל פליטות ובהתאם להתפתחויות האחרונות גם דל פחמן.

סוכנות האנרגיה הבינלאומית (IEA) פרסמה בדו"ח השנתי[1] (2019) את המגמות העולמיות לביקוש לאנרגיה עד שנת 2040. בתרחיש המדיניות המוצהרת, הביקוש לאנרגיה עולה ב- 1% בשנה עד לשנת 2040. מקורות דלי פחמן, בעיקר ממקור סולארי מספקים כחצי מהגידול השנתי, כאשר גז טבעי וגז טבעי נוזלי מהווים שליש נוסף. הביקוש לנפט משתטח בעשור הבא כמו גם שיעור השימוש בפחם, וחלקים מסקטור האנרגיה עוברים טרנספורמציה מהירה לשימוש בחשמל. עם זאת, נראה כי המומנטום העומד מאחורי קידום טכנולוגיות לאנרגיה נקייה אינו מספיק בכדי לקזז את ההשפעות של עלייה בביקוש לאנרגיה בעקבות כלכלה עולמית מתרחבת ואוכלוסייה גדלה. כלומר, עליית פליטות גזי החממה מאטה, אך ללא צמצום משמעותי נוסף לפני שנת 2040, העולם לא יוכל לעמוד במטרה המשותפת לעצור את השפעות משבר האקלים.

ע"פ נתוני הלמ"ס 83% מסך פליטות גזי החממה בישראל מקורם במשק האנרגיה (נתון זה כולל גם פליטות של סקטור התחבורה והתעשייה). אם כך, ברור שהפחתה משמעותית של הפליטות עוברת בראש ובראשונה בסקטור האנרגיה.

ללא הצעדים המרכזיים אותם מתכנן משרד האנרגיה להוציא לפועל כאמור בצירוף צעדים נוספים שיפורטו להלן, נראה כי בתרחיש "עסקים כרגיל" (המשך שימוש בפחם, 17% התייעלות באנרגיה עד לשנת 2030 ו17% אנרגיה מתחדשת בתמהיל הדלקים) וללא פעולות נוספות, סך פליטות גזי החממה, כפי שמוצג בגרף שלהלן, ממשק האנרגיה בשנת 2050 יגדל ב-35% ביחס לערכיהם בשנת 2015.

במשק האנרגיה הישראלי חלו התפתחויות רבות בשנים האחרונות- משרד האנרגיה ביחד עם שותפיו במשרדי הממשלה פועל רבות כדי לקדם אנרגיה יעילה, חסכונית וסביבתית. לשם כך המשרד מקדם רפורמות, הקמת תשתיות והשקעות רבות במחקר ופיתוח בתחומי האנרגיה. בשנת 2018, קידם המשרד מהלכים הכרחיים ליצירת התנאים למעבר משקי התחבורה והתעשייה לעולם נטול נפט, לרבות, תמיכה בפרישת תשתיות טעינה לרכב חשמלי ותחנות תדלוק בגז טבעי דחוס והעמקת התמיכה הממשלתית בפרישת רשת חלוקת הגז הטבעי. בנוסף, בשנת 2017 החליט שר האנרגיה על צמצום השימוש בפחם למינימום תפעולי. בשלהי שנת 2019 הבריז שר האנרגיה על הסבה של כל תחנות הכוח הפחמיות לגז טבעי

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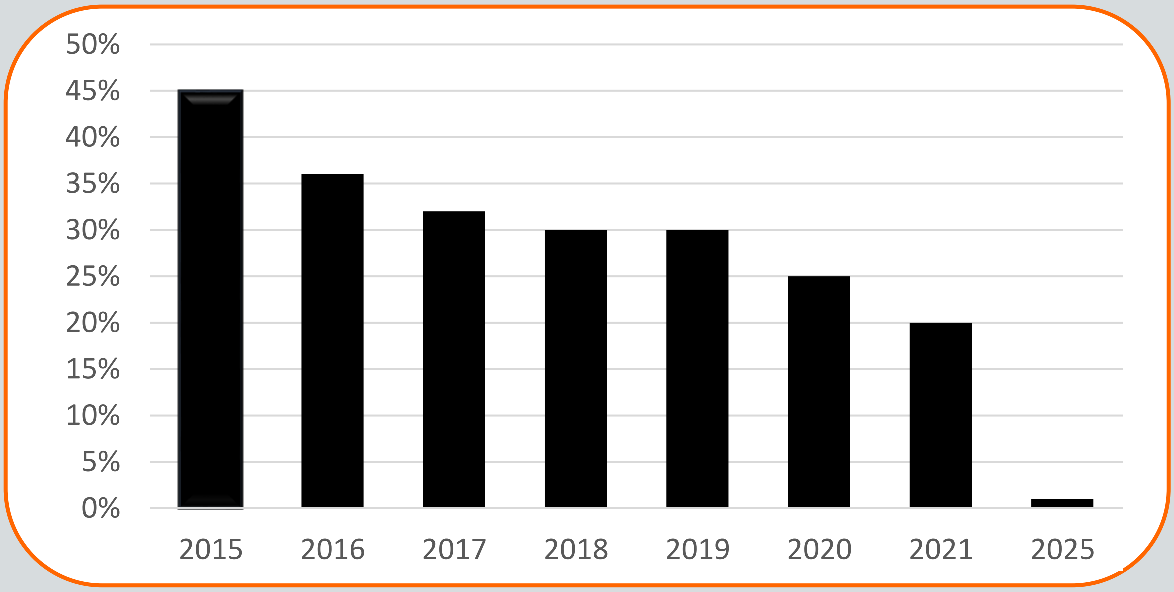
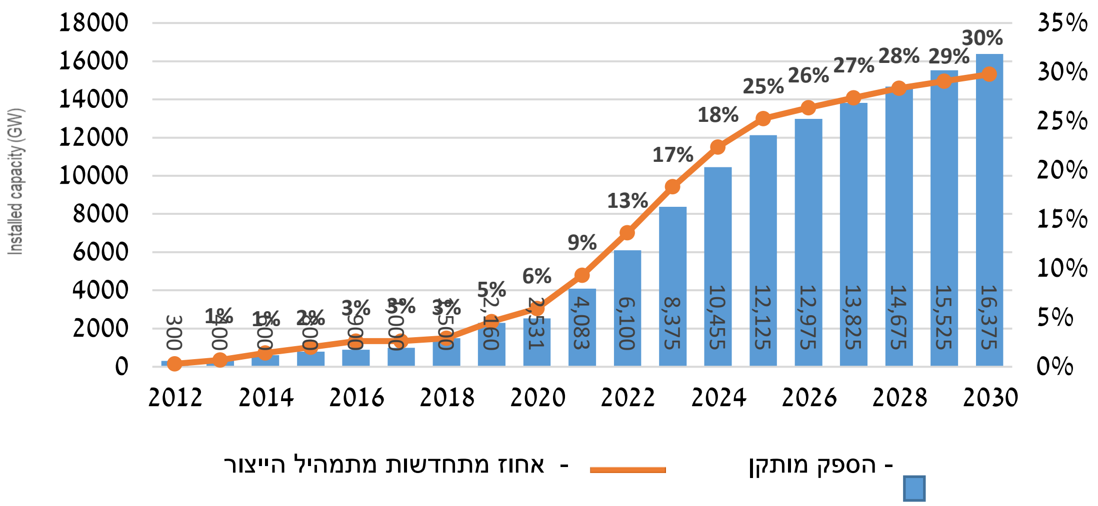
[1] https://www.iea.org/reports/world-energy-outlook-2019#

עד לשנת 2025 ובכך סימן את סוף עידן הפחם הישראלי. קצב הפחתת השימוש בפחם בישראל הוא המהיר ביותר- בתוך 7 שנים, ישראל צמצמה את השימוש בפחם בשני שליש, מ-60% מהיקף תמהיל הייצור ל-20%, ובתוך כך, ישראל תהיה מהמדינות הראשונות שתפסיק לחלוטין שימוש בפחם בתהליך ייצור החשמל (לצד בריטניה שנקודת המוצא שלה הייתה 40% מתמהיל הייצור). בגרף שלהלן ניתן לראות את הירידה החדה בייצור בפחם עד להפסקת הייצור הצפויה בשנת 2025.



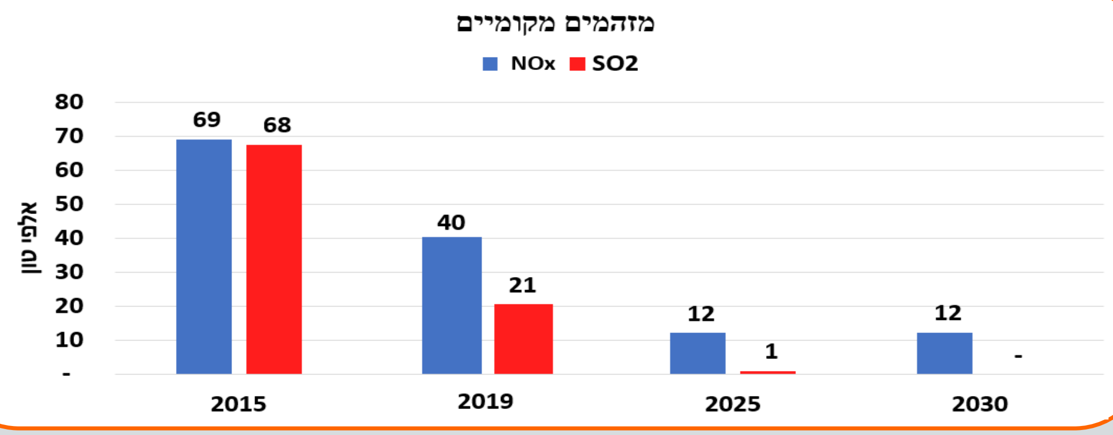
תרשים 1: תחזית אחוז הייצור בפחם מתוך תמהיל ייצור החשמל באותה שנה, משרד האנרגיה, 2020.

בנוסף לכך, לפני כשנתיים יצאה אל הדרך הרפורמה במשק החשמל. רפורמה זו מאפשרת פיתוח משק חשמל תחרותי ויעיל תוך הקצאת המשאבים הנדרשים לפיתוח רשת החשמל לצורך קליטת אנרגיות מתחדשות. כמו כן, הכריז שר האנרגיה על יעדי משק האנרגיה לשנת 2030. היעדים כוללים את הפחתת השימוש במוצרי דלק מזהמים ובפרט הפסקת השימוש בפחם והפסקת רובו המכריע של השימוש בתזקיקי נפט, תוך שמירה על אמינות ורציפות אספקת האנרגיה. בשנת 2020 אימצה הממשלה את יעדי משרד האנרגיה וקיבלה החלטה להעלות את יעדי ייצור החשמל מאנרגיות מתחדשות ל30% מתמהיל הייצור, מרביתן ייצור סולארי, עד לשנת 2030. לפי פרסומים של ה-IEA, כבר היום, ישראל נמצאת בעשרת המקומות המובילים בעולם בייצור חשמל מאנרגיית שמש ובזכות היעד השאפתני של 30% ישראל תמשיך להיות בצמרת העולמית. בנוסף, הושלמה ההכנה של תכנית לאומית להתייעלות באנרגיה עד לשנת 2030 הקובעת יעד של 1.3% שיפור שנתי בעצימות האנרגיה. להלן גרף המציג את ההספק המותקן באנרגיות מתחדשות, רובו ככולו מהשמש, בתחזית לעשור הקרוב. עוד ניתן לראות כי על אף שיעד המתחדשות שולש (מיעד של 10% בשנת 2020 ליעד של 30% בשנת 2030) סך ההספק המותקן צריך לגדול פי 6 (!) בין העשור השני לשלישי וזאת כיוון שאנרגיית השמש מוגבלת לשעות מסוימות ביממה ובשנה.



תרשים 2: תחזית ההספק המותקן באנרגיות מתחדשות, רובה המכריע מהשמש, לעשור הקרוב.
עיבוד רשות החשמל, 2021.

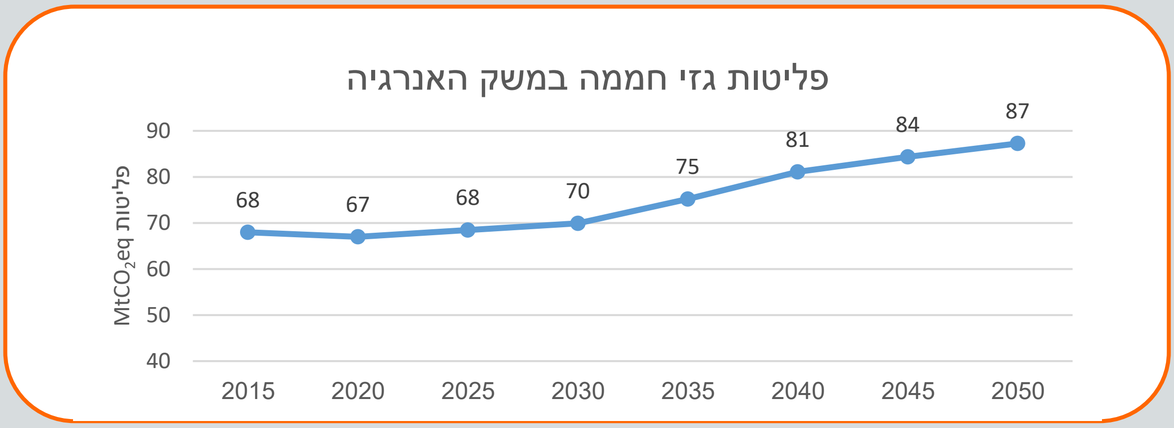
מדיניות המשרד בשנים האחרונות צפויה להביא לירידה חדה במזהמים המקומיים ולמגר כמעט לחלוטין את זיהום האוויר כתוצאה מייצור חשמל. בתרשים 3 שלהלן ניתן לראות את הירידה במזהמים כתוצאה מצעדי המדיניות. לצעדי מדיניות אלו, בראשם צמצום היצור בפחם עד להפסקתו בשנת 2025 וכן העלאת יעד האנרגיות המתחדשות, חשיבות מכרעת להקטנת זיהום האוויר בישראל. כבר היום, הזיהום המקומי מסקטור האנרגיה קטן משמעותית ואף ימשיך ויצטמצם עם השלמת צעדי המדיניות שפורטו כאמור. בגרף שלהלן ניתן לראות את המזהמים המקומיים העיקריים בסקטור החשמל בהשוואה לפי שנים וכן התחזית לשנת 2030.



תרשים 3: תחזית פליטות מזהמים באלפי טון בהשוואה בין השנים 2015 ל 2030, עיבוד משרד האנרגיה על נתוני מפל"ס,[2]2020.

בבל הקשור להפחתת פליטות, צעדים אלה – ההחלטה על הפחתת השימוש בפחם בתהליך ייצור חשמל עד להפסקת השימוש באופן מלא בשנת 2025, לצד העלאת יעד מתחדשות ל-30% שמרביתן ייצור סולארי, ועמידה ביעדי ההתייעלות באנרגיה צפויים להפחית משמעותית את המזהמים המקומיים במשק ובכן להקטין את פליטות גזי החממה ממשק החשמל עד לשנת 2030 בב- 30% ביחס לשנת בסיס 2015. יש לציין כי הפחתה זו מתקיימת חרף העובדה כי בישראל קצב גידול האוכלוסייה הינו כ- 1.7% בשנה, בשונה ממרבית מדינות ה- OECD, כך שבמונחי פלטות לנפש ההפחתה גדולה הרבה יותר. בזכות יעדים אלה, וצעדים תומכים נוספים, המשק הישראלי פוגש את המחויבויות הבינלאומיות שלו בהסכמי פריז, ואף צפוי להקדים אותן, ובכך הם מציבים את ישראל בקדמת הבמה בבל הקשור להפסקת השימוש בפחם, ליעד ייצור מאנרגית שמש ולהפחתת פלטות הפחמן הדו חמצני.

מתוך כך, ללא הצעדים המרכזיים אותם מתכנן משרד האנרגיה להוציא לפועל כאמור בצירוף צעדים נוספים שיפורטו להלן, נראה כי בתרחיש "עסקים כרגיל" (המשך שימוש בפחם, 17% התייעלות באנרגיה עד לשנת 2030 ו- 17% אנרגיה מתחדשת בתמהיל הדלקים) וללא פעולות נוספות, סך פליטות גזי החממה ממשק האנרגיה בשנת 2050 היו גדלים ב-35% מערכיהם בשנת 2015, כפי שמוצג בגרף שלהלן.



תרשים 4: פליטות גזי חממה ממשק האנרגיה עד שנת 2050 בתרחיש "עסקים כרגיל" ע"פ מודל אנרגיה, משרד האנרגיה, 2020.

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[2] https://www.gov.il/he/departments/topics/prtr

תחזית זו, כפי שיפורט בהמשך, מציבה בפני משק האנרגיה הישראלי, אתגר משמעותי כפול – הצבת **יעדים שאפתניים** למשק תוך שמירה על **משק אנרגיה אמין** וחיזוק **צמיחה כלכלית בת קיימא**.

התוכנית קובעת מספר עקרונות אסטרטגיים אשר נדרשים ליצירת התשתית לעמידה ביעדים השאפתניים:

1. מעבר המשק לאנרגיית שמש, ואתו הצורך באגירת אנרגיה מאסיבית.
2. השקעה ובחינה של טכנולוגיות חדשניות, בין היתר מימן ותפיסת פחמן, כמו גם אנרגיות מתחדשות עתידיות, דוגמת אנרגיות מתחדשות שמקורן בים.
4. פיתוח רשת החשמל, תכנון תשתיות מקיים ומתוך כך הטמנת קווי מתח במקום קווים עיליים, ביזור רשת החשמל וקירוב הייצור לצריכה.
6. טרנספורמציית אנרגיה של מבני מגורים לרבות חשמול המגזר הביתי, תוך החלפת השימוש בגז הבישול בשימוש בחשמל.
7. מעבר לרכב חשמלי תוך הפסקת השימוש במנועי בעירה מבוססי סולר ובנזין.

חזון ויעדי התכנית

משק האנרגיה בישראל בשנת 2050 יהיה משק אנרגיה אמין, בר השגה ובר קיימא. משק האנרגיה יבטיח את איכות החיים המודרניים בישראל ע"י אבטחת אספקת אנרגיה אמינה ורצופה. המשק יהיה דל זיהום, ובו תצומצם ככול הניתן טביעת הרגל הפחמנית לרבות תפיסת הקרקע. אלה יושגו תוך שאיפה מתמדת לקידום משק תחרותי וצומח, כזה שמקדם טכנולוגיה וחדשנות כערך והכל במחירי אנרגיה הוגנים ובני השגה.

על מנת לעמוד בעקרונות אלה תצטרך ישראל לטפח טכנולוגיות, תהליכים ומערכות במחירים נמוכים ככל האפשר. זאת על מנת להגן על עסקים ומשקי בית מעלויות אנרגיה גבוהות ובכן על מנת להשיג יתרון תעשייתי וכלכלי במעבר הגלובלי לכלכלה דלת פחמן. בנוסף, על מנת שמדינות אחרות, במיוחד מדינות מתפתחות, ילכו בעקבות הדוגמה של ישראל, אנו זקוקים לטכנולוגיות דלות פחמן בעלויות נמוכות. כיוון שלא ניתן לחזות כל פריצת דרך טכנולוגית שתעזור לנו לעמוד ביעדים, עלינו ליצור את הסביבה הטובה ביותר האפשרית למגזר הפרטי לחדש ולהשקיע., ולהבטיח שאנחנו המקום הטוב ביותר עבור חדשנות וצמיחת עסקים חדשים.

בנוסף לתמיכה בחדשנות, אנו מתמקדים במדיניות המספקת יתרונות חברתיים, סביבתיים וכלכליים מעבר לצורך להפחתת פליטות גזי חממה. מבנים משמרי אנרגיה הם מקומות בריאים יותר לחיות ולעבוד בהם וזולים יותר לתחזוקה. מעבר מלא לתחבורה מאופסות פליטות הינה זכייה משולשת במונחים של הזדמנות תעשייתית, אוויר נקי יותר ופליטות גזי חממה נמוכים יותר. באופן מכריע, רבות מהפעולות ישפרו את ביטחון האנרגיה של ישראל. לצד פעולות אלה, אנו מניחים את היסודות להחלטות מרכזיות בתחומים בהם אנו מתמודדים עם חוסר וודאות גבוהה ואתגרים משמעותיים ביותר: שילוב כמויות גבוהות של אנרגיה סולארית ברשת, אגירה ומחסור בקרקע.

משק האנרגיה מספק את האנרגיה החיונית לתפקוד תקין של כלל הסקטורים בישראל כמו גם של כל אזרחי ישראל ולכן משפיע באופן ישיר ומהותי הן על כלכלת ישראל והן על איכות חייהם של תושביה. שלושת העקרונות המנחים של תכנון משק האנרגיה הם – ביטחון אנרגיה, כלכלה וסביבה.

למשק הישראלי מאפיינים ייחודיים: ישראל היא אי אנרגטי גאו-פוליטי ומאופיינת בצפיפות אוכלוסייה גבוהה יחסית, בקצב גידול אוכלוסייה גבוה, בעתודות גז טבעי גדולות, בפוטנציאל לייצור חשמל מאנרגית השמש אולם במיעוט אפשרויות ליצירת אנרגיה ממקורות מתחדשים אחרים.

תכנון יעדים ארוכי טווח במשק האנרגיה מתכלל את עקרונות המשק תוך התייחסות והתחשבות במאפייניה הייחודיים של ישראל וזאת על רקע השאיפה להפחתה משמעותית של פליטת גזי החממה שמקורם במשק האנרגיה.

יעדים בתחום האנרגיה

משרד האנרגיה הגדיר ארבעה 'יעדים ראשיים' שישקפו את המטרה האסטרטגית של הפחתת הפליטות, ובנוסף לכך יעדים סקטוריאליים תומכים בעזרתם ניתן יהיה להשיגה. 'יעד העל' מוגדר **כהפחתת פליטות גזי חממה ממגזר האנרגיה בשיעור של 80%** ביחס לשנת הייחוס 2015 וזאת עד לשנת 2050.

היעדים והמדדים עבור סקטור האנרגיה מוצגים בלוח הבא:

***לוח 1**: יעדי תכנית האנרגיה*

יעדים ראשיים	מדד	2018	יעד 2030	יעד 2050
הפחתת פליטות גזי חממה במשק האנרגיה	אחוז הפחתת פליטות גזי חממה ביחס לשנת 2015	0%	22%	**80%**
הפחתת פליטות גזי חממה במגזר החשמל	אחוז הפחתת פליטות גזי חממה ביחס לשנת 2015	7.5%	30%	**85%-75%**
יעילות באנרגיה	אחוז שיפור שנתי בעצימות אנרגיה (טרה-וואט/מלש"ח)	0.7%	שיפור שנתי של 1.3% בעצימות האנרגיה	**שיפור שנתי של 1.3% בעצימות האנרגיה**
שימוש בפחם	אחוז פחם בתמהיל ייצור החשמל	30%	0%	**0%**

יעדים אלו נבחרו מכיוון שהם משקפים את המטרות האסטרטגיות של התכנית ובפרט, הפחתת פליטות גזי חממה ומזהמי אוויר.

יעד המשנה בעל התרומה המשמעותית ביותר להפחתת הפליטות בסקטור האנרגיה הינו הפחתת 75%-85% מפליטות גזי החממה במגזר ייצור החשמל ביחס לשנת 2015. הפחתת הפליטות יכולה להיות מושגת ע"י מספר כלים עיקריים ביחסים שונים:

1. הגדלת אחוז אנרגיית השמש (סולארית) בתמהיל ייצור החשמל
2. תפיסת הפחמן הנפלט מתחנות הכח ושימוש חוזר או הטמנתו
3. חיבור רשת החשמל למדינות שכנות או לאירופה
4. בחינת השימוש באנרגיה גרעינית
5. שימוש במימן כחול המופק מגז טבעי
6. טכנולוגיות עתידיות לרבות אנרגיה מתחדשת ממקורות ימיים או אחרים

לכל אחד מהכלים המוצעים לעיל יתרונות וחסרונות כמו גם מידת ישימות שונה נכון להיום.

אחוז גבוה (מעל 30%) של אנרגיה מתחדשת בתמהיל הייצור כרוך באתגרים רבים הנוגעים בין השאר בהיבטים תכנוניים, סביבתיים, פיננסיים, ובעיקר ביציבות ושרידות מערכת החשמל, קצב התקדמות טכנולוגיות האגירה ואיתור שטחים לצורך הקמת מערכות סולאריות. פיתוח של מקורות מתחדשים שאינם קיימים כיום, כגון אנרגיית רוח במים עמוקים, גלים או גיאותרמיקה עמוקה, יכול לסייע לשילוב והגדלת חלקם של המקורות המתחדשים.

מבחינת טכנולוגיות להפחתת פליטות, אין מדובר בטכנולוגיה אחת, אלא בחבילה שלמה של טכנולוגיות ותהליכים. הטכנולוגיה המובילה בימים אלה הינה תפיסת והטמנת פחמן (CCS). כיום קיימים מספר פרויקטים בעולם, חלקם פועלים בהצלחה כבר עשרות שנים, בעוד אחרים נמצאים בשלבי פיתוח או בשלבי מעבר לשימוש בקנה מידה תעשייתי. ללא קפיצה טכנולוגית שתאפשר יישום בקנה מידה נרחב ואיתור אזורים מתאימים לכליאת פד"ח, לא יתאפשר יישום טכנולוגיות תפיסת ואחסון פחמן בישראל.

אחת הגישות המובילות להפחתת פליטות הינה גישה המבוססת על אגירה כימית של עודפי חשמל ממקורות מתחדשים - ניצול עודפי החשמל לתהליך אלקטרוליזה של מימן, תהליך שאינו מפיק פליטות או מזהמים. שימוש במימן כחול לצורך התהליך, כלומר מימן המופק מגז טבעי (הכולל פחמן ומימן בלבד), מייצר תרכובות פחמן שניתן לתפוס ולנצל בשנית. את המימן ניתן לאגור ולהזין לטורבינות ייעודיות לייצור חשמל, בתעשייה כחלופה לדלקים מזהמים, או לתאי דלק, ההופכים מימן וחמצן למים תוך כדי ייצור חשמל.

לצד טכנולוגיות אלה, קיימת האפשרות ליצור חשמל מאנרגיה גרעינית הנפוצה מאוד בעולם, אולם היא נתקלת בהתנגדויות משמעויות ועל כן יש לבחון נושא זה בזהירות. הכלי האחרון הוא קישוריות – כלומר חיבור רשת החשמל למדינות אחרות והיכולת לסחור בחשמל נקי מצד אחד ומצד שני לייצא את

המערכת של ביקוש והיצע וכך להגיע למערכת מאוזנת ויעילה יותר, בייחוד בעידן של הגדלת הייצור מאנרגיות מתחדשות. נכון להיום אין חיבור מסוג זה אך מתקיימים מהלכים שיאפשרו זאת בעתיד.

לאור זאת, ובהתחשב באי הוודאות הגדולה לתכנון שלושה עשורים קדימה, משרד האנרגיה החליט לקבוע יעדים שאפתניים אך לאפשר למשק האנרגיה גמישות במציאת הדרך הטובה ביותר להשגת היעדים, וזאת ע"י הערכה תקופתית של קצב ההתקדמות הטכנולוגית, המדינית ושינויים במחירים.

בנוסף, עמידה ביעדים בסקטורים משלימים (תעשייה, תחבורה ומבנים) היא כתלות בשיתוף הפעולה בין בעלי העניין השונים ובפרט בין הגורמים הממשלתיים. האתגרים העומדים בפנינו מורכבים ועל כן לטיפול בהם נדרשת גישה הוליסטית, ניצול משאבים וחלוקת אחריות.

יובהר כי, למימוש יעדים אלה, היתכנות טכנית ויתרונות כלכליים וסביבתיים שבאים לידי ביטוי בחסכון בעלויות דלקים, צמצום פליטת גזי חממה ומזהמים ובהפחתת התלות בנפט. עם זאת, על מנת שיישום תכנית זו יצליח, ישנם תנאים ההכרחיים בלעדיהם לא יתאפשרו המהלכים המפורטים בהמשך וכתוצאה, מדינת ישראל לא תוכל לעמוד בהתחייבויותיה.

תנאים הכרחיים למימוש היעדים

כאמור, השגת היעדים המוצגים לעיל תלויה בשני פרמטרים עיקריים: העלאת אחוז האנרגיה המתחדשת והאגירה באופן משמעותי, בשילוב הטמעת טכנולוגיות חדשות שיובילו להפחתת פליטות. ללא עמידה בפרמטרים אלה לפחות, לא תתאפשר הפחתת פליטות שאפתנית כפי שהוצע בסקטור זה. מתוך כך ניתן לומר כי השגת היעדים תלויה בקיומם של מספר תנאים הכרחיים:

תנאי הכרחי	2020	יעד 2030	יעד 2050
הערכת השטח הנדרש להקמת מערכות אנרגיה מתחדשת		כ- 160 אלף דונם	500-900 אלף דונם
אגירה	0.3 GW	3.5 GW	34-57 GW
הטמעת טכנולוגיות להפחתת פליטות- CCS, גרעין, מימן, טכנו' עתידיות	יעודכן בהתאם להתפתחויות הטכנולוגיות		
פיתוח הרשת – הערכה ליכולת הולכת אנרגיה מתחדשת	3-4 GW	11 GW	>30 GW
פיתוח הרשת – הערכה להשקעה ברשת החלוקה	יעודכן בהמשך		
עמידה ביעדים של משקים משלימים – תחבורה ותעשייה	לפי צוותי תחבורה ותעשייה		
חיבור בין מדינות – יכולת חיבור רשת החשמל עם מדינות שכנות וקניית חשמל נקי	חיבור יציב לרשתות חשמל אזוריות: חיבור לרשת אירופאית ובעדיפות גם לרשתות חשמל נוספות באזור		

טכנולוגיה ומעבר למתחדשות

מעבר למשק אנרגיה מאופס פחמן כולל מהלכים במקטע התמרת האנרגיה והשימושים הסופיים של מוצרי אנרגיה במשק הישראלי. יישום המדיניות למימושם צפוי ליצור שינויים משמעותיים במערך ייצור החשמל, וענפי התחבורה והתעשייה. תמורות אלו יצריכו השקעות בתשתיות, שינוי בהרכב צריכת הדלקים והעלויות הנובעות מכך ובן שינויים בעלויות התפעול. מחירי העלות והתפעול של טכנולוגיות חדשות להפחתת פליטות גזי החממה ישפיעו על קצב אימוצם והטמעתם בישראל.

אנרגיות מתחדשות

בעשור האחרון חלות תמורות בתמהיל ייצור האנרגיה בעולם שהבולט בהם הוא שינוי בתמהיל מקורות האנרגיה לייצור חשמל. מבין שינויים אלה, המגמה הברורה ביותר היא הסתמכות הולכת וגדלה על טכנולוגיות בתחום האנרגיה מתחדשת, ובעיקר אלו המנצלות את אנרגית הרוח והשמש במקום השימוש המסורתי במתקני ייצור קונבנציונליים. הסבר לכך מצוי במגמות העולמיות להתמודדות עם משבר האקלים ובירידה המתמשכת במחירי האנרגיות המתחדשות אשר מאפשרת להקים הספק רב יותר בעלות נמוכה יותר על פני זמן. מחיר ההתקנה של וואט פוטו-וולטאי ירד בכ- 80% בעשור האחרון, וצפוי להשלים ירידה של כ- 30% נוספים על פני העשור הבא.

עמידה ביעדים משמעותיים של ייצור באנרגיות מתחדשות בישראל כרוכה באתגרים רבים הנוגעים בין השאר בהיבטים תכנוניים, סביבתיים, פיננסיים וטכנולוגיים, אשר מתאפיינים בהשפעה מכרעת על משק החשמל. בין ההשפעות הבולטות על המשק ניתן למנות את תוספת העלויות הישירות והעקיפות הנובעות משילוב אנרגיות מתחדשות במערכת ומגולמות בתעריף החשמל המשולם על ידי כלל הצרכנים, כמו גם את ההשפעות על יציבות ושרידות מערכת החשמל, על ביטחון האנרגיה, על הקצאת משאב הרשת ועוד.

בהיעדר פוטנציאל לייצור אנרגיה מתחדשת ממקורות קבועים כגון מקורות הידרו-אלקטריים וגיאותרמיים, ובשל החסמים הרבים הנוגעים לקידום מתקנים בטכנולוגיות אחרות, ההנחה בבסיס העבודה היא שלצורך עמידה ביעד, תוספת ההספק שתידרש תהיה ברובה המוחלט בהתבסס על אנרגית שמש. כך, עומדת ישראל להפוך לאחת המובילות העולמיות בחלק היחסי של הייצור הסולארי מתוך סך הייצור. למרות היתרונות הכלכליים של ייצור סולארי ומאפייני האקלים בישראל, קיימת מורכבות רבה בניהול מערכת חשמל המסתמכת באופן כמעט בלעדי על מקור אנרגיה מתחדשת אחד בלבד, בפרט סירוגי (שאינו ניתן לשליטה על ידי מנהלי הרשת ואינו בעל כושר אספקה רציף). לאור האמור, יש חשיבות רבה לשימור ולהרחבת הפעולות שננקטו כדי להקל על שילובם של מתקנים

סולאריים, לקידום סוגים נוספים של אנרגיות מתחדשות ובפרט טכנולוגיית הרוח, כמו גם לשימוש במתקני אגירה לצורך קליטת עודפי ייצור סולארי והגמשת מערך הייצור.

לישראל מספר מאפיינים נוספים המעצימים את האתגר הנובע משילוב משמעותי של אנרגיות מתחדשות, ובפרט שילוב מתקנים סולאריים. ראשית, לישראל אין חיבור משמעותי עם מדינות שכנות שמאפשר הזרמת עודפי חשמל או גיבוי במקרה של מחסור. בנוסף, ישראל היא מדינה קטנה ובעלת צפיפות אוכלוסין גבוהה. בהשוואה לייצור קונבנציונלי, כמות האנרגיה שמיוצרת לתא שטח באמצעות מתקנים פוטו-וולטאים נמוכה משמעותית. תא השטח הנדרש לייצור מגה וואט סולארי גבוה פי 100 עד 150 מתא השטח הנדרש לייצור חשמל מגז טבעי. יצוין בהקשר זה כי יותר מ – 70% מייצור החשמל בישראל מיוצר בדרום הארץ בעוד ש- 70% מהביקושים ומוקדי הצריכה העיקריים מרוכזים באזור המרכז. יתרה על כך, מלאי פוטנציאל השטחים הפנויים הגדול ביותר להקמת מתקני ייצור קרקעיים נמצא באזור הדרום, בו צריכת החשמל נמוכה. כתוצאה מכך, נדרש פיתוח משמעותי של רשת ההולכה לצורך העברת האנרגיה ממוקדי הייצור למוקדי הצריכה במרכז הארץ, משאבי הרשת העיליים של מערכות ההולכה תופסים שטחים נרחבים[3], בנוסף נדרש ניצול מרבי של יכולת הקמת מערכות ייצור בשימוש כפול בשטחים הבנויים במרכז הארץ בפרט וכן בשאר האזורים.

בעתיד ישנה אפשרות כי תתפתחנה טכנולוגיות נוספות שניתן יהיה ליישם בישראל, כגון טורבינות רוח צפות בים העמוק, ניצול גלים או זרמי ים, וניצול אנרגיה גיאותרמית מעומק האדמה. במידה וטכנולוגיות אלו יגיעו לבשלות טכנולוגית וכלכלית, הן תישקלנה ליישום בישראל ויאפשרו להקל על האינטגרציה ברשת החשמל.

<u>טכנולוגיות לתפיסת פחמן והטמנתו/ שימוש חוזר</u>

תפיסת ואחסון פחמן (CCS) הינו תהליך בו פחמן דו-חמצני (פד"ח) נתפס מפליטות של תהליכים תעשייתיים ותהליכי הפקת חשמל, ומאוחסן ללא יכולת להיפלט לאטמוספירה. מטרת התהליך לצמצם את האפקט של פליטת גזי חממה ממקור אנושי על שינוי האקלים. אין מדובר בטכנולוגיה אחת, אלא בחבילה שלמה של טכנולוגיות ותהליכים. חלק מהם פועלים בהצלחה כבר עשרות שנים, בעוד אחרים נמצאים תחת פיתוח או בשלבי מעבר לשימוש בקנה מידה תעשייתי. ללא קפיצה טכנולוגית שתאפשר יישום בקנה מידה נרחב ואיתור אזורים מתאימים לכליאת הפד"ח, לא יתאפשר יישום של טכנולוגיות תפיסת ואחסון פחמן בישראל.

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[3] 70,000 מ"ר על כל קילומטר של קו 400 ק"ו

באופן בסיסי CCS מורכב משלושה שלבים עיקריים:

1. תפיסה - הפרדת הפד"ח מגזים אחרים בתהליך התעשייתי או בתהליך הפקת חשמל, לאחר מכן הפד"ח נדחס לקראת שינוע.
2. שינוע - העברת הפד"ח, בד"כ באמצעות צינורות, מאתר תפיסתו אל אתר אחסנה.
3. אחסון - הזרקת הפד"ח אל תצורות קרקע או אקוויפרים תת-קרקעיים לשם כליאה ארוכת טווח. לחילופין, ניתן לשלבו בתהליכים תעשייתיים ליצירת מוצרים אחרים (CCU).

כיום, CCS כלכלי רק בחלק מצומצם של מקרים, כאשר מקורה של מרבית העלות בתהליך תפיסת הפד"ח .חסמים נוספים הם קושי בשימוש בפד"ח כחומר גלם, חוסר וודאות רגולטורי, צורך בתשתיות הולכה לפד"ח, אי קבלה ציבורית, קושי באיתור ואפיון אתרי אחסון, אי הכרה בעלויות החיצוניות של פליטת גזי חממה, ונושאי חבות (מי נושא באחריות במקרים של נזק).

בעולם פועלים נכון ל-2020, 26 מפעלים בקנה מידה גדול, ועוד כ-3 מפעלים בהקמה, כ-13 מפעלים בשלבי פיתוח מתקדם וכ-21 בשלבי פיתוח ראשוניים. המפעלים הפועלים היום בעלי קיבולת תפיסה של 40 MtCO2 בשנה. בנוסף, ישנם עוד 34 מתקני חלוץ והדגמה פועלים או בתהליכי הקמה. בישראל בוצעה עבודה ראשונית למיפוי פוטנציאל הטמנת הפד"ח על ידי המכון הגיאולוגי ובכוונת המשרד להעמיק בחינה זו.

<u>מימן</u>

אחת הגישות המובילות להפחתת פליטות הינה גישה המבוססת על אגירה כימית של עודפי חשמל ממקורות מתחדשים - ניצול עודפי החשמל לאלקטרוליזה של מימן. תהליך שריפת המימן הינו תהליך נקי המפיק חום רב ומים בלבד כתוצר לוואי. אפשרות אחרת היא ניצול המימן בתאי דלק, הממירים אותו ישירות לחשמל בנצילות גבוהה. לכן המימן מיועד לשמש כדלק נקי בעתיד מופחת פליטות. אולם כיום, בישראל ובעולם בכלל, רובו המוחלט של המימן מופק מדלקים פוסיליים תוך פליטה משמעותית של פד"ח. מימן המופק בתהליך זה מכונה "מימן אפור" והוא לא יכול להוות בסיס לכלכלה דלת פליטות עתידית. מימן כחול לעומת זאת, הוא מימן המופק מגז טבעי (הכולל פחמן ומימן בלבד), כאשר בהליכי ההפקה נוצרות תרכובות פחמן שניתן לתפוס ולנצל (בדומה לטכנולוגיות ה-CCU). את המימן ניתן לאגור ולהזין לטורבינות ייעודיות לייצור חשמל (טורבינות הדומות לטורבינות גז עם שינויים מסוימים), לתנורים תעשייתיים כחלופה לדלקים מזהמים, או לתאי דלק, ההופכים מימן וחמצן למים תוך כדי ייצור חשמל.

טכנולוגיות מימן נקי עדין בשלבי פיתוח וניסוי ראשוניים בעולם, וללא קפיצה טכנולוגית שתאפשר יישום כלכלי בקנה מידה מספק, לא יתאפשר יישום של טכנולוגיה זו בישראל. המשרד משקיע משאבים בקידום טכנולוגיה מימן בישראל באמצעות תמיכה במחקרים, בחברות הזנק ובמתקני חלוץ.

אנרגיה גרעינית

ייצור חשמל מאנרגיה גרעינית נפוץ מאוד בעולם, למרות התחושה בציבור כי מדובר בטכנולוגיה הנמצאת בתהליך מתמשך של דעיכה. בפועל, כ-10% מכלל החשמל בעולם מיוצר על ידי אנרגיה גרעינית (IEA ,2018), ובמדינות ה-OECD השיעור עומד על 17.7%. כ-400 GW חשמל המיוצרים ב-452 כורים גרעיניים ב-31 מדינות בעולם. ניתן לראות כי כמעט בכל מדינות ה-OECD (למעט יפן שנאלצה לסגור את רוב תחנות הכוח שלה בעקבות אסון פוקושימה) חלק החשמל המיוצר באנרגיה גרעינית עולה על הממוצע העולמי. נכון להיום היקף ייצור החשמל מאנרגיה גרעינית גדל, אם כי הוא גדל בקצב קטן מהגידול בסך צריכת החשמל, כך שחלקו בתמהיל יורד. תהליך זה מקבל גיבוי מדעת הקהל הציבורית וחלק מהגופים הירוקים. בכל הקשור למשק האנרגיה ישראלי, יש לבחון את היתרונות והחסרונות של הטכנולוגיה כמו גם את מידת הישימות של הטמעתה במשק הישראלי. יש לציין כי לישראל מספר מאפיינים ייחודיים המקשים על השימוש בטכנולוגיית גרעין. לצד זאת ככל שמגמות עולמיות של הפחתת פלטות פד"ח יובילו לפיתוחים טכנולוגים בתחום ולהגברת השימוש בטכנולוגיה מבוססת גרעין במדינות ה OECD, יהיה מקום לבחון זאת גם בישראל.

הפחתת פליטות בסקטורים משלימים- תעשייה, תחבורה ומבנים

כאמור, המשך הפיתוח הכלכלי בישראל מוביל לגידול מתמשך בביקוש לאנרגיה. הקשר בין תעשייה, תחבורה וסקטור המבנים לאנרגיה הוא קשר ישיר כיוון ששלושת התחומים תלויים באנרגיה לפעילותם השוטפת, עם זאת האתגר והאחריות למעבר לאנרגיה נקייה בסקטורים אלה משותף ותלוי במספר בעלי עניין.

מגזר התעשייה:

ישנם שלושה מקורות עיקריים לפליטות במגזר התעשייה: פליטה ישירה מהתהליכים התעשייתיים עצמם, פליטה עקיפה עקב שימוש בחשמל ופליטה ישירה עקב שריפת דלקים וגז. בעולם, משקיעים בתהליכים המנסים לצמצם פליטות אלו וגם בישראל, משרד האנרגיה בשיתוף משרד הכלכלה, רשות החדשנות והתאחדות התעשיינים משתפים פעולה במטרה לקדם תהליכי מחקר, פיתוח ויישום של תהליכים מופחתי פליטות בתעשייה.

התהליכים הנדרשים להסבת התעשייה לתעשייה דלת או מאופסת פליטות גזי חממה הינם ארוכי טווח ודורשים הן בחינה הנדסית עמוקה והן השקעה כספית משמעותית. היות וכך יש להתחיל לקדם את התהליכים במהירות האפשרית בכדי לאפשר לתעשייה את הזמן הנדרש למעבר. ללא הסבה לגז טבעי בשלב הראשון במקביל לתהליכי חשמול ומעבר למימן בטווח הארוך, לא נוכל להפחית פליטות בסקטור זה ולעמוד ביעד העל.

להלן יעדי מגזר התעשייה:

יעד	מדד	יעד 2030	יעד 2050
הפחתת פליטות גזי חממה של התעשייה	הפחתת פליטות גזי חממה ביחס לשנת 2015	15%	54%

מגזר התחבורה:

כיום קיימת תלות כמעט מוחלטת בנפט כמקור אנרגיה לתחבורה בארץ ובעולם. למעלה מ-90% מצריכת האנרגיה בתחבורה העולמית מקורה בנפט ובישראל התלות אף גדולה יותר. למצב זה ישנן השלכות שליליות ביותר הן מההיבט הסביבתי, כתוצאה מפליטות גזי חממה, הן מההיבט הבריאותי עקב מזהמים שונים הנפלטים לאוויר בקרבה לאוכלוסייה, הן מההיבט הכלכלי, מאחר ומחירי הנפט מתאפיינים בתנודתיות גבוהה, והן מההיבט הגיאופוליטי, מאחר והנפט מצוי בחלקו הגדול במדינות התורמות לחוסר יציבות פוליטית.

על מנת להפחית את הפליטות מסקטור זה יש לעודד חדירת רכב חשמלי ע"י חבילת תמריצים הכוללת הטבות מיסי רכישה ומכס, פריסת תשתיות ועמדות טעינה, השקעות ברשת החשמל בבדי שתוכל לספק את הביקוש התוספתי והשקעה במו"פ. בנוסף יש צורך לאמץ את התקנים האירופאים לפליטות ברכבים חדשים ולקבוע יעדי מכירות וייבוא. מבחינת התחבורה הכבדה שלא צפויה לעבור חשמול בעשורים הקרובים, יש צורך בהשקעה בתחליפי דלקים כגון מימן, גט"ן וביו דלקים.

להלן יעדי מגזר התחבורה כפי שנקבעו על ידי צוות בהובלת משד התחבורה:

יעד	מדד	2018	יעד 2030	יעד 2050
רכבים מאופסי פליטה	אחוז רכבים מאופסי פליטה מסך מצבת הרכבים*	0%	25% עבור רכבים קלים מתחת ל-3.5 טון ואוטובוסים 10% עבור משאיות כבדות	100%
יעילות באנרגיה	צריכת אנרגיה סופית מתחבורה לתושב לשנה (MWh/capita)	7.7	6-7	2-3
הפחתת פליטות גזי חממה שמקורן מתחבורה	הפחתת פליטות גזי חממה ביחס לשנת 2015	-	11%	94%

מגזר המבנים:

בישראל, סקטור המבנים אחראי על כשליש מפליטות גזי החממה, בעיקר כתוצאה מצריכת אנרגיה לתאורה, לחימום ולקירור. אימוץ תקני בנייה ירוקה יוביל לחיסכון של עד- 30% בצריכת האנרגיה במבנים, אולם, אימוץ של בנייה ירוקה אינו ממצה את פוטנציאל הפחתת פליטות גזי החממה ויש צורך למעבר לבנייה מאופסת אנרגיה, כך שייצור האנרגיה שווה לצריכת האנרגיה ומאזן האנרגיה הינו אפסי ואף חיובי במבנים אלה.

להלן יעדי מגזר המבנים להתחלות בנייה מאופסת אנרגיה כפי שנקבעו ע"י צוות מבנים וערים בהובלת מנהל התכנון:

יעד	מדד	יעד 2030	יעד 2050
בתי מגורים צמודי קרקע	מהתחלות הבנייה	**100%**	**100%**
מבני מגורים בבנייה רוויה 3-5 קומות	מהתחלות הבנייה	**100%**	**100%**
מבני מסחר	מהתחלות הבנייה	**50%**	**100%**
מבני ציבור	מהתחלות הבנייה	**100%**	**100%**
מבני חינוך	מהתחלות הבנייה	**100%**	**100%**
מבני ממשלה בבעלות מנהל הדיור הממשלתי	מהתחלות הבנייה	**100%**	**100%**

- היעדים משקפים את אחוז המבנים שיעברו התעדה למימוש פוטנציאל האיפוס בהתאם למאפייני המבנה.

שיתוף פעולה בין משרדי ומגזרי

שיתוף פעולה בין משרדי ומגזרי הינו קריטי על מנת להגיע למטרה המשותפת של השגת יעדי הפחתת הפליטות הלאומיים של ישראל. האתגרים העומדים בפנינו מורכבים ולכן לטיפול בהן נדרשת גישה משולבת ובהתבסס על יעילות ניצול המשאבים של כל משרד ועל חלוקת אחריות; תיאום יכול ליצור יתרון לגודל - מהלך של מספר משרדים הוא עוצמתי ויעיל יותר. אולם, קיים קושי לסנכרן ולתאם שגרה ונהלים ארגוניים, אשר מייצר חסם משמעותי לשת"פ, בנוסף, לכל אחד מהגופים משתפי הפעולה יש מטרות ולחצים שונים שיכולים לפגוע במהלך הכולל. סוגיית השטח למשל, הינה דוגמא לאתגר שנוכל להתגבר עליו רק על ידי הבנה הדדית וחתירה למטרה זהה, שילוב נכסים והסכמה על ערך משמעותי שלכל אחד מהמשרדים יש סיבה ערכית אמתית לקדם אותו.

סוגיית השטח

סוגיית השטח היא אתגר לא פשוט כיוון שקרקע בישראל הינה משאב מוגבל מאוד. על כן, יש להשתמש בו בצורה מידתית ומושכלת על מנת לשלב ולאזן בין כושר הנשיאה הסביבתי של אזור נתון, הנגזר מהיצע המשאבים, לבין עומס הפיתוח, הנגזר מהביקוש לשימושי קרקע שונים באותו שטח.

לשימוש בקרקע ישנן השפעות על:

1. תשומות בכלכליות – הקרקע הינו משאב שערכו נקבע על פי השימוש ומקומו הגאוגרפי ועל כן לשטחים שונים ערך כלכלי שונה.
2. סביבה – לקרקע ערך נופי ואקולוגי. ישנה חשיבות רבה בשימור קרקע בצורתה הטבעית על מנת לשמר את האיזון האקולוגי לרווחת בעלי החיים והפעילות האנושית.
3. פיתוח – ישנה תחרות רבה על פיתוח הקרקע לצרכי האדם: מבני מגורים, תעשייה, תחבורה, מסחר, בטחון ותשתיות חיוניות. לעיתים קרובות שטחים מוגדרים לא יוכלו לשמש לצרכים נוספים (דו שימוש בקרקע).

לא יהיה אפשרי לעמוד ביעדי הייצור השאפתניים של אנרגיות מתחדשות ללא מיצוי ייצור אנרגיה בשטחים מבונים. זאת, משום שאנו חוסכים פעמיים: מייצרים את החשמל באזור הביקוש ובכך מייעלים את השימוש בהספק המיוצר וחוסכים את משאבי הרשת לצורך העברת החשמל. כאמור יש צורך בשטחי קרקע נרחבים לטובת ייצור החשמל באנרגיה סולרית (מפורט בסוגיית השטח בעבודה זו), על כן יש צורך בשיתוף פעולה לשם מקסום השימוש הכפול בקרקע לייצור סולארי, כמו גם להגיע להסכמות לגבי הקצאת שטחים פתוחים בין משרדי הממשלה השונים (משרד האוצר, רשות מקרקעי ישראל, מנהל התכנון, המשרד להגנת הסביבה ועוד).

רשות החשמל ביצעה הערכה ראשונית של פוטנציאל השטחים להקמת מתקני ייצור פוטו-וולטאים לצורך מימוש יעד הביניים של 30% אנרגיה מתחדשת בתמהיל האנרגיה בשנת 2030[4]. מובן שפוטנציאל השטחים העתידי תלוי בשיקולים ובגורמים רבים כמו גם בהתפתחויות טכנולוגיות. הערכת סך פוטנציאל השטחים להקמת מתקני ייצור סולאריים מפורטים בטבלה הבאה:

לוח 2 - פוטנציאל השטח וההספק לפי סוג

סוג פוטנציאל	פוטנציאל בדונם	הספק (MW)
קרקעי[5]	84,920	8,416
גגות	41,933	5,079
מאגרים	45,888	5,558
מחלפים	2,420	240
שימושים דואליים נוספים	5,000	606
סה"כ	**180,161**	**19,898**

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[4] https://www.gov.il/he/departments/publications/Call_for_bids/shim_2030yaad

[5] מתוך זה, פוטנציאל קרקעי בשטחי יהודה ושומרון, שטחי אש וקרקעות בדואים פרטיות עומד על 50,000 דונם, הספק של MW/ 8,416

מתוצאות אלו ניתן ללמוד כי קיים פוטנציאל שטח שיאפשר עמידה ביעד של 30%. עם זאת, היקף הפוטנציאל שמופה הוא בעל יתירות מצומצמת באופן יחסי וכדי לעמוד ביעד יש למצותו כמעט עד תום. בנוסף, הפוטנציאל הממופה בטבלה לא תואם אל מול כלל הגורמים שאמורים לאשרו ולכן קיימת אי ודאות לאפשרויות מימוש. פוטנציאל זה עשוי לגדול בשל שטחים נוספים אפשריים, הן דואליים והן קרקעיים, שנסקרו אך לא נלקחו בחשבון במסגרת העבודה עקב אי וודאות ביחס ליכולת לממש אותם. מיצוי פוטנציאל זה והגדלתו תתאפשר רק על ידי טיפול בחסמים הרלוונטיים וקידום משלים של צעדי רגולציה.

לשם עמידה ביעד של לפחות 50% אנרגיה מתחדשת בתמהיל האנרגיה בשנת 2050, הערכות מודל משרד האנרגיה המשמש לעבודה זו עומדות על צורך בהקמה של הספק מותקן של 58,000 מגה-וואט על פני כ- 520,000 דונם. העלאת אחוז המתחדשות לכדי 80% תדרוש כ-940,000 דונם. שימוש נרחב כל כך בשטח, גם אם בשימושים דואליים, מציב אתגר חסר תקדים בכל הנוגע לייצור אנרגיה בטכנולוגיה סולארית ויכולת קליטתה ברשת. הלכה למעשה לא קיימת כל יכולת להקצות שטחים בהיקף זה לייצור אנרגיה, בוודאי בהינתן קצב גידול האוכלוסייה ואתו הביקוש ההולך וגובר למשאבי קרקע. לפיכך, היכולת להטמיע אנרגיה סולארית בהיקפים כה גדולים תלויה ביכולת למקסם שימוש כפול בקרקע ובהתקדמות טכנולוגית שתאפשר ניצול טוב יותר של אנרגית השמש ליחידת שטח כמו גם התקנת מערכות בשימושים נוספים דוגמת קירות מסך ואחרים.

תחום נוסף המתפתח כיום בעולם הינו שימוש כפול בשטחי חקלאות, או "אגרי-וולטאי". נמצא כי ניתן לייצר חשמל סולארי מעל שטחי חקלאות תוך פגיעה מזערית בגידולים, ולעיתים אף תוך שיפור התנובה. ייצור סולארי בשטחי החקלאות יאפשר שיפור הוודאות הכלכלית של החקלאים התלויים כיום באיתני הטבע ובתמיכה ממשלתית. בישראל, פיתוח יכולת אגרי-וולטאית הינו רכיב מפתח ביכולת להשגת יעדי משק האנרגיה.

אגירה

אגירת אנרגיה מחליפה הקמת תוספת ייצור וחוסכת בשטחים. השימוש באגירה הוא אמצעי מפתח לפתרון בעיית הפקת חשמל מאנרגיה סולארית. השימוש באגירה, בין אם בסוללות או בכל טכנולוגיה אחרת, יכול לפתור את בעיית הייצור העודף באמצעות קליטת עודפי הייצור בשעות הצהריים ופריקתה בערב ובלילה. בנוסף, לאמצעי האגירה יכולת תגובה מהירה והם יכולים לתת מענה לחלק מהבעיות הדינמיות המקשות על שמירת יציבות הרשת. לאגירה בסוללות יתרונות נוספים כגון זמני הקמה מהירים יחסית, גודל המתקנים והיכולת לשלב אותם בתשתיות קיימות ויכולת הקמה מודולרית.

יש לציין כי טכנולוגיית האגירה באמצעות סוללות עדיין בחיתוליה ואין ניסיון רב בעולם בתפעול מערכת חשמל הכוללת כמות גדולה מאד של מערכות אגירה באמצעות סוללות. בנוסף, קיימת אי וודאות רבה לגבי עלויות הטכנולוגיה, מחזורי החיים שלה ואף לגבי היכולות שלה.[6] עם זאת, השימוש בטכנולוגיה זו הולך וגדל ברחבי העולם וקיימת מגמה ברורה של ירידת מחירים כאשר הצפוי הוא להמשך המגמה לאורך העשור הקרוב לפחות[7].

על מנת לספק את הביקוש בשנת 2030 כאשר תמהיל האנרגיה יכיל 30% אנרגיה מתחדשת, ובשנת 2050 כאשר תמהיל האנרגיה יכיל מינימום 50% אנרגיה מתחדשת, יהיה צורך בכמות אגירה מותקנת של כ-17,200 ו-150,000-265,000 מגה-וואט-שעה בהתאמה[8]. בבחינת העלות העודפת והחיסכון המשקי של הגדלת יעד המתחדשות ל 30% עולה כי הטווח נע בין עלות עודפת של כ- 4 מיליארד ₪ לבין חיסכון של כ- 8 מיליארד ₪. עד לשנת 2050 צפוי חיסכון של כ-3 מיליארד ₪ בשנה, אך ערך זה הינו נמוך ביחס לאי הוודאות בנוגע לעלויות בטווח הזמן של 30 שנים.

פיתוח הרשת

רשת החשמל מהווה תשתית לאומית עיקרית וחיונית שתפקידה, בין היתר, להעביר את האנרגיה המיוצרת בתחנות הכוח אל מרכזי הצריכה ברמת האמינות והאיכות הנדרשת. פיתוח מערכת ההולכה וההשנאה נדרש על מנת לתת מענה להתפתחות הביקוש הצפוי במשק החשמל, הצורך בשדרוג הרשת לשם הגברת שרידות המערכת, אמינות ויתירות ההספקה ולחיבור של מתקני ייצור ובכללם מתקני ייצור באמצעות אנרגיה מתחדשת הנדרשים למשק החשמל.

יחידת תכנון ופיתוח טכנולוגיות (תפ"ט) בחברת ניהול המערכת אחראית על תכנון מערכת ההולכה בהתייחס לביקוש הצפוי במשק החשמל על פי אזורים גיאוגרפיים, טכנולוגיות הייצור תוך שמירה על שרידות ואמינות האספקה.

פרויקטים במקטע ההולכה מקודמים במסגרת תכניות מתאר ארציות על ידי המועצה הארצית לתכנון ובנייה או הוועדה לתשתיות לאומיות (ות"ל). מעבר לקושי המערכתי בפיתוח מקטע ההולכה, הליך התכנון של הפרויקטים כולל חסמים רבים ואורך זמן רב. קושי זה הולך וגדל עם העלייה במגמה של ביזור ייצור החשמל, כאשר במקביל העיכובים בפיתוח הרשת מונעים הקמה של מערכות ייצור, ובפרט מערכות סולאריות בדרום. תכנון ופיתוח רשת החשמל אמור תמיד היה לתת מענה להובלת החשמל מתחנות הכוח ואתרי הייצור אל אזור הביקושים מכאן שבתהליך התכנון נעדר השיקול לאופטימיזציה

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[6] ראו גם: NREL – Cost projections for Utility-Scale Battery Storage, June 2019

[7] ראו גם: IRENA – Electricity storage and renewables: Cost and markets to 2030

[8] כמות ההספק המדויקת, תלויה במספר גורמים ובעיקר בתמהיל של סוגי המתקנים, זאת לאור רמות התפוקה הממוצעות השונות

תכנונית של הרשת. החשיבות לתכנון רשת אופטימלית במדינה שבה משאב הרשת מצומצם והצפיפות לנפש היא מהגבוהות בעולם היא רבה מאוד, מאידך יש לשמור במקביל על אמינות האספקה ושרידות למרות השאיפה לתכנון אופטימלי.

תוספת הספק מותקן באנרגיות מתחדשות, בוודאי מסוג סירוגי אחד (סולארי), עשויה שלא לחסוך כמעט בכלל הספק קונבנציונלי, שנדרש לצורך גיבוי מתקני הייצור באנרגיות מתחדשות בשעות בהן אין ייצור מהם.[9] מכיוון שהרשת צריכה לתת מענה לקליטת האנרגיה מכל מתקני הייצור ולהעברתו ממוקדי הייצור אל מוקדי הצריכה, הוספה של מתקנים פוטו-וולטאים בהיקף של אלפי מגה-וואט מחייבת התאמה של פיתוח הרשת והגדלת היקף ההשקעות במקטעי הרשת.

קושי נוסף נובע מכך שהייצור הסולארי מרוכז בכ-5 שעות ביום בממוצע, כך שייצור סולארי דורש הספק הולכה מרבי גבוה פי 3 לערך ביחס לייצור דומה ממקורות קונבנציונליים. מכאן שהגדלת הייצור הסולארי מטילה דרישות כבדות על הרשת. שימוש משמעותי באגירה יכול להפחית דרישות אלו ולכן יש לתכנן את הרשת במקביל לתחזיות הייצור הסולארי והאגירה.

הספק מותקן בגז טבעי ואמינות האספקה

הבטחת אמינות האספקה ופיתוח כלכלי של המשק הם תנאי בסיס כאמור בתכנון אסטרטגי של המשק. לפיכך יעדי התכנון וכן אבני הדרך חייבים להיבחן באופן תמידי ובכל עת.

אחת השאלות בנוגע לאמינות האספקה, במשק שהוא אי אנרגטי ומבוסס כמעט בלעדית על מקורות סולאריים, היא כיצד תובטח האספקה גם בשבוע מעונן שבו תפוקת המערכות הסולאריות הינה מינימלית. אם נבחן את היעדים לשנת 2050, נמצא כי שיא הביקוש לחשמל בשנה זו צפוי להיות כ-32 GW. אולם, גם בשבוע הקשה ביותר בשנה אין צורך להחזיק הספק קונבנציונלי בגובה זה.

היות ומתקנים סולאריים מפיקים אנרגיה רק כ-20% מהזמן בממוצע, הרי שבבדי להפיק כמות אנרגיה בדומה למתקן בגז טבעי, יש להקים הספק גבוה פי 3 לערך (מתקן בגז טבעי פועל בממוצע כ-60% מהזמן). מכאן שלפי תוצאות המודל, בשנת 2050 יהיה צורך בכ-58-109 GW של הספק סולארי מותקן (בהתאם לתרחיש). גם אם בימי החורף המעוננים הספק זה יוכל למלא את הביקוש לחשמל בשעות הצהריים, לא ייווצרו עודפים שיאפשרו אגירת אנרגיה לקראת שיא הערב והלילה שלאחריו. על פי מודל החשמל נמצא כי גם בשעורי החדרה גבוהים ביותר של אנרגיה נתחדש (מעל 80%) עדיין יהיה צורך בהספק גז טבעי של כ-16 GW שיפעל ברציפות במשך כל היממה בכדי לטעון את הסוללות

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[9] שילוב של אמצעי אגירה לצד מתקני האנרגיות המתחדשות יכול כמובן לחסוך בהספק קונבנציונלי.

בצהריים, בכמות מספקת שתאפשר את אספקת האנרגיה הדרושה בערב ובלילה, וזאת במקביל ליחידות הקונבנציונליות שתמשכנה לפעול בהספק המכסימלי גם אז.

מכאן, שעודף ההספק הסולארי, יכולות האגירה, יחד עם יחידות הגז טבעי שעוד צריכות לקום, שיהוו הספק של כ-50% משיא הביקוש השנתי, יאפשרו אספקת חשמל לכל צרכי המשק גם בתקופות של מספר ימים מעוננים רצופים בהם תפוקת החשמל הסולארי תהיה מינימלית.

יש לציין כי ניתוח זה אינו מתייחס לרזרבה הנדרשת במערכת לגיבוי בעת תקלה. בניתוח שנערך על בסיס המודל בהתאם לעקומות הייצור והביקוש הצפויות בשנת 2050 נמצא כי עודפי הייצור הגבוהים במשק (ייצור סולארי של מעל 100 GW, בתוספת אגירה והספק בגז טבעי) יחזיקו הספק עודף ברוב שעות השנה שיאפשר להתמודד עם תקלה ביחידת ייצור בת 600 MW ואף מעבר לכך. אולם, עבור אותם שבועות מעוננים, בהם יכולת הייצור תהיה קרובה לגבול יכולתה, יהיה צורך להחזיק רזרבה של 1-2 GW ביחידות בגז טבעי מעל ל-32 GW הנדרשים לאספקה הסדירה (וזאת ביחס לכ-20% רזרבה הנדרשת כיום). לפיכך סך ההספק הנדרש בג טבעי בשנת 2050 יעמוד לכל הפחות על כ- 18 GW וזאת גם בתרחיש הכולל התבססות על אנרגיית שמש בשיעורים הגבוהים ביותר האפשריים. הספק זה יעבוד בשעות מעטות יחסית, אך יבטיח אספקת חשמל יציבה למשק. לא מן הנמנע, כי הספק זה יופעל בעתיד על ידי מימן בשילוב עם גז טבעי או במקומו, ובכך יביא להפחתת פלטות הפד"ח הנגרמות מייצור החשמל.

בעתיד בו יכולת הייצור תהיה מוטה למערכות סולאריות מבוזרות בתוספת יכולת אגירה משמעותית שגם היא תהיה מבוזרת בחלקה, עם יכולות לאספקת אנרגיה מקומית, תהיה עליה מובנית בביטחון האספקה ותצטמצם התלות ברשת ההולכה לאספקת חשמל לצרכנים. בנוסף, חיבור הגריד הישראלי למדינות שכנות ולמדינות אירופה, יהווה גם הוא מקור לסיוע בשעת חירום ויאפשר שיפור בביטחון האספקה.

במקביל, ככול שיוטמעו במשק החשמל טכנולוגיות אחרות וגיוון מקורות האנרגיה יעלה כך גם תשפר אמינות האספקה במיוחד כאשר מדובר בטכנולוגיות ייצור משלימות ליצור סולארי. כך למשל, אגירה ארוכת טווח באמצעות מימן תאפשר לייצר מימן מחשמל עודף באביב ובקיץ, ולהשתמש באנרגיה זו לייצור חשמל בשבועות המעוננים בחורף. טכנולוגיה נוספת שמתפתחת במהירות לאחרונה היא טורבינות רוח צפות בים העמוק. באם טכנולוגיה זו תגיע לכדאיות כלכלית, ניתן יהיה להקים טורבינות צפות 20 ק"מ בעומק הים, מעבר לקו האופק, ולהפיק מהן אנרגיה נוספת שתסייע לאזן את המשק בשעות הערב ובימים המעוננים.

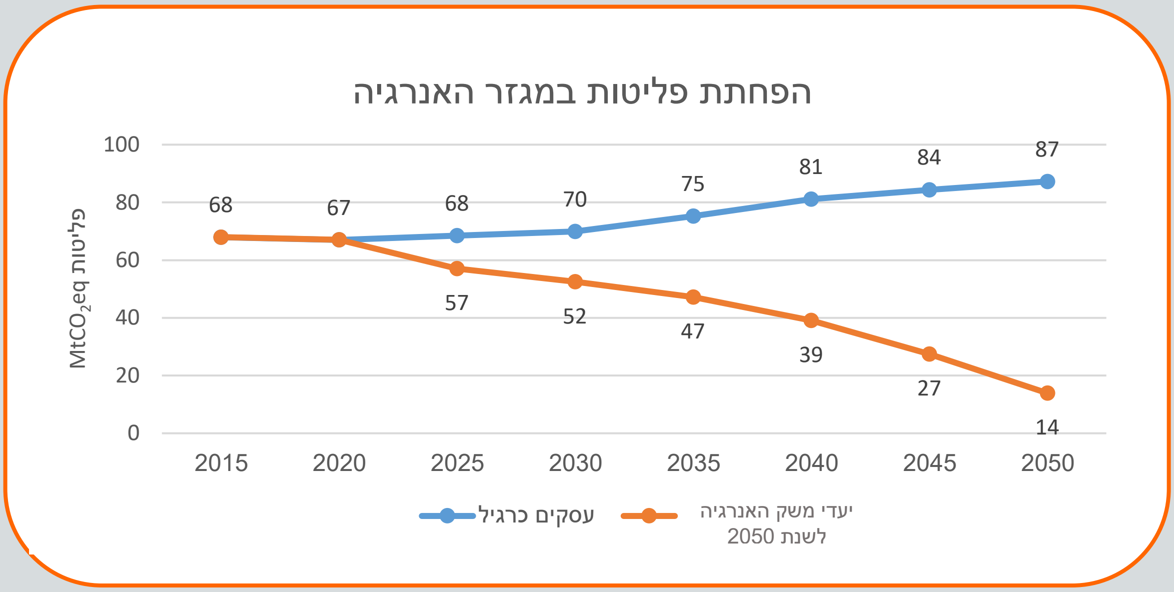
מתוך כך וכפועל יוצא של קביעת היעדים יבחן לאורך זמן קריטריון אמינות הרשת וכן גם היערכות המשק לשעת חירום.

עוד נציין כי המעבר למשק אנרגיה המאופיין באנרגיות מתחדשות מכריח התייחסות לפיתוח משק הגז הטבעי אשר הופך לדלק מעבר. בשנים הקרובות השימוש בגז טבעי עדיין גבוה אולם בעשורים הבאים הוא עשוי להתמתן ועלכן עולה הצורך בבחינת מדיניות היצוא של ישראל.

על כן, פיתוח כלכלי של המשק כתלות ביעדי התוכנית מחייב התייחסות נרחבת לפיתוח אוצרות הטבע של ישראל ובראשם הגז הטבעי.

יעד הפחתת הפליטות

בתרחיש "עסקים כרגיל" (המבוסס על התחייבות ישראל בהסכמי פריז) וללא פעולות נוספות סך פליטות גזי החממה ממשק האנרגיה בשנת 2050 יגדלו ב-28% מערכיהם בשנת 2015 (87.3 ו- 68.2 MtCO2e/y בהתאמה). לעומת זאת, כתוצאה מעמידה ביעדי המשרד שנת 2050 (לרבות המדיניות לעשור הקרוב: העלאת יעד מתחדשות ל30% בשנת 2030 וסגירת התחנות הפחמיות) וכן הפעולות המשלימות בכלל הסקטורים במשק האנרגיה (לרבות תחבורה ותעשייה), סך פליטות גזי החממה ממגזר האנרגיה צפוי לפחות לשיעור מזערי של כ-13.9 $MtCO_2e$ בשנת 2050, הפחתה של 80% לעומת שנת 2015.



תרשים 5: פליטות גזי חממה ממשק האנרגיה עד שנת 2050 בתרחיש "עסקים כרגיל" ובתרחיש הפחתה ע"פ מודל אנרגיה שנכתב לצורך עבודה זו. משרד האנרגיה, 2020.

תרומת משק האנרגיה להפחתת פליטות גזי החממה במשק הישראלי הינה התרומה המשמעותית ביותר מבין הסקטורים בישראל ומהווה הפחתה של כ71% מפליטות גזי החממה הצפויים בשנת 2050.

תכנית האנרגיה – צעדי המדיניות

כאמור, משק האנרגיה הינו הסקטור המשמעותי ביותר להבטחת מעבר לאיפוס פחמני ובכלכלה דלת פחמן במדינת ישראל. תכנית האנרגיה נכתבה לאור שלושה עקרונות: משק אנרגיה אמין, נקי ובר השגה ובהתייחס לתמורות העולמיות במשקי האנרגיה בעולם והמגמות הטכנולוגיות.

התכנית כוללת חבילה משולבת של אמצעי מדיניות שמטרתם להשלים את ההשקעות בתשתיות הפיסיות. יובהר כי קביעת מדיניות בהסתכלות שלושה עשורים קדימה, בתחום מורכב כל כך שבו הטכנולוגיה משתנה בקצב גובר והולך, מאופיינת ברמת חוסר וודאות גבוהה. לפיכך, חבילת המדיניות פורשת את כלל האמצעים להפחתת פליטות במשק האנרגיה, אך ההחלטות לגבי יישום המדיניות בכל אחד מהסקטורים במשק האנרגיה יתקבלו בטווח הקצר-בינוני (עשר שנים קדימה) על פי עמידה ביעדי הביניים כמו גם בהתאם לקצב ההתקדמות הטכנולוגית. מפת דרכים זו תעודכן מדי חמש שנים, כך שיתאפשר תכנון מיטבי של משק האנרגיה בכל זמן נתון ובעזרת מודל אנרגיה מלווה. להלן יפורטו צעדי המדיניות לצורך עמידה ביעדי התכנית:

הפסקת השימוש בפחם

משק החשמל מבוסס כיום על שלושה סוגי דלקים עיקריים: גז טבעי, פחם ואנרגיה מתחדשת. בנוסף, חשמל בהיקף מצומצם מיוצר עדיין באמצעות סולר ובמזוט, בעיקר בשעות שיא ביקוש בהן הספקת הגז למשק, המבוססת עדיין על מאגר גז אחד, אינה מספקת, או כתוצאה מתקלה או תחזוקה במאגרי הגז. שיעור ייצור החשמל באמצעות פחם הופחת בשנים האחרונות באופן משמעותי מהיקף של כ-60% מהצריכה המשקית לכ-30% בשנת 2018. הפסקת השימוש בפחם כמקור אנרגיה לייצור חשמל עד שנת 2025 הינה החלטה היסטורית בחשיבותה בניהול משק האנרגיה הישראלי. משמעותה היא הפחתה מהירה ודרסטית של פליטות גזי חממה ומזהמי אוויר. הספק פחמי זה יוחלף בייצור חשמל ממקורות מתחדשים ומגז טבעי, בהתבסס על הסבת היחידות הפחמיות קיימות ליחידות דו-דלקיות המשתמשות בגז טבעי כדלק עיקרי ובפחם כדלק משני, המשמש בעת אירוע חירום או תקלה באספקת הגז. בשל האמור לעיל ותחזיות עולמיות לעלייה בשימוש בגז טבעי כדלק מעבר, יש צורך בבחינה מחודשת של מדיניות הייצוא של גז טבעי ישראלי - כבכל פרויקט, האפשרות להקדים את ההכנסות מגדילה את כדאיותו ומקדמת הכנסות למדינה. במקביל, מגמה נוספת בסקטור הגז הינה התאמת תשתיות הולכת הגז הטבעי להעברת מימן ודלקים ביולוגים. מכיוון שרשתות ההולכה והחלוקה בישראל נבנות בסטנדרטים מחמירים מאוד, מידת התאמתם לשימוש זה גבוהה ויש צורך לאמץ את הרגולציה האירופאית בהקשר זה.

הפחתת פליטות בסקטור ייצור החשמל

על מנת לעמוד ביעד של הפחתת פליטות גזי חממה בשיעור של 75-85% בסקטור ייצור החשמל, יש להעלות את אחוז ייצור החשמל מאנרגיה מתחדשת. יעד של 30% ייצור באנרגיה מתחדשת בשנת 2030 נקבע במדיניות המאזנת בין שאיפותיה של ישראל לעמוד בשורה אחת עם מדינות העולם בהיבטי אנרגיות מתחדשות והצורך להפחתת זיהום האוויר המשקי, ובין העלויות, ההשלכות והאתגרים הנובעים מכך. ניהול משק חשמל המתבסס במידה רבה על אספקת אנרגיה בלתי יציבה מצד אחד ומבוזרת מאוד מצד שני, דורש הערכות משמעותית ברשת החשמל ובניהול הייצור והאספקה. הערכות הנדסית זו כרוכה בהשקעות משמעותיות ברשת החשמל, הן בתוספת קווי הולכה, בתוספת אגירה, והן במערכות ניהול חכמות שיוכלו לקלוט את החשמל הבלתי יציב והמבוזר תוך אופטימיזציה של משאבי הייצור והרשת הקיימים וניהול הביקוש לחשמל. לצד אתגרים אלו, שההתמודדות עימם תלויה בעיקרה בריכוז מאמץ ממשלתי, קיימים משתנים חיצוניים, אשר עשויים להשפיע במידה רבה על יכולתו של המשק לעמוד ביעדי ייצור מאנרגיה מתחדשת גבוהים יותר. כל זאת מתעצם כאשר בוחנים יעד שאפתני אף יותר של 50-80% אנרגיה מתחדשת בתמהיל ייצור החשמל עד שנת 2050. על כן יש לנקוט במספר צעדים חיוניים:

1. **פיתוח מואץ של רשת החשמל-** פיתוח רשת החשמל מהווה תנאי הכרחי ליישום היעדים. על כן, נדרש לגבש בהקדם תכניות פיתוח למערכת המסירה ולרשת החלוקה שתיתן מענה לקליטת ההספק הנדרש. יש לפתח את רשת ההולכה כך שתאפשר ייצור חשמל סולארי מסיבי בפריפריה ובעיקר בדרום הארץ, ואת רשת החלוקה והאספקה כך שתוכל לנהל ביציבות ייצור כמויות גדולות של חשמל סולארי על גגות הבתים. בנוסף, היות וקיימים חסמים משמעותיים לפיתוח הרשת, נדרש לקדם בהקדם תכנית להסרת חסמים, להאצת פריסת הרשת ולייעול ההליכים התכנוניים למתקני רשת.
2. **הטמנת קווי מתח עליון -** הטמנת קווי מתח עליון מסירה את המופע העילי והפגיעה הנופית, מונעת פגיעה בבעלי כנף, מצמצמת את פוטנציאל הפגיעה בעקבות הקצנת תופעות מזג אוויר ופגיעות אדם ומצמצמת תפיסת שטחים. לאור הצפיפות ההולכת וגדלה והצורך בהקמת קווי מתח עליון נוספים, לא מן הנמנע שיידרש שילוב מוגבר של קווים מוטמנים באזורים בנויים וגם בשטחים פתוחים.
3. **הולכה בזרם ישר (DC)** – בעקבות ההתפתחויות בתחום ממירי המתח, התפתח בשנים האחרונות גם תחום ההולכה בזרם ישר. לזרם ישר מספר יתרונות, ובפרט בקווי מתח מוטמנים. אובדן האנרגיה בהולכה בזרם ישר הינו נמוך מאד והעלויות נמוכות יחסית, וזאת ביחס לאובדן הגבוה בקווי הולכה מוטמנים בזרם חילופין (AC) ועלויות גבוהות פי 5-7 ביחס לקווי מתח עיליים. בנוסף, פליטת הקרינה מקווי זרם ישר נמוכה ומרחקי הבטיחות הנדרשים

הינם נמוכים משמעותית. משמעות הדבר היא כי ניתן להטמין קווי DC לצד תשתיות קיימות כגון כבישים או קווי מתח עיליים, ובכך לפשט ולזרז את הליכי התכנון וההפקעה המורכבים הנדרשים לצורך הקמת קווי מתח עיליים.

אולם, קווי DC מסוגלים להוליך אנרגיה רק מנקודה לנקודה, ובשני קצות הקו יש להקים תחנות המרה גדולות ויקרות. היות וכך, יש לבחון כבלי הולכה בזרם ישר כפתרון לצורך הולכת הספקים גבוהים מאד של אנרגיה מאתרי הייצור הסולארי בפריפריה ישירות לרשת החשמל במרכז הארץ באזורי הצריכה, אך כבלים אלו לא יוכלו להחליף את רשת ההולכה הקיימת על כל מורכבותה.

4. **מנהרות תשתית רב מערכתיות** - מנהרת תשתיות היא ללא ספק הדרך הטובה ביותר תכנונית וסביבתית להעברת תשתיות "בכפיפה אחת" באזורים בנויים צפופים. על מנת לקדם מנהרות תשתית יש לקדם הקמת גורם מקצועי מתכלל שירכז בידיו את הסמכויות לקידום, ניהול, תפעול וטיפול במנהרות תשתית כמו גם לייצר מנגנונים כלכליים להסדרת מקורות המימון והתפעול של הקמת המנהרה. בנוסף, יש צורך להטמיע הגדרות וכללים לאיתור מנהרות תשתית רב מערכתיות המתייחסים להיבטי כלכלה, יעילות תפקודית, סביבה ותכנון בהליכי קידום תכניות למנהרות.

5. **תכנון אנרגיה נקייה בשטחים המבונים** – יש להטמיע הנחיות בתהליך התכנון הכוללות בחינה של הבינוי בהתייחס לאפשרות למצותו לייצור להפקת אנרגיה ממקורות מתחדשים לצורך ייעול ניצול הקרקע בתוכנית. לרבות, אך לא רק: הנחיות למקסום פוטנציאל ייצור אנרגיה בשטחים מבונים קיימים ובתוכניות חדשות; שמירת שטחים למערכות חשמל וחדרי ההשנאה הנדרשים לקליטת חשמל ממקורות ייצור מרובים ומבוזרים; תכנון ושמירת אתרים להטענת רכבים חשמליים בשטחים הפרטיים והציבוריים; קביעת הנחיות ברורות ופשוטות להתקנת מערכות ייצור אנרגיה נקייה המיועדות לרשות המקומית ולאזרח, כמו גם הנחיות ומנגנוני גמישות שיאפשרו שילוב ועדכון חידושים טכנולוגיים בהתאם להתפתחויות ולצרכים המשתנים; ניצול והפקת חשמל נקי ביעילות ובטכנולוגיה המיטבית במירב השטח המבונה על כל שימושיו (למשל בבבישים). גופים מקצועיים תכנוניים מנהלים ומתכללים יסייעו לקדם וללוות את הליך הפקת החשמל ממקורות מתחדשים בשטחים מבונים, במסגרת זאת יש לכלול: א) מדריך להליכי הקמת אנרגיה מתחדשת בשטחים מבונים. ב) הכשרת אנשי מקצוע לליווי ההליך וסיוע בהסרת חסמים. ג) מעקב אחר פוטנציאל הייצור החזוי מהשטח המבונה אל מול המימוש בפועל וניתוח החסמים והפערים. ד) הסקת מסקנות והמלצות להמשך מיצוי הפוטנציאל. ה) קידום הסרת החסמים ויצירת מנגנוני עידוד על בסיס הלמידה והניסיון. ו) הנגשת המידע ופרסומו לציבור בעזרת מאגרי מידע ונתונים מקוונים.

6. **ביזור מערכת האנרגיה בישראל** - הקמת אמצעי ייצור ואגירה מקומיים בסמיכות למוקדי הביקוש כמו גם יצירת מערכות כלכליות שיביאו למקסום פוטנציאל זה תחסוך משאבי קרקע של הולכת רשת למרחקים, הגדלת הניצולת של ייצור החשמל המקומי והפחתת אובדן, כל זאת תוך הגדלת אמינות אספקה ושירות ליישובים מרוחקים ו/או מבודדים. קידום והטמעת רשת חכמה לניהול מערכות החשמל כחלק מתוכניות פיתוח הרשת– קביעת לו"ז להטמעה ואימוץ רשת חכמה לניהול מערכת החשמל לפי שלבים ואבני דרך. שינוי תפיסת הרשת על ידי הרגולטור וקידום אמצעים חוקיים ורגולטורים שיאפשרו הקמת מערות כאמור ושילובן לתוך משק החשמל הישראלי.
7. **אגירת חשמל –** לבחון את אופן ההטמעה של מתקני אגירה באופן מיטבי בהתאם להתפתחות הטכנולוגית, מחירי האגירה וצרכי המשק. יש לקדם מגוון מערכות אגירה - מגוון טכנולוגיות אגירה מתפתחות במקביל ויש להניח שיהיו פתרונות מגוונים לאגירת אנרגיה ברמה ארצית ומקומית. יש לשמור על אפשרות הקמה והטמעת הטכנולוגיות בעתיד לרבות שיחלופן ככל שיתקדמו ופיזורן גיאוגרפית בהתאם למיקום האופטימלי. מתקני אגירת אנרגיה בליווי מערכות קצה חכמות, יכולות לתת מענה לגיבוי ולניהול יעיל יותר של הרשת כך שניתן יהיה לנתב ולתעל את האנרגיה לצרכנים לפי הביקוש.
8. **קרקע** - תמ"א 41, תכנית מתאר ארצית לתשתיות אנרגיה לשנים 2030 ו-2050, איתרה אתרים לקידום אנרגיות מתחדשות ברמה הארצית. לאור מגבלת הקרקע, נדרש להגדיל ולמצות את פוטנציאל השטח על ידי זיהוי האזורים בהם מומלץ וניתן לקדם ייצור סולרי במתקנים קרקעיים גם ברמת המחוזות. משרד האנרגיה מקדם עבודה כאמור בשיתוף פעולה עם לשכות התכנון המחוזיות. בנוסף, יש לבחון אפשרות להטמעה של מתקנים פוטו-וולטאים כשימוש נלווה בתכניות, יצירת וודאות ליזמים בנוגע לתנאים לשימוש בקרקע, חיוב התקנת מתקנים פוטו-וולטאים בבניה חדשה וקביעת האופן בו ניתן להשתמש בקרקע לצורך מיצוי פוטנציאל השטחים הדואליים (כבישים ומחלפים, חניונים, מאגרי מים וייעודים נוספים).
9. **אגרו וולטאי** – עקב מיעוט השטחים הטבעיים בישראל, פיתוח יכולת אגרי-וולטאית הינו רכיב מפתח ביכולת להשגת יעדי משק האנרגיה, אך בד בבד מהווה הזדמנות כלכלית ייחודית לפיתוח מובילות עולמית. נמצא כי ניתן לייצר חשמל סולארי מעל שטחי חקלאות תוך פגיעה מזערית בגידולים, ולעיתים אף תוך שיפור התנובה. לאחרונה משרד האנרגיה ומשרד החקלאות, בשיתוף משרדים וגופי ממשל נוספים, מקדמים הקמה של מערכות אגרי-וולטאיות ראשונות בהן תיחקר השפעת המערכות הסולאריות על הגידולים שמתחתן ויפותחו ממשקים חקלאיים אופטימליים בתנאים אלו. בישראל, קיימת חקלאות מתקדמת וגם יכולת טכנולוגית מפותחת, השילוב בין השתיים עשוי למצב את המדינה בחזית תחום האגרי-וולטאי המתפתח

במהירות בעולם ולהוות עוד ענף ייצוא ומנוע צמיחה למשק. על כן יש צורך להמשיך ולהשקיע בטכנולוגיה זו ולקדם פיילוטים בתחום.

10. **אסדרות** - יש לוודא קיומם של פתרונות אסדרתיים לטווח ארוך על מנת ליצור אופק לתעשייה הסולארית. בכלל זה, יש להמשיך ולקיים באופן סדיר הליכים תחרותיים ובנוסף לתת מענה רציף בדמות אסדרות בסיסיות. האסדרות ייקבעו ללא תלות במכסה, או באמצעות אפשרות להשתלב בממסחר הסיטונאי הכללי בשוק החשמל. בנוסף, יש לבחון אילו התאמות נדרשות באסדרות הרלוונטיות של מתקני ייצור קונבנציונליים, על מנת לאפשר התאמה שלהם למשטרי ההפעלה שיידרשו.

11. **ניהול מערך הייצור** - לשם התמודדות עם האתגרים בניהול מערך הייצור, יש צורך להטמיע ולהפעיל מגוון כלים אשר יסייעו בהיערכות מערך הייצור ובהם הוספת אגירה בהיקפים משמעותיים, הוספת גמישות למערך הייצור באמצעות שינוי התמהיל הקונבנציונלי, שינוי משטר ההפעלה של היחידות הקונבנציונליות הקיימות במערכת, ניהול ביקושים, ואף קיטום של הייצור הסולארי בשעות שיא הייצור. הטמעה והפעלה של כלים כאמור, בהיקפים גדולים, עשויה להיות מורכבת ולדרוש שינויים הנדסיים ורגולטוריים שתהיה להם השפעה נרחבת על מערך הייצור ועל אופן ניהול הייצור והביקוש.

12. **ניהול ביקושים** – כלי ראשון במעלה להגדלת הגמישות ברשת הינו ניהול הביקוש. עם העלייה בחדירת האנרגיה הסולארית לרשת יש להכניס את ניהול הביקושים כחלק אינטגרלי של ניהול המערכת, גם ברמת רשת החלוקה. יש להרחיב את הסדרי ניהול הביקוש, לאסדר את הפעלת חברות האגרגציה, חברות המאגדות ומנהלות צרכנים רבים לכדי "תחנות כוח וירטואליות" המסוגלות להגיב לדרישות מנהל המערכת ולתרום ליציבות הרשת.

13. **שיתוף פעולה רב מגזרי** - על אף צעדים רבים שכבר קודמו והמאמצים הרבים שהושקעו מצד משרדי הממשלה ושחקנים נוספים בשילוב אנרגיות מתחדשות, קיימים עדיין מגוון חסמים ואתגרים. הגדלת היעד תחייב מאמץ ושיתוף פעולה חוצה מערכות לטובת מגוון צעדים של ייעול הליכים, צמצום חסמים ויצירת תמריצים.

14. **תמריצי מימון -** הקמת קרן הלוואות בערבות המדינה לרשויות לטובת הקמת מתקני ייצור סולארי ואגירת אנרגיה. במטרה להגדיל את היקף ייצור החשמל ממקור סולארי על גבי מבנים ציבוריים, לפתור את חסמי המימון ולייצר תמריץ לרשויות המקומיות, בינואר 2020 הושקה קרן הלוואות להאצת הטמעת אנרגיות מתחדשות ברשויות המקומיות בישראל. הקרן תספק הלוואות בהיקף של כ-500 מיליון ₪. לאור הצלחת הקרן והביקוש הגבוה מצד הרשויות המקומיות, נכון יהיה להקצות משאבים נוספים בהיקף של 500 מלש"ח למימון ותמיכה בהתקנת מערכות נוספות לייצור חשמל מקומי ובפרט באמצעות מנגנוני סיוע לרשויות המקומיות.

התייעלות באנרגיה

על מנת לעמוד ביעד של שיפור שנתי של 1.3% בעצימות האנרגיה, הוכנה תכנית לאומית להתייעלות באנרגיה לשנים 2016-2030[10], יעדיה וצעדיה גובשו על בסיס ניתוח מגמות המתרחשות במשק האנרגיה הישראלי ובחינת צעדים בינלאומיים מקובלים בעולם. אמצעי התוכנית הלאומית להתייעלות באנרגיה צפויים לחסוך בצריכת האנרגיה, הן במשק החשמל והן בצריכת דלקים, ולהביא לחיסכון באנרגיה המוערך בכ- 16.5 Twh בשנה[11], הפחתת פליטות של כ- 6 $MtCO_2e$ ותועלת משקית מצטברת של כ-87 מיליארד ₪ בשנת 2030. התכנית הלאומית פורסת מגוון אמצעי מדיניות לעמידה ביעד ובניהם:

1. יש לבצע **עדכון תקנות מקורות אנרגיה** (בתחום מיזוג האוויר, מכשירי חשמל ביתיים ועוד) ועדכון המפרט של סקר אנרגיה המחויב לפי חוק באופן שוטף ועל פי ההתקדמות הטכנולוגית. בנוסף לכל אלו, תחויב הטמעה של ת"י ISO 50001 למערכות ניהול אנרגיה בקרב גופים המחויבים בהיתר פליטה ותצא לפועל רפורמה ביבוא מוצרי חשמל.
2. **תמריצים, מענקים והלוואות** - לצורך עמידה ביעדים שפורטו לעיל, יש צורך בתקציב חמש שנתי בסך כמיליארד ש"ח (עבור השנים 2021-2025), להרחבת התמיכה בפרויקטים להתייעלות באנרגיה והפחתת פליטות גזי חממה.
3. **חיוב מבני ממשלה ויחידות סמך ביעדי אנרגיה מתחדשת ויעילות באנרגיה**- קידום החלטת ממשלה במשרדי ממשלה ויחידות סמך שתכלול שני רכיבים עיקריים שייושמו במשרדי הממשלה ויחידות הסמך: התקנת מערכות לייצור אנרגיה סולארית על גבי גגות מבני המשרדים והתייעלות בצריכת האנרגיה.
4. **חינוך, הכשרה והסברה**- על מנת להגביר מודעות ולשנות את הרגלי הצריכה בתחום האנרגיה יש צורך להרחיב את היקף פעילות החינוך, ההכשרה וההסברה.
5. **חשמול המגזר הביתי**- בחינת תיקון תקנות התכנון והבנייה כך שתבוטל החובה לפרישת תשתית גפ"מ בבנייה חדשה למגורים, ובחינת האפשרות אף לאסור על פרישתה.
6. **בנייה מאופסת אנרגיה** – חיוב תקן בנייה בת-קיימא (בנייה ירוקה) במסגרת בקשות להיתרי בנייה למבנים חדשים הנבנים במשק.
7. **פתיחת מגזר אספקת החשמל לתחרות** צפויה ליצור מערך תמריצים תעריפיים מקומיים לניהול ביקושים והתייעלות. מספקים מקומיים יוכלו אף לתמוך בהתקנת אמצעי התייעלות בקרב הצרכנים – בגלל שחיסכון באנרגיה עולה פחות מייצור אותה כמות אנרגיה, הרי שיש

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[10] https://www.gov.il/BlobFolder/news/energy_2030/he/energy_2030_updated.pdf

[11] הערכת חיסכון באנרגיה לאחר ניכוי השפעות צולבות בין אמצעי מדיניות

בדאיות לספקים לשלם לצרכנים ליישם צעדי התייעלות מאשר לרכוש חשמל. עם פתיחת השוק לספקים פרטיים ניתן יהיה גם לחייב אותם ביישום צעדי התייעלות באחוז מסוים מסך הביקוש שהם מנהלים, מודל הנקרא Energy Efficiency Portfolio Standard (EEPS)

<u>סקטור הגז הטבעי</u>

ההחלטה העקרונית למעבר לכלכלה דלת פחמן והשאיפה לצמצום פליטות דורשים חישוב מחדש של הערכת הביקוש לגז טבעי. הגדלה משמעותית של נפח האנרגיה הסולארית, משמעותה הפחתת הביקוש לגז הטבעי, ומכאן להגדלת מלאי הגז הטבעי הזמין לייצוא. יתרה מכך, המגמה העולמית מחד לחשמול מגזר התחבורה, המגזר הביתי ובמידה מסוימת המגזר התעשייתי ומאידך, המגמה העולמית להפסקת השימוש בפחם והתייחסות לגז טבעי כ"דלק מעבר" בשנים הקרובות, עשויה להביא, בהתאם לתרחישים מסוימים, להגדלת הביקוש העולמי לגז טבעי עד לנקודת שיא לקראת סיום העשור הנוכחי, ולאחר מכן לירידה בביקוש העולמי בשל המעבר לאנרגיות חלופיות.

המשמעות היא שנוצר "חלון הזדמנויות" מוגבל בזמן, וכי גז טבעי שלא יימכר ב 10-20 השנים הבאות, קטנים הסיכויים שיימכר כלל.

1. **בחינת מדיניות הייצוא -** בבבל פרויקט, האפשרות להקדים את התקבולים מגדילה את כדאיותו. לאור הצפי לגידול משמעותי בהיקף הייצור העולמי מאנרגיות מתחדשות, ולאור העובדה כי המשק המקומי מאופיין כמשק מוגבל ביקוש, יצוא הוא הנתיב המרכזי המאפשר הקדמת ההכנסות מהפרויקט וניצול משאבי הטבע לרווחת המדינה.
2. **עידוד המשך פיתוח והפקה -** בשל תרומתו של הגז הטבעי למשק הישראלי מבחינה כלכלית, סביבתית ואסטרטגית, ישנה חשיבות להמשיך ולעודד חיפוש והפקה של גז טבעי בטווח הקרוב, ולקדם מיצוי חכם ואופטימלי של עתודות האנרגיה הקיימות בישראל.
3. **יצירת אפיקי ייצוא בעיקר למדינות שכנות –** מיצוי פוטנציאל הגז וייצוא הגז מחייבים יצירתם של אפיקי ייצוא. ככל שאפיקים אלו הינם למדינות בעלות קרבה גיאוגרפית, גלומים יתרונות סביבתיים ביחס לכל אמצעי אספקה אחר. לפיכך, יש לפעול ליצירת שיתופי פעולה שיאפשרו הקמת תשתיות לייצוא גז טבעי.
4. **מדיניות בנושא לכידת ואגירת פחמן**: ללכידה ואגירת פחמן תפקיד משמעותי ביותר בהפחתת הפליטות בארץ ובעולם. פרויקטים עתידיים והמשך השימוש בגז לצרכים מקומיים ייתכן ויותנו בפרויקטים של אגירת פחמן. לצורך כך יש להסדיר את הנושא מבחינה רגולטורית ולבצע: סקירה עולמית כלכלית, הנדסית ורגולטורית בנושא אגירת פחמן ושימוש בפחמן בתעשייה (CCS ו- CCU).

5. **החלפת גז טבעי במימן/ביוגז** - האירופאים מתירים להחדיר לרשת הגז הטבעי מימן בשיעור של עד 20% מהכמות ברשת הגז הטבעי – מבלי שהדבר ישפיע על בטיחות הרשת ועל צורת השימוש[12]. מכיוון שרשתות ההולכה והחלוקה בישראל נבנים בסטנדרטים מחמירים מאוד, מבחינת הבטיחות ככל הנראה הרשת בישראל יכולה לעמוד בשיעור זה[13]. על כן מומלץ בשנים הקרובות לצאת לפיילוט שיבחן שילוב מימן ברשת ולהרחיבו בשלב מאוחר יותר בהתאם לממצאים.

6. **בחינת תחזיות ומדיניות הגז טבעי והדלקים בישראל** - יש לבצע עבודה מעמיקה לבחינת הצרכים של המשק בתקופת הביניים למעבר למשק אנרגיה מאופס פליטות והדרכים להשגתם. העבודה תכלול, בין השאר, תחזית ישראלית לשימוש בדלקים נוזליים בהתאם למדיניות המעבר לתחבורה נקייה.

שיתופי פעולה אזוריים וחיבור רשתות:

מדינת ישראל אשר ראתה עצמה כאי אנרגטי במשך רוב תקופת קיומה, ורק לאחרונה ביססה עצמה בבעלת עצמאות באנרגיה, החלה גם כן בשנים האחרונות להוות מקור אנרגיה לחלק משכנותיה. שיתופי הפעולה עשויים להיות אבן דרך משמעותית בקידום היעדים במשק האנרגיה. להלן פירוט של נושאים שיש לקדם על מנת לייצר מערכת אנרגיה אזורית משותפת, יעילה והרמונית הפועלת לרווחתם של כל תושביה.

1. **חיבור רשת החשמל הישראלית לרשתות שכנות**- לאחרונה, עקב חתימת הסכמי נורמליזציה עם איחוד האמירויות הערביות ובחריין, יש לבחון חיבור הרשת הישראלית למדינות השכנות לרבות לאירופה ולמדינות במזרח התיכון. החיבור של מדינת ישראל למערכת כזו יספק בטחון אנרגיה במקרי חירום ומהצד השני יאפשר גם לישראל למכור את העודפים שייווצרו מאנרגית השמש בשעות מסוימות ובכן לקנות חשמל נקי משכנותיה וכך לייצר מערכת יציבה ויעילה יותר. לאחרונה מקודם חיבור כבל תת ימי לקפריסין ואל יבשת אירופה. קידום הכבל מתוכנן לחבר בין ישראל, קפריסין, כרתים וחצי האי היווני וכך לחבר את רשת החשמל הישראלית לרשת החשמל האירופאית.
2. **חיבור רשת הגז הטבעי לרשתות שכנות**- מתוך הבנה כי על אף המעבר למתחדשות, לגז הטבעי יהיה ביקוש לשנים ארוכות קדימה ברחבי העולם כדלק מעבר, יש לקדם את פרויקט ה- EAST MED אשר נחתם לאחרונה עם קפריסין ויוון והמתעתד להיחתם גם עם איטליה. אין ספק שבשלבים הבאים גם מצריים וקפריסין יחלו לפתח את המאגרים שבשטחיהן

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[12] https://hydeploy.co.uk/faqs/hydrogen-level-set-maximum-20/
[13] בהתבסס על שיחה עם מהנדסי נגב גז

ויצטרפו לייצוא הגז באמצעות צינור ה- EAST MED. בנוסף, על מנת לעודד יצוא גז טבעי, סביר להניח כי מתקני הנזלת הגז במצריים יופעלו ויחזרו לשימוש וכן יוקמו מתקני הנזלת גז צפים רבים באזורינו. על כן תתפרס צנרת נוספת מהמאגרים שבשטחינו אל מתקני היצוא. צינור הגז המתוכנן לאילת אף הוא יקדם את יצוא הגז הטבעי, הקמתו תעודד הקמת מתקני הנזלה בסיני אשר ינזילו את הגז וכך יאפשרו גם יצוא גז אל מדינות אסיה, בהן הדרישה לגז בטבעי נמצאת במגמת עליה חדה אשר תמשיך לעלות בכל שמדינות אלו עוברות מגמת התפתחות וצמיחה מהירות. באזורינו קיימות עוד שתי מערכות גז בינלאומיות: מערכת פאן ערבית המחברת בין ירדן, מצריים וסוריה, וכן מערכת הגז של מדינות המפרץ אשר מגיעה עד ליאנבו השוכנת במערב סעודיה, לחופי הים האדום. מתוך כך ניתן לקדם מערכת אשר תחבר בין שלושת המערכות הללו ותייצר מערכת מסחר משוכללת ויעילה להובלת הגז ממדינות המפרץ לאירופה בצנרת או בעזרת הנזלה. הפרויקטים המקודמים היום של חיבור צינור הגז אל תחנת הכוח בג'נין כמו גם הצינור לעזה והרחבת תחנת הכוח הפועלת שם תוך הסבתה לגז טבעי במקום הנפט עליו היא מתבססת היום, יביאו לרווחת התושבים, אספקת חשמל טובה וזולה יותר וקידום צמיחה כלכלית ותעסוקה תוך שימוש בדלקים נקיים יותר והפחתת זיהום האוויר באזורים אלו.

מחקר ופיתוח

שווקי האנרגיה בעולם עוברים שינויים משמעותיים שהבולט בהם הוא שינוי בתמהיל מקורות האנרגיה לייצור חשמל על מנת להתמודד עם משבר האקלים. מבין שינויים אלה, המגמה הברורה ביותר היא הסתמכות הולכת וגדלה על טכנולוגיות בתחום האנרגיה מתחדשת, וטכנולוגיות לתפיסת פחמן.

בהיעדר פוטנציאל ישראלי לייצור אנרגיה מתחדשת ממקורות קבועים כגון מקורות הידרו-אלקטריים וגיאותרמיים, עמידה ביעדים משמעותיים של ייצור באנרגיות מתחדשות בישראל כרוכה באתגרים רבים הנוגעים בין השאר בהיבטים תכנוניים, סביבתיים, פיננסיים וטכנולוגיים, אשר מתאפיינים בהשפעה מכרעת על משק החשמל. לאור האמור, יש חשיבות רבה לפיתוח וקידום טכנולוגיות המתאימות להפחתת פליטות בישראל ועל כן יש לקדם מספר אמצעי מדיניות:

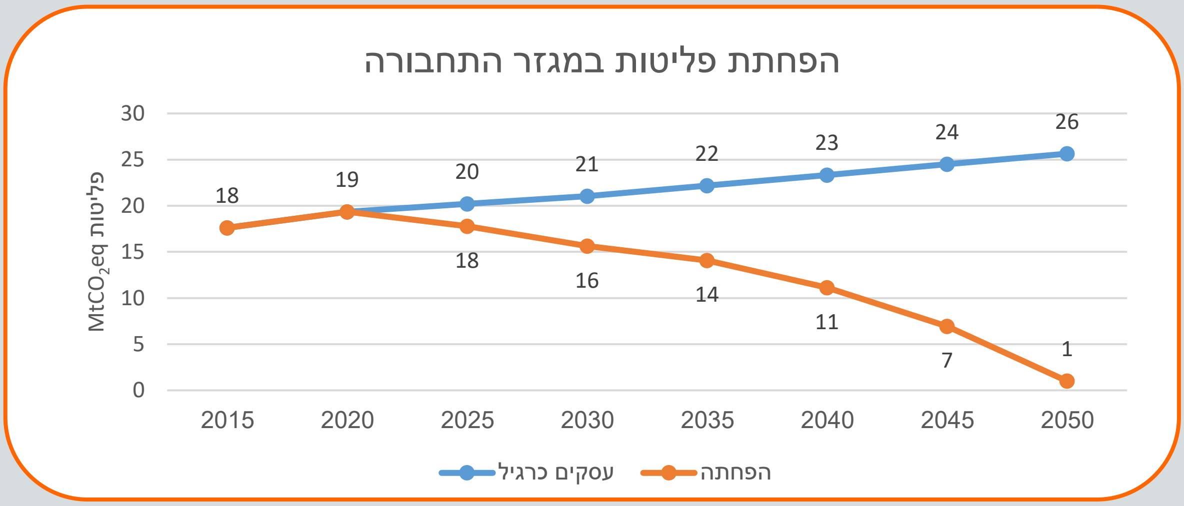
7. **הקצאת תקציבים** למשך עשור לצרכי השקעות במחקר ופיתוח בתחום האנרגיה הנקייה ובפרט תחבורה נקייה ותפיסת פחמן. התקציב יאפשר לממן חוקרים באקדמיה, חברות ומיזמים פורצי דרך בתחום האנרגיה הנקייה, ויתרום למיצובה של ישראל כאומת סטארט-אפ גם בתחומי האנרגיה.
8. **תכנית משותפת לאנרגיה בתעשייה**- סיוע בהקמת תעשייה מתקדמת בתחומי האנרגיה (דוגמת מפעלים לייצור סוללות, אמצעי אגירת חום ופאנלים סולאריים

מתקדמים), על ידי הקצאת תקציב ייעודי לתחום זה במשרד הכלכלה, ושיתוף משרד האנרגיה בתהליכי קבלת ההחלטות. יש לייצר מסלול מואץ לאישורים בתחום זה.

9. **הקמת מכונים לאומיים** - יש להקים מכונים לאומיים לאנרגיה בתחום אגירת האנרגיה, מימן, רשת החשמל ואנרגיית השמש.
10. **עיבוי פעילות המכונים הקיימים**- יש לעבות את הפעילות המחקרית של המכונים (המכון הגיאולוגי וחקר ימים ואגמים לישראל) וביצוע מחקרים בינתחומיים בשת"פ עם חוקרים מתחומים נוספים (הנדסה, כלכלה ועוד).
11. **רגולציה מאפשרת** – קידום רגולציה שתאפשר פיתוח חידושים טכנולוגיים והטמעתם במשק הישראלי ביעילות ובמהירות.

<u>תחבורה מאופסת ודלת פליטות</u>

הפחתה בצריכת תזקיקי נפט בתחבורה היבשתית מבוססת על מעבר לשימוש בהנעה חשמלית והנעה מבוססת גז טבעי דחוס (גט"ד). בהתאם לכך הכריז שר האנרגיה דאז כי החל משנת 2030 תיאסר כניסת כלי רכב קלים מונעים בבנזין או בסולר לישראל. רכבים חשמליים מיועדים להיקלט באופן מלא בסקטור הרכבים הפרטיים ובאופן חלקי בסקטור הרכבים הכבדים. רכבים מונעי גז טבעי דחוס (גט"ד) מיועדים להיקלט בסקטור הרכבים הכבדים ובעיקר בקטגוריית משאיות במשקל מעל 3.5 טון. במקביל, בעולם מתפתח שוק רכבים כבדים מונעים במימן וכאשר הטכנולוגיה תבשיל, יפותח מגזר זה גם בישראל. על פי התכנית סקטור התחבורה יפחית את פליטות גזי החממה מערך צפוי של 25.6 $MtCO_2e$ בשנת 2050 ל- 1 $MtCO_2e$ המהווה הפחתה של כ94% ביחס לשנת 2015 (תרשים 6).



תרשים 6: פליטות מזהמים ממגזר התחבורה בתרחיש "עסקים כרגיל" ובתרחיש הפחתה עד שנת 2050. מודל אנרגיה, משרד האנרגיה 2020.

להלן מספר צעדי מדיניות עיקריים בתחום:

1. **היערכות תשתיות** – לאור הצפי לחדירה של מאות אלפים ואף מיליוני רכבים חשמליים, יש לוודא כי מערכת החשמל ערוכה לספק את החשמל הנוסף שיידרש למשק, בייחוד בשעות העומס. יש להכין בתוך שנתיים תכנית להתאמת הרשת ופיתוחה לקליטת עמדות לטעינת כלי תחבורה חשמליים (רכבים, אוטובוסים, ודו-גלגליים) במרחב הציבורי והפרטי. יש לקדם טעינה מנוהלת (טעינה חכמה) לשם הסטת הטעינה לשעות השפל, על מנת שהשפעת הרכב החשמלי על שיא ביקוש החשמל תהיה מצומצמת עד כמה שניתן. התכנית תתייחס בין היתר לאפשרות להזין את רשת החשמל באמצעות הרכבים החשמליים (זרימה דו כיוונית V2G).
2. **הטבת מס רכישה ומכס** – בשנת 2019 האריכה הממשלה את הטבת המיסוי על רכבים חשמליים מלאים עד לשנת 2024. עד שנת 2022 המיסוי על רכב חשמלי יעמוד על 10% ולאחר מכן יעלה בהדרגה עד ל-35% בשנת 2024. התחזית מראה כי עלות רכב חשמלי תהיה גבוהה מעלות רכב קונבנציונלי עד שנת 2026, ולכן יש לבחון בשנת 2022 את הארכת הטבת המיסוי, ככל והפער בין הרכבים לא הצטמצם באופן מלא לאחר הטבת המס. בנוסף, יש לבטל את המכס בסך 7% לרכבים חשמליים המיובאים מסין או הכוללים חלקים מסין (למשל סוללות) עד שנת 2026 לפחות.
3. **יעד מכירות** – יש לאמץ יעדים של מדינות מובילות בעולם ולקבוע יעד של 100% מכירות רכבי אפס פליטות פרטיים (Zero Emission Vehicles) בשנת 2030.
4. **מנגנון הפחתת פליטות לרכבים קלים-** לצורך הגעה ליעד כאמור בסעיף 3 לעיל, וכפי שמקובל באיחוד האירופי, יש לבחון הטלת חובה על יבואנים לעמידה ביעדי פליטות ממוצעות או לחילופין הטלת חובת שילוב מכסות מינימאליות להנעה חלופית במסגרת מצאי הרכבים המיובאים לארץ. יש להחיל מנגנון זה על רכבים פרטיים ולבחון הרחבת המנגנון – בשינויים מתחייבים, גם למשאיות קלות.
5. **פריסת רשת עמדות טעינה-** עד שנת 2030 תידרשנה בישראל כ-60 אלף נקודות טעינה איטיות ציבוריות וכ-1,000 נקודות טעינה מהירות בעלות של 1 מיליארד ש"ח. עד היום השקיעה הממשלה כ-30 מלש"ח בהקמה של 2,500 נקודות טעינה (איטיות ומהירות). נקודות אלו יספקו מענה מלא לרכבים שיעלו על הכביש ב-2-3 השנים הקרובות. לאחר מכן יש לבחון תמיכה נוספת בהקמת עמדות טעינה, בתלות בהתפתחות שוק הרכב החשמלי בישראל.
6. **תשתיות טעינה בבניה חדשה** – יש לפעול בתוך שנה לתיקון תקנות התכנון והבנייה ולהחלת חובה להקמת תשתית חשמל מקדמית בבנייני מגורים חדשים לחיבור עמדות טעינה עתידיות, בהתבסס על ממצאי עבודת משרד הבינוי והשיכון. יש לפעול לניסוח והחלת הנחיות דומות במבני צבור, מסחר ותעסוקה.

7. **הקמת עמדות טעינה בבתים משותפים** – יש לפעול בתוך שנה לתיקון חוק המקרקעין על מנת לאפשר הקמת עמדות טעינה בחניונים פרטיים במבני מגורים משותפים ללא צורך בהסכמת כלל דיירי בבניין.
8. **כלי רכב ממשלתיים** – יש לקבוע מעבר הדרגתי של רכבי ממשלה להנעות חלופיות כך שהחל משנת 2025, ירכשו או יוחכרו ע"י הממשלה רכבים חשמליים בלבד. יש לקבוע יעדי ביניים בתוך שנה, ולהחיל הנחיה דומה על חברות ממשלתיות.
9. **שווי שימוש ואגרת רישוי** – יש לפעול להארכת הטבת שווי שימוש לרכבים חשמליים עד שנת 2026 וכן להעניק הנחה באגרת הרישוי עבור רכב חשמלי בסך של 50% לפחות בייחס לרכבי מנוע בעירה פנימית.
10. **מוניות חשמליות** – יש לפעול בתוך שנה ליישום החלטת ממשלה מספר 529 מיום 6.9.2015 בדבר הקניית זכות ציבורית באגרה מופחתת למוניות המונעות בהנעה חשמלית (יש להקנות זכות זו לכלל ציבור נהגי המוניות בישראל).
11. **חניה מועדפת לכלי רכב חשמליים** – יש לקבוע בתוך שנה מנגנון להקצאת חניות ייעודיות ומוזלות לכלי רכב חשמליים בחניוני תחנות רכבת ובחניונים של פרויקטים תחבורתיים לאומיים המתוכננים כיום ובעתיד.
12. **איסור כניסת רכבים למרכזי ערים** – יש לפעול בתוך שנתיים, בשיתוף הרשויות המקומיות, להכנת תכנית לקביעת יעדים לאיסור כניסת רכבים מונעי סולר למרכזי הערים או לאזורים מתוחמים החל משנת יעד.
13. **הסברה** – יש לצאת בפרסום לפי סקטורים, וציבור המשתמשים, ולמקד את הציבור ביתרונות התחבורה החשמלית בתוך שנה. הפרסום יכלול ימי עיון וסדנאות, בשיתוף הסקטור הפרטי והרשויות המקומיות, בהם הציבור יוכל להתנסות ולהכיר מקרוב רכבים חשמליים.
14. **רכבי מימן** – יש לפעול בתוך שלוש שנים לאימוץ תקינה בינלאומית והכנת תשתית רגולטורית שתאפשר שימוש ברכבי מימן בישראל, ככל ותהיה פריצת דרך בטכנולוגיה זו בשנים הבאות. עד פריצת הדרך, יש לפעול לביצוע הדגמות לשימוש ברכבי מימן באמצעות תקציבי מחקר ופיתוח במשרד האנרגיה.
15. **דו-גלגליים חשמליים** –דו-גלגליים פועלים בחלק גדול מהזמן במרחב העירוני ועל כן הנזקים שהם מסבים לסביבה, הן מבחינת זיהום האוויר והן מבחינת הרעש הנם משמעותיים ביותר. יש לפעול להכנת תכנית להאצת המעבר לדו-גלגליים חשמליים בתוך שנה.
16. **מערך תמריצים ברור**- מערך התמריצים הנדרש לעמוד בפני בעלי העניין השונים במשק צריך להיות מקיף וכוללני. מערך התמריצים צריך לכוון את כל שרשרת האספקה של ציי הרכב לחלופות דלות פחמן. התמריצים צריכים להתייחס לכל בעלי העניין (ציי רכב, יבואני רכב כבד, ספקי תשתית תדלוק, ספקי דלקן/חברות דלק וביוצ"ב ולטווח ארוך המייצר וודאות רגולטורית.

17. **רגולציה בינלאומית מחייבת**- הפחתת פליטות בתחום התעופה אינה יכולה להתבצע מיוזמה מקומית וחייבת להיות משולבת עם רגולציה גלובלית. כמו לדוגמה, חובה לשילוב של דלקים מתחדשים בתחבורה אווירית, הטלת מיסוי על דס"ל בטיסות בינלאומיות וכיוצ"ב.

18. **תכנית להעברת סקטור הספנות לדלקים נקיים**- מידת ההשפעה של התעבורה הימית על היקף פליטות גזי החממה ותרומתה לזיהום האוויר בערי נמל הינה משמעותית. תקנות של ארגון הספנות הבינלאומי מחייב ספינות להפחתת הפליטות באמצעים שונים. אחד האמצעים שלאחרונה צוברים תאוצה הוא החלפת הדלק המשמש לספינות (מזוט) בסוגים אחרים של הנעה וביניהם גז טבעי נוזלי. השימוש בגט"ן הינו כלכלי ובעל פוטנציאל להפחתה דרמטית בהיקף הפליטות של כלל המזהמים וביניהם גזי חממה. אולם, הוא מחייב השקעה ניכרת בהתאמת מנועי הספינות ויצירת תשתית תדלוק בנמלים. בנוסף, קיים אתגר משמעותי בהפחתה של דליפות מתאן (Methane slip) שעשויות לקזז חלק מהתועלת האקלימית בשימוש בדלק מסוג זה. התכנית המוצעת כוללת שיתוף פעולה אזורי בינלאומי (מדינות הים התיכון) ליצירת תשתית תדלוק מתאימה בשילוב עם מערך תמריצים להסבת הספינות. התכנית בשלבי הכנה במסגרת פעילות קבוצת עבודה ייעודית לנושא במסגרת פורום הגז של מזרח הים התיכון (EMGF).

19. **העברת מערך האוטובוסים העירוניים לחשמל** - העברת מערך האוטובוסים העירוניים לחשמל, כך שהחל משנת 2026 לא יכנסו אוטובוסים חדשים מונעי סולר לשירות. ההעברה תתבצע דרך שילוב חובה במכרזי הפעלת אשכולות תחבורה ציבורית. בנוסף, עשויה להינתן תמיכה להעברת יתרת צי התחבורה הציבורית לגז טבעי.

20. **תמיכה בהקמת תשתית תדלוק גט"ד בתחנות ציבוריות**- מתן מענקים פיננסיים.

21. **העברת משק הפסולת להנעה חלופית** מבוססת גז טבעי– מתן תמריצים להקמת תחנות תדלוק, הסבת צי משאיות, מתן תמריצים רגולטוריים וכיוצ"ב.

22. **פיילוט ותקינה של תחנת תדלוק במימן והסדרה של גט"ן**- מימון פרוייקט חלוץ של תקינה לתחנת מימן ושל שימוש בגט"ן במשאיות כבדות/כבדות מאד.

23. **קידום רגולציה על סקטור המשאיות הקלות** – כפי שמקובל באיחוד האירופי וכפי שמוצע גם לגבי מכוניות פרטיות, יש לבחון הטלת חובה על יבואנים לעמידה ביעדי פליטות ממוצעות או לחילופין חיוב שילוב של הנעה חלופית במסגרת מצאי המשאיות אותן הם מייבאים לארץ.

24. **קידום רגולציה המחייבת חברות דלק לשילוב דלקים מתחדשים ממקור מקומי**- רגולציה זו, בשונה מ"חובת המהילה" הקיימת במדינות אירופה לשילוב ביודלקים, שאינה רלוונטית לישראל בה אין ייצור ביודלקים מדור ראשון, עשויה להוביל לחובה הדרגתית ומידתית לשילוב דלקים מתחדשים ונקיים במסגרת סה"כ הדלקים הנמכרים על ידי חברות הדלק/בתי הזיקוק וכו'.

תעשייה- השלמת מעבר לגז טבעי וחשמול התעשייה

לאור החשיבות הרבה בצמצום הפליטות בסקטור זה, הפסקת השימוש בדלקים מזהמים בתעשייה והחלפתם במקורות אנרגיה יעילים ונקיים יותר, מקדמת הממשלה בשנים האחרונות מדיניות תמיכה לעידוד חיבור מפעלים לרשת חלוקת הגז הטבעי. להעברת משק התעשייה לשימוש נרחב בגז טבעי לטווח הזמן הקצר והבינוני היתכנות טכנית ובדאיות כלכלית וסביבתית. אולם, גם גז טבעי הינו דלק מחצבי הגורר פליטה של מזהמים וגזי חממה, ולצורך איפוס הפליטות ממגזר זה יהיה צורך לעבור בשלב הבא לחלופות נקיות יותר כגון חשמל ממקור סולארי או מימן.

על פי התכנית של צוות התעשייה, סקטור התעשייה יפחית את פליטות גזי החממה מערך צפוי של 12.7 $MtCO_2e$ בשנת 2050 ל- 5.9 $MtCO_2e$ המהווה הפחתה של כ 53% ביחס לשנת 2015.

להלן צעדי מדיניות עיקריים בתחום:

25. מימוש החזון יחייב **ביצוע השקעות ברשת החלוקה**. לפני מתן המענקים, ייבחנו המקטעים והצריכות הפוטנציאליות על רקע הצעדים הנעשים לקידום הרשת.
26. **הקמת בסיס נתונים** של צריכת אנרגיה בתעשייה שיאפשר לנתח את פוטנציאל הצריכה בהתאם למאפייני צריכת האנרגיה, מיקום גיאוגרפי ומאפייני הצרכן ופעילותו.
27. יש **לבחון בכל תקופת זמן, חסמים רגולטורים** של צרכנים להסבות לגז טבעי, ולקדם פתרונות לטיפול בהם.

התהליכים להסבת התעשייה לתעשייה דלת פליטות גזי חממה הינם ארוכי טווח ודורשים הן בחינה הנדסית עמוקה והן השקעה של סכומים גבוהים. היות וכך מומלץ להתחיל לקדם את התהליכים כבר כעת, אף אם הטכנולוגיה תבשיל בעוד עשור או שניים.

מבנים- בנייה ירוקה ומאופסת פליטות

לסקטור המבנים השפעה נרחבת על צריכת האנרגיה במשק הישראלי. צריכת האנרגיה במבנים בישראל עומדת על כ- 30% מסך צריכת האנרגיה הסופית במשק. נתון זה בעל משמעות הולכת וגוברת כתוצאה מגידול האוכלוסין ועלייה מתמדת ברמת חיי התושבים, המשפיעים באופן ישיר על צריכת האנרגיה. היקפי צריכת האנרגיה, כמו גם השפעות סביבתיות נרחבות נוספות אשר באות לידי ביטוי במגוון תחומים רחב, החל משלבי התכנון והבניה וכלה בשימושי מבנים והפעילות המבוצעת במסגרתם, גרמו לכך שגברה המודעות בשנים האחרונות לבנייה בטכנולוגיות יעילות באנרגיה וייצור חשמל מקומי.

יישום צעדי מדיניות בתחום המבנים הינו נושא מורכב הדורש תכנון ושיתוף פעולה של גורמים רבים ברמה הלאומית. חשוב להדגיש כי לצעדים אלה אמנם השפעה משמעותית על צריכת האנרגיה

במבנים גם בטווח הבינוני- קצר (עד שנת 2030), אך פוטנציאל החיסכון באנרגיה צפוי לבוא לידי ביטוי ביתר שאת במהלך העשורים הבאים.

בנייה בת קיימא (בנייה ירוקה)

בשנת 2005 נכתבה לראשונה סדרת ת"י 5281 לבנייה בת קיימא (בנייה ירוקה), כאשר מאז בוצעו מספר עדכונים ותוספות לגרסה הראשונית. התקן מתייחס להיבטים בעלי השפעה סביבתית, בראשן צריכת האנרגיה של המבנה, המהווה את הרכיב המשמעותי ביותר בתקן.

משרד הבינוי והשיכון בשיתוף משרד האנרגיה והמשרד להגנ"ס פועלים לעדכון תקנות התכנון והבניה[14] במטרה להביא לחיוב תקן בנייה בת קיימא (בנייה ירוקה) במסגרת בקשות להיתרי בנייה של מבנים חדשים הנבנים במשק. בתוך כך, בחודש מרץ 2020 אושר בוועדת המשנה של המועצה הארצית לתכנון ובנייה עדכון לתקנות אלו באופן המחייב את התקן באופן הדרגתי החל מיולי 2021.

בנייה מאופסת אנרגיה

ייצור עצמאי של אנרגיות מתחדשות במרחב האורבני מאפשר שמירה על שטחים פתוחים וזאת באמצעות ניצול מיטבי של השטח הקיים. בשונה מהקמת תחנות כוח (לרבות תחנות לייצור חשמל מאנרגיות מתחדשות), הצורכות שטח רב, הקמת מערכות לייצור אנרגיה סולארית במרחב הבנוי תאפשר ניצול מיטבי של השטח. מאחר וישראל מוגבלת במשאבי הקרקע הזמינים להקמה של שדות סולאריים, לניצול משאבי קרקע באופן מושכל חשיבות גדולה אף יותר.

בנייה מאופסת אנרגיה מוגדרת כבנייה בה צריכת האנרגיה של כל מבנה מסופקת באופן עצמאי. כדי לתמוך בבניה מאופסת אנרגיה, קבעו משרד האנרגיה, מנהל התכנון והמשרד להגנ"ס יעדים המגדירים כי כבר בעשור הקרוב נתח משמעותי מהתחלות הבנייה במשק יהיו מבנים מאופסי אנרגיה.

איפוס אנרגיה במבנים כולל שני רכיבים עיקריים:

רכיב התייעלות באנרגיה, המורכב מאמצעים פאסיביים (כדוגמת בידוד) ואמצעים אקטיביים (כדוגמת מיזוג אויר) שמטרתם להביא לצמצום צריכת החשמל. התייעלות באנרגיה מסייעת בכך שמפחיתה את היקף ייצור החשמל הנדרש לקיום הפעילויות המתרחשות בתחום המבנה. הטכנולוגיה העיקרית לייצור חשמל מקומי באנרגיות מתחדשות הינה מערכות PV המותקנות על גגות.

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[14] תקנות התכנון והבניה (תכן הבניה – בניה בת -קיימא), התש"ף – 2020

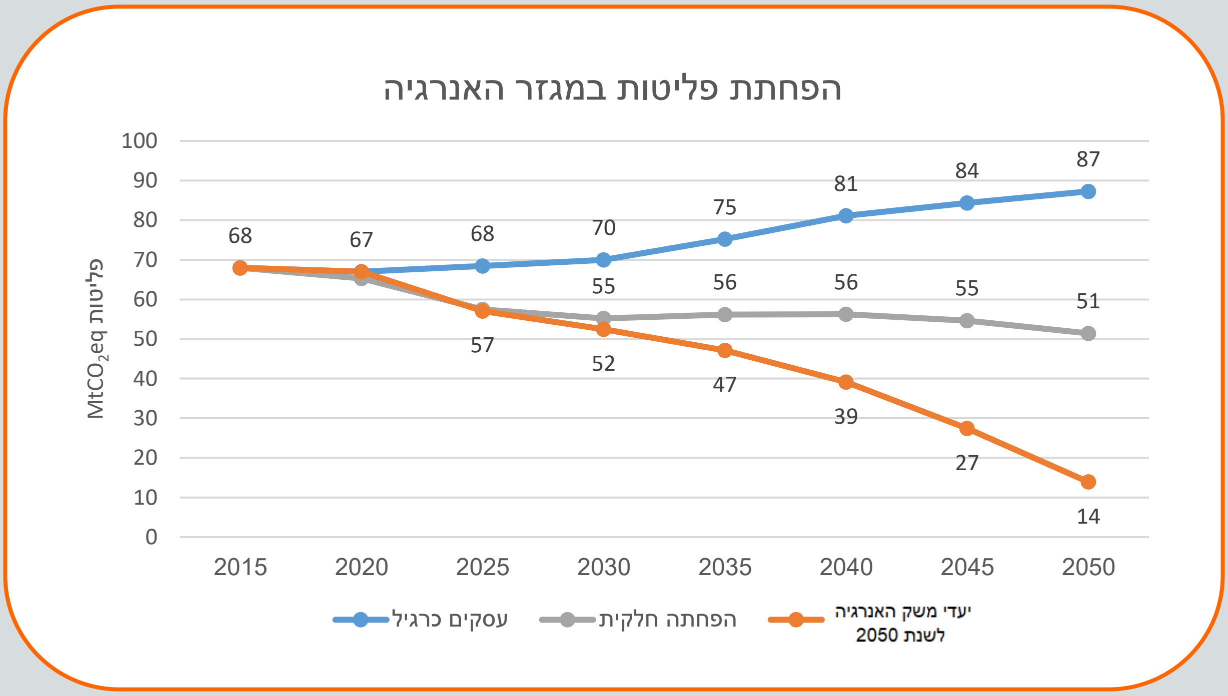
במסגרת תהליך ישראל 2050 לכלכלה משגשגת בסביבה מקיימת ולצורך השגת היעדים הלאומיים, משרד האנרגיה, יחד עם מנהל התכנון, המשרד להגנת הסביבה ומשרד הבינוי והשיכון, מגבשים בימים אלה את מפת הדרכים לאיפוס אנרגיה של מבנים. מפת הדרכים צפויה לכלול, בין היתר, צעדים בתחום החקיקה והתקינה; הכשרות לבעלי מקצוע רלוונטיים בענף הבנייה; הסרת חסמים, לרבות חסמי מימון; עידוד חדשנות בתחום הבנייה; הטמעת פתרונות טכנולוגיים להתייעלות באנרגיה. בפרט, במסגרת גיבוש מפת הדרכים יקודם עדכון לתקנות התכנון והבנייה, כך שתחול חובת איפוס אנרגיה במתן היתר בנייה למבנה מגורים צמוד קרקע החל משנת 2025.

עמידה ביעדי התכנית

משרד האנרגיה הגדיר ארבעה 'יעדים ראשיים' שישקפו את המטרה האסטרטגית ויעדים סקטוריאליים תומכים בעזרתם ניתן יהיה להשיגה. 'יעד העל' מוגדר כהפחתת פליטות גזי חממה ממגזר האנרגיה בשיעור של 80% ביחס לשנת הייחוס 2015 וזאת עד לשנת 2050.

בחינת השפעת התכנית והעמידה ביעדים נעשית על ידי שימוש במודל טכנו-כלכלי הכולל שני חלקים – מודל טכני המבצע סימולציה של תפעול רכיבי הייצור השונים במשק מול עקומת הביקוש, ומודל כלכלי המתבסס על ממצאי המודל הטכני ובאמצעותם מעריך את העלויות המשקיות השנתיות למגזר החשמל בהתאם למחירים הצפויים לרכיבים השונים בעתיד.

נקבעו שני תרחישים לעמידה ביעדים- תרחיש של עמידה חלקית ביעדים (הפחתה חלקית) ותרחיש עמידה מלאה ביעדי התכנית (יעדי משק האנרגיה לשנת 2050) (תרשים 7) . בעזרת המודל, ביצענו ניתוחי רגישות של עמידה ביעדים בתרחישים שונים והמשמעויות למשק הישראלי כפי שמפורט בהמשך עבודה זו.



תרשים 7 : הפחתת פליטות גזי חממה בתרחיש "עסקים כרגיל" (יעדים כפי שנקבעו בהסכמי פריז) של עמידה חלקית ביעדים (הפחתה חלקית) ותרחיש עמידה מלאה ביעדי התכנית (יעדי משק האנרגיה לשנת 2050). משרד האנרגיה, 2020.

בתרחיש "עסקים כרגיל" (יעדים כפי שנקבעו בהסכמי פריז), סך פליטות גזי החממה ממגזר האנרגיה צפויות לגדול בב- 28% לעומת שנת הייחוס 2015 ולעמוד על 87.3 $MtCO_2e$ בשנה. לעומת זאת, בתרחיש "הפחתה חלקית", סך פליטות גזי החממה ממגזר האנרגיה צפויות להצטמצם בב-25% לעומת שנת הייחוס 2015 ולעמוד על 51.4 $MtCO_2e$ בשנה, ובתרחיש עמידה מלאה ביעדי התכנית (יעדי משק האנרגיה לשנת

2050), סך פליטות גזי החממה ממגזר האנרגיה צפויות להצטמצם ב- 80% לעומת שנת הייחוס 2015 ולעמוד על 13.9 $MtCO_2e$ בשנה. היעדים לשנים 2030 ו-2050 נבחרו על בסיס תרחיש עמידה מלאה ביעדים (יעדי משק האנרגיה לשנת 2050) וזאת מתוך מטרה להביא להפחתה מרבית של פליטות גזי חממה במשק האנרגיה הישראלי.

משק האנרגיה העולמי והמקומי

בשנת 2015, המדינות החברות באמנת האו"ם בדבר שינויי האקלים (UNFCCC) וביניהן ישראל אימצו הסכם אקלים מחייב. במסגרתו קבעה ישראל עד שנת 2030: יעד של צמצום צריכת החשמל בשיעור של 17% לפחות ביחס לצריכת החשמל הצפויה באותה שנה, וייצור חשמל מאנרגיה מתחדשת בשיעור של 17%. ועידת האקלים הבאה (2021), בה צפויות להשתתף 196 מדינות, נחשבת לחשובה ביותר מאז ועידת האקלים בפריז ב-2015, שכן במסגרתה המדינות השונות יציגו התחייבויות וצעדים משמעותיים ביותר להגבלת פליטת גזי חממה, במטרה לעמוד ביעד השאפתני של צמצום הפליטות במחצית עד סוף שנת 2030 והגעה לאיפוס פחמני עד 2050. העמקת היעדים תאפשר להגביל את ההתחממות הגלובלית ל-1.5 מעלות (לעומת עלייה צפויה של כ-3 מעלות), וכך להימנע מההשלכות החמורות וההרסניות ביותר שלה. כמו כן, התחייבו המדינות, ביניהן ישראל, להגיש עד סוף 2020 תכניות ארוכות טווח למעבר לכלכלה דלת פליטות עד 2050.

סוכנות האנרגיה הבינלאומית (IEA) פרסמה בדו"ח השנתי[15] (2019) את מגמות האנרגיה העולמיות לשנת 2040. בתרחיש המדיניות המוצהרת, הביקוש לאנרגיה עולה ב-1% בשנה עד לשנת 2040. מקורות דלי פחמן, בעיקר ממקור סולארי (PV) מספקים כחצי מהגידול השנתי, כאשר גז טבעי וגז טבעי נוזלי (LNG) מהווים שליש נוסף. הביקוש לנפט משתטח בעשור הבא כמו גם שיעור השימוש בפחם. חלקים מסקטור האנרגיה, עוברים טרנספורמציה מהירה לשימוש בחשמל. עם זאת, המומנטום העומד מאחורי קידום טכנולוגיות לאנרגיה נקייה אינו מספיק בכדי לקזז את ההשפעות של כלכלה עולמית מתרחבת ואוכלוסייה צומחת. עליית הפליטות מאטה, אך ללא האטה משמעותית לפני שנת 2040, העולם לא יוכל לעמוד במטרה המשותפת לעצור את השפעות משבר האקלים.

לצד משבר האקלים, משקי האנרגיה בעולם עוברים טרנספורמציה טכנולוגית חסרת תקדים. פיתוחים בתחום המתחדשות, האגירה, ניהול ביקושים ועוד מאפשרים שינויים דחופים יחסית במשקים השונים ומשנים את כללי המשחק.

לאור השאיפה לקידום משק נקי ודל פליטות, התקדמות טכנולוגית והשינויים העולמיים באופיים של משקי אנרגיה, עולה הצורך לגבש מדיניות ארוכת טווח אשר תכין את התשתית כבר היום ותוביל את משק האנרגיה הישראלי להתמודדות עם השינויים הצפויים תוך מענה על הצורך להפחתת פליטות גזי חממה הנובעים מסקטור מרכזי זה. לצד הביטוי למגמות עולמיות, תהליך קביעת יעדים בתחום האנרגיה צריך לקחת בחשבון את מאפייניו הייחודיים של המשק הישראלי; ישראל היא אי אנרגטי גאו-פוליטי, המאופיינת בצפיפות אוכלוסייה גבוהה יחסית, בקצב גידול אוכלוסייה גבוה, במיעוט בשטחים פתוחים באזור המרכז, בעתודות גז

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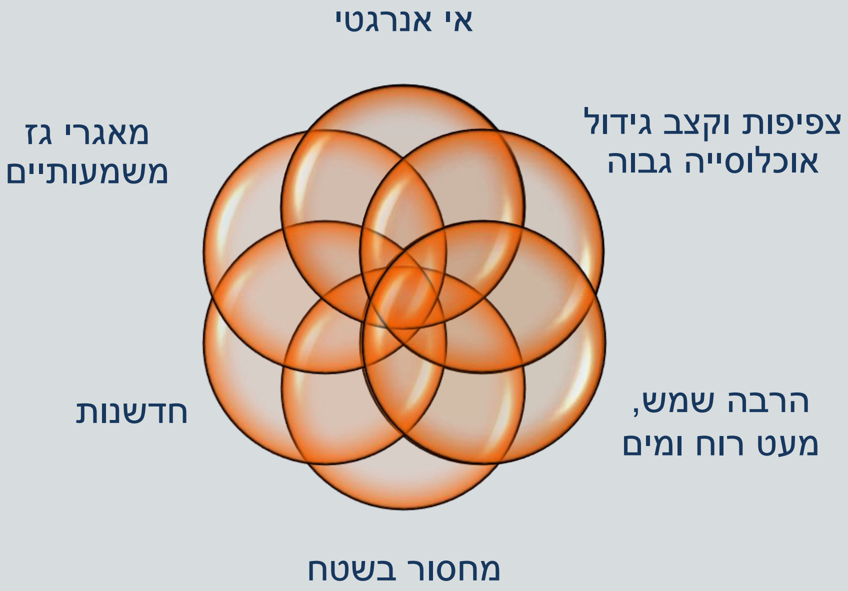
[15] https://www.iea.org/reports/world-energy-outlook-2019#

טבעי גדולות, בפוטנציאל ייצור חשמל גבוה מאנרגיית השמש לעומת אפשרויות מוגבלות לייצור אנרגיה ממקורות מתחדשים אחרים.

מאפייני ישראל



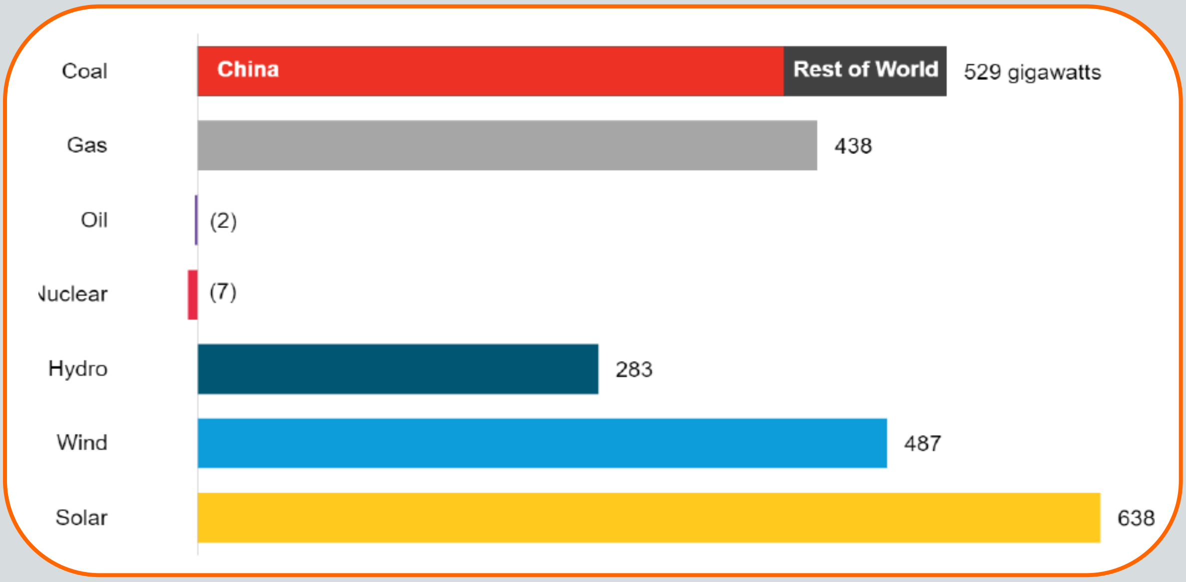
קביעת יעדים שאפתניים ארוכי טווח בתחום מורכב וחיוני כל כך, מחייבת בחינה רחבה של המשק ומחויבות לעמידה ביעדי ביניים כבר בעשור הקרוב. מתוך כך נבחנים כבר עכשיו באופן מעמיק יעדי הביניים לצד קביעת יעדים ארוכי טווח לשנת 2050.

בפרקים הבאים נפרט את בחינת האסטרטגיה ארוכת הטווח במשק האנרגיה הכוללת קביעת יעדים ובחינת צעדי המדיניות נדרשים, תוך שימוש במודל טכנו כלכלי. הבחינה נערכה על פני מספר סקטורים כפי שיוצג בפרק הבא.

משק החשמל

משק החשמל עובר שינויים לא מעטים בשנים האחרונות, והמהותי שבהם, מלבד הגידול בצריכה החשמל העולמית וחשמול סקטור התחבורה, הוא המעבר לאנרגיות מתחדשות. בשנים האחרונות, כ120 מדיניות הצהירו על תכניות אסטרטגיות ארוכות טווח להפחתת פליטות, חלקן מעוגנות במסגרת חוקית וחלקן נמצאות בסטטוסים משתנים בין התחייבות הצהרתית, לתכנית בפיתוח לעקרונות מדיניות כלליים ועוד. לצורך השוואה בין-לאומית נבחנו מגמות רוחביות והתבססנו על נתונים במסגרת מפת הדרכים של ארגון IRENA (International Renewable Energy Agency) ל-2050.[16]

תרשים 8 שלהלן ממחיש את המעבר העולמי לאנרגיות מתחדשות. האיור מציג את סך ההספק שהותקן בעולם לייצור חשמל לפי טכנולוגיות בעשור האחרון. מהאיור ניתן לראות כי ההספק הסולארי שנוסף עולה לבדו על ההספק בפחם ובגז (להוציא סין). מלבד זאת, סך ההספק המתחדש, הכולל אנרגיה סולארית, רוח והידרו עולה משמעותית על ההספק הפוסילי, שרובו הותקן בסין.



תרשים 8: סך התקנות באמצעי ייצור שונים בשנים 2009-2019 בעולם (ג'יגה וואט)

על אף קצב הגידול בהספק הסולארי, עיקר ייצור החשמל עדיין מבוסס על דלקים פוסיליים כך שנפלטת כמות פליטות גזי חממה משמעותית. איור 9 שלהלן מציג את אחוז פליטות גזי החממה בחלוקה

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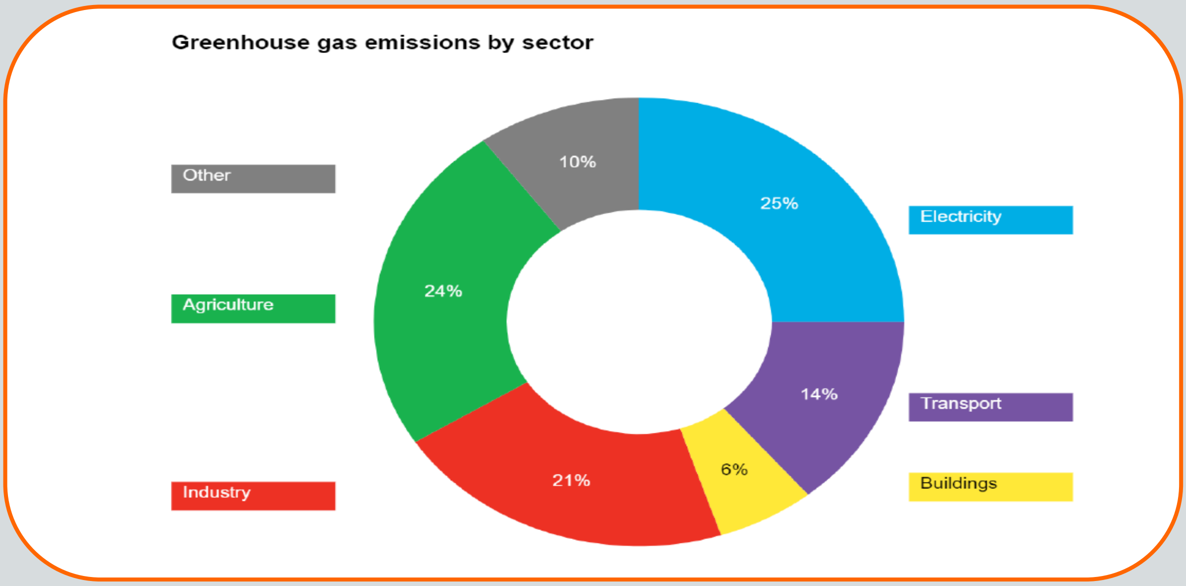
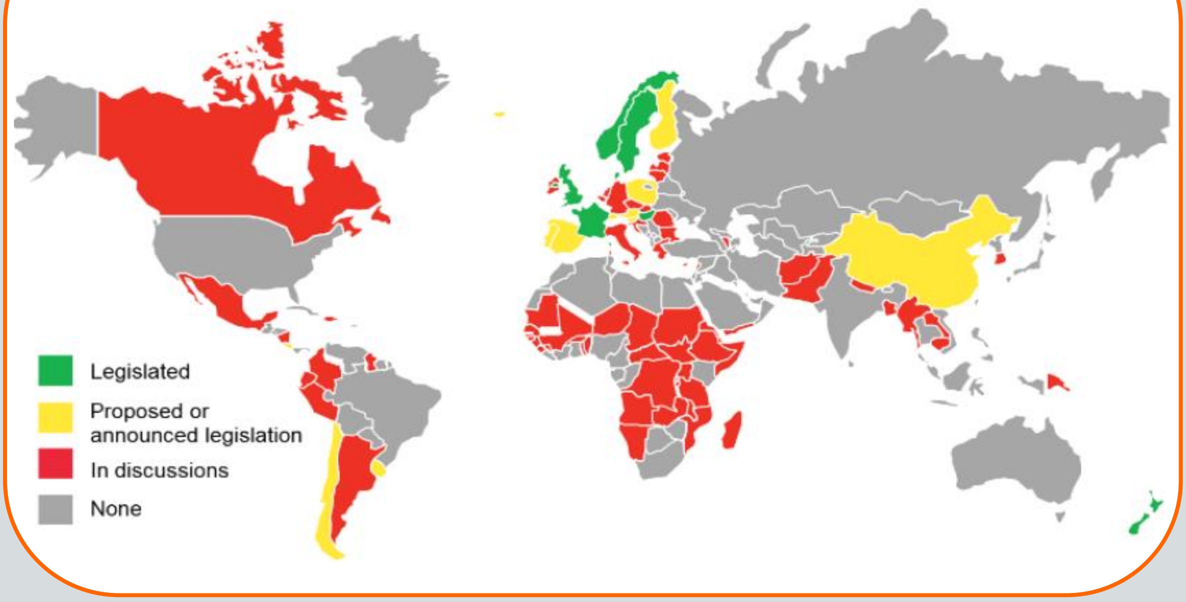
[16] https://www.irena.org/publications/2019/Apr/Global-energy-transformation-A-roadmap-to-2050-2019Edition

לסקטורים עיקריים בעולם בשנת 2019. מהאיור ניתן לראות כי סקטור החשמל הוא הפולט העיקרי - 25%, ולאחריו סקטור החקלאות והתעשייה עם 24% ו-21% בהתאמה.



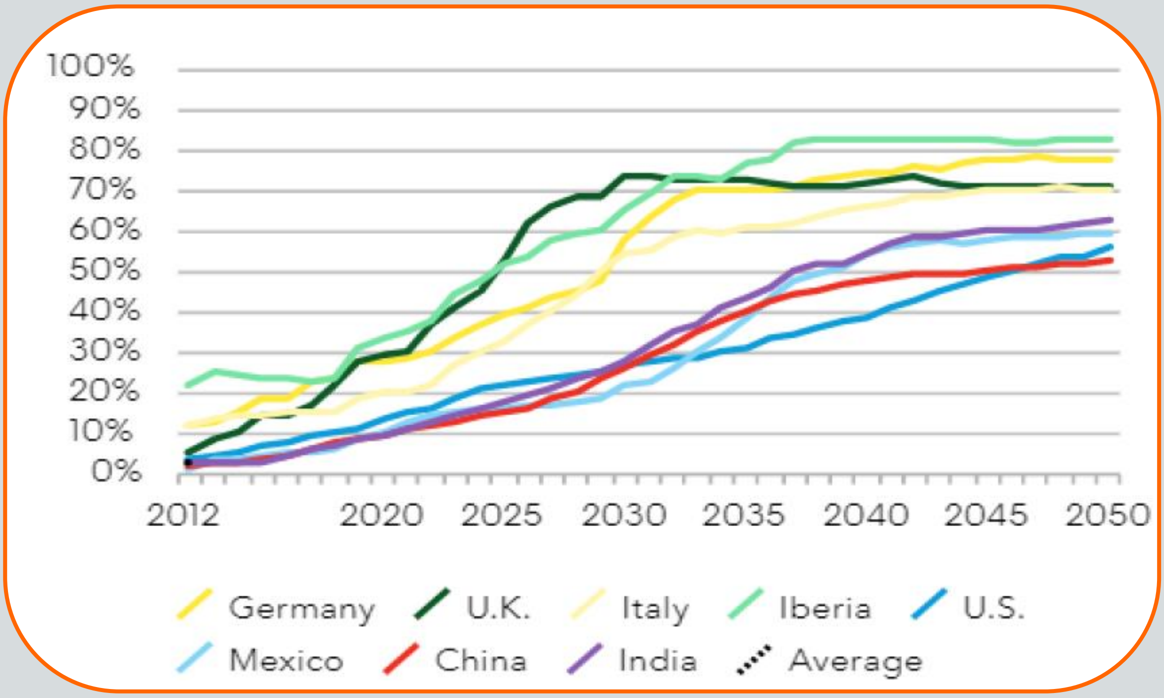
תרשים 9: פליטות גז חממה לשנת 2019 בחלוקה לסקטורים עיקריים

על מנת לצמצם את היקף פליטות גזי החממה ומזהמים אחרים, מדינות רבות החלו בכתיבת תכניות וקביעת יעדים ארוכי טווח למעבר לייצור חשמל מתחדש. תרשים 10 שלהלן מציג את השלבים בהם נמצאות מדינות העולם השונות. מהאיור ניתן לראות כי חלקן הגדול של המדינות נמצא בתהליכי עבודה, אך רובם טרם קבעו יעדים באמצעות חקיקה.



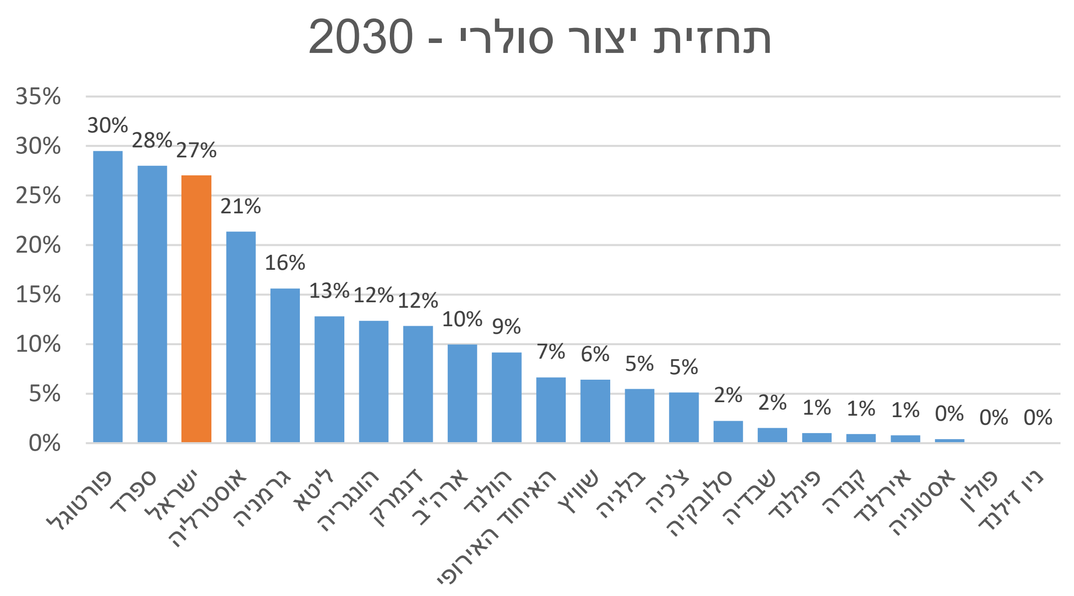
תרשים 10: שלבים לקביעת יעדים ארוכי טווח להפחתת פליטות.

ברור כבר עכשיו כי שיעור המתחדשות יעלה עד מאוד בעיקר עד שנת 2050, וכבר כיום ישנן אינדיקציות לאחוזי החדירה העתידיים של אנרגיות מתחדשות במדינות רבות. תרשים 11 שלהלן מציג תחזית של בלומברג לשיעור המתחדשות הכולל המבוסס על רוח ואנרגיה סולארית במדינות נבחרות עד שנת 2050. מהתרשים ניתן לראות כי שיעור המתחדשות המבוססות על רוח ושמש יותר ממשלש את עצמו במרבית המדינות בין השנים 2020 ו-2050 ומגיע עד לכ-80% במספר מדינות.



תרשים 11: שיעור מתחדשות במדינות נבחרות עד שנת 2050 לפי אומדני בלומברג.

המושג אנרגיות מתחדשות כולל סוגים שונים של מקורות אנרגיה ועל כן יש לשים לב באופן מיוחד לתחזיות הייצור הסולארי לשנים 2030 ו- 2050 שכן מדובר בייצור חשמל שאינו יציב (סירוגי) ועל כן מעלה אתגרים רבים בהסתמכות עליו באופן בלעדי ועל כן משמש כחלק מתמהיל האנרגיות המתחדשות בכל מדינה. תרשים 12 מציג את תחזית הייצור הסולארי במדינות נבחרות לשנים 2030.



תרשים 12*:* תחזית ייצור סולארי במדינות נבחרות לשנת 2030. IEA, 2021[17].

בבחינת הנתונים הנ"ל, ניתן ללמוד כי תחזית ייצור החשמל ממקור סולארי בכל המדינות הנבחנות לא עולה על 30% בשנת 2030 כאשר ישראל עומדת לצד המדינות השאפתניות ביותר ומרביתן המוחלט של המדינות עומדות על אחוזים בודדים בלבד. כאשר בוחנים את התחזית לשנת 2050 רואים כי על אף אחוזי האנרגיה המתחדשת הגבוהה החזויה במדינות השונות, אחוז האנרגיה הסולארית מתמהיל האנרגיה המתחדשת הינו נמוך. בארה"ב למשל, אחוז האנרגיה המתחדשת החזוי לשנת 2050 עומד על כ- 55% מתוכם רק 17% מייצור בסולארי, גם בגרמניה ניתן לראות שעל אף תחזית גבוהה של כ 80% אנרגיה מתחדשת לשנת 2050 רק 26% מתוכם צפויים להיות מיוצרים מאנרגיית השמש.

האפשרות לשלב רוח ושמש בהיקפים משמעותיים מוגבלת נוכח אופי יצור החשמל המתחדש, המשתנה כתלות במזג האוויר ושעות היום, ומצריכה הערכות מיוחדת. בראש וראשונה נדרשת אגירה שתאפשר זמינות אנרגיה גם בשעות בהן היא איננה מיוצרת (למשל בלילה עבור אנרגיה סולארית). בעוד שמרבית האגירה הקיימת כיום הנה אגירה שאובה, כ-96% מסך הספק של 176 ג'גה-וואט לשנת 2017, בשני העשורים הקרובים משקלה צפוי לרדת, ואגירה באמצעים אחרים, מודולריים, כמו סוללות, תלך ותגדל. תרשים 13 שלהלן מציג תחזית של בלומברג להספק המצטבר של מתקני אגירה במשק החשמל, ללא אגירה שאובה, עד שנת 2050, לפי מדינות העולם. מהתרשים נראה כי בעוד

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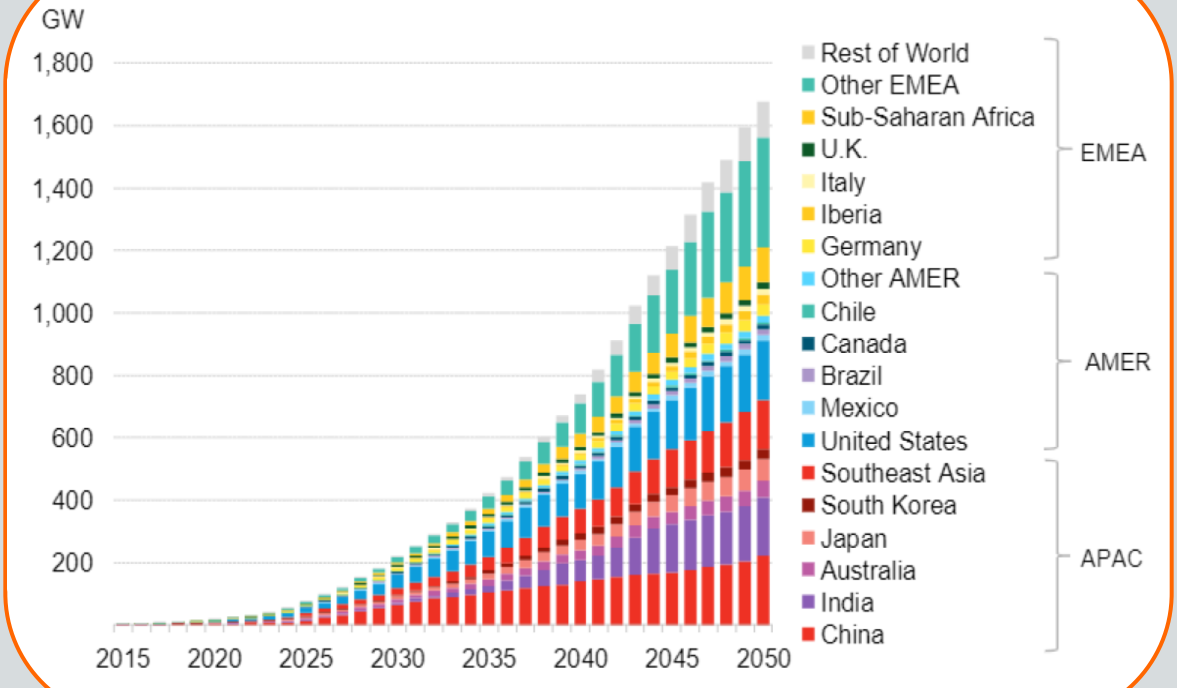
[17] Projections: energy policies of IEA countries http://data.iea.org/payment/products/114-projections-energy-policies-of-iea-countries.aspx

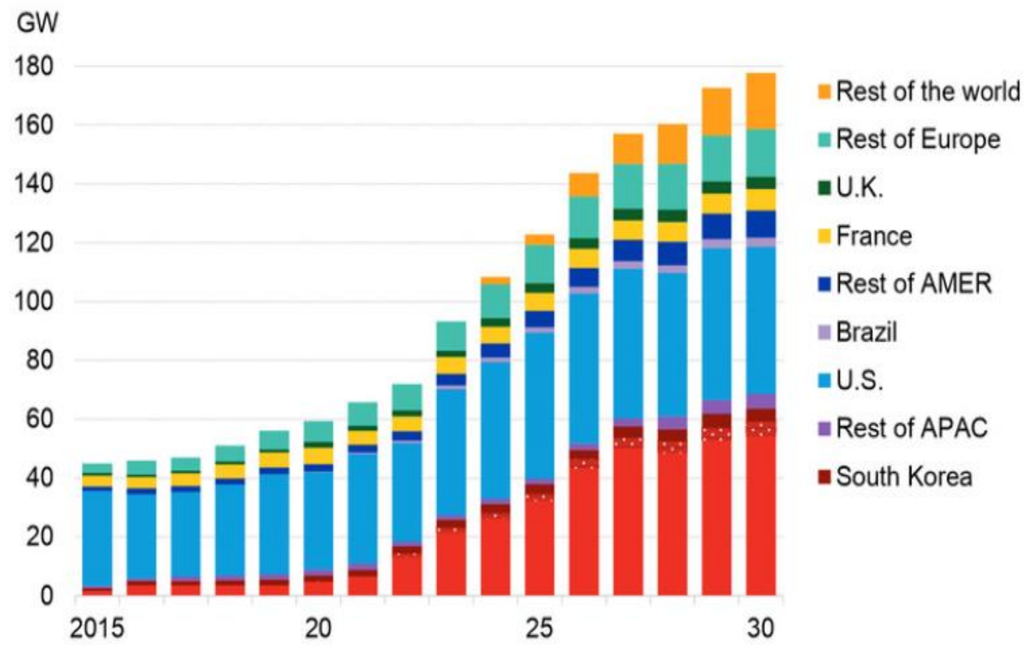
שכיום היקף האגירה הוא כמעט אפסי (ללא אגירה שאובה), עד שנת 2050 ההספק המצטבר יגיע לכ-1,700 ג'יגה-וואט, כאשר ארה"ב ומדינות אסיה, בראשן סין, יובילו את המגמה.



תרשים 13: הספק אגירה מצטבר עד שנת 2050 לפי מדינות, בלומברג.

התנודתיות בתפוקת האנרגיה מהמקורות המתחדשים (שמש ומעט רוח), וחוסר היכולת לשלוט על תפוקת האנרגיה במגזר זה, הלוקח נתח גדל והולך בסך הייצור, דורש ממערך הייצור גמישות גבוהה. מערך ייצור האנרגיה המסורתי – טורבינות קיטור וגז – מתקשה לעקוב אחר התנודות והשינויים המהירים בתפוקת המקורות המתחדשים. אגירת אנרגיה יכולה לספק חלק מהגמישות הנדרשת – סוללות מסוגלות להיכנס לפעולה ולהגיב לצרכי הרשת בשברירי שנייה, אך כיום הן יקרות ובעלות תכולת אנרגיה מוגבלת. אמצעי אחר להשגת הגמישות הנדרשת ברשת הינו מנגנון ניהול צד הביקוש.

ניהול ביקושים/ניהול צד ביקוש (Demand Response/Demand Side Management) מתייחס לפעולות יזומות (dispatchable) הנעשות לבקשת מנהל המערכת, בצד הביקוש לחשמל, אשר מאפשרות לווסת את צריכת החשמל ולאזן בין ההיצע לביקוש. ניהול ביקושים (DR) נמצא בשימוש בעולם כבר למעלה מעשור, ובשנים האחרונות נראה כי השימוש בו הולך וגובר. תרשים 14 שלהלן מתאר את הספק ה-DR המותקן בעולם, לפי מדינות, החל משנת 2015 ועד לשנת 2030 (סין איננה מופיעה במקרא בשל טעות דפוס, אך נמצאת באדום על גבי הגרף). מהאיור ניתן לראות כי בעוד שכיום אנו נמצאים בכ-50 ג'יגה-וואט הספק כולל, רובו מרוכז בארה"ב, עד 2030 ההספק בעולם צפוי להגיע לסך של כ-180 ג'גה-וואט, כאשר שתי הכלכלות הגדולות, ארה"ב וסין, יחזיקו בעיקר ההספק.

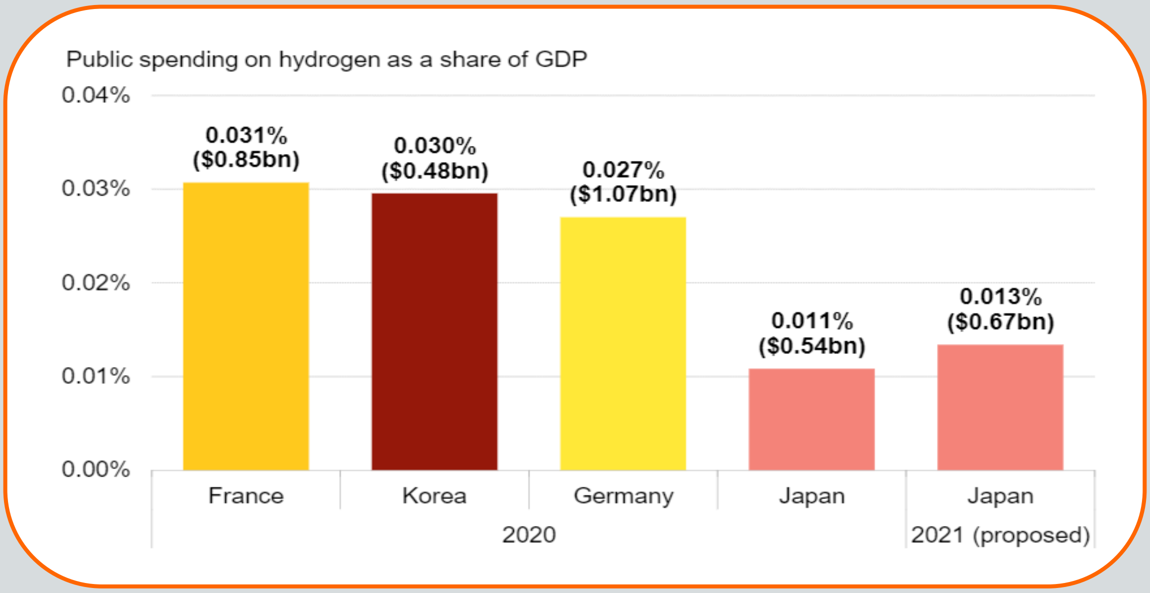


תרשים 14: הספק מצטבר לניהול ביקושים עד שנת 2030 לפי מדינות, בלומברג.

מאחר והשימוש באמצעי אגירה, בייחוד סוללות, מוגבל למספר שעות, ומכוון שהשימוש בניהול ביקושים מוגבל לרמת היכולת של הפרטים לשנות את צריכתם, נדרשת טכנולוגיה נוספת שתאפשר לצרוך אנרגיה מתחדשת גם בימים בהם אין יצור מתחדש בכלל. דוגמא לטכנולוגיה כזו היא מימן – חשוב במיוחד בסקטור החשמל, בין היתר בשל תכונותיו, המאפשרות לאגור אותו בכמות גבוהה, לפרק זמן ארוך, ולייצר ממנו חשמל נקי בשלב מאוחר יותר.

את המימן אפשר לייצר באמצעות אלקטרולייזר המשתמש בחשמל לפצל מים למימן וחמצן (מוגדר כמימן "ירוק" אם החשמל מגיע ממקורות מתחדשים), או בדרכים אחרות, למשל באמצעות התמרה (רפורמציה) של גז טבעי באמצעות קיטור (מוגדר כמימן "אפור" – מימן שבתהליך הייצור שלו נפלטים גזי חממה). את המימן האפור ניתן להפוך למימן "כחול" אם תופסים את הפחמן הדו-חמצני הנפלט בהליך ייצור המימן. שיטה נוספת להפקת מימן "כחול" היא פירוליזה ישירה של גז טבעי – בתהליך מפוצל הגז הטבעי (מתאן) למימן ופחמן, והפחמן מתגבש לפחמן מוצק טהור המוסר מהמערכת. לאחר הפקת המימן הוא ניתן לאגירה במכלים בלחץ גבוה של 300-700 אטמוספרות, במכלים במצב מונזל בטמפרטורה של $-240\ C^{o}$, או לאחר התמרה כימית לחומרי אכסון כגון אמוניה או משפחת חומרים הנקראתLiquid Organic Hydrogen Carriers (LHOC). בכדי להשתמש במימן ניתן להזינו לתא דלק - תא אלקטרו כימי הממיר מימן וחמצן למים וזרם חשמלי, או לשרוף אותו בדומה לגז טבעי, כאשר תוצרי השריפה הם אדי מים בלבד.

בשל השימושים הרבים למימן והפוטנציאל שלו להפוך תעשיות שלמות לנטולות פליטות, מדינות רבות החלו לפתח תכניות ארוכות טווח להשקעות בפרויקט מו"פ ובהטמעה של מימן. בין המדינות, הולנד, גרמניה, אוסטרליה, סין, יפן, קליפורניה, ספרד, פורטוגל, קוריאה הדרומית ועוד. תרשים 15 שלהלן מציג את ההשקעה הצפויה בחלק מהמדינות הללו בשנים הקרובות במונחי אחוז מהתמ"ג ובאופן אבסולוטי. מהתרשים ניתן לראות כי צרפת מתכננת להשקיע כ- 0.85 מיליארד דולר (או 0.031% מהתמ"ג) בשנת 2020, קוריאה כ- 0.48 מיליארד דולר (או כ-0.03% מהתמ"ג), גרמניה כ- 1.07 מיליארד דולר (או כ- 0.027% מהתמ"ג) ויפן כ- 0.54 מיליארד דולר וכ-0.67 מיליארד דולר (או כ- 0.011% וכ- 0.013%) עבור השנים 2020 ו-2021 בהתאמה.[18]



תרשים 15: השקעה ממשלתית במימן במספר מדינות בעולם.

בנוסף להשקעת כספים, מדינות רבות בעולם ובייחוד באירופה, החלו לקבוע יעדים להתקנת אלקטרולייזרים ליצירת מימן ירוק. תרשים 16 שלהלן מציג את יעדי ההתקנה במונחי ג'יגה וואט עד שנת 2030 במספר מדינות באירופה ובסה"כ באיחוד האירופאי. סך היעד באיחוד האירופאי עומד על כ- 40 ג'יגה וואט, כאשר צרפת, גרמניה, ספרד, הולנד ופורטוגל קבעו יעדים של 6.5, 5, 4, 3, ו-2.1 ג'יגה וואט בהתאמה.

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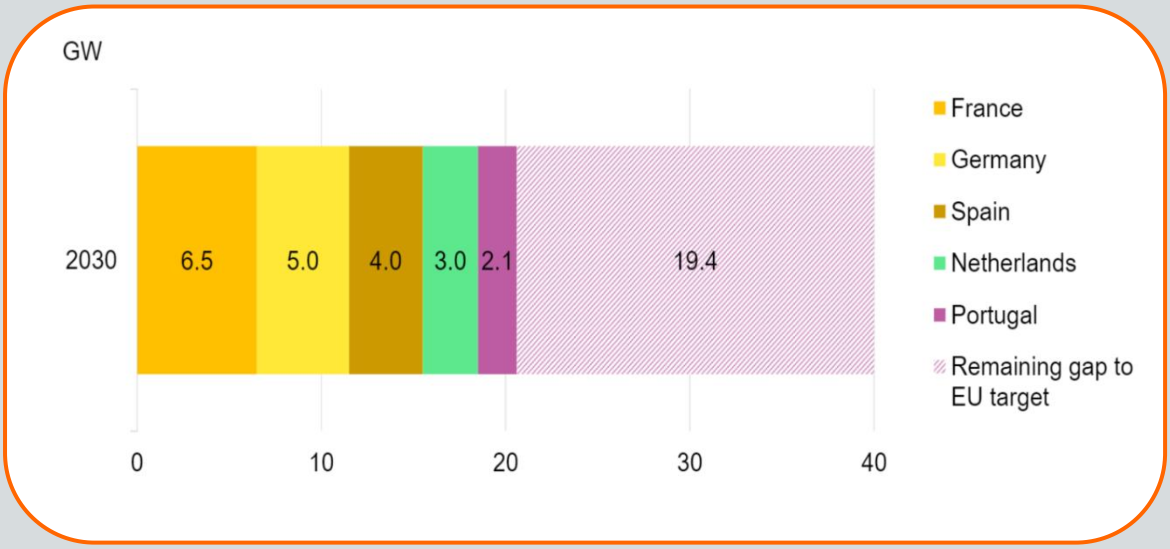
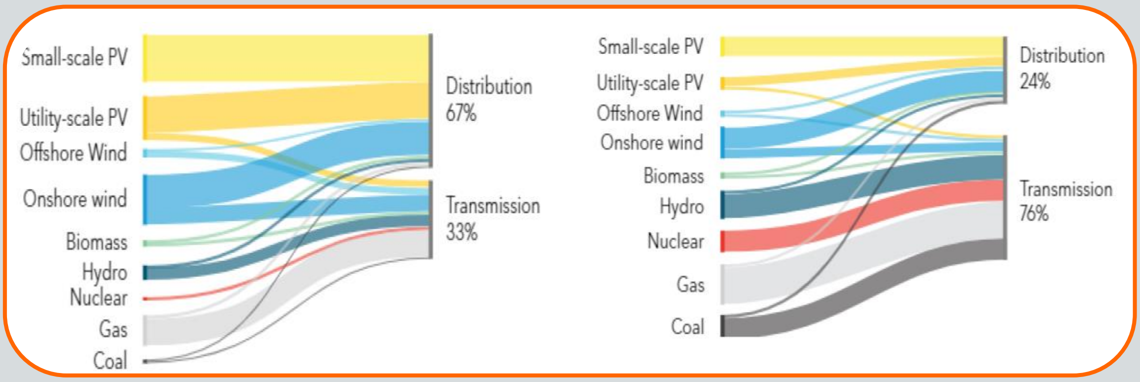
[18] המדינות המצוינות באיור 4 צפויות לבצע השקעה שנתית דומה על פני כול העשור הקרוב.



תרשים 16: יעדים להתקנת אלקטרולייזרים עד שנת 2030, בלומברג.

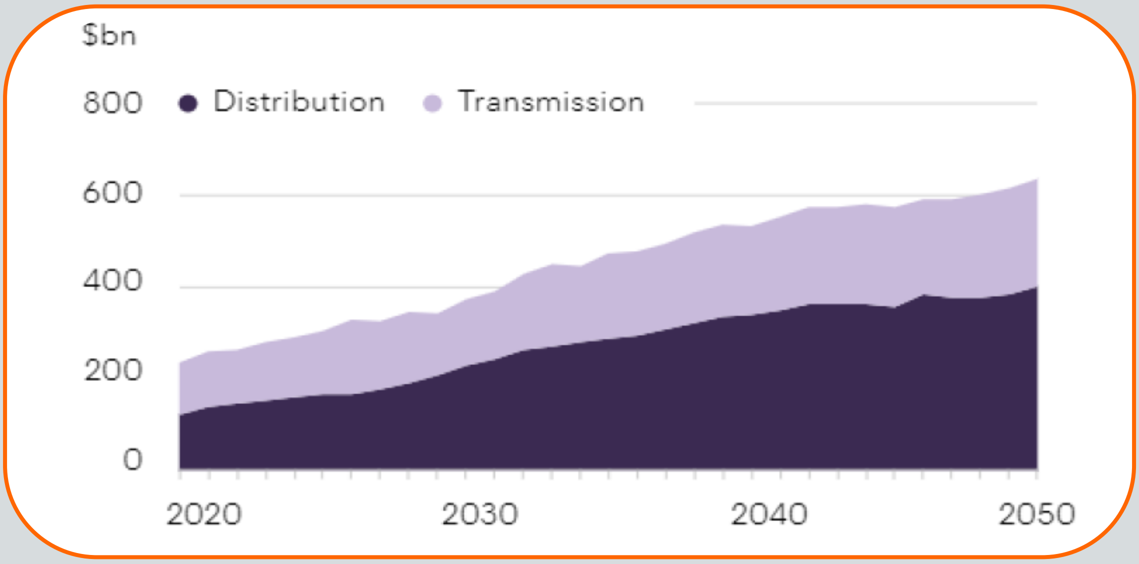
מלבד אופי ייצור החשמל המתחדש, המשתנה כאמור כתלות במזג האוויר ושעות היום, ישנה סוגיית המיקום של מתקן הייצור. בעוד שכיום מרבית הייצור מרוכז בתחנות כוח גדולות המחוברות לרשת ההולכה, הרי שהמעבר לשימוש הולך וגדל באנרגיה מתחדשת, מביא לביזור הדרגתי באמצעי הייצור על כלל שטחי המדינות, ולהקטנת גודל המתקן הטיפוסי, כך שיותר ויותר מתקנים יתחברו לרשת החלוקה. תרשים 17 שלהלן מתאר את תמונת המצב היום (מימין), כשעיקר הייצור הוא פוסילי ומחובר לרשת ההולכה, ואילו צד שמאל מתאר את מצב העולם הצפוי לשנת 2050, לפי תחזיות בלומברג, כאשר עיקר הייצור הוא מתחדש ומחובר לרשת החלוקה. בעוד שבשנת 2020 כ-76% מהייצור בעולם מחובר לרשת ההולכה, בשנת 2050 צפוי כי המצב ישתנה ו-66% מהייצור יהיה מחובר לרשת החלוקה.



תרשים 17: אחוז ייצור מחובר לרשת חלוקה ורשת הולכה בשנת 2020 (צד ימין) ושנת 2050 (צד שמאל), בלומברג.

שינוי זה טומן בחובו התאמות נדרשות רבות הן ברשת החלוקה והן ברשת ההולכה, לשם קליטה מיטבית וניהול של אנרגיה מתחדשת. תרשים 18 שלהלן מציג את ההשקעה השנתית הנדרשת ברשת ההולכה ורשת החלוקה עד שנת 2050 לפי תחזיות בלומברג. מהאיור ניתן לראות כי בעוד שכיום ההשקעה מתחלקת באופן שווה בין רשת החלוקה וההולכה, עד שנת 2050 צפוי כי ההשקעה ברשת

החלוקה תגדל באופן משמעותי ביחס לרשת ההולכה, וזאת כאמור לצורך שילוב הולך ועולה של אנרגיות מתחדשות.



תרשים 18: השקעה שנתית נדרשת ברשת החלוקה ורשת ההולכה עד שנת 2050, בלומברג

כמו כן בעולם ישנן טכנולוגיות נוספות אשר מתפתחות עם הדרישה להפחתת פליטות מסקטור האנרגיה. אחת מטכנולוגיות אלה היא תפיסת ואחסון פחמן (CCS). תהליך זה הוא תהליך בו פחמן דו-חמצני (פד"ח) נתפס מפליטות של תהליכים תעשייתיים ותהליכי הפקת חשמל, ומאוחסן ללא יכולת להיפלט לאטמוספירה. אין מדובר בטכנולוגיה אחת, אלא בחבילה שלמה של טכנולוגיות ותהליכים. חלק מהם פועלים בהצלחה כבר עשרות שנים, בעוד אחרים נמצאים תחת פיתוח או בשלבי מעבר לשימוש בקנה מידה תעשייתי. ללא קפיצה טכנולוגית שתאפשר יישום בקנה מידה נרחב ואיתור אזורים מתאימים לכליאת הפד"ח, לא יתאפשר יישום של טכנולוגיות תפיסת ואחסון פחמן בישראל.

באופן בסיסי CCS מורכב משלושה שלבים עיקריים:

- תפיסה - הפרדת פד"ח מגזים אחרים בתהליך התעשייתי או בתהליך הפקת חשמל. לאחר מכן הוא נדחס לקראת שינוע.
- שינוע - העברת הפד"ח, בד"כ באמצעות צינורות, מאתר תפיסתו אל אתר האחסנה.
- אחסון - הזרקת פד"ח אל תצורות קרקע או לאקוויפרים תת-קרקעיים לשם כליאה ארוכת טווח. לחילופין, ניתן לשלבו בתהליכים תעשייתיים ליצירת מוצרים (CCU).

כיום, CCS כלכלי רק בחלק מצומצם של מקרים, כאשר מרבית העלות מקורה בתהליך תפיסת הפד"ח. חסמים נוספים הם קושי בשימוש בפד"ח כחומר גלם, חוסר וודאות רגולטורי, צורך בתשתיות הולכה לפד"ח, אי קבלה ציבורית, קושי באיתור ואפיון אתרי אחסון, אי הכרה בעלויות החיצוניות של פליטת גזי חממה, ונושאי חבות (מי נושא באחריות במקרים של נזק).

בעולם פועלים נכון ל-2020, 26 מפעלים בקנה מידה גדול, ועוד כ3 מפעלים בהקמה, כ-13 מפעלים בשלבי פיתוח מתקדם וכ-21 בשלבי פיתוח ראשוניים. המפעלים הפועלים היום בעלי קיבולת תפיסה של MtCO2 40 בשנה. בנוסף, ישנם עוד 34 מתקני חלוץ והדגמה פועלים או בתהליכי הקמה.

לצד טכנולוגיות אלה במשך שנים רבות מדינות פונות לייצור אנרגיה באמצעות גרעין. יצור חשמל מאנרגיה גרעינית נפוץ מאוד בעולם, למרות התחושה בציבור כי מדובר בטכנולוגיה הנמצאת בתהליך מתמשך של דעיכה. בפועל, כ-10% מכלל החשמל בעולם מיוצר על ידי אנרגיה גרעינית (IEA ,2018), ובמדינות ה-OECD השיעור עומד על 17.7%. כ-GW 400 חשמל המיוצרים ב-452 כורים גרעיניים ב-31 מדינות בעולם. ניתן לראות כי כמעט בכל מדינות ה-OECD (למעט יפן שנאלצה לסגור את רב תחנות הכוח שלה בעקבות אסון פוקושימה) חלק החשמל המיוצר באנרגיה גרעינית עולה על הממוצע העולמי. נכון להיום היקף ייצור החשמל מאנרגיה גרעינית גדל, אם כי הוא גדל בקצב קטן מהגידול בסך צריכת החשמל, כך שחלקו בתמהיל יורד. תהליך זה נתמך על ידי דעת הקהל הציבורית וחלק מהגופים הירוקים. בכל הקשור למשק האנרגיה ישראלי, יש לבחון את היתרונות והחסרונות של הטכנולוגיה כמו גם את מידת הישימות של הטמעתה במשק הישראלי.

אתגרי השטח שמביאים איתם פיתוח מואץ של טכנולוגיות ייצור בפאנלים סולריים מחייבים שימושים דואליים. בעולם, וגם בישראל, ניתן לראות שימושים דואליים נפוצים על גגות בתים ומאגרי מים, אולם בשנים האחרונות מתפתחת מגמה נוספת של שימוש כפול בשטחי חקלאות, או "אגרי-וולטאי". נמצא כי ניתן לייצר חשמל סולארי מעל שטחי חקלאות תוך פגיעה מזערית בגידולים, ולעיתים אף תוך שיפור התנובה. בישראל עוצמת קרינת השמש, וביחוד בדרום הארץ, הינה גבוהה מאד ולעיתים אף חזקה מידי עבור הגידולים. בנוסף, הצמח זקוק לכמויות קרינה משתנות לאורך חייו ולא תמיד זקוק למלוא עוצמת הקרינה. ניתן להקים מערבות סולאריות מעל לשדות חקלאיים תוך בקרה מדויקת של חלוקת הקרינה בין הצמח למערכת הסולארית, כך שהצמח יקבל את כל צרכי הקרינה להם הוא נדרש, והמערכת הסולארית תנצל את השאר להפקת אנרגיה. היות ובישראל כארבעה מיליון דונם של אדמות חקלאיות, שימוש בחלק זעיר משטח זה יאפשר את השגת יעדי האנרגיה תוך פגיעה מינימלית בשטחים הטבעיים או בחקלאות. ייצור סולארי בשטחי החקלאות יאפשר בנוסף שיפור הוודאות הכלכלית של החקלאים התלויים כיום באיתני הטבע ובתמיכה ממשלתית.

משק החשמל בישראל

בשנים האחרונות קודמו במשק החשמל מספר צעדי מדיניות שתרמו משמעותית למעבר למשק אנרגיה נקי. בין צעדים אלה ניתן למנות את מעבר המשק לגז הטבעי, הגדלת יעדי האנרגיה מתחדשת וצמצום משמעותי של השימוש בפחם. כמו כן בתחילת שנת 2018 הכריז שר האנרגיה דאז על תכנית ליעדי משק האנרגיה לשנת 2030. היעדים כוללים את הפחתת השימוש במוצרי דלק מזהמים ובפרט הפסקת השימוש בפחם וכן יעדים אגרסיביים במעבר לתחבורה חשמלית. בשנת 2018 אושרה גם רפורמה מקיפה, בעלת השלכות משמעותיות על משק החשמל, במסגרתה הוסכם על ביצוע שינוי מבני מקיף בחברת החשמל. כחלק מהרפורמה, מקטע הייצור יעבור ברובו לבעלות פרטית, מקטע האספקה ייפתח לתחרות וניהול המערכת יעבור מחברת החשמל לישראל לחברה ממשלתית חדשה-מנהל המערכת. כמו כן, במסגרת הרפורמה הוחלט על מכירת 5 תחנות כוח בשנים הקרובות מחברת החשמל ליצרנים פרטיים כמו גם על סגירת יחידות 1-4 בפחמיות בתחנת הכח בחדרה והקמת שני מחזמ"ים במקומן על ידי חברת החשמל.

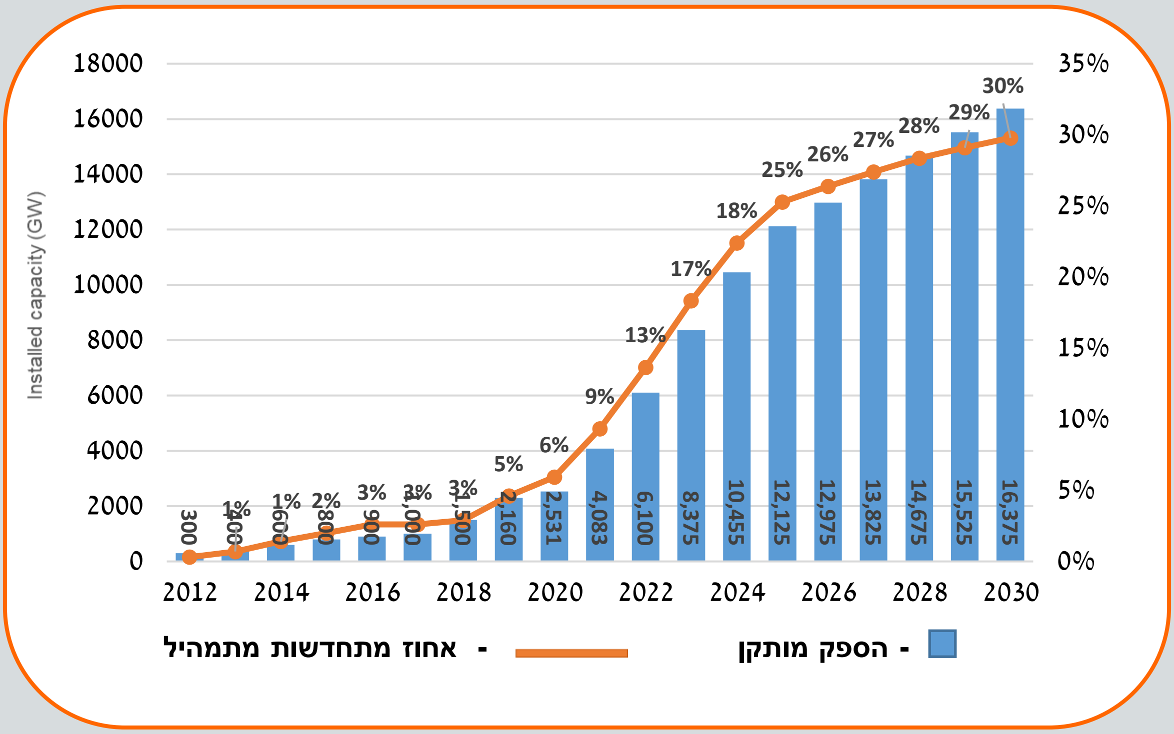
יעד הפסקת השימוש בפחם הוא צעד המדיניות האחרון בשורה של צעדי מדיניות במגמה להפחית את הזיהום וייצור החשמל בפחם. בשנת 2015 החליט שר האנרגיה להפחית את השימוש בפחם ב15%. במסגרת היתרי הפליטה שניתנו בספטמבר 2016 לתחנות הפחמיות, על ידי המשרד להגנת הסביבה, הוגבל הייצור פחמי בכל היחידות עד השלמת הקמת המתקנים להפחתת פליטות. בשנת 2017 החליט שר האנרגיה דאז לבטל את פרויקט D ולא להקים תחנת כח פחמית נוספת בישראל. עוד באותה השנה החליט שר האנרגיה על הפעלה מינימלית של התחנות הפחמיות. החלטה זו הביאה לעבודה בעומס מינימלי בתחנות הפחמיות במשך מרבית שעות השנה. ב -2018, החלטת ממשלה 4080 , קבעה כי יחידות 1-4 באורות רבין יפסיקו לפעול עד יוני 2022 וחלף יחידות אלו יוקמו על ידי חברת החשמל באתר זה 2 תחנות כח מסוג מחז"מ.

תחום האנרגיות המתחדשות עבר גם הוא תהפוכות משמעותיות בעשות האחרון. בנובמבר 2002 נקבע לראשונה יעד רשמי לייצור חשמל באנרגיות מתחדשות, בהחלטת ממשלה 2664 שקבעה כי החל משנת 2007, 2% מהחשמל המסופק לצרכנים ייוצר על ידי מתקני אנרגיה מתחדשת. בינואר 2009 החלטת ממשלה מס' 4450 קבעה יעד לייצור חשמל מאנרגיה מתחדשת בהיקף של 10% מצורכי האנרגיה בחשמל של המדינה לשנת 2020. כמו כן, בהחלטה נקבע יעד ביניים של 5% בשנת 2014 אשר לא הושג. ההחלטה כללה שורה של צעדים תומכי מדיניות, בעיקר בתחום הקצאת הקרקעות ותמריצי מיסוי, וכן במסגרתה הוטל על רשות החשמל לבחון אסדרות שיאפשרו את יישום המדיניות. בספטמבר 2015, התקבלה החלטת ממשלה מס' 542 בעניין הפחתת פליטות גזי חממה וייעול צריכת האנרגיה במשק. בין היתר קבעה ההחלטה יעד ייצור חשמל מאנרגיה מתחדשת בשיעור של 17% לפחות מסך צריכת החשמל בשנת 2030 וכן יעד ביניים של 13% בשנת 2025. בהמשך

להחלטה 542, התקבלה באפריל 2016, החלטת ממשלה מס' 1403 אשר כללה שורת צעדים אופרטיביים למימוש יעדי הממשלה בתחומי המיסוי, המקרקעין, האסדרה ועוד.

במקביל, לאורך העשור האחרון אושרו החלטות נוספות על ידי הממשלה וכן על ידי שר האנרגיה דאז אשר קבעו מכסות לטכנולוגיות השונות - תרמו סולארי, פוטו-וולטאי, רוח, ביוגז וביומאסה. כאשר לאורך השנים התמהיל שונה באמצעות הסטות בין המכסות ותוספות.

באוקטובר 2020 התקבלה החלטת ממשלה מס' 465 אשר קובעת יעד חדש של 30% ייצור חשמל מאנרגיות מתחדשות בשנת 2030 וכן יעד ביניים של 20% בשנת 2025. עוד קובעת ההחלטה שורה של צעדי מדיניות לעמידה ביעדים. להלן תרשים 19 המתאר את ההספק המותקן משנת 2012 ועד להספק החזוי בשנת 2030 (עמודות) וכן את אחוז הייצור באנרגיות מתחדשות (בקו). הגרף מראה את האתגר הגדול ביעד המתחדשות- הכפלת ההספק פי 6 בתוך עשור. הגדלת הספק האנרגיה הסולארית באופן משמעותי כל כך נובעת מאחד האתגרים הגדולים ביותר של המשק הישראלי – ביקוש החשמל שנמצא במגמת עלייה עקבית לאור צמיחת המשק והגידול באוכלוסייה בישראל.



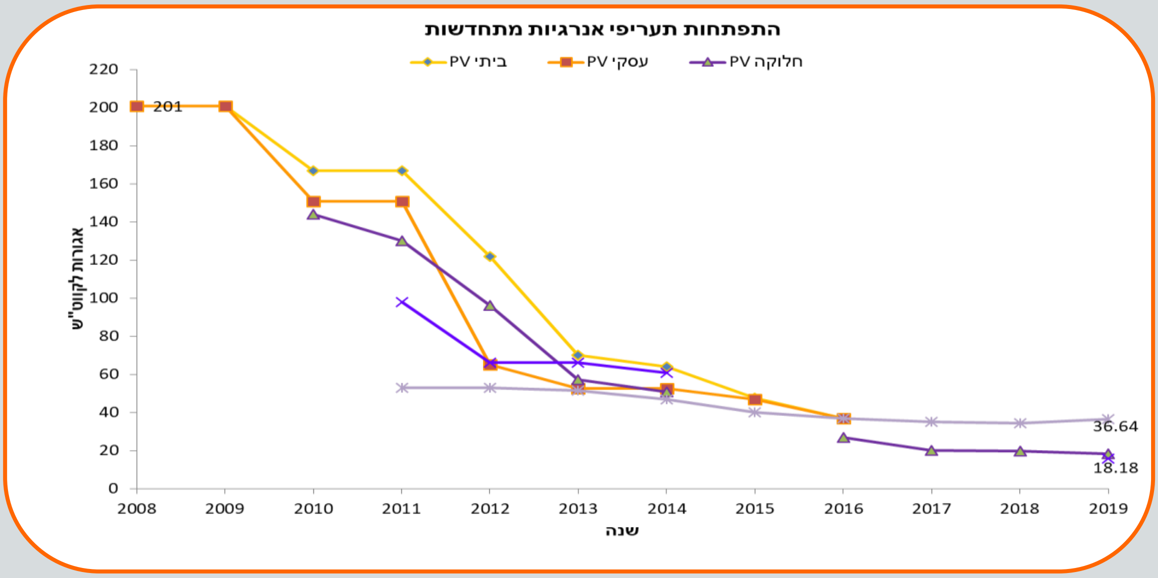
תרשים 19: תחזית ההספק המותקן באנרגיות מתחדשות, רובה המכריע מהשמש, לעשור הקרוב. עיבוד לעבודת רשות החשמל, 2021.

עוד נציין כי ייצור חשמל מאנרגיית שמש בהיקפים גדולים בישראל כרוך באתגרים רבים הנוגעים בין השאר בהיבטים תכנוניים, סביבתיים, פיננסיים וטכנולוגיים, אשר מתאפיינים בהשפעה מכרעת על משק החשמל. העלאת הייצור מאנרגיית שמש בישראל תדרוש היקף נרחב יחסית של השקעות

בשנים הבאות, תוספת עלויות ישירות ועקיפות הנובעות משילוב אנרגיות מתחדשות במערכת ומגולמות בתעריף החשמל המשולם על ידי כלל הצרכנים. עוד נציין כי הגדלת הייצור מאנרגיה סולארית תצריך מספר צעדי מדיניות משלימים ובראשם הצורך האדיר באגירה אשר תאפשר את המעבר למתחדשות וכן צפויה לתרום רבות לחיסכון בסוגיית הרשת וייצוב התדר, כמו גם צעדים להתמודדות עם ההשפעות על יציבות ושרידות מערכת החשמל, ביטחון באנרגיה, הקצאת משאב הרשת ועוד.

במסגרת בחינת עדכון יעד המתחדשות לשנת 2030 סימנה רשות החשמל בעבודתה שתי מגמות עיקריות במשק הישראלי: ירידת מחירי האנרגיה הסולארית וכן עדכון תמהיל הייצור המתחדש – מתחזית מגוונת של טכנולוגיות להסתמכות כמעט מוחלטת על אנרגיית שמש. בנוסף מציינת הרשות כי חלו שינויים רגולטוריים משמעותיים בראשם המעבר למתכונת אסדרתית של מכרזים תחרותיים.

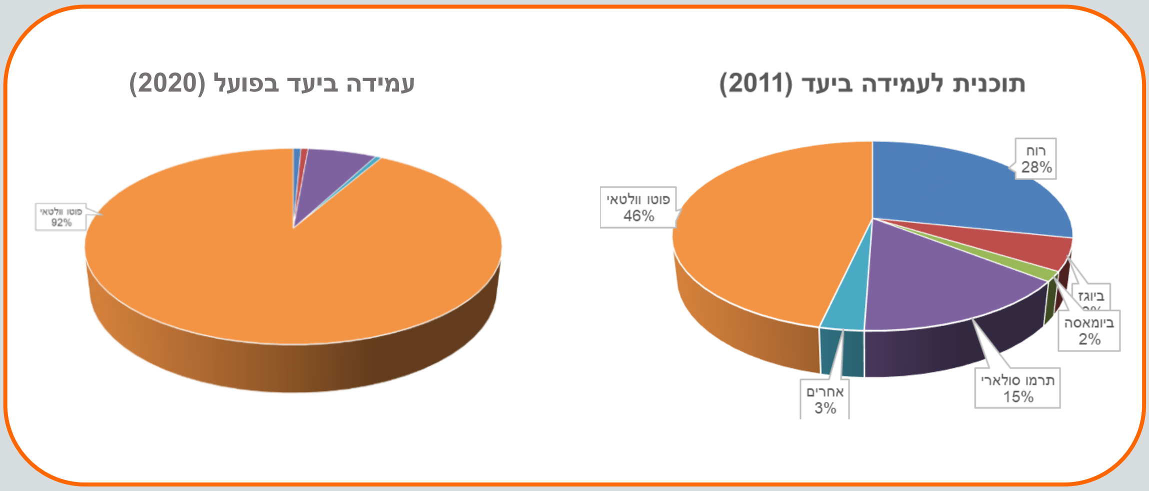
כאמור, בעשור האחרון חלה ירידה חדה בעלות ההקמה של מתקני ייצור בטכנולוגיה הפוטו-וולטאית, בהתאם לירידת המחירים העולמית, נרשמה הפחתה עקבית בתעריפים המשולמים בישראל למתקני ייצור בטכנולוגיה פוטו-וולטאית כמוצג בתרשים 20. בתרשים זה מפורטים מחירי המכרזים שהוציאה הרשות בחלוקה לפי סוגי המכרזים השונים.



תרשים 20: תעריפי אסדרות פוטו-וולטאיות על פני השנים 2008-2019. רשות החשמל

עלפי רשות החשמל ירידת המחירים החדה בישראל בטכנולוגיה הפוטו-וולטאית אינה מאפיינת את יתר הטכנולוגיות. בנוסף לכך נראה כי האתגרים וחסמים תכנוניים, סביבתיים וביטחוניים שונים הביאו לקושי במימוש של מכסות הרוח, הביוגז והביו-מאסה. באשר לטכנולוגיה התרמו-סולארית, למעט המתקנים אשר הוקמו במסגרת פרויקט אשלים על ידי המדינה, יתר המכסות הוסבו למכסות פוטו-וולטאיות בשל שיקולים כלכליים.

מתוך כך, לאור השינויים הטכנולוגיים והכלכליים שחלו בעשור האחרון, ולאור החסמים והאתגרים הייחודיים שחוו חלק מהטכנולוגיות בארץ, עודכנה על פני השנים התכנית לעמידה ביעד המתחדשות. תרשים 21 מציג השוואה בין התכנית המקורית למימוש יעד 2020 כפי שהוצגה בתחילת העשור, לעומת האופן בו יושג היעד בפועל עד סוף השנה הנוכחית. כפי שניתן לראות, על רקע אי-הודאות בתכנון ארוך-טווח, התכנית המקורית התאפיינה במגוון רחב של טכנולוגיות ומקורות ייצור לעומת התכנית הנוכחית, בה קיימת דומיננטיות טכנולוגית מובהקת למתקנים הפוטו-וולטאים ביחס ליתר הטכנולוגיות.



תרשים 21: תכנית העמידה ביעד אנרגיות מתחדשות בראשית העשור לעומת אופן העמידה ביעד בפועל.

מתוך כך, בהיעדר פוטנציאל לייצור אנרגיה מתחדשת ממקורות קבועים כגון מקורות הידרו-אלקטריים וגיאותרמיים, ובשל החסמים הרבים הנוגעים לקידום מתקנים בטכנולוגיות אחרות, ההנחה בבסיס העבודה היא שתוספת ההספק הנדרש למשק תהיה ברובה המוחלט באמצעות מתקני ייצור סולאריים. למרות היתרונות הכלכליים של ייצור סולארי ומאפייני האקלים בישראל, קיימת מורכבות רבה בניהול מערכת חשמל המסתמכת באופן כמעט בלעדי על מקור אנרגיה מתחדשת אחד בלבד, בפרט סירוגי (שאינו ניתן לשליטה על ידי מנהלי הרשת ואינו בעל כושר אספקה רציף). לאור האמור, יש חשיבות רבה להסרת חסמים בכדי להקל על שילובם של מתקנים פוטו-וולטאים, לקידום סוגים נוספים של אנרגיות מתחדשות ובפרט טכנולוגיית הרוח, לשימוש באמצעי ייצור נוספים ובאמצעים נוספים להפחתת פלטות הפחמן הדו חמצני, כמו גם לשימוש במתקני אגירה לצורך קליטת עודפי ייצור סולארי והגמשת מערך הייצור.

על רקע העלאת אחוז הייצור באנרגיית שמש הולך ומתעצם אתגר השטח. בהשוואה לייצור קונבנציונלי, כמות האנרגיה שמיוצרת לתא שטח באמצעות מתקנים פוטו-וולטאים נמוכה משמעותית (תא השטח הנדרש לייצור מגה וואט סולארי גבוה פי 100-150 מתא השטח הנדרש לייצור חשמל מגז

טבעי). יצוין בהקשר זה כי מוקדי הצריכה העיקריים מרוכזים באזור המרכז, בעוד שפוטנציאל השטחים הפנויים הגדול ביותר להקמת מתקני ייצור קרקעיים נמצא באזור הדרום, בו צריכת החשמל היא נמוכה. כתוצאה מכך, נדרש פיתוח משמעותי של רשת ההולכה לצורך העברת האנרגיה ממוקדי הייצור למוקדי הצריכה.

על מנת לשלב אחוז גבוה של ארגיה מתחדשת בתמהיל הדלקים, יש צורך בשטחי קרקע נרחבים, על כן יש צורך בשיתוף פעולה לשם מקסום השימוש הכפול בקרקע לייצור סולארי, כמו גם להגיע להסכמות לגבי הקצאת שטחים פתוחים בין משרדי הממשלה השונים (משרד האוצר, רשות מקרקעי ישראל, מנהל התכנון, המשרד להגנת הסביבה).

<u>למעשה ניתן לחלק את השפעות שימושי הקרקע באופן הבא:</u>

1. תשומות כלכליות – הקרקע הינו משאב שערכו נקבע על פי השימוש ומקומו הגאוגרפי ועל כן לשטחים שונים ערך כלכלי שונה.
2. סביבה – לקרקע ערך נופי ואקולוגי. ישנה חשיבות רבה בשימור קרקע בצורתה הטבעית על מנת לשמר את האיזון האקולוגי לרווחת בעלי החיים ופעילות אנושית.
3. פיתוח – ישנה תחרות רבה על פיתוח הקרקע לצרכי האדם: מבני מגורים, תעשייה, תחבורה, מסחר, בטחון ותשתיות חיוניות. לעיתים קרובות שטחים מוגדרים לא יוכלו לשמש לצרכים נוספים (דו שימוש בקרקע).

במסגרת העבודה נדון באופן תאורטי בסוגיית הקרקע אולם יש לבצע עבודת המשך אשר בוחנת את העלויות וההשפעות על הייצור הסולארי בשנים הקרובות בעניין זה.

על מנת לזהות את פוטנציאל השטח שיאפשר העלאת יעד המתחדשות ל30% בשנת 2030 , ביצעה רשות החשמל הערכה ראשונית של פוטנציאל השטחים להקמת מתקני ייצור פוטו-וולטאים לצורך מימוש יעד הביניים של 30% אנרגיה מתחדשת בתמהיל האנרגיה בשנת 2030[19]. מובן שפוטנציאל השטחים העתידי תלוי בשיקולים ובגורמים רבים כמו גם בהתפתחויות טכנולוגיות.

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[19] https://www.gov.il/he/departments/publications/Call_for_bids/shim_2030yaad

הערכת סך פוטנציאל השטחים להקמת מתקני ייצור סולאריים מפורטים בטבלה הבאה:

לוח 3: פוטנציאל השטח וההספק על פי סוג

סוג פוטנציאל	פוטנציאל בדונם	הספק (MW)
קרקעי[20]	84,920	8,416
גגות	41,933	5,079
מאגרים	45,888	5,558
מחלפים	2,420	240
שימושים דואליים נוספים	5,000	606
סה"כ	**180,161**	**19,898**

מתוצאות אלו ניתן ללמוד כי קיים פוטנציאל שטח שיאפשר עמידה ביעד של 30%. עם זאת, היקף הפוטנציאל שמופה הוא בעל יתירות מצומצמת באופן יחסי וכדי לעמוד ביעד יש למצות אותו כמעט עד תום. מנגד, פוטנציאל זה עשוי לגדול בשל שטחים נוספים אפשריים, הן דואליים והן קרקעיים, שנסקרו אך לא נלקחו בחשבון במסגרת העבודה עקב אי וודאות ביחס ליכולת לממש אותם. מיצוי פוטנציאל זה והגדלתו תתאפשר רק על ידי טיפול בחסמים הרלוונטיים וקידום משלים של צעדי רגולציה וכן מדיניות ממשלתית אשר תעודד הקמת אנרגיות מתחדשות בשטחים דואליים נרחבים כגון חקלאות וכבישים.

ואכן לאחרונה משרד האנרגיה ומשרד החקלאות, בשיתוף משרדים וגופי ממשל נוספים, מקדמים בימים אלו הקמה של מערכות אגרי-וולטאיות ראשונות בהן תיחקר השפעת המערכות הסולאריות על הגידולים שמתחתן ויפותחו ממשקים חקלאיים אופטימליים בתנאים אלו. בישראל, קיימת חקלאות מתקדמת וגם יכולת טכנולוגית מפותחת, השילוב בין השתיים עשוי למצב את המדינה בחזית תחום האגרי-וולטאי המתפתח במהירות בעולם ולהוות עוד ענף ייצוא ומנוע צמיחה למשק. אם כך, עקב מיעוט השטחים הטבעיים בישראל, פיתוח יכולת אגרי-וולטאית הינו רכיב מפתח ביכולת להשגת יעדי משק האנרגיה, אך בד בבד מהווה הזדמנות כלכלית ייחודית לפיתוח מובילות עולמית.

אתגרי המעבר לאנרגיית שמש בראשם אתגר השטח הם המפתח לקביעת יעדי המשק וכן הם מכריחים, בין היתר, את הצורך בתכנון תשתיות אנרגיה יעיל ומקיים.

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[20] מתוך זה, פוטנציאל קרקעי בשטחי יהודה ושומרון, שטחי אש וקרקעות בדואים פרטיות עומד על 50,000 דונם, הספק של MW/ 8,416

תכנון תשתיות על רקע המחסור בשטח

תכנון תשתיות אנרגיה היא משימה מורכבת, אחד האתגרים המשמעותיים הוא התחרות על משאב הקרקע. ישראל היא מהמדינות הצפופות בעולם, עם ממוצע של 405 תושבים לקילומטר מרובע. יתרה על כך, תחזית הצמיחה של הלמ"ס מלמדת כי אוכלוסיית ישראל צפויה להכפיל את עצמה עד לשנת 2065, אז יחיו בישראל כ-20 מיליון איש. בהתאם לכך, מקודמות עשרות אלפי יחידות דיור אשר צפויות לתת מענה לתחזיות אלו. לכך יש להוסיף את אספקת התשתיות הדרושות לאותן יחידות דיור באמינות גבוהה וביתירות.

בשנים האחרונות פועל משרד האנרגיה בשיתוף עם משרדי הממשלה השונים ושותפים נוספים לתכנון תשתיות תוך עידוד הייעול בשטח לייצור אנרגיה והולכתה וכן להסרת חסמים לעידוד הקמה של אנרגיות מתחדשות. בין הצעדים הרבים שקודמו ניתן למנות הסרת חסמים בעולמות המקרקעין והמיסוי וכן קידום של תמ"אות ייעודיות להגדרת שטחים לאנרגיות מתחדשות.

בראייה צופה פני עתיד, מורכבות תכנון התשתיות רק הולך ומתעצם על רקע השאיפה להגדיל חלקן של האנרגיות המתחדשות בתמהיל הייצור, שיתבסס על חשמל סולארי שמאופיין ב: 1) צורך בשטחים נרחבים ביחס לייצור באמצעים אחרים; 2) ייצור חשמל מבוזר; 3) צורך באיתור שטחים עבור רשת חשמל מבוזרת בפריסה רחבה.

רשת החשמל מהווה תשתית לאומית עיקרית וחיונית שתפקידה, בין היתר, להעביר את האנרגיה המיוצרת בתחנות הכוח אל מרכזי הצריכה ברמת האמינות והאיכות הנדרשת. פיתוח מערכת ההולכה וההשנאה נדרש על מנת לתת מענה להתפתחות הביקוש הצפוי במשק החשמל, הצורך בשדרוג הרשת לשם הגברת שרידות המערכת, אמינות ויתירות ההספקה ולחיבור של מתקני ייצור ובכללם מתקני ייצור באמצעות אנרגיה מתחדשת הנדרשים למשק החשמל. יחידת תכנון ופיתוח טכנולוגיות (תפ"ט) בחברת ניהול המערכת אחראית על תכנון מערכת ההולכה בהתייחס לביקוש הצפוי במשק החשמל על פי אזורים גיאוגרפיים, טכנולוגיות הייצור תוך שמירה על שרידות ואמינות האספקה.

פרויקטים במקטע ההולכה מקודמים במסגרת תכניות מתאר ארציות בהליכי תכנון במועצה הארצית או בוועדה לתשתיות לאומיות (ות"ל). מעבר לקושי המערכתי בפיתוח מקטע ההולכה, הליך התכנון של הפרויקטים כולל חסמים רבים ואורך זמן רב. קושי זה הולך וגובר עם העלייה במגמה של ביזור ייצור החשמל, מאידך העיכובים בפיתוח הרשת מונעים הקמה של מערכות ייצור, ובפרט מערכות סולאריות בדרום.

הרשת צריכה לתת מענה לקליטת אנרגיה מכל מתקני הייצור ולהעבירה ממוקדי הייצור אל מוקדי הצריכה, הוספה של מתקנים פוטו-וולטאים בהיקף של אלפי מגה-וואט מחייבת התאמה של פיתוח הרשת והגדלת היקף ההשקעות במקטעי הרשת.

קושי נוסף נובע מכך שעיקר הייצור הסולארי מרוכז בכ-5 שעות ביום בממוצע, כך שייצור סולארי דורש הספק הולכה מרבי גבוה פי 3 לערך ביחס לייצור דומה ממקורות קונבנציונליים. יוצא מכך שהגדלת הייצור הסולארי מטילה דרישות כבדות על הרשת. שימוש משמעותי באגירה יכול להפחית דרישות אלו ולכן יש לתכנן את הרשת במקביל לתחזיות הייצור הסולארי והאגירה.

בהתאם לזאת, יש צורך חיוני בצמצום תפיסת השטח של תשתיות הייצור והובלת האנרגיה בהתייחס לאנרגיות מתחדשות וכן בקידום איחוד של תשתיות במנהרה. במסגרת עבודה זו נבחנו שלושה נושאים משמעותיים לקידום ייעול השימוש בקרקע:

מקסום ייצור אנרגיה בשטחים מבונים – ייעול השימוש בקרקע וחיסכון בתוספת מערכות הובלת חשמל ע"י שימוש דואלי בשטחים הבנויים.

הטמנת קווי מתח עליון- רשת הולכה תת קרקעית שתנקז ותוליך את האנרגיה המתחדשת מאזורי הייצור הבינוניים והגדולים אל אזורי הביקוש ובכך תפנה רצועות קרקע לטובת שימושים אחרים.

תכנון והקמת מנהרות תשתית רב מערכתיות (Multi System Utility Tunnels) שתאחד מספר תשתיות בתת הקרקע.

תכנון אנרגיה נקייה בשטחים מבונים ושימוש דואלי

הפקת חשמל נקי מפליטות בשטחים מבונים מייעלת את השימוש בקרקע (דו-שימוש בקרקע) ומצמצמת פגיעה בשטחים לצורך הגדלת יכולת הייצור ותוספת הולכה. לצד אלו קיימים יתרונות נוספים כגון צמצום איבוד חשמל[21] בהולכה וביזור הייצור. הטמעת הנושא בהליך התכנון של השטחים המבונים, יסייע בהפיכת ייצור חשמל נקי בשטחים אלו לפרקטיקה נפוצה.

שר האנרגיה דאז החליט כאמור על הגדלת חלקן של האנרגיות המתחדשות בתמהיל ייצור החשמל ל-30% עד לשנת 2030. המענה התכנוני להפקת חשמל נקי סולארי בכלל, לרבות בשטחים מבונים ניתן על ידי "תכנית מתאר ארצית למתקנים פוטו וולטאים" הקובעת את כללי קידום התכנון וההקמה של האנרגיה המתחדשת בישראל ומעודדת בין היתר דו - שימוש בקרקע, קרי הקמת מתקנים פוטו וולטאים על גבי שימושי קרקע קיימים בשטחים מבונים. בתכנית המתאר הארצית המופקדת

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[21] הגדלת יעדי ייצור החשמל באנרגיות מתחדשות לשנת 2030, עמ' 25

לתשתיות משק האנרגיה נשמרו מתחמים בהיקף של למעלה מ – 40,000 דונם לקידום תכניות מפורטות לייצור חשמל באמצעות אנרגית השמש. שטחים אלו מחולקים לשטחים שיקודמו לתכנון מפורט לשנת 2030 ושטחים שיקודמו לתכנון מפורט עד לשנת 2050. "מסמך אנרגיה לשטחים מבונים" שמקדם משרד האנרגיה בימים אלו, מתוכנן להשלים את המעטפת התכנונית בנושא ולעודד קידום ייצור אנרגיה מתחדשת בתכניות של שטחים מבונים ואפשרות להקמת מתקני אגירה.

במקביל לעידוד ייצור האנרגיה בשטחים מבונים ומתוך ראייה כוללת של ייעול השימוש בקרקע, בשנים האחרונות מעודד המשרד ביחד עם שותפיו במשרדי הממשלה השונים ייצור חשמל בשימושים דואליים (ייצור חשמל במקביל לשימוש קרקע אחר) בין היתר על מאגרי מים ובריכות דגים, במחלפים, חניונים ובתי עלמין.

בראייה ארוכת טווח נראה כי הגדלת הייצור במתחדשות אחרי שנת 2030 תצריך בחינה מחודשת של פוטנציאל הקרקע הזמינה. מתוך כך מקודמת בימים אלה בחינה מקיפה ביחד עם משרד החקלאות באשר לאפשרות לקידום ייצור אנרגיה סולארית במקביל (מעל לרוב) לגידולים חקלאיים (אגרי- וולטאי).

<u>הטמנת קווי חשמל – מתח עליון</u>

השאיפה להגדיל את חלקן של האנרגיות המתחדשות בתמהיל הייצור צפויה להגדיל את ביזור הייצור ולחייב פיתוח רשת הובלת חשמל רחבה. קידום תכנון של קווי מתח עליון (161 ק"ו) ועל עליון (400 ק"ו) הופך למשימה מורכבת שאורכת שנים רבות[22] וזאת בין השאר מהסיבות הבאות: התרחבות השטחים הבנויים, צפיפות הולכת וגדלה, פיתוח תשתיות מואץ ותחרות על אותן רצועות קרקע, ביזור הייצור ובעקבות אלו קושי לאתר תוואים ולהתגבר על חסמים. המופע העילי של תשתית החשמל והחשש מהקרינה והפגיעה הסביבתית, מעוררים קושי ודרישה להרחיק את הקווים מאזורים בנויים ככל הניתן, דרישה המתנגשת עם עקרון הצמדת התשתיות וגורמת לתפיסת שטח רבה יותר ולהליך תכנון ארוך ומסורבל.

הטמנה של קווי מתח חשמל ובפרט קווי הולכה המוגדרים כקווי מתח מוטמנים הינה פרקטיקה מוכרת זה מספר עשורים. יחד עם זאת מדיניות משרד האנרגיה בשנים האחרונות תמכה בהטמנת קווי מתח עליון רק בשטחים בנויים צפופים עקב העלויות הגבוהות במיוחד, לעומת החלופה הרווחת של פיתוח והקמת קווי מתח עיליים. נכון להיום, מעגלי כבלי הולכה תת-קרקעיים של 161 ק"ו מהווים בשלושה אחוזים (3%) מסך כל מעגלי רשת ההולכה של קווים אלו. לצורך השוואה, נערכה

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[22] בממוצע יותר מ – 8 שנים לאישור תכניות של רשתות אזוריות/ארציות

בדיקה במאגר מיפוי תשתיות ההולכה האמריקני והאירופאי ונמצא כי אחוז קווי ההולכה המוטמנים בארה"ב עומד על כארבעה אחוזים (4%), ואחוזים בודדים משוערים באירופה[23]. בדומה לאחוז ההטמנה בישראל.

הסיבות העיקריות להטמנת קווי חשמל:

1. השפעה סביבתית – הטמנת קווים מצמצמת את הפגיעה בערכי סביבה ונוף, מצמצמת הפרת שטחים פתוחים ומצמצמת פגיעה בבעלי כנף המתנגשים בתיילים. במחקר שערכה המועצה הבינלאומית למערכות חשמל גדולות (CIGRÉ)[24] נמצא כי הגורם העיקרי להתנגדות הציבור לקווי הולכה היא הפגיעה הנופית.
2. הגורם הכלכלי – צמצום רצועת שטח מגבלות פיתוח ושימוש חלופי לשטח זה. העברת קו מתח של 161 ק"ו למשל מצריך תפיסת שטח ברוחב מגבלות של 40 מטרים[25]. לעומת רצועת קו מוטמן ברוחב של 10 מטרים עם מגבלות פיתוח מצומצמות יותר. בנוסף, קיים חשש מצד בעלי נכסים סמוכים לירידת ערך של הנכסים בבעלותם. החיסכון בשטח באזורים בהם ערך הקרקע גבוה במיוחד עשויים להצדיק הטמנת הקווים.
3. אמינות ושרידות הרשת החשמלית – הקצנת תופעות מזג האוויר מדגישות את הצורך בהפחתת אירועי הפסקות החשמל על ידי הטמנת רשת ההולכה. יתרון נוסף הינו הורדת רמת החשיפה של קווי החשמל לנזקי אדם ורלוונטית מאוד בהקשר הישראלי של אזורי עימות.

אתגרים בהטמנת קווי מתח עליון

1. עלות הטמנת קווי מתח עליון - הסיבה העיקרית להימנעות מהטמנה היא העלות הגבוהה. בסיסי נתונים מחברת החשמל לישראל, התקבלו לשנים 2013 ו- 2019 והם מציגים את עלויות הקמת קווי חשמל מתח עליון עיליים (161 ק"ו) ומוטמנים באלפי ₪ לק"מ רץ (קילומטר אורך). נמצא כי יחס ההשקעה בין הטמנת קווים להקמת קווים בטווח העילי עומד על 1:7 ו- 1:4 בשנת 2013 ו-2019 בהתאמה, כאשר חלופת ההטמנה היא החלופה היקרה מבין השתיים. עם זאת, מהנתונים ניתן ללמוד כי היחס בעלויות בין קווים עיליים וקווים מוטמנים הולך ומצטמצם עם השנים.
2. איבוד חשמל בקווים מוטמנים - תופעת איבוד חשמל בקווים מוטמנים ידועה ונגרמת כתוצאה מכך שקווי המתח העליון מתחממים מהולכת החשמל[26] בשל הצימוד החזק של

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[23] https://www.entsoe.eu/data/map/ .

[24] ארגון קהילתי בינלאומי שהוקם ב 1921 אשר מטהו ממוקם בפריז. מונה קהילה של מומחים בתחומי אנרגיה מרחבי העולם. ראה: https://www.cigre.org/GB/about/introducing-cigre

[25] https://www.iec.co.il/ElectricityProfessionals/DocLib6/MERHAKIM.pdf

26 אופייני לקווי זרם חליפי (AC)

השדות המגנטיים והחשמליים עם הקרקע כך שעלול להיגרם בלאי מואץ[27] ואיבוד חשמל מוגבר ביחס לקווים עיליים. תופעה זו גורמת לכך שלא ניתן להעביר באופן מעשי קווי זרם חילופין מוטמנים למרחקים של יותר מכמה עשרות קילומטרים. עם זאת הטמנה של קווי מתח ישר, אינה גוררת הפסדים משמעותיים.

3. תוואי השטח, תקלות ושדרוג/שחלוף קווים - בשונה מקווים עיליים, בעת הטמנה קיימת חוסר וודאות לגבי תוואי השטח בתת הקרקע עד לחפירה בשטח. ישנו קושי נוסף לשנות תוואי של קו מוטמן בשל אילוצים דוגמת תשתיות מוטמנות אחרות, בעלות על הקרקע ובטיחות הקו. באופן רוחבי - מאחר ודרוש זמן רב יותר לאתר תקלות בקו מוטמן, כמו גם לחפור בשטח ולתקן אותן; בשונה מקו עילי, תיקון תקלות בתת הקרקע עלול לקחת זמן ארוך (שבועות וחודשים) ולפגוע באמינות האספקה לאורך זמן רב. על כן, כאשר יש צורך בשדרוג, או שחלוף קו מוטמן - נוטים להחליפו בקו חדש לחלוטין (לעיתים באתר סמוך) כך שהתהליך הופך ליקר בניגוד לפירוק קו עילי והחלפתו.
4. תוחלת החיים של קווי החשמל- בניגוד לטענה כי תוחלת החיים של קווי המתח המוטמנים גבוהה יותר, ישנן אינדיקציות שונות מחברות תפעול ותחזוקה כי תוחלת החיים של קווי המתח המוטמנים נמוכה משמעותית ואף מגיעה לפער של כ 50% לעומת קווי הולכה עיליים. מבחינה תפעולית עולים מספר קשיים בהטמנת קווי מתח אשר מהווים אנטי-תזה לטענות בעד הטמנת קווי ההולכה[28]. ראשית, ישנו קושי בהגעה לטיפול בקווים, דבר אשר יכול להגיע במקרים קיצוניים למצב של ניתוק הצרכנים לפרקי זמן ממושכים. שנית, קיימת מגבלת מרחק ידועה בהטמנת קווי מתח המבוססים על זרם חליפי (AC) כך שיכולת העברת המתח מוגבלת למרחק של קילומטרים ספורים. בנוסף נטען, כי הטמנת הקווים מייצרת סיכונים סביבתיים משלה כגון סכנת התפוצצות תת קרקעית בשל התחממות יתר של קווי ההולכה, אי חסינות מאירועי שיטפונות, רגישות גבוהה יותר לאירועי רעש אדמה וחשיפה לאירועי אקלים מסוימים כגון סופות ברקים (למרות ההטמנה).

מנהרות תשתית רב מערכתיות Multi System Utility Tunnels

מנהרת תשתית רב מערכתית הינה מבנה תת קרקעי הכולל קווים ומתקנים נלווים של תשתיות ומאפשר הקמה, תחזוקה, ניטור והחלפה של כל אחד מקווי התשתית ללא צורך בחפירה נוספת. בעולם קיימות מנהרות תשתית במדינות רבות, כאשר המניעים להקמתן מגוונים. נערכה סקירה

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[27] המשמעות של בלאי מואץ מתורגמת בעלות לתחזוקה תכופה יותר וצורך בכבל נוסף להעברת הספק החשמל שאבד, כך שנוצרת עלות נוספת על פני הקמת קו עילי באותו הספק.

[28] https://www.chelanpud.org/docs/default-source/commission/underground-vs-overhead.pdf

כללית של מנהרות התשתית בעולם[29]. מהסקירה ניתן ללמוד כי מנהרות תשתית רב מערכתיות מוקמות בעיקר במקומות בהם ישנו מחסום פיסי, כאשר ישנה התנגשות עם תשתיות אחרות ובאזורים המאוכלסים בצפיפות. אורכן של מנהרות התשתית שנסקרו נע בין מאות מ' לקילומטרים בודדים והן משלבות בין תשתיות הולכה לתשתיות חלוקה כתשתית נלווית. קיים מספר גדול של מנהרות תשתית רב מערכתיות במתחמים סגורים, כאשר יש יותר מנהרות תשתית חד מערכתיות מאשר מנהרות תשתית רב מערכתיות.

יתרונות מנהרת תשתיות רב מערכתיות

1. ניצול תת הקרקע למספר תשתיות בצוותא– העברת מספר התשתיות במנהרה, מאחדת את המגבלות של התשתיות, מסירה מגבלות פיתוח מעל פני השטח, מפנה ומשחררת שטחים על פני הקרקע ומאפשרת פיתוח וניצול השטח העל קרקעי לשימושי קרקע חלופיים.
2. תחזוקה, בקרה ותפעול נוחים יותר – המנהרות מכילות מעברים ומסדרונות שירות אשר מאפשרים לטפל ולתחזק את התשתיות מבלי שיהיה צורך לחפור את פני הקרקע. הדבר מאפשר גם בדיקה שוטפת וניטור קל יותר של דליפות למשל וכן תחזוקת התשתית באופן שוטף ללא צורך בחפירה ועל כן הפסקת השירות בעת התחזוקה היא לזמן קצר יחסית.
3. עלויות שמירה, אבטחה ותפעול נמוכות יותר – מאחר והמנהרות מקבצות כמה תשתיות יחד, השמירה האבטחה והתפעול יעשו במשותף והעלויות יחולקו בין בעלי התשתית.
4. צמצום חשיפה לקרינה אלקטרומגנטית - קווי חשמל במנהרות תשתית, בתת הקרקע מצמצמים ומונעים חשיפה לשדות אלקטרומגנטיים.
5. צמצום פגיעה בתנועה לצרכי תחזוקת תשתיות בשטחים צפופים - מנהרות תשתית בשטחים מבונים, מצמצמות את הצורך לחפור כדי להגיע לתשתית שמתחת לדרכים בכדי לתחזק אותה ובכך מונעים פגיעה בתנועה, בעולם יתרון זה מקבל משקל גבוה לתשתיות שנמצאות באזורים צפופים לאורך כבישים ומתומחרות כחלק מכדאיות הכלכלית להקמת המנהרה.
6. צמצום מפגעים נופיים והפחתת עומס ויזואלי – מנהרת התשתית היא בתת הקרקע, אזי אין פגיעה ויזואלית ונופית. מאחר והיא נגישה אין צורך לחפור בשטח, קרי לפגוע בנוף, בכדי לגשת אל המנהרה, פרט כמובן לתקופת הקמתה.
7. צמצום סיכוני חומ"ס - הובלת חומ"ס במנהרת תשתית מפחיתה את הפוטנציאל לזיהום הקרקע ומי התהום ביחס לצנרת חומ"ס קונבנציונלית.

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[29] הולנד, צרפת , פינלנד, סינגפור, דרום קוריאה, דובאי, בריטניה, ספרד.

לישראל מספר מאפיינים מיוחדים המשפיעים על הקמת מנהרות תשתית:

1. מציאות ביטחונית מורכבת –מתקני תשתית גדולים, ו/או מנהרות הכוללות תשתיות בעלי חשיבות לאומית היוו ומהווים מטרה אסטרטגית, וזאת בשל הרצון לפגוע ברציפות התפקודית ובכך להביא לפגיעה בכלל המשק. לפיכך, בפרויקטים של מנהרות תשתית רב מערכתיות נדרש לתכנן את המנהרה כך שתעמוד באיומי הייחוס. מנגד, האיום ביטחוני עשוי להצדיק ואף לדחוף לשימוש במנהרות תשתית באזורים מסוימים במדינה לצורך הגנתם.
2. מבנה משק התשתיות בישראל - בישראל, מרבית חברות התשתית הינן חברות בבעלות ממשלתית, הכפופות לרגולציה מטעם רשויות המדינה, בעיקר כשהדבר נוגע לתקציב החברות. מצב זה שונה ממבנה משק התשתיות במדינות מערב אירופה, בארה"ב ואף ביפן, בהן יש דומיננטיות לשוק הפרטי. שיתוף פעולות בין חברות התשתית ובין רשויות התכנון, דורשת מעורבות של משרדי הממשלה, בעיקר סביב נושא השתתפות החברה במימון עלויות ההקמה של המנהרה, הנושא נעשה סבוך עוד יותר כשמדובר בעלויות של העתקת תשתיות.
3. ביטוח מנהרות התשתית - במרבית המקרים, תשתיות ציבוריות, מחזיקות בביטוח מקיף, הכולל את כל רכיבי הפרויקט. מנהרות התשתית הרב מערכתיות, ברוב מדינות העולם, קיבלו התייחסות דומה לכלל מבני התשתית (כמו לדוגמה גשר, קו חשמל או צינור מים) ולא קיבלו כיסוי ביטוחי פרטני. לעומת זאת, במנהרות התשתית אשר נבנו בישראל הוחלט על כיסוי ביטוחי מלא לכל המנהרות, כולל ביטוח למבנה כמו גם ביטוחי צד ג'. בדרך זו כפי שקיים בישראל, מצטמצם הסיכון של מקימי המנהרה, יחד עם זאת, עלות הביטוח בשיטה זו, הינה גבוהה מאוד ביחס למדינות אחרות, ומביאה לגידול בהוצאות התחזוקה והבקרה של המנהרות בכ-50%.

התייעלות באנרגיה

שימוש יעיל באנרגיה מקטין את הביקוש לאנרגיה ובכך תורם לצמצום בצריכת מקורות האנרגיה ולהקטנת ההשקעות הנדרשות בתשתיות חשמל ודלקים. הנזקים העקיפים משימוש בדלק – שינויי האקלים, מחלות, תמותה עודפת, פגיעה ביבולים חקלאיים ועלויות חברתיות, כלכליות וסביבתיות נוספות, נמדדים בעלויות משקיות כבדות. מעבר לכך, מאגרי הדלק הינם סופיים ולתלות ביבוא משמעויות מדיניות וכלכליות מרחיקות לכת. שימוש יעיל באנרגיה מכונה בעולם "הדלק החמישי" מאחר והוא מחליף מקורות אנרגיה אחרים שהיו צורכים אלמלא ההתייעלות. "הדלק החמישי" הינו מקור האנרגיה הזול והנקי ביותר, שכן עלותו אפסית אך הוא בעל תועלת רבה: הפחתת הצורך בהשקעה בתשתיות חשמל ותחנות כוח, מזעור התלות ביבוא דלקים, היעדר פליטות מזהמי אוויר והעלאת החוסן האנרגטי של מדינת ישראל.

<u>הדירקטיבה האירופאית להתייעלות באנרגיה</u>

הדירקטיבה האירופאית להתייעלות באנרגיה נחשבת לדירקטיבה המקיפה ביותר שנקבעה תחת חוק האיחוד האירופאי והיא הוטמעה בחוק לאומי בכל מדינה החברה באיחוד. תחת הדירקטיבה (Energy Efficiency Directive 2012/27/EU), נקבע יעד התייעלות באנרגיה של 20% עד 2020 (בהשוואה לתרחיש עסקים כרגיל שנקבע ב-2007). יעד זה תורגם ליעדים במונחי צריכת אנרגיה אבסולוטית ראשונית – לא יותר מ-1483 Mto_e ולצריכת אנרגיה סופית – לא יותר מ-1087 Mto_e. הדירקטיבה מכסה את כל צרכני הקצה לרבות התייעלות באנרגיה בסקטור התחבורה. דירקטיבה זו החליפה את ה"דירקטיבה לשירותי אנרגיה" (Energy Services Directive 2006/32/EC) לרבות את יעדי ההתייעלות שנקבעו בה.

ב-2018, נכנסה לתוקף חבילת המדיניות של האיחוד האירופאי בנושא אנרגיה נקייה (Clean energy for all Europeans package) שכללה עדכון שורה של אמצעי מדיניות בתחום האנרגיה, בדגש על מעבר מדלקים מזהמים לאנרגיה נקייה. במסגרת שינוי המדיניות, הוחלט על עדכון לדירקטיבה להתייעלות באנרגיה, במטרה לקבוע יעדי התייעלות באנרגיה לכלל האיחוד – 32.5% התייעלות באנרגיה עד 2030 (בהשוואה לתרחיש עסקים כרגיל שנקבע ב-2007). יעד זה תורגם ליעדים במונחים של צריכת אנרגיה ראשונית – לא יותר מ-1273 Mto_e ולצריכת אנרגיה סופית – לא יותר מ- 956 Mto_e. בנוסף, הוחלט כי ב-2023 הנציבות האירופאית תבחן עדכון ליעדים.[30]

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[30] https://ec.europa.eu/energy/en/topics/energy-efficiency/targets-directive-and-rules/energy-efficiency-directive

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לצורך השגת יעדים אלה, מדינות האיחוד מחויבות בהכנה של תכניות לאומיות עשר-שנתיות לאנרגיה ושינוי אקלים המפרטות את הפעילות הממשלתית לעמידה ביעדי ההתייעלות באנרגיה והפחתת הפליטות עד שנת 2030.[31]

עוד במסגרת קביעת הדירקטיבה, בוצעה בחינת השפעת רגולציה (RIA – Regulatory Impact Assessment), מסקנות הבחינה הראו כי בכדי להשיג התייעלות משמעותית באנרגיה, אשר תביא לעמידה ביעד הכלל אירופאי, נכון לחייב יישום של כלי מדיניות משמעותיים במדינות החברות (כדוגמת צעדי התייעלות במבנים, התייעלות באנרגיה בקרב ספקי חשמל, רגולציה על מוצרים ועוד) ולא בהכרח להתמקד בחיוב יעדים ספציפיים עבור כל מדינה[32].

משום כך הוחלט כי המדינות יקבעו לעצמן יעדים לאומיים (לרבות המשמעות במונחי צריכת אנרגיה ראשונית וסופית) ותינתן גמישות בקביעת היעד באחת מהאפשרויות הבאות:

1. עצימות צריכת אנרגיה – הפחתה בצריכת האנרגיה ליחידת תוצר.
2. צריכת אנרגיה ראשונית/סופית– יעד במונחי סך צריכת אנרגיה ראשונית/סופית.
3. חיסכון באנרגיה – יעד במונחי החיסכון באנרגיה ראשונית/סופית.

במסגרת עדכון התוכנית להתייעלות באנרגיה, נידון באופן נרחב המדד הרלוונטי ביותר בישראל ונקבע כי עצימות באנרגיה הינו המדד המשקף באופן מיטבי את יעילות האנרגיה של המשק הישראלי, שכן הוא מקשר בין צריכת האנרגיה לתפוקה המושגת, ומתאים למצב של צמיחה כלכלית וגידול באוכלוסייה. בנוסף, נרמול הצריכה ליחידת פעילות כלכלית מאפשר השוואה בין מדינות בעלות מאפיינים שונים המשפיעים על צריכת האנרגיה (כדוגמת שטח/מספר תושבים).

לפי פרסומי הסוכנות הבינ"ל לאנרגיה [33], בין השנים 2000-2018 חלה התייעלות בצריכת אנרגיה סופית בעולם[34]. מגמה זו בולטת בתרשים 22, המתאר את השיפור השנתי בעצימות צריכת האנרגיה הסופית בעולם ובחתך לפי מדינות.

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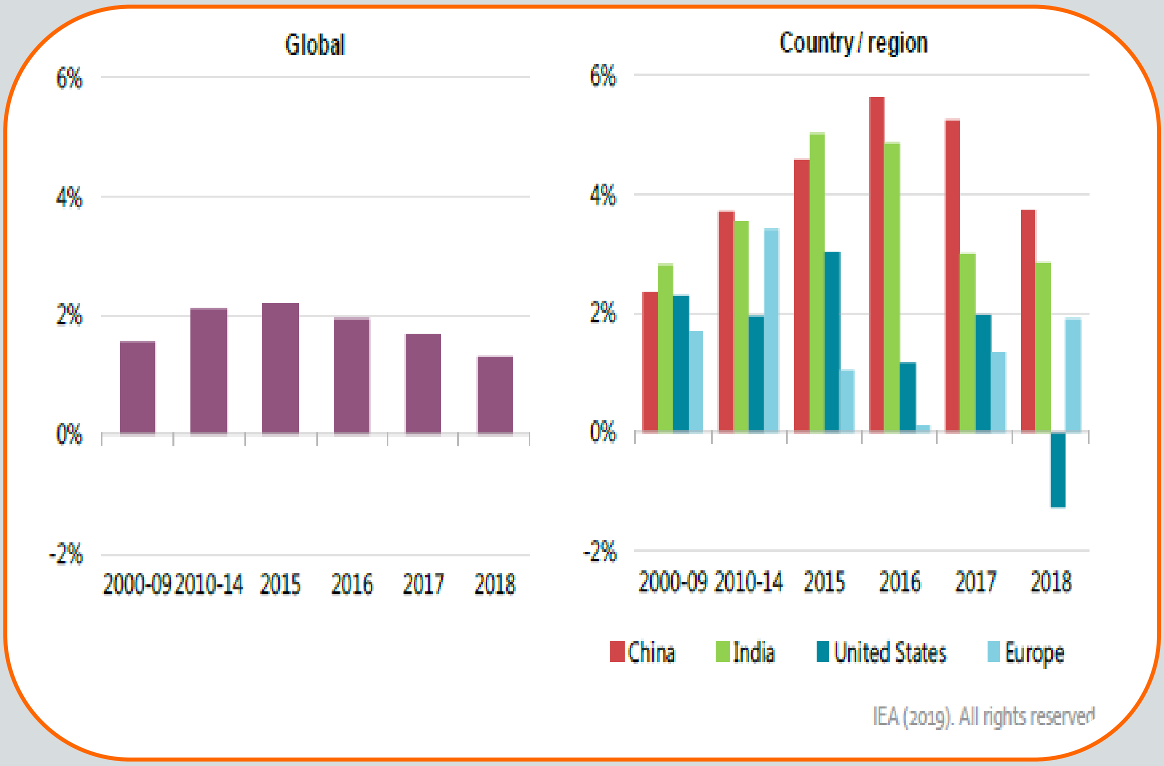
[31] https://ec.europa.eu/energy/topics/energy-strategy/national-energy-climate-plans_en

[32] https://ec.europa.eu/energy/sites/ener/files/documents/sec_2011_0779_impact_assessment.pdf

[33] IEA – International Energy Agency

[34] Energy efficiency, IEA, 2019/ https://www.buildup.eu/sites/default/files/content/energy_efficiency_2019.pdf



IEA (2019). All rights reserved

תרשים 22: שיפור שנתי בעצימות האנרגיה בעולם, IEA 2019.

ניתן לראות בתרשים 22, כי משנת 2000 ועד שנת 2015 קצב ההתייעלות השנתי העולמי עלה בממוצע כאשר משנת 2015 עד שנת 2018 אחוז השיפור השנתי הלך וקטן. לפי סוכנות האנרגיה העולמית, ניתן לייחס האטה זו לעלייה בשימוש בדלקים בשנים 2017-2018, שינויים בכלכלה העולמית ומזג אוויר קיצוני ובתוצאה מכך דרישה מוגברת לאנרגיה ועלייה בצריכה הממוצעת לאדם.

בהתאם לכך ובמסגרת החזון האסטרטגי אותו מגבשות המדינות, נקבעו יעדי מטרה מרכזיים להתייעלות באנרגיה והפחתת פליטות המפורטים בלוח 4:

לוח 4: יעדים לאומיים להתייעלות באנרגיה והפחתת פליטות

	חזון הפחתת פליטות	**התייעלות באנרגיה**	
מדינה/ ישות	**2050**	**2030**	**2050**
EU	אפס פליטות נטו	לפחות 32.5%[35] התייעלות באנרגיה עד שנת 2030 (ביחס לשנת 2007). חיסכון שנתי של 0.8%[36] באנרגיה הסופית בין 2021-2030.	-

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[35] https://ec.europa.eu/clima/sites/clima/files/long_term_strategy_brochure_en.pdf

[36] https://ec.europa.eu/clima/sites/clima/files/docs/pages/com_2018_733_analysis_in_support_en_0.pdf

גרמניה	הפחתת פליטות גזי החממה ב-80%-95%[37] לעומת היקפי הפליטה שנמדדו במדינה בשנת 1990	30%[38] התייעלות בצריכת אנרגיה ראשונית. שיפור שנתי של 2.1% ביעילות צריכת אנרגיה סופית[39]	הפחתת צריכת אנרגיה ראשונית ב-50% לעומת 2008, עד שנת 2050[40] צמצום עצימות צריכת האנרגיה הסופית ב-2.1% בכל שנה לעומת 2008, עד שנת 2050[41]
בריטניה	אפס פליטות נטו	הפחתה של 37% עד 2032 בהשוואה לשנת 2015 [42], שיפור שנתי של 2.7% בצריכת האנרגיה הסופית	טרם נקבע
צרפת	הפחתת פליטות גזי החממה ב-75% לעומת היקפי הפליטה שנמדדו במדינה בשנת 1990[43]	הפחתה של 20% בצריכת האנרגיה הסופית ביחס לשנת 2012[44]	הפחתה של 50% בצריכת האנרגיה הסופית ביחס לשנת 2012[45]
יפן	הפחתה של 80% בפליטות גז"ח (לא צוינה שנת הבסיס)[46]	-	-
שבדיה	-	הפחתת עצימות האנרגיה ב-50% עד 2030, בהשוואה לשנת 2005[47], שיפור שנתי של 2.7% באנרגיה ראשונית	-
לטביה	-	שיפור עצימות הצריכה ב-48% עד שנת 2030 ביחס לשנת 2007[48], שיפור שנתי של 3.1% .	-
סלובקיה[49]	-	קביעת יעד זהה ליעד שייקבע בעתיד על ידי האיחוד האירופי באנרגיה הראשונית	-

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[37] https://www.bmu.de/fileadmin/Daten_BMU/Pools/Broschueren/klimaschutzplan_2050_en_bf.pdf

[38] https://www.bmu.de/fileadmin/Daten_BMU/Pools/Broschueren/klimaschutzplan_2050_en_bf.pdf

[39] https://ec.europa.eu/energy/sites/ener/files/documents/de_neeap_2017_en.pdf

[40] https://cleanenergyaction.files.wordpress.com/2012/10/german-federal-governments-energy-concept1.pdf

[41] https://cleanenergyaction.files.wordpress.com/2012/10/german-federal-governments-energy-concept1.pdf

[42] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/700496/clean-growth-strategy-correction-april-2018.pdf

[43] https://ec.europa.eu/energy/sites/ener/files/documents/fr_neeap_2017_en.pdf

[44] https://ec.europa.eu/energy/sites/ener/files/documents/fr_neeap_2017_en.pdf

[45] https://ec.europa.eu/energy/sites/ener/files/documents/fr_neeap_2017_en.pdf

[46] https://www.env.go.jp/earth/earth/ondanka/mat3.pdf

[47] https://ec.europa.eu/energy/sites/ener/files/se_neeap_2017_en.pdf

[48] https://www.pkc.gov.lv/sites/default/files/inline-files/LIAS_2030_en_1.pdf

[49] https://ec.europa.eu/energy/sites/ener/files/sk_final_necp_main_en.pdf

ניתן לראות כי מדינות מפותחות כמו גרמניה ובריטניה בחרו יעד עצימות במונחי אנרגיה סופית המנחה שיפור של למעלה מ -2% עד שנת 2030. מעבר לכך, חשוב לציין כי יכולת השיפור בעצימות צריכת האנרגיה בכלכלות מפותחות, בהן קצב הצמיחה בתוצר נמוך באופן יחסי, פחותה בהשוואה לכלכלות צומחות בדוגמת ישראל. כצפוי, יעדי המדינות שהגדירו שיפור בעצימות צריכת אנרגיה ראשונית (כמו לטביה, מלטה ושוודיה) גבוהים באופן יחסי וזאת משום שהיכולת להגיע לצמצום צריכת אנרגיה ראשונית גבוהה מהיכולת להגיע לחיסכון באנרגיה סופית.

נכון להיום, ערים אחראיות לכ-75% מפליטות הפחמן בעולם, כאשר שיעורים אלה צפויים לעלות עם הזמן, שכן הערים צפויות להמשיך לגדול[50]. עלייה באיכות החיים, שימוש הולך ונרחב במכשירים אלקטרוניים וכן עלייה בצריכת חשמל למיזוג אויר (כתוצאה מעלייה במשך ותדירות גלי חום בעקבות משבר האקלים), מייצרים אתגרים משמעותיים בתחום האנרגיה בערים.

ייצור עצמאי של אנרגיה מתחדשת במרחב האורבני מאפשר שמירה על שטחים פתוחים באמצעות ניצול מיטבי של השטח הקיים. זאת בשונה מהקמת תחנות כוח (לרבות תחנות לייצור חשמל מאנרגיות מתחדשות) הצורכות שטח רב. מאחר וישראל מוגבלת במשאבי הקרקע הזמינים להקמה של שדות סולאריים, לניצול מיטבי של משאבי קרקע חשיבות גדולה אפילו יותר לעומת חלק מהמדינות המובילות בתחום, עבורן משאב הקרקע לאו דווקא מהווה שיקול מרכזי. כמו כן, שימוש באנרגיה מתחדשת במרחב האורבני מאפשר ביזור של מקורות ייצור חשמל, חסכון עלויות בהקמת תשתיות להולכת אנרגיה והפחתת הפסדי הולכת אנרגיה. יתרה מכך, רשת הספקת החשמל מתרחקת ממודל של רשת חד כיוונית בה חשמל מועבר מתחנות כוח לצרכנים, והופכת לכזו שכוללת יצרני אנרגיה רבים בקנה מידה קטן יותר. בתוך כך, ערים מובילות הפנימו את הצורך בייצור אנרגיה מתחדשת במרחב העירוני. עד סוף שנת 2018 יותר מ-200 ערים ברחבי העולם אימצו יעדים ל-100% חשמל מאנרגיות מתחדשות[51].

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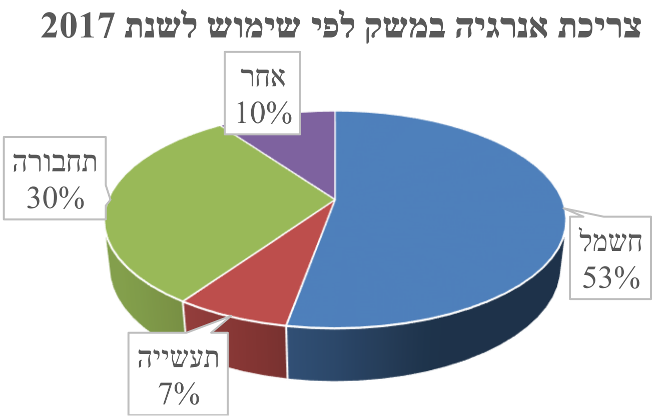
[50] https://www.ren21.net/wp-content/uploads/2019/05/gsr_2019_full_report_en.pdf

[51] https://www.ren21.net/wp-content/uploads/2019/05/gsr_2019_full_report_en.pdf

התייעלות באנרגיה- ישראל

עבור מדינות צפופות ודלות בשטחים פתוחים, כמו ישראל, התייעלות באנרגיה היא עמוד השדרה במאמצים להפחית את פליטות גזי החממה, בייחוד לאור העובדה שקצב גידול האוכלוסין, העלייה ברמת החיים והצמיחה הכלכלית המהירה תורמים לעלייה בצריכת האנרגיה. בד בבד, מהלכים לצמצום צריכת האנרגיה צפויים להוביל לחיסכון כלכלי לא מבוטל, הן ברמת הצרכנים והן ברמת המשק, וליצירה של מקומות עבודה חדשים. התועלות הכספיות המשקיות שבהתייעלות באנרגיה נובעות מארבעה גורמים עיקריים: חיסכון בדלקים, חיסכון בהון, חיסכון במניעת אבודים בהולכת וחלוקת החשמל לצרכנים.

בישראל, רמת החיים וקצב גידול האוכלוסייה גבוהים, כאשר החלק הארי (53%) של משק האנרגיה בישראל מופנה לייצור חשמל (תרשים 23).



אחר = שימוש למגזר הביתי, מסחר ושירותים חקלאות, בנייה וכבישים

תרשים 23: צריכת האנרגיה במשק הישראלי לפי סוג השימוש בשנת 2017.

ישראל התחייבה לעמוד ביעד לאומי של צמצום צריכת החשמל בשיעור של 17% לפחות עד שנת 2030 ביחס לצריכת החשמל הצפויה לפי תרחיש "עסקים כרגיל". לשם כך הוכנה תכנית לאומית להתייעלות במשק החשמל בשנת 2017 אשר עודכנה והורחבה בשנת 2020. לתכנית לאומית להתייעלות באנרגיה.

במהלך השנים האחרונות נעשו מספר צעדים נרחבים לשיפור יעילות האנרגיה בישראל אשר רובם התרכזו בסקטור התעשייתי. להלן פירוט צעדי המדיניות העיקריים :

1. התכנית הלאומית להתייעלות באנרגיה: בשנת 2016 נכתבה התכנית הלאומית להתייעלות באנרגיה. בסוף שנת 2017 אושרה התכנית בהחלטת ממשלה מספר 3269.

2. רגולציה ותקינה: עדכון וקידום תקנות קיימות וכתיבת תקנות חדשות בתחום צריכת האנרגיה והתייעלות באנרגיה בכלל המגזרים וכן קביעת תקנים לדירוג אנרגיה של מבנים.

3. מתן תמריצים לקידום התייעלות באנרגיה במגזר התעשייתי והמסחרי-ציבורי. המשרד מעניק תמריצים לפרויקטים נבחרים בכל המגזרים על מנת לקדם התייעלות באנרגיה, להגביר את המודעות לטכנולוגיות מתקדמות ולשכלל את ההיבט המתודולוגי. במסגרת החלטת ממשלה 542, הוקצו 300 מלש"ח למענקים לפרויקטים להתייעלות באנרגיה והפחתת פליטות. בעקבות החלטות אלו, הוקם בשיתוף משרד האנרגיה, משרד הכלכלה, משרד האוצר והמשרד להגנת הסביבה מסלול סיוע להשקעות בפרויקטים להתייעלות באנרגיה והפחתת פליטות גזי חממה. במסגרת המסלול ניתנת עדיפות לרשויות מקומיות חלשות, עסקים קטנים ובינוניים וטכנולוגיות חדשניות ישראליות.

4. התייעלות באנרגיה ברשויות: רשויות מקומיות נמצאות במוקד האסטרטגיה לצמצום פליטות גזי חממה. על כן, המשרד מלווה ומסייע לרשויות המקומיות להכין תכניות פעולה מקומיות למעבר לאנרגיה מקיימת שמהן נגזרות תכנית עבודה ופרויקטים להיערכות לשינויי אקלים והפחתת פליטות בהתאמה למצב המקומי ולאופי היישוב. התוכניות המצליחות בתחום זה בעולם מבוססות על אינטגרציה בין רמות השלטון השונות, ומייצרות מנגנונים מותאמים לדפוסי הפעילות של השלטון המקומי והמרכזי.

5. חינוך, הסברה ואכיפה: משרד האנרגיה פועל להעלאת מודעות לחיסכון באנרגיה באמצעות חינוך הכשרה והסברה במגוון דרכים: המשך הטמעת התכנית החינוכית, פיתוח תכנים חדשים מתוקשבים לרבות תחום בנייה חסכונית באנרגיה, הכשרת בעלי מקצוע בתחום התייעלות באנרגיה ואנרגיה נקייה בכל המגזרים, קידום הכשרה מקצועית של הנדסאים במוסדות להכשרה טכנולוגית, פרסום קמפיינים בטלוויזיה ובמדיה החברתית להעלאת המודעות לצריכת חשמל מושכלת. בנוסף, מודל האכיפה השתנה עם תיקון חוק מקורות אנרגיה. ע"פ המודל החדש ניתנו סמכויות רבות יותר ליחידת האכיפה כגון אפשרות להטלת עיצומים כספיים על הפרות.

6. חשמול המגזר הביתי: כחלק מהמאמץ למעבר לייצור אנרגיה נקייה והפחתת השימוש בדלקים במגזר הביתי, ביצע משרד האנרגיה השוואה טכנו-כלכלית לבחינת חלופות לאספקת אנרגיה בבנייה חדשה במגזר הביתי[52], שמטרתה השוואה בין יישומים מבוססי גפ"מ לבין חלופותיהם החשמליות. הניתוח בחן, בין השאר, את הפוטנציאל המשקי מחשמול מלא של כל המבנים החדשים שיבנו עד לשנת 2050 עבור כלל שימושי הגפ"מ במגזר הביתי יחדיו

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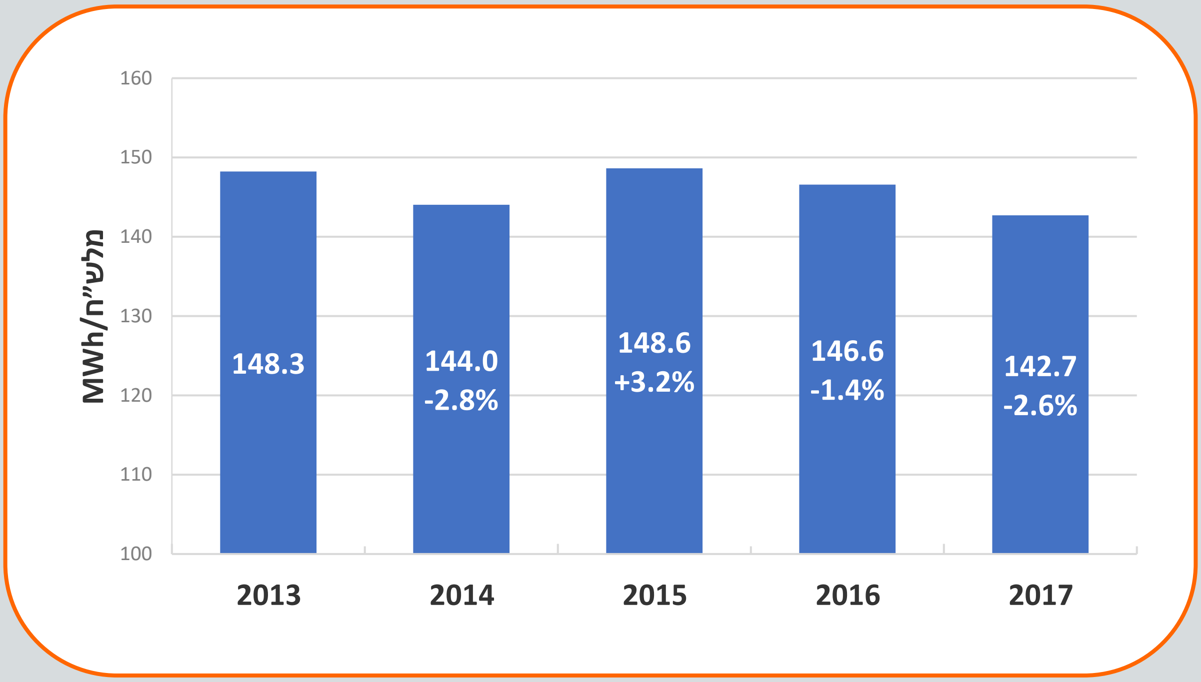
[52] https://www.gov.il/he/departments/news/press_121120

(בישול, חימום מי צריכה והסקת מבנים) ומצא כי הסרת החובה הרגולטורית[53] לפיה יש לחבר כל מבנה מגורים חדש למערכת גז בשילוב חשמול מלא של המגזר הביתי יחסוך למשק כ- 66,000 tCO2e, 480,000 MWh ותועלת כלכלית של 700 מלש"ח עד לשנת 2050.

כאמור, בשנת 2017 פרסם המשרד תכנית לאומית להתייעלות באנרגיה ובנובמבר 2020 פורסם עדכון התוכנית אשר נכתבה בשיתוף עם בעלי עניין רבים ומשרדי ממשלה. התכנית המעודכנת מתייחסת לכלל מגזרי האנרגיה ומציעה יעד חדש להתייעלות באנרגיה – שיפור שנתי של 1.3% בעצימות האנרגיה.

עצימות האנרגיה הכוללת משקפת את צריכת האנרגיה במשק, ביחס לסך התמ"ג המשקי. בין השנים 2013-2017 עלה התמ"ג במשק בב- 14%[54], אך עצימות האנרגיה ירדה בב-3.7% (תרשים 24). נתון המצביע על התייעלות כוללת בצריכת האנרגיה ליחידת תוצר.



תרשים 24: עצימות אנרגיה סופית בישראל בשנים 2013-2017.

את עיקר הירידה בעצימות הכוללת ניתן לשייך למגזר התעשייתי והמגזר המסחרי-ציבורי, כאשר מגזר התחבורה נמצא כבעל השפעה חיובית אך מצומצמת. מנגד, המגזר הביתי הינו גורם מעכב להתייעלות באנרגיה במשק (לוח 5).

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[53] חובה רגולטורית הפועלת מתוקף תקנות התכנון והבנייה (תשס"ג-2003)

[54] לוח 11.3 - תוצר מקומי גולמי של כלל המשק, לפי ענף כלכלי

לוח 5: שינוי צריכת מגזרים ביחס לתמ"ג המשקי הכולל בשנים 2013-2017[55]

שם המגזר	שינוי בעצימות
תעשייתי	-17.6%
מסחרי-ציבורי	-7.6%
ביתי	+1.7%
תחבורה	-0.7%
סה"כ	**-3.7%**

מתוך כך עולה כי יש לרכז מאמץ בסקטור הביתי, ואכן המשרד עושה מאמץ אדיר בשנים האחרונות על מנת להתייעל במשק. בין הצעדים הרבים ניתן למנות:

1. תיקון חוק מקורות אנרגיה (דצמבר 2020) המקל את היבוא של מוצרים חשמליים לישראל בהקשר של דרישות הנצילות באנרגיה מהווה אימוץ הגישה האירופית על מנת להקל על הייבוא ולקצר זמנים ועלויות.
2. הכנת תכנית להתייעלות באנרגיה הפורטת שורת צעדי מדיניות להתייעלות במגזר הביתי אך לא רק (דצמבר 2020).
3. בחינת חשמול המגזר הביתי.

עוד נציין כי בשנים האחרונות מרכז המשרד מאמצים בתחום הרשויות המקומיות מתוך הבנה כי רשויות שונות בעלות מאפיינים שונים ועל כן יש צורך "לתפור חליפת פתרונות" מותאמת בעזרת שיתוף פעולה הדוק עם השלטון המקומי. הבנה זו רק התחזקה בתקופה האחרונה, בזמן מגפת הקורונה בה ראינו שבהרבה מהמקרים הפתרון נבע מהרמה המקומית ולאו דווקא מהשלטון המרכזי.

על כן, משרד האנרגיה הקים תכנית המעניקה מעטפת נרחבת של תכנון וייעוץ מקצועי לגיבוש תכניות פעולה להיערכות לשינוי אקלים ואנרגיה מקיימת. הסיוע שיקבלו 12 הרשויות שנבחרו לתכנית יינתן על ידי יועצים ומומחים בתחום, תוך שימוש בכלים ייעודיים ויכלול סיוע תקציבי בעתיד לקידום מהלכים מסוג זה. ראשית, הרשויות והאשכולות ימפו את ההשפעות החזויות של שינויי האקלים ואת פליטות החממה בשטח הרשות, וכמענה לכך יגבשו תכניות פעולה שיסייעו להן להיערך לשינויי האקלים ולהפחית את הפליטות תוך שאיפה להגיע ל-30% ייצור אנרגיה מתחדשת עד 2030, בהתאם לחזון משרד האנרגיה. הרשויות יעשו זאת, בין היתר, באמצעות התקנת פאנלים סולאריים על מבני ציבור

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[55] פרט למגזרים העיקריים המוצגים בטבלה, קיימת עלייה של כ-45% בסקטורים האחרים. חשוב לציין כי הצריכה הכוללת של מגזרים אלו קטנה מאוד ביחס לסך הצריכה (6%) ולכן לא מנותחת בפרק זה

ומשקי בית פרטיים, התייעלות באנרגיה בתשתיות העירוניות, הצללת רחובות, הקמת עמדות טעינה לכלי רכב חשמלי, נטיעת עצים ברחבי הרשות ועוד. מכלול צעדי המדיניות, אשר חלקם מפורטים במסמך זה, מפורטים באופן נרחב בתוכנית הלאומית להתייעלות באנרגיה שפרסם המשרד[56].

החיסכון הפוטנציאלי לחברה מהטמעת תכניות להתייעלות באנרגיה המתורגמות לחיסכון של עלויות אנרגיה ועלויות סביבתיות הוא עצום. יחד עם זאת, קיימים אתגרים רבים המעכבים את מימוש הפוטנציאל בישראל ובעולם. ארבעה אתגרים מהותיים בולטים במיוחד:

1. יעילות באנרגיה דורשת בד"כ השקעות גדולות מראש כדי להשיג חיסכון שנצבר מאוחר יותר.
2. חוסר מודעות ציבורית- בעלי העניין אינם מודעים לתועלות הכלכליות הגלומות בהפחתת צריכת האנרגיה כמו גם לחשיבות הסביבתית בצמצום צריכת האנרגיה במשק.
3. ההזדמנויות להתייעלות באנרגיה מפוצלות להרבה מאוד מכשירים כמו גם למיקומים שונים ואינם "חבילה אחת" ועל כן מקשה על יישום רחב.
4. קושי במדידת החיסכון - קושי ביכולת מדידת החיסכון כתוצאה מהתייעלות באנרגיה מפחית את המוטיבציה להשקיע בפרויקטים מסוג זה.

בעלי בתים בדרך כלל בעלי מודעות נמוכה לגבי צריכת האנרגיה שלהם או כיצד לצמצם אותה ובסופו של דבר ממעיטים בערך החיסכון. עבור רוב המשפחות, הקצאת כספים לאמצעים להתייעלות באנרגיה הינה מאתגרת: הוצאות הליבה סופגות כ- 90 אחוז מתקציבי משקי הבית הממוצעים.

במגזר התעשייתי, לעיתים קרובות אנרגיה מהווה חלק קטן יחסית מהעלויות, כך שמנהלים בכירים עשויים להתנגד להשקעות רציניות. בדומה למגזר המסחרי, זמני ההחזר, אילוצי ההון והרכש עלולים להיות בעייתיים. באתרי תעשייה, למשל, חברות רבות דורשות כיום החזר של שנה וחצי עד שנתיים וחצי להחזר השקעות. מנהלים עשויים להתעלם מפרויקטים אטרקטיביים של התייעלות באנרגיה מהחשש לפגוע בדירוג האשראי שלהן על ידי גיוס חוב. בנוסף, החשש גורם גם למנהלי מפעלים שוחרי סיכון להחליף ציוד כושל באותם דגמים ולא בדגמים חסכוניים יותר באנרגיה.

עם כל זאת התייעלות באנרגיה הינה האמצעי המועדף ל"ייצור" אנרגיה. התייעלות באנרגיה זולה יותר מכל מקור אנרגיה אחר בכל תרחיש, ונקיה יותר מאחר והיא אינה פולטת מזהמים או גזי חממה ואינה דורשת שטחים פתוחים או שדרוג מערכת ההולכה. אולם, גם להתייעלות יש מחיר ועלויות.

משרד האנרגיה מעודד יישום של אמצעי התייעלות שונים בעשורים האחרונים, ומנתוני העבר, בשילוב החיסכון שהושג, ניתן לראות כי העלות הממוצעת לכל קוט"ש שנחסך עומדת על כ-15 אג'. עלות זו

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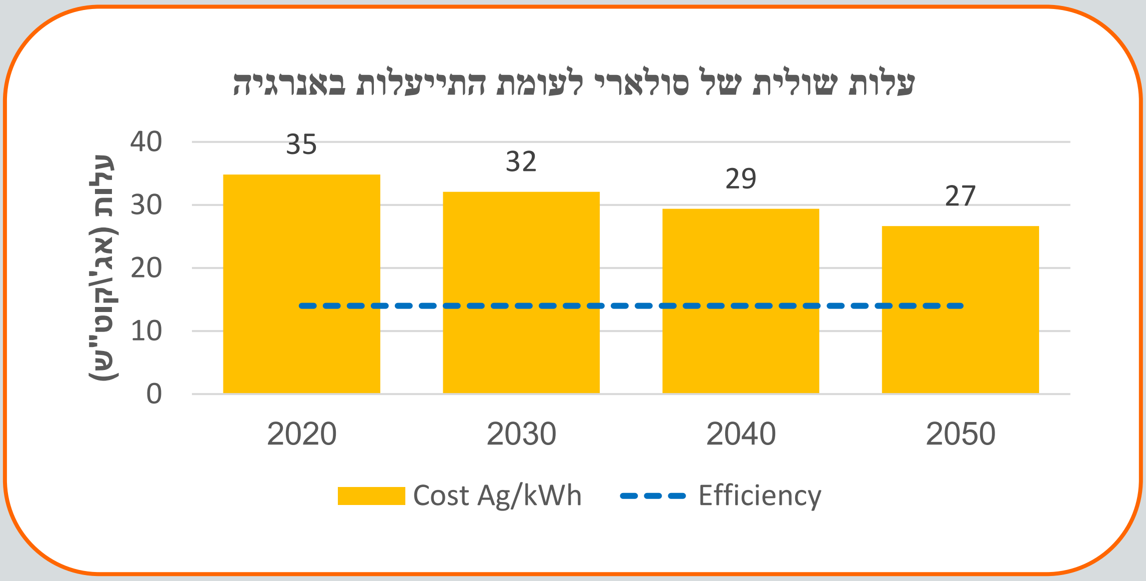
[56] https://www.gov.il/BlobFolder/news/energy_2030/he/energy_2030_updated.pdf

נמוכה משמעותית מעלות הייצור בגז (כ- 22 אג' לקוט"ש), ונמוכה גם מעלות הייצור באנרגיה סולארית במשק. בתרשים 25 להלן מוצגת עלות הייצור הכוללת באנרגיה סולארית בעשורים השונים מהיום ועד ל-2050, וזאת על פי תחשיב מודל טכנו-כלכלי של משק האנרגיה, משרד האנרגיה. המודל לוקח בחשבון הן את עלויות הפאנלים אך גם את עלות האגירה ותוספת עלות היחידות הקונבנציונליות המשמשות לגיבוי ותמיכה בייצור הסולארי. ניתן לראות כי גם במחירים הצפויים בשנת 2050 לאנרגיה סולארית ואגירה, המחיר הכולל גבוה מסף ה-15 אג' לקוט"ש עבור התייעלות באנרגיה.

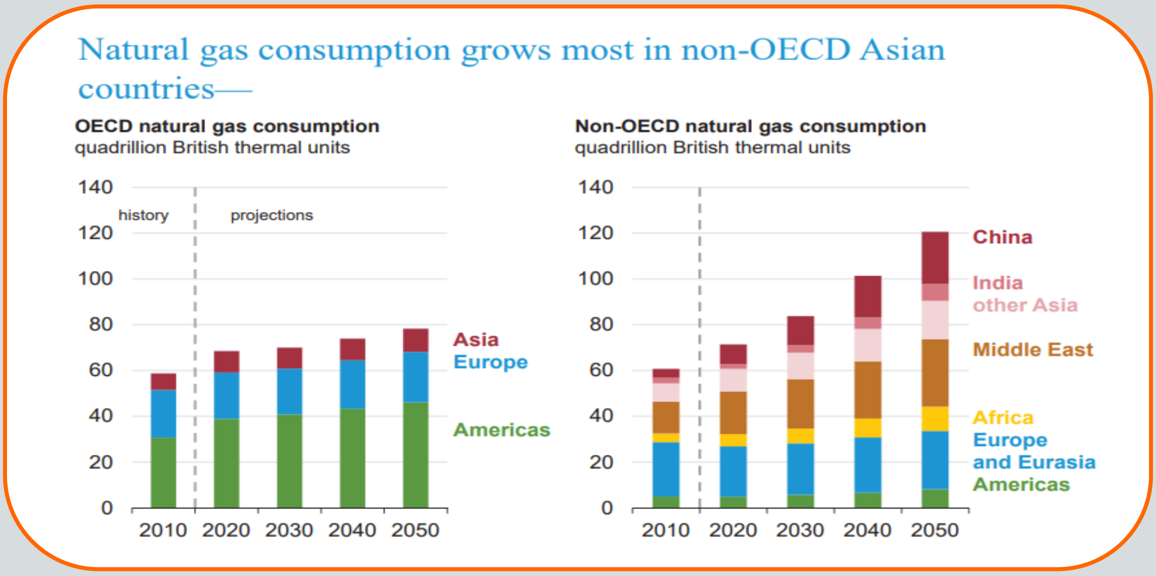


תרשים 25: עלות שולית של אנרגיה מתחדשת מול התייעלות, מודל האנרגיה, משרד האנרגיה.

משק הגז טבעי

לאור משבר האקלים, מדינות העולם החלו בתהליכים של שינוי מקורות ייצור החשמל מייצור חשמל המבוסס על דלק פוסילי לייצור חשמל המבוסס על מקורות אנרגיה מתחדשים. עם זאת, הגז הטבעי הפך בעשורים האחרונים לפתרון הנקי יותר ליצור חשמל, כמו גם מקור אנרגיה חשוב במגזר התעשייתי והביתי עקב המגבלות הטכנולוגיות והכלכליות אשר אינן מאפשרות התבססות על אנרגיה ממקורות מתחדשים בלבד.

סקירת תחזיות עולמיות שונות מראה כי הביקוש לגז הטבעי צפוי לעלות בלמעלה מ-40% לעומת 2018 (תרשים 26), באשר אחוז הגז הטבעי בסל הדלקים העולמי צפוי להישאר ללא שינוי בשל העלייה הכללית בביקוש לאנרגיה[57,58,59,60]. כמו כן הגז הטבעי ומערכות ההולכה צפויים לשחק תפקיד מרכזי בשמירת אמינות האספקה וכמערכת חלופית למערכת החשמל.



תרשים 26: גידול בצריכת גז טבעי בעולם[61].

גם במבט הבוחן את תמהיל השימוש בגז טבעי אל מול דלקים אחרים ניתן לראות כי על אף העלייה באנרגיות המתחדשות ממשיך הגז הטבעי לשחק תפקיד מרכזי במשקי האנרגיה בעולם (תרשים 27).

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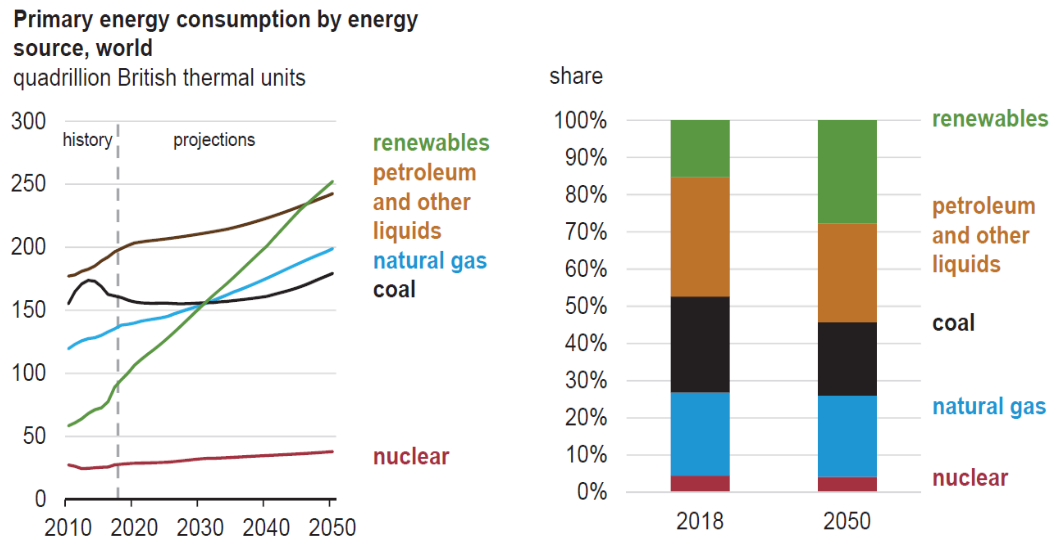
[57] EIA 2019. International Energy Outlook 2019 with projections to 2050. US. Energy Information Administration, U.S. Department of Energy. https://www.eia.gov/outlooks/ieo/

[58] iea 2019. World Energy Outlook 2019. https://www.iea.org/reports/world-energy-outlook-2019

[59] World Energy Council. World Energy Scenarios Composing energy futures to 2050. https://www.worldenergy.org/assets/downloads/World-Energy-Scenarios_Composing-energy-futures-to-2050_Executive-summary.pdf

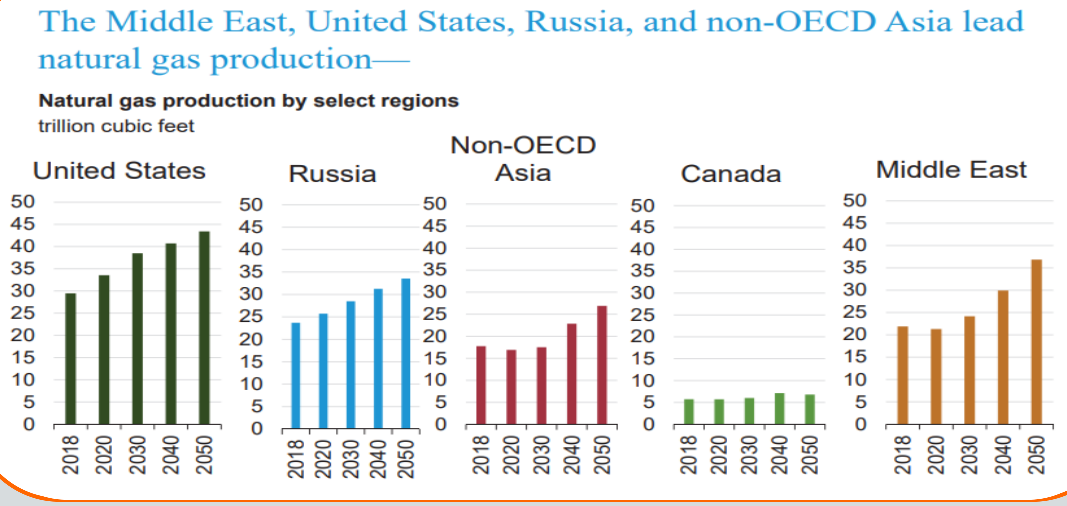
[60] World Energy Council. Natural Gas Perspectives. 2017. https://www.worldenergy.org/assets/downloads/WEC-PERSPECTIVES-Word-Gas-Report-WEB.pdf

[61] 61 EIA 2019. International Energy Outlook 2019 with projections to 2050. US. Energy Information Administration, U.S. Department of Energy. https://www.eia.gov/outlooks/ieo/



תרשים 27: *צריכת אנרגיה עולמית על פי מקורות האנרגיה. EIA International Energy Outlook 2019. הגז הטבעי שומר על כמותו היחסית יחד עם העליה בביקושים.*

במדינות הנסקרות כמו גם במדינות אחרות התחזית צופה כי השימוש בגז טבעי ימשיך גם בשנת 2050 והפחתת הפליטות מסקטור זה מוגבל לשלב ההפקה וכן בשימוש מתוכנן נרחב בטכנולוגיה של לכידת פחמן. כפי שניתן לראות בתרשים 28, המדינות המפיקות גז טבעי מתכננות להמשיך את החיפוש והשימוש של הגז הטבעי כמו גם הייצוא, גם אם חלקן של האנרגיות המתחדשות בתמהיל הייצור גדל באופן משמעותי.



תרשים 28: תחזית המשך הפקת גז טבעי באזורים נבחרים בעולם[62]

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[62] EIA 2019. International Energy Outlook 2019 with projections to 2050. US. Energy Information Administration, U.S. Department of Energy. https://www.eia.gov/outlooks/ieo/

בבחינה של תכניות אסטרטגיות להפחתת פליטות, לא נמצאו מדינות רבות כדוגמת דנמרק המצהירות על הפסקת חיפושי הגז והנפט, אך קיימות דוגמאות רבות למדינות המצהירות על המשך שימוש בגז טבעי, ואף עידוד חיפושי גז ונפט עד שנת 2050.

אירלנד למשל, קבעה יעדים שאפתניים של הפחתת פליטות במגזר האנרגיה של 80-95% ביחס לשנת 1990[63]. בשנת 2017 51% מהחשמל יוצר בגז טבעי, ובסה"כ 30% מצריכת האנרגיה מסופקת על ידי גז טבעי[64]. על פי התכנית האסטרטגית[65,66,67], אירלנד מתכננת הקטנה משמעותית של דלקים פוסיליים מזהמים עד 2050 על ידי מעבר לשימוש בגז טבעי[67], כאשר המתחדשות ייתפסו 70% בייצור אנרגיה לחשמל. אירלנד מעודדת חיפושי גז טבעי בים וצופה גידול בשימוש במחז"מים יחד עם הגידול במתחדשות תוך סגירת תחנות פחמיות ותחנות קבול.

הממלכה המאוחדת הייתה אחת הראשונות לזיהוי הסכנה במשבר האקלים וב-2008 חוקקה את חוק שינוי האקלים. החוק קובע יעד של הפחתת 80% מהפליטות עד 2050 ביחס ל-1990[68]. עקב ירידת ההפקה בים הצפוני, הממלכה המאוחדת עברה מהפך ממדינה שיש לה מספיק גז לספק את כל צרכיה בשנת 2000 למדינה שמייבאת 50% מהגז הדרוש לה ב-2017. בהתאם למספר תרחישי שימוש אפשריים, הצפי הוא כי מאגרי הגז בים הצפוני השייכים לממלכה יידלדלו בין 2042-2050 ויהיה צורך בהמשך ייבוא נרחב. לכן הממשלה משקיעה בחיפוש ובפיתוח מקורות אנרגיה בים ואף אישרה לאחרונה את האפשרות לשימוש בהפקה לא קונבנציונלית הכוללת שבירה הידראולית. הרגולטור האחראי על חיפושי הגז והנפט (OGA) פרסם הצהרה כי לא יעשו פעולות להפחתת פליטות המנוגדות לפיתוח מואץ ומקסום התועלת הכלכלית מהפקת גז ונפט.

לנורבגיה יעד של איפוס פליטות עד 2050[69]. נורבגיה היא אחת מהמדינות מפיקות הגז והנפט הגדולות בעולם ומובילה בהפחתת פליטות מהסקטור ובשימוש באגירת פד"ח. נורבגיה מנצלת כ-12% מהאנרגיה שהיא מפיקה ואת השאר היא מייצאת, לרוב בצורה גולמית של גז טבעי ונפט[70]. ב-2018 נורבגיה הפיקה וייצאה 25% מהביקוש לגז טבעי באיחוד האירופי והיא היצואנית השנייה בגודלה

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[63] Department of communications, Energy & Natural Resources. 2015. Ireland's Transition to a Low Carbon Energy Future 2015-2030.

[64] SEAI Sustainable Energy Authority of Irland. 2018. Energy in Irland, 2018 report.

[65] Paul Deane, John Curtis, Alessandro Chiodi, Maurizio Gargiulo, Fionn Rogan, Denis Dineen, James Glynn, John FitzGerald and Brian Ó Gallachóir. 2013. Technical support on developing low carbon sector roadmaps for Ireland. Low Carbon Energy Roadmap for Ireland. Economic & Social Research Institute (ESRI), E4sma, Environmental Research Institute University College Cork. pp 124.

[66] Climate Action and Low Carbon Development Act 2015. Number 46 of 2015.

[67] Department of communications, Energy & Natural Resources. 2015. Ireland's Transition to a Low Carbon Energy Future 2015-2030.

[68] The Climate Change Act 2008

[69] Ministry of Climate and Environment. 2014. The agreement on climate policy. https://www.regjeringen.no/en/topics/climate-and-environment/climate/innsiktsartikler-klima/agreement-on-climate-policy/id2076645/

[70] iea. 2017. Energy Policies of IEA Countries, Norway 2017 review. International Energy Agency, OECD

בעולם אחרי רוסיה[71]. ההערכה היא שרק 1/3 ממשאבי הגז הטבעי הופקו עד כה וההפקה צפויה להמשיך בקצב גבוה ב- 15-20 שנים הקרובות. עם זאת, כ-98% מהחשמל בנורבגיה מופק ממתחדשות, בעיקר מהידרואלקטרי, כך שרוב הגז מיועד לייצוא (לפי נתוני 2015[70]). אין כוונות להפסיק או לצמצם באופן יזום את הפקת הגז והנפט, והתחזיות ל-5 השנים הבאות צופות עליה בכמות הגז המיוצא[72].

בהתאם לנתונים מהשנים 2017-2018, הגז הטבעי באוסטרליה מהווה כ-25% מתמהיל הדלקים, נפט כ-39%, פחם כ- 30% ומתחדשות כ- 6%[73]. הגז הטבעי מהווה נדבך גדל והולך בתמהיל ייצור חשמל ומחליף בהתמדה, יחד עם המתחדשות, ייצור חשמל מבוסס פחם (כ-60% מיצור החשמל[113]). בשנים האחרונות אוסטרליה הייתה אחת משתי יצואניות הגז הנוזלי (LNG) הגדולות בעולם (ביחד עם קטר)[74], ובשנת 2019, הפכה ליצואנית העולמית הגדולה ביותר. לא נמצא כי סוכנויות הרגולציה הפדראליות מתכננות להגביל או למתן חיפוש והפקה של נפט וגז, ונראה כי יש כוונה להמשיך ולהפיק. על פי התחזיות לפחות עד 2032 יש עליה בביקוש לגז ברמה המקומית ובין לייצוא[75]. מדיניות יצוא הגז הטבעי באוסטרליה ככלל מתירה יצוא באופן חפשי כל עוד יש אספקה מספקת לשוק המקומי[76].

במבט קדימה, מדינות רבות בוחנות את עתיד השימוש ברשתות הולכת הגז המקומיות ועל כן, נושא שילוב הגז הטבעי ומערכות ההולכה והחלוקה בתוכניות האסטרטגיות להפחתת פליטות מהווה אחת הסוגיות האסטרטגיות המרכזיות שעמדו בפני מדינות האיחוד האירופי. בפועל הועלו שלושה סוגי תרחישים לגבי משק הגז הטבעי לקראת 2050[77] :

תרחיש א': תרחיש המבוסס על גידול משמעותי בבושר ייצור חשמל ממקורות מתחדשים כבסיס לעמידה ביעדי הפחתת הפליטות. במסגרת זו, תבוצע השקעה מהותית במעבר לשימוש ביישומים חשמליים בכל מגזרי הצריכה. במסגרת תרחיש זה יש צורך בהשקעות גדולות בשלושה תחומים -

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[71] https://www.norskpetroleum.no/en/production-and-exports/exports-of-oil-and-gas/

[72] https://www.norskpetroleum.no/en/production-and-exports/production-forecasts/

[73] https://www.energy.gov.au/publications/australian-energy-update-2019

[74] https://www.eia.gov/todayinenergy/detail.php?id=40853https://www.eia.gov/todayinenergy/detail.php?id=40853

[75] Haylen and Montoya (2013). Gas: resources, industry structure and domestic reservation policies. Briefing paper No 12/2013. NSW Parliamentary Research Services, https://www.parliament.nsw.gov.au/researchpapers/Documents/gas-resources-industry-structure-and-domestic-re/Gas%20-%20resources,%20industry%20structure%20and%20domestic%20reservation%20policies.pdf

[76] https://www.industry.gov.au/regulations-and-standards/australian-domestic-gas-security-mechanism

[77] https://www.frontier-economics.com/media/3120/value-of-gas-infrastructure-report.pdf

אחסון חשמל[78], שיפור החיבוריות במערכת החשמל (שתאפשר גמישות בהעברת עודפי חשמל) ולכידת פחמן. בתרחיש זה הולכת וחלוקת האנרגיה לצרכנים לקראת 2050 תבוצע באמצעות מערכת החשמל ועל כן במדינות שיבחרו בתרחיש זה השימוש בתשתית הקיימת של הולכה וחלוקה של גז טבעי ילך ויפחת ועל כן אין צורך בהשקעות חדשות בתשתית זו.

<u>תרחיש ב':</u> תרחיש המבוסס על גידול משמעותי בבושר ייצור חשמל ממקורות מתחדשים בשילוב עם ייצור חשמל המבוסס על סוגי גז ממקורות מתחדשים (כדוגמת CNM[79], ביו-מתאן ומימן) תוך הפחתת שימוש בגז טבעי ליצור חשמל. חלוקת האנרגיה לצרכנים לקראת 2050 תבוצע באמצעות מערכת החשמל, אך מערכות ההולכה והאחסון של גז טבעי משחקות תפקיד חשוב בהזרמת CNM, ביו-מתאן ומימן. לפיכך, במדינות שיבחרו בתרחיש זה ימשיכו להשתמש בתשתית הקיימת של הולכת הגז הטבעי ואף יצטרכו להשקיע השקעות נוספות במערכות ההולכה והאחסון. מאידך, במערכות החלוקה אין צורך בהשקעות חדשות.

<u>תרחיש ג':</u> תרחיש המבוסס על גידול משמעותי בבושר ייצור חשמל ממקורות מתחדשים בשילוב עם ייצור חשמל המבוסס על סוגי גז ממקורות מתחדשים כמו גם מתן פתרונות המשלבים העברת גזים ממקורות מתחדשים לצרכני הקצה בכל המגזרים (ולא רק ליצור חשמל), תוך שילובם במערכות ההולכה והחלוקה של הגז הטבעי. בתרחיש זה, מערכות ההולכה והחלוקה של הגז הטבעי משחקות תפקיד מהותי בתמהיל האנרגיה הלאומי הן ביצור חשמל מגזים מתחדשים והן ע"י הצרכנים הסופיים (למשל מערכות CHP[80] בתעשייה). לפיכך, בתרחיש זה יהיה צורך בביצוע השקעות נוספות במערכות ההולכה והאחסון בנוסף על השקעות במערכת החלוקה שתאפשר שימור הקיים, שימוש בתשתית להעברת הגזים לצרכנים חדשים וכן הסבת קווי חלוקה להעברת מימן[81].

לפחות בטווח הביניים היקפי ההשקעה בתשתית הגז הטבעי יושפעו משיקולים נוספים, כמו, גידול בצריכת הגז הטבעי והצורך בהוספת צרכנים חדשים למערכת. בנוסף, עצם קיומה של מערכת הולכת וחלוקת גז, צפויה להשפיע גם היא על שיקולי הטווח הארוך. קיומה של מערכת הולכת גז טבעי במערב אירופה המאפשרת הולכת גז בהיקף גדול משמעותית מזה של מערכות חיבור החשמל. קיומה של מערכת הולכת גז טבעי בהיקפים אלו, וקיומו של מערך אחסון לב- 500 TWh

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[78] שיאפשרו התמודדות עם תנודות בהיקפי אספקת החשמל שאופייניים למערכות מבוססות שמש ורוח. במסגרת זו הועלו חלופות כמו מערכת ריבוי סוללות (שימוש בסוללות EV כגורם ממתן תנודות), משאבות אוויר דחוס וכו'

[79] מתאן "ניטרלי" שנוצר ממקורות מתחדשים ואינו תורם להתחממות כדור הארץ לפי התהליך $CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$. מבוסס על מימן ממקורות חשמל מתחדשים ופחמן דו חמצני מתהליך לכידת פחמן, מקורות אורגניים או שנתפס בטכנולוגיית Elevated temperature (מכונה לעיתים גם SNG – גז טבעי סינתטי)

[80] תחנות קו- גנרציה קטנות יחסית המשמשות ליצור משולב של חשמל וחום. נחשבות כפתרון בעל יעילות אנרגיה גבוהה.

[81] ע"פ המחקרים ניתן לערבב בגז טבעי/מתאן עד 20% מימן מבלי לגרום לסכנות בטיחותיות מחד וללא צורך בשינוי מבערים מאידך

מול מערך אחסון חשמל שהיקפו נאמד ב-0.6 TWh בלבד, צפוי לדחוף את מקבלי ההחלטות ליישום תרחישים ב' וג' על פני תרחיש א' – אשר דורש השקעות כבדות בתשתית חיבור ואחסון חשמל [82]. לפיכך, ניתן לצפות כי במרבית מדינות אירופה תימשך ההשקעה במערכות ההולכה של הגז הטבעי בטווח הביניים תידרש השקעה במערכות ההולכה (וככל הנראה) גם במערכות החלוקה, גם בטווח הארוך, לשם שימור הקיים או התאמת המערכת להולכת גזים ממקור מתחדש (בעיקר תערובות עם מימן בשיעור שגבוה מאפשרויות המערכת).

כדי לבחון את מידת יישום העקרונות לעיל בצענו סקירה של התוכניות האסטרטגיות להפחת פליטות לשנת 2050 במדינות נבחרות והמשמעויות הנגזרות מהן למשק הגז הטבעי.
ממצאי הסקירה מרוכזים בלוח 6:

לוח 6: ריכוז ממצאים עיקריים מתוכניות אסטרטגיות להפחתת פליטות בשנת 2050 במדינות נבחרות.

מדינה	עיקרי תכנית הפחתת הפליטות	משמעויות במשק הגז הטבעי – טווח בינוני	משמעויות במשק הגז הטבעי – טווח ארוך
גרמניה	השקעות משמעותיות במקורות אנרגיה מתחדשת, ייצור גזים ירוקים, חיסכון והתייעלות באנרגיה	עליה בצריכת הגז הטבעי והשקעות בתשתית הולכה בשל סגירת תחנות כוח פחמיות וגרעיניות	ירידה משמעותית בצריכת הגז הטבעי. המשך השקעות בתשתית הולכה וחלוקה תוך שילוב גזים ירוקים
בריטניה	דגש על לכידת פחמן, חיסכון באנרגיה, התייעלות בחימום והפקת מימן	השקעות בשיפור ביטחון אספקה של גז טבעי כולל גז טבעי מקומי וגז פצלים.	חשיבות גבוהה לגז טבעי. ירידה בצריכת הגז הטבעי בטווח הארוך (אין פירוט לגבי אופן השגת הירידה). המשך השקעות בתשתית הגז
הולנד	דגש מרכזי על "חשמול": מעבר לרכבים חשמליים וחימום בתים ע"ב חשמל, כמו גם השקעות נרחבות בחיסכון באנרגיה במגזר הביתי	ירידה בצריכת הגז הטבעי בעיקר באמצעות ניתוק שכונות מגורים מגז טבעי	צפי לשינוי מדיניות ומעבר לשימוש בצנרת החלוקה להזרמת תערובות גז טבעי בשילוב גזים ירוקים
יוון	אין תכנית. התבססות על הפחתה שנובעת ממערכות ייצור חשמל יעילות ומיבוא "חשמל נקי"	עליה משמעותית בצריכת גז טבעי במעבר ל-CCGT לרבות השקעות בתשתית הולכה	חיסכון באנרגיה (אין פירוט) ו-CHP. בפועל, המשך גידול בצריכת גז טבעי.

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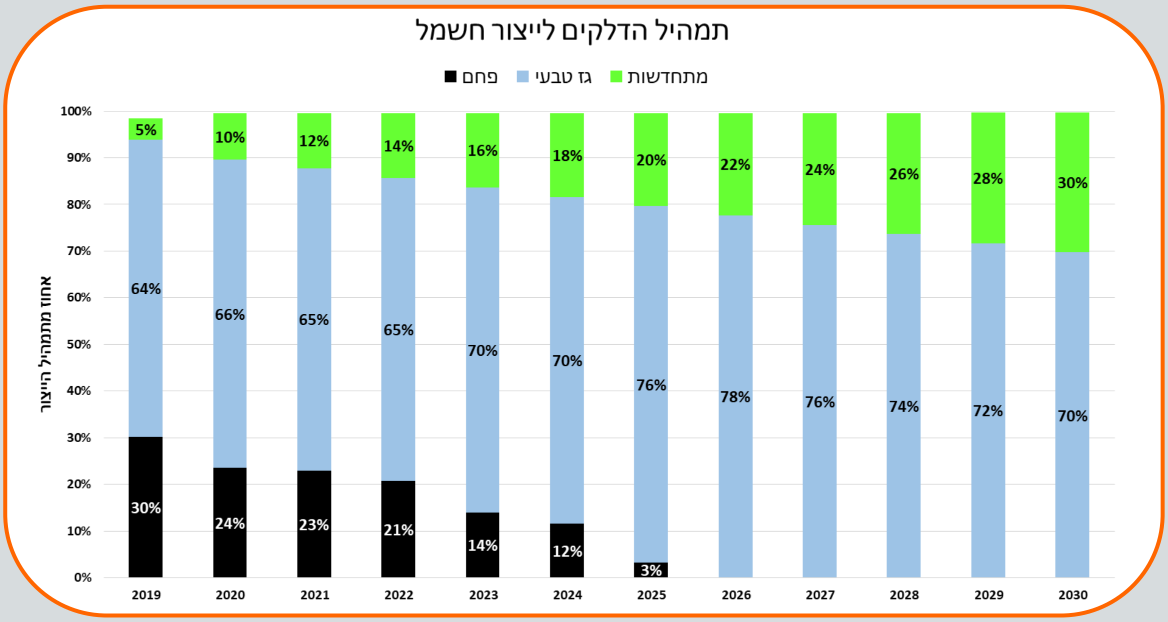
[82] https://www.frontier-economics.com/media/3120/value-of-gas-infrastructure-report.pdf

מסקירת המדינות המוצגות וכן מסקירת התחום בעולם ניתן לראות כי לגז הטבעי תפקיד חשוב במעבר מדלקים מזהמים (בעיקר פחם) בטווח הקצר והבינוני. בטווח הארוך נראה כי המדינות רואות ברשת ההולכה והחלוקה פלטפורמה להובלת דלקים מתחדשים כגון מימן ועלכן לא סביר שיחדלו בהשקעה ברשתות החלוקה וההולכה.

משק הגז הטבעי- בישראל

משק הגז הטבעי עבר תהפוכות בשנים האחרונות עקב גילוי מצבורי גז טבעי בשטחי המדינה. כיום מדינת ישראל עוברת תהליך נרחב של הטמעת השימוש בגז טבעי מקומי שיחליף ייבוא של דלקים מזהמים יותר ואף החלה לייצא גז טבעי למדינות השכנות. גילוי מאגרי הגז הטבעי אפשרו למשק האנרגיה הישראלי לעבור מאנרגיה שמבוססת על פחם ודלקים שונים ומזהמים לגז טבעי זול וסביבתי יותר. היום, מאגרי הגז "תמר" ו-"לוויתן" מספקים גז טבעי לכלל המשק הישראלי ולייצוא למצריים וירדן, ובמחצית השנייה של 2022 עתיד להצטרף מאגר נוסף - "כריש תנין" שיקדם את המהפכה בתחום האנרגיה בישראל ויאפשר ייצוא נוסף למדינות השכנות לה. משרד האנרגיה מעודד מעבר לשימוש בגז טבעי ודלקים תחליפיים אחרים כמקורות אנרגיה נקיים וידידותיים יותר לסביבה, כבר היום כ- 70% ממשק החשמל פועל על גז טבעי, ועד שנת 2026 ייגמל מהשימוש בפחם (תרשים 29). התפתחויות אלו צפויות להמשיך את מגמת העלייה בביקוש לגז טבעי בישראל ולהוביל לצמצום התלות האסטרטגית והכלכלית של ישראל בנפט ובפחם, להקטין את טביעת הרגל הפחמנית, ולשפר את איכות האוויר בישראל.



תרשים 29: ייצור חשמל לפי סוג דלק עיקרי בשנים 2019-2030

בשנת 2019, חלקו של הגז הטבעי בתמהיל ייצור החשמל בישראל עמד על 64%. צריכת הגז החליפה את השימוש בפחם ובתזקיקי נפט מזהמים יותר, סולר ומזוט. בתרשים 29 ניתן לראות את העלייה הצפויה בשימוש בגז טבעי לייצור חשמל על חשבון שימוש בפחם עד להפסקת השימוש בפחם בשנת 2026 ועליית שיעור השימוש בגז טבעי לשיא של 78%. משנת 2026 שיעורו של הגז הטבעי ילך ויקטן בהתאם לעלייה בשיעור האנרגיה המתחדשת בתמהיל הייצור.

בנוסף לתפקידו המשמעותי בהפחתת הפליטות כתוצאה בהפסקת השימוש בדלקים מזהמים יותר, הגז הטבעי תורם להפחתת מחירי האנרגיה והחשמל בישראל והינו מקור הכנסות למדינה מתמלוגים וממיסים[83]. על פי הערכת רשות הגז הטבעי, החיסכון המשקי בשנים 2019-2004 הנובע ממעבר לגז טבעי הינו כ- 71.3 מיליארד ש"ח למשק הישראלי בעלויות ישירות של אנרגיה[84], כ- 78% מהחיסכון המשקי נובע מהפחתת עלויות בייצור חשמל ובכך תורם להפחתה משמעותית בתעריפי החשמל במשק, והיתרה מקורה בחיסכון בסקטור התעשייה.

בשנים הקרובות צפוי המשך פיתוח משק הגז הטבעי, הן בצד ההיצע בעקבות פיתוחם של מאגר תנין וכריש ועידוד פיתוח מאגרים נוספים והן בצד הביקוש בשל גידול צפוי בביקוש לגז טבעי בסקטור החשמל, בסקטור התעשייה ובסקטור התחבורה כתוצאה מהמעבר הצפוי של רכבים פרטיים מדלק קונבנציונלי לרכבים חשמליים.

עם זאת, המעבר לאנרגיות מתחדשות בישראל מעלה שאלות מהותיות בנוגע למדיניות יצוא גז טבעי בישראל. מדיניות היצוא אשר נקבעה במהלך השנים מבקשת לשמור על עתודות גז טבעי למשק הישראלי. כעת, לאור המגמות העולמיות, ההחלטה העקרונית למעבר לכלכלה דלת פחמן והשאיפה לצמצום פליטות דורשים חישוב מחדש של הערכת הביקוש לגז טבעי. הגדלה משמעותית של נפח האנרגיות המתחדשות, או אנרגיה חלופית אחרת, בסל הדלקים לחשמל, משמעותה הפחתת הביקוש לגז הטבעי, ומכך להגדלת מלאי הגז הטבעי הזמין לייצוא.

יתרה מכך, המגמה העולמית ל"גמילה" מדלקים מזהמים, והתייחסות לגז טבעי כ"דלק מעבר" בשנים הקרובות, עשויה להביא, בהתאם לתרחישים מסוימים, להגדלת הביקוש העולמי לגז טבעי עד לנקודת שיא לקראת סיום העשור הנוכחי, ולאחר מכן לירידה בביקוש העולמי בשל המעבר לאנרגיות חלופיות[85]. המשמעות היא שנוצר "חלון הזדמנויות" מוגבל בזמן, וכי גז טבעי שלא יימכר ב 10-20 השנים הקרובות, קטנים הסיכויים שיימכר כלל, וזאת בנוסף לתועלת הכלכלית הנובעת מהקדמת ההכנסות. משכך, נבחנות בימים אלה ההגבלות על יצוא הגז הטבעי במסגרת ועדה בין-משרדית[86].

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[83] נציין כי בשנת 2019 משרד האנרגיה גבה כ 839 מלש"ח בגין תמלוגים על גז טבעי ובעתיד צפויות הכנסות משמעותיות נוספות גם מהיטל על הגז הטבעי.

[84] החישוב לפי הערכת רשות הגז הטבעי ובהשוואה למשק ללא גז טבעי ועם הקמת תחנות פחמיות D ו E לפי התכנון מקורי.
הערכה זו מתייחסת לחיסכון כלכלי בלבד ואינה מגלמת את התועלות הסביבתיות במעבר לגז טבעי

[85] https://www.iea.org/reports/world-energy-outlook-2019/gas

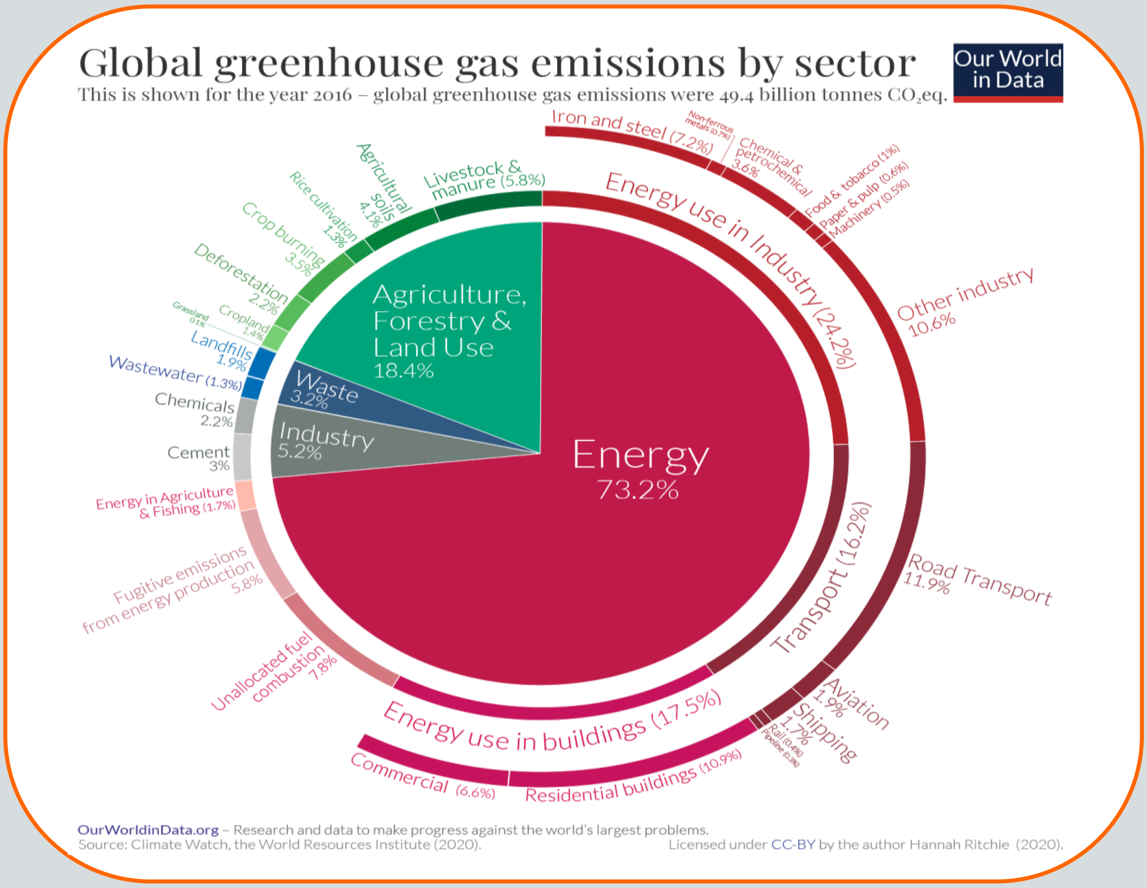
[86] החלטת ממשלה 465 , סעיף 13 2020_ https://www.gov.il/he/departments/policies/dec465

בנוסף, בדומה למדינות אחרות גם המשק הישראלי פיתח במהלך השני האחרונות מערכות הולכה וחלוקה של גז טבעי. מערכות אלה, כפי שמתחיל לקרות גם בעולם, צפויות לעבור התאמה להובלת דלקים נקיים יותר ולשילוב מימן כפי שפורט לעיל.

תחבורה

תחבורה- מגמות בינ"ל

בכלל, התחבורה אחראית על כ- 16.2% מכלל פליטות גזי החממה בעולם (תרשים 30). עם זאת בעולם המערבי הנתח הינו גבוה יותר. לפי האיחוד האירופי, נתח התחבורה כולל תחבורה ימית ואווירית עומד על כ 26% אחוזים, לפי האסטרטגיה האמריקאית להפחתת פליטות, התחבורה מהווה נתח של 34% מסך פליטות גזי החממה.


Global greenhouse gas emissions by sector

This is shown for the year 2016 – global greenhouse gas emissions were 49.4 billion tonnes CO_2eq.

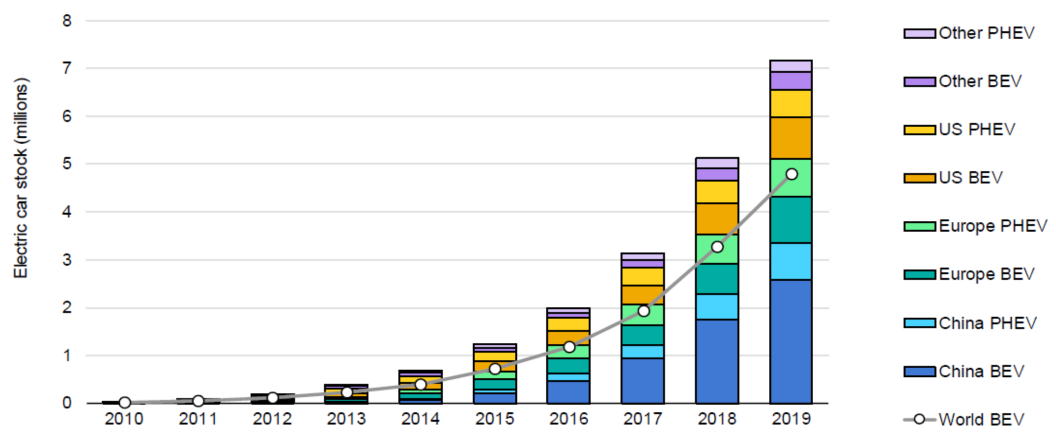
OurWorldinData.org – Research and data to make progress against the world's largest problems.
Source: Climate Watch, the World Resources Institute (2020).
Licensed under CC-BY by the author Hannah Ritchie (2020).

תרשים 30 : פילוח פליטות גזי חממה עולמי לפי שימושים.

התלות בנפט כמקור אנרגיה לתחבורה בארץ ובעולם היא כמעט מוחלטת. למעשה, למעלה מ-90% מצריכת האנרגיה בתחבורה העולמית מקורה בנפט, בישראל התלות אף גדולה יותר. לתלות זו ישנן השלכות שליליות ביותר מההיבט הסביבתי (כתוצאה מפליטות גזי חממה ומזהמים אחרים), בהיבט הכלכלי (מאחר ומחירי הנפט מתאפיינים בתנודתיות גבוהה), ובהיבט הגיאופוליטי (מאחר והנפט מצוי בחלקו הגדול במדינות התורמות לחוסר יציבות פוליטית). לאור הנזק הסביבתי, כלכלי וגיאופוליטי, מדינות רבות הציבו לעצמן יעדים ברורים להפחתת התלות בנפט.

מסקירת התחום עולה כי למדינות רבות תכניות אסטרטגיות לשנת 2050 בכל הנוגע לתחבורה. כך למשל האסטרטגיה של ארה"ב לכלכלה דלת פחמן לאמצע המאה[87], מציגה עבור סקטור התחבורה כולו, הפחתה משמעותית בצריכת הדלקים תוך מעבר לדלקים ביולוגיים וחשמל, בשיעורים שווים. על אף שהתכנית מציגה הפחתה משמעותית בצריכת דלקים בשנת 2050 לעומת תרחיש עסקים כרגיל, מדובר בתכנית פחות שאפתנית מהתכנית שמציג האיחוד האירופי[88]. ארה"ב משרטטת חזון כללי למדי בתחום התחבורה הכולל שלוש אבני יסוד (בסדר הזה): שיפור משמעותי של יעילות כלי הרכב, פיתוח של רכבים ודלקים דלי פחמן והפחתת הנסועה. חשיבות הסדר נעוצה בדגש ובסדר האמצעים המוצגים בחזון, כאשר ברור כי שיפור יעילות כלי הרכב הקונבנציונאליים הינה מוגבלת יחסית.

האיחוד האירופי מציג את התכנית הקיימת במסגרת ה *EU Mobility strategy*. תכנית שאושרה על ידי חברות האיחוד ב 2016, המציבה יעד של בין 60-100% הפחתה של פליטות גזי חממה בשנת 2050 ביחס לשנת 1990 במגזר התחבורה. התכנית כוללת שלוש "חבילות" חקיקה שעסקו במכלול של נושאים הקשורים לתחבורת כביש בעיקר, ביצועים של כלי רכב, תשתיות טעינה ופיתוח סוללות. בשנים האחרונות אנו עדים לעלייה ניכרת בתפוצת רכבי נוסעים חשמליים בעולם, וזאת בין היתר, בשל התפתחויות טכנולוגיות וירידת מחירי הסוללות. בשנת 2019 מספרם חצה את סף השבעה מיליון, גידול שנתי ממוצע של 60% לשנים 2014-2019 (תרשים 31), ובסוף שנת 2020 מספרם עבר את ה- 10 מיליון רכבים. כ-70% מכלי הרכב החשמליים בעולם הינם חשמליים מלאים והיתרה הם פלאג-אין היברידיים.



תרשים 31: מצאי רכבים פרטיים חשמליים בשנים 2010-2019 לפי אזורים נבחרים בעולם, IEA 2020

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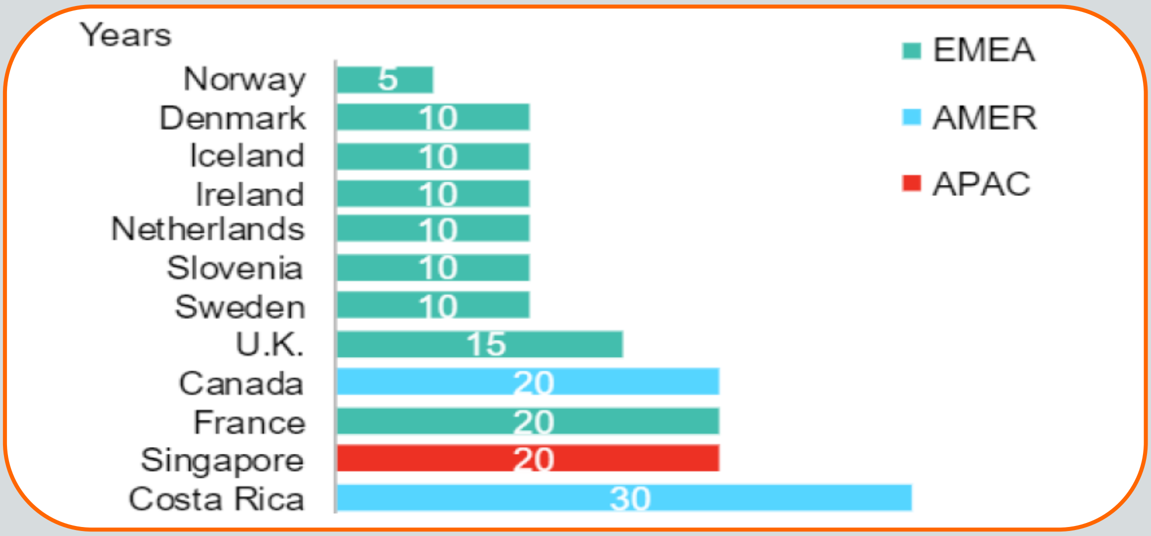
[87] Mid-Century Strategy, נובמבר 2016

[88] חשוב לציין כי התכנית הוצגה בסוף שנת 2016 ועל כן חלק מההתפתחות שחוותה תעשיית הרכב החשמלי לא נכנסו לאמדנים.

מגמת הגידול במספרם המוחלט ובנתח השוק של רכבים חשמליים צפויה להימשך בעתיד ואף לצבור תאוצה, בין היתר כתוצאה מאימוץ יעדים המגבילים את השימוש במנועי בעירה פנימית מחד, ומעודדים את השימוש ברכבים חשמליים מאידך, על ידי ממשלות ויצרניות רכב.

כעשר מדינות, הכוללות בשטחן כשני שליש מסך מלאי הרכבים בעולם, ביניהן סין, הודו, יפן, קנדה וצרפת, הצהירו על יעד חדירה של 30% עד שנת 2030, חלק מקמפיין בינלאומי להאצת השימוש בתחבורה חשמלית EV30@30. ישנן מדינות, אשר הלכו צעד נוסף קדימה והכריזו על כוונתן לאסור מכירת רכבים מונעים במנוע בעירה פנימית בעתיד (תרשים 32 מציג חלק מהמדינות). בנורבגיה איסור זה אמור להיכנס לתוקף כבר בשנת 2025 ואילו בהולנד, אירלנד, דנמרק, איסלנד, סלובניה ושבדיה שנת היעד היא 2030. מדינות עם צי רכבים גדולים נוטות להחיל את האיסור בשלב מאוחר יותר, ובהתאם לכך צרפת, אנגליה, ספרד וקנדה הכריזו על 2040 כשנת יעד לאיסור מכירת כלי רכב מונעים במנוע בעירה פנימית. יש לציין כי במרבית המדינות יעדים אלו טרם עוגנו רשמית.



תרשים 32: שנים שנותרו לאיסור על מכירת כלי רכב עם מנועי בעירה פנימית במדינות נבחרות לפי שנת 2020 (BNEF, 2020).

מגמת הגידול הצפויה בשוק הרכבים החשמליים בעולם מוצאת ביטוי גם בתכניותיהן של יצרניות הרכב. לאחרונה, יצרניות רבות הכריזו על יעדים ברורים הן במספר הדגמים החשמליים אשר יוצעו והן באחוז שלהם מסך הדגמים והמכירות. קבוצת רנו, למשל, הכריזה כי עד 2022, 20% מכלי הרכב הנמכרים יהיו חשמליים, וולוו הכריזה כי עד שנת 2025, 50% מכלי הרכב הנמכרים יהיו חשמליים, ואילו פולקסווגן ומרצדס קבוע יעד מכירות של 25% עד אותה שנה. כמו כן, פורד, פג'ו-קרייזלר, וג'יאם

מתכננות להשיק 40, 28 ו-20 דגמים חשמליים חדשים עד שנת 2023, בהתאמה. פולקסווגן שמובילה בהיקף הדגמים החשמליים המתוכננים עד 2025, מתכננת להשיק כ-80 דגמים חדשים.

מדינות רבות בעולם החלו לנקוט בשורה של צעדים לקידום המעבר לרכבים חשמליים. האיחוד האירופאי, ארה"ב וסין כוללות בשטחן למעלה מ-95% ממצאי הרכבים החשמליים בעולם. מבחינת אמצעי המדיניות במדינות אלה, בולטים במיוחד הצעדים הבאים:

- סטנדרט לצמצום פליטות פד"ח בקרב הרכבים הנמכרים במדינה.
- אימוץ דירקטיבה חדשה הקובעת דרישות מינימום לתשתית מקדמית להתקנת עמדות טעינה במבנים חדשים ובמבנים שמיועדים לשיפוץ.
- תמריצים לרכישת רכבים חשמליים (הטבות מס ומענקים).
- קביעת יעדים לחדירת רכבים חשמליים ובחלק מהמקרים גם יעדים להקמת עמדות טעינה.
- העברה הדרגתית של ציים ממשלתיים וציבוריים לרכבים מופחתי פליטות.

בניגוד לעולם התחבורה הקלה, אשר עתיד לעבור חשמול בעשור הקרוב עקב התפתחות מהירה של טכנולוגית הסוללות, בענפי התחבורה האחרים התמונה הינה מורכבת, וקיימות מספר טכנולוגיות שונות אשר ישמשו כולן במגזרי התחבורה השונים, בשלבים שונים במהלך העשורים הבאים. כפי שעולה ממרבית התכניות האסטרטגיות והסקירות הבינלאומיות (האיחוד האירופי, ארה"ב, צרפת, בריטניה, דנמרק, צ'כיה[92,91,90,89]), חשמול באמצעות סוללות, שהינה טכנולוגיה דומיננטית בעולם התחבורה הקלה נתקלת בקשיים משמעותיים בעולם התחבורה הכבדה (משאיות שבטווח שמעל 12- 15 טון). חשוב להדגיש כי קיימים נעלמים טכנולוגיים משמעותיים, באשר לקצב הפיתוח וההבשלה של מרבית מטכנולוגיות אלו, כך שקשה לקבוע בשלב זה מה תהייה הטכנולוגיה הדומיננטית, כמו גם נעלמים אחרים משמעותיים כגון מחירי הנפט, המודעות הסביבתית והפתרונות הטכנולוגיים בענפי האנרגיה המקבילים.

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[89] A time of unprecedented change the transport system

[90] France National low Carbon Strategy

[91] clean planet for all

[92] United States Mid-Century Strategy FOR DEEP DECARBONIZATION

תחבורה- בישראל

הערכות המשק למעבר לתחבורה מאופסת ודלת פחמן מטופלת בתכניות האסטרטגיות של משרד התחבורה, אולם בשל החשיבות המכרעת של הסקטור על משק האנרגיה הישראלי, נדון בעבודה זו בעיקרי המגמות העולמיות ותוכניות הכוללות צעדי מדיניות משלימים למעבר לתחבורה נקייה.

בישראל, סקטור התחבורה אחראי לכ- 20% מסך הפליטות והינו המקור העיקרי לזיהום אוויר במרכזי ערים ובריכוזי אוכלוסין[93].

על אף התפוצה ההולכת וגוברת של רכבים חשמליים בעולם, המעבר בישראל לרכב חשמלי הוא עדין מצומצם. מתוך כ-3 מיליון כלי רכב פרטיים בישראל, רק כ -16 אלף הם חשמליים, ומתוכם כ-3,000 הם חשמליים מלאים. יחד עם זאת, בשנת 2020 לבדה נכנסו לישראל למעלה מ-1,500 רכבים חשמליים מלאים, יותר מכל השנים האחרונות ביחד[94]. ישראל יכולה להאיץ את כניסת הרכב החשמלי בשל התנאים הייחודים שלה, המעניקים לה יתרון משמעותי באימוץ הנעות חלופיות בייחס למדינות העולם:

- שטח מדינת ישראל הוא קטן יחסית ומרחקי הנסיעה בה קצרים, עובדה המאפשרת פריסה נוחה ומצומצמת יחסית של תשתיות טעינה.
- מחירי הדלקים הפוסיליים בישראל גבוהים ביחס למחירי החשמל הנמוכים יחסית (גם בניכוי המיסוי).
- לישראל יש מקורות אנרגיה עצמיים לייצור חשמל (מאגרי גז טבעי גדולים ושעות שמש רבות), ולעומת זאת אין לה כמעט עתודות נפט.
- ישראל היא מהמדינות החדשניות ביותר בעולם, והציבור בה נוהג לאמץ ולהוביל חדשנות טכנולוגית.

שילוב תנאים אלו עם מגמות עולמיות, בראשן ירידת מחירי הרכבים עד שנת 2026 ועליית טווח הנסועה, יכולים לסייע לישראל להיות בין המדינות המובילות בעולם בחדירת רכב חשמלי. בשנת 2018 הגדיר משרד האנרגיה יעדים שאפתניים לחדירת רכב חשמלי בישראל עד שנת 2030[95]. במקביל החל המשרד, ביחד עם משרדי ממשלה נוספים, לפעול לקידום עמידה ביעדים אלו, בין היתר באמצעות מתן מענקים בסך של 30 מלש"ח להקמת 2,500 נקודות טעינה ציבוריות (מהירות ואטיות), הארכת מתווה המיסוי המתמרץ לרכבים חשמליים עד לשנת 2024 (משרד האוצר)[96], והכנת טיוטות

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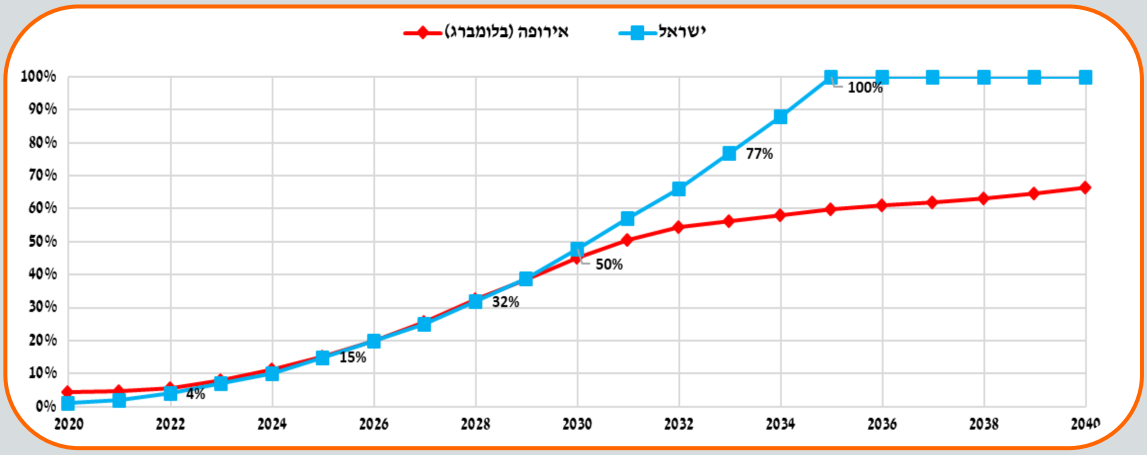
[93] התכנית הלאומית להפחתת זיהום אוויר, 2018

[94] שנת 2020

[95] יעדי משק האנרגיה לשנת 2030 : https://www.gov.il/BlobFolder/news/plan_2030/he/2030summary.pd

[96] עד שנת 2022 המיסוי על רכב חשמלי יעמוד על 10% ולאחר מכן יעלה בהדרגה עד ל-35% בשנת 2024.

להנחיות ושינוי חקיקה להקמת תשתיות לעמדות טעינה בבתים משותפים בשלב הבניה ולאחריה (משרד הבינוי והשיכון, משרד המשפטים ומנהלת תחליפי דלקים).



תרשים 33: יעדי חדירת רכב חשמלי לישראל והתחזית באירופה (% ממכירות).

תרשים 33 שלעיל מתאר את תרחיש החדירה הממוצע לאירופה לפי תחזיות בלומברג ואת תרחיש החדירה המוצע לישראל. מהתרשים ניתן לראות כי עד 2030 עקומת החדירה בישראל מתנהגת באופן דומה לממוצע האירופאי, אך לאחר 2030, העקומה בישראל עולה בקצב מהיר יותר. עליה זו משקפת את היתרונות הייחודים של ישראל באימוץ תחבורה חשמלית, ותלויה כאמור בהנחות על גורמים חיצוניים כגון היצע הדגמים שיהיה זמין עבור השוק הישראלי, מחירי הרכבים לפני הטבות מס, מרחקי הנסיעה של הרכבים, וכן בהסתמכות על גורמים אנדוגניים לישראל ובראשם צעדי הממשלה לעידוד התחבורה החשמלית. ללא כל אלו, המעבר לא יוכל להתרחש בקצב הנדרש ועל כן הוא מותנה באימוץ הצעדים המוצעים לקידום תחבורה חשמלית בישראל ובהתפתחויות הטכנולוגיות של הרכבים החשמליים.

עד 2025 יעדי החדירה של הרכבים החשמליים (תרשים 33) יכללו רכבי פלאג-אין ומ- 2025 היעדים יתייחסו רק לרכבים שאינם פולטים מזהמים באופן ישיר בעת הנסיעה (Zero Emission Vehicles), לדוגמא רכבים חשמליים מלאים, רכבי מימן, וכל טכנולוגיה אחרת שעשויה להתפתח עד אז, ככל ותעמוד בדרישות אלו.[97] על פי תרחיש זה, החל מ- 2030 תאמץ ישראל את הרגולציה המקובלת בעולם ותאמץ מדיניות של "אפס רכבים שאינם נכללים בקטגוריית ZEV" .

נכון לשנת 2019 מצבת הרכבים הכבדים עמד על 312 אלף משאיות וכ- 21 אלף אוטובוסים. סה"כ צריכת התעופה האזרחית עמדה על כ 1300 אלף טון דס"ל בשנה, צריכת התחבורה הימית נאמדה

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[97] רכבי פלאג-אין יותרו למכירה גם לאחר 2025 (ועד שנת 2035) אך לא יספרו ביעדי החדירה.

בב- 250 אלף טון מזוט וסולר, ,צריכת הדלק של הרכבת בישראל נאמדת בב- 70 אלף טון סולר כאשר צריכת כלי הצמ"ה בישראל מוערכת בב- 600 אלף טון.

אחד המאפיינים העיקריים של מדיניות האנרגיה של ישראל בשנים האחרונות היא המוטיבציה לנצל את מאגרי הגז הטבעי שנתגלו לחופיה, וזאת בניגוד למוצרי נפט שהינם מיובאים. מוטיבציה זו פועלת הן לשימוש בגז הטבעי באופן ישיר בכלי תחבורה (גז טבעי דחוס/נוזלי) או באופן עקיף ככלי רכב חשמליים. הגז הטבעי עשוי להיכנס כדלק חלופי בעיקר במשאיות הכבדות והאוטובוסים הבינעירוניים, ובאופן חלקי גם לתחבורה הימית. כניסתו של הגז עדיין מוטלת בספק לאור הקשיים הרבים הקשורים בתשתיות התדלוק, המחירים, היצע הדגמים ובעיות נוספות. כניסתו תלויה בצירוף של מספר רב של גורמים, חלקם גלובליים כמו מגמות עולמיות של יצרני המשאיות, מחירי הנפט בשנים הקרובות וכיוצ"ב, וחלקם גורמים מקומיים כמו מערך התמריצים והמדיניות הממשלתית, והמאמצים של הגורמים הרלוונטיים בהתנעת סקטור הגז לתחבורה.

למרות שמרבית ההנעה הכבדה בישראל יכולה להסתמך על גז טבעי דחוס, הרי שקיים פוטנציאל לא מבוטל דווקא בגט"ן, המתאים לצריכת משאיות כבדות מאד, ויכול להסתמך על מערך תשתית תדלוק מצומצם ביחס לגט"ד. כמו גם היצע הרכבים בגט"ן הולך וגדל וזאת לאור העובדה כי מחירי הגט"ן הם בין הנמוכים בעולם הצפויים להישאר נמוכים לאורך זמן כך שחלופה זו כדאית יותר ויותר. כרגע אין לישראל גישה לגט"ן מיובא במחירים אלו, אך יתכן כי אופציה זו תיפתח בשנים הבאות. חשוב להדגיש כי בעולם, בשנים האחרונות, ההנעה בגז טבעי משולבת בתכניות לניצול ביוגז באופן ישיר.

הנעה חשמלית באמצעות סוללות הינה אופציה כרגע גם בתחום של המשאיות הקלות וגם בתחום של המשאיות הבינוניות, אם כי כרגע נראה כי חלופה אמיתית באמצעות סוללות מתרחקת ככל שמשקל המשאית גדל.

המימן הינו חלופה מבטיחה במובן זה שהוא מאפשר שילוב של מנוע חשמלי ללא סוללה גדולה שעלות ייצורה (הישירה והסביבתית) הינה גבוהה. עם זאת, כרגע המימן סובל מעלות גבוהה מאד בכל שרשרת הייצור: ייצור המימן, תשתית התדלוק ועלות הרכב. גם אם תהיה פריצה בתחום הוזלת הטכנולוגיה באחד המקטעים בשרשרת צפוי עוד זמן רב עד שיוזלו במידה ניכרת כל המקטעים.

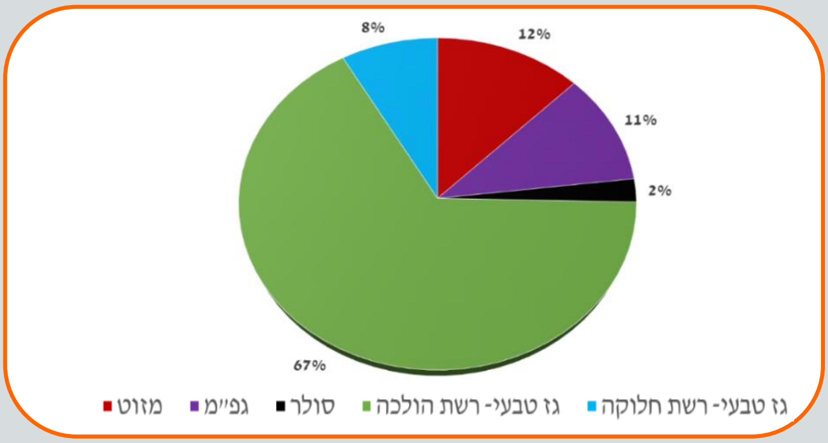
סקטור תחבורה נוסף שבו צפוי להתחולל שינוי כבר בעשור הקרוב הינו סקטור התחבורה הימית אשר נשען כיום על דלקים זולים, לא יעילים ומזהמים כמו סוגים שונים של מזוט. עקב החמרת הדרישות הסביבתיות וסיבות נוספות, פונה הסקטור לאמצעים שונים להפחתת טביעת הרגל הפחמנית וזאת באמצעות דלקים חלופיים וביניהם גז טבעי נוזלי. הגז הטבעי, בעקבות מחירו הזול, עשוי להשתלם כלכלית מאד בטווח הקצר והבינוני, אך מחייב השקעות ניכרות בתשתיות תדלוק והתאמת מנועי הספינות.

תעשייה

הערכות המשק למעבר לתעשייה מאופסת ודלת פחמן מטופלת בתכניות האסטרטגיות של משרד הכלכלה, אולם לאור הממשק עם סקטור האנרגיה, נידונים בעבודה זו צעדי מדיניות משלימים למעבר לתחליפי דלקים בתעשייה.

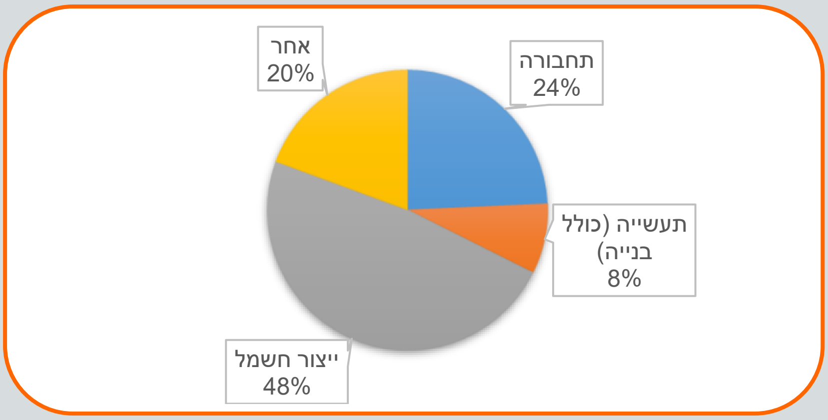
התעשייה בישראל מגוונת במיוחד ומתפרשת על פני אופקים רבים. בין התעשיות החשובות ביותר של ישראל ניתן למצוא את ענפי התעשייה הכימיים, תעשיית המזון והמשקאות, תעשיית ליטוש היהלומים, תעשיות פרמבצטיות, אלקטרוניקה, תעשיות ביטחוניות ותעשיות אנרגיה.

נכון לשנת 2017 סך צריכת הדלקים המזהמים בתעשייה עומדת על יותר מ- 500 אלף טון. דלקים אלו כוללים מזוט, גפ"מ וסולר. בנוסף לדלקים אלו, נצרכו בשנת 2017 בתעשייה כ- 1.81 BCM גז טבעי (תרשים 34). שיעורם של הדלקים המזהמים מסך צריכת האנרגיה בתעשייה בשנת 2017 עמד על כ-25%.



תרשים 34 : צריכת אנרגיה בתעשייה הישראלית בשנת 2017, למ"ס.

נכון לשנת 2016, פליטות התעשייה היוו 8% מפליטות גזי החממה בישראל כך שסקטור התעשייה הינו הסקטור השלישי בגודלו אחרי סקטור ייצור החשמל והתחבורה (תרשים 35).



תרשים 35: פליטות גזי חממה (**CO_2e**) לפי סקטורים מרכזיים במשק. [98]

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[98] למ"ס 2018

לאור החשיבות הרבה בצמצום הפליטות בסקטור זה, הפסקת השימוש בדלקים מזהמים בתעשייה והחלפתם במקורות אנרגיה יעילים ונקיים יותר, מקדמת הממשלה בשנים האחרונות מדיניות תמיכה לעידוד חיבור מפעלים לרשת חלוקת הגז הטבעי.

להעברת משק התעשייה לשימוש נרחב בגז טבעי יש היתכנות טכנית וכדאיות כלכלית וסביבתית. סך צריכת הגז הטבעי הצפויה מחיבור של כ-450 צרכני תעשייה פוטנציאלים לרשת החלוקה עד שנת 2030 הינה כ- BCM 0.72, ומהווה כ-80% מפוטנציאל הצריכה התעשייתית הקלה, כאשר התועלת המשקית עד שנת 2040 נאמדת בכ-10.6 מיליארד ₪. עם השלמת המהלך הכולל, ייחסכו למשק בכל שנה כ- 900 מיליון ₪. התועלת המשקית מחיבורם של כ-250 צרכנים נוספים (קטנים יותר, שסך צריכתם עומד על BCM 0.27) עומדת על סך של כ- 5.3 מיליארד ₪. תועלת זו נובעת בעיקר מחיסכון בעלות דלקים שנאמדת בכ-3.2 מיליארד ₪ (כולל הכנסות ממיסוי גז טבעי של כ-2.6 מיליארד ₪) ותועלת סביבתית, שעיקרה הפחתת פליטות מזהמים, שנאמדת בכ-2.6 מיליארד ₪. עם השלמת חיבור צרכנים אלו, ייחסכו למשק בכל שנה כ- 500 מיליון ₪ נוספים.

אולם, למרות יתרונותיו של הגז הטבעי בהפחתת פליטות גזי חממה ומזהמים מקומיים חלף דלקים מזהמים יותר, הוא אינו דלק נקי לחלוטין או מתחדש. מתוך כך במבט צופה פני עתיד, ברור שלצורך איפוס הפליטות ממגזר זה יהיה צורך לעבור בשלב הבא לחלופות נקיות כגון חשמל ממקור סולארי בתעשיות אשר שימושי האנרגיה בהן מאפשרים זאת או מימן כחול/ירוק.

בנוסף וכפי שפירטנו לעיל, אחד ממנועי הפחתת הפליטות המשמעותיים הוא האנרגיה שלא נצרכה, כלומר התייעלות באנרגיה בסקטור התעשייה. בתוכנית הלאומית להתייעלות באנרגיה שפורסמה בסוף שנת 2020, מפורט חלקה באמור של התעשייה ומתוך כך עולה כי בין השנים 2017-2013 הצריכה הכוללת של המגזר התעשייתי ירדה בכ- 99.6%. מגזר התעשייה הינו המגזר היחיד אשר הפחית את צריכתו באופן אבסולוטי בשנים אלו.

התייעלות זו ניתנת להסבר באמצעות מספר סיבות:

- הסבת מפעלי תעשייה לגז טבעי - הסבת תזקיקי נפט לגז טבעי לרוב מלווה בשיפור נצילות התהליך.
- תמריצים ומענקים שחולקו לתעשייה במטרה לקדם טכנולוגיות יעילות באנרגיה.
- צעדים רגולטוריים בתעשייה, כדוגמת חובת ביצוע סקרי אנרגיה.
- התייעלות בתעשייה הנובעת משיפורים טכנולוגיים וחדירה של טכנולוגיות חדשות לשוק.

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[99] ע"ב פרסומי הלשכה המרכזית לסטטיסטיקה - מאזני אנרגיה בשנים 2017-2013. עדכון: 6.1.2019

המשך הפחתת הפליטות במגזר התעשייה צפוי להמשיך ולרדת בעקבות שינוי פרופיל התעשייה, חיבור מפעלים לתשתית הגז הטבעי והמשך מעבר התעשייה לשימוש בגז טבעי חלף דלקים מזהמים וכן חשמול התעשייה שמאפשרת זאת, כמו גם המשך השקעה בפרויקטים של התייעלות באנרגיה המלווה ברגולציה מעודדת הפחתת פליטות במגזר זה.

שיתופי פעולה אזוריים

המגמות במשקי האנרגיה העולמיים כמו גם השינויים והמאפיינים של המשק הישראלי והאזור: הסכמי השלום ההיסטוריים ממזרח, השאיפה לביטחון באנרגיה, המעבר לאנרגיה נקייה ומתחדשת וגילויי הגז שהעניקו לישראל עצמאות באנרגיה והפכו אותה לשחקנית בתחום, הם הבסיס לחזון האנרגיה האזורי של משק האנרגיה הישראלי.

מתוך חזון משק האנרגיה לשנת 2050 ומתוך הסתכלות על האיומים וההזדמנויות שמציב בפנינו העתיד, נראה כי יש לפעול כבר היום לביסוס שיתופי פעולה עם המדינות השכנות. השאיפה להפחתת פליטות ואתה המעבר לאנרגיות מתחדשות מזמן הזדמנות מחודשת לשיתופי פעולה אזוריים שיאפשרו חיבור רשתות חשמל, יצוא גז טבעי, רכישת חשמל ירוק משכנותינו וביצוע פרוייקטי תשתית בינלאומיים שיהוו בסיס לשיתוף פעולה כלכלי אזורי הנסמך על משק האנרגיה. הסכם השלום ההיסטורי עם איחוד האמירויות הערביות, שהוביל לתגובת שרשרת של הסכמים דומים עם מדינות שכנות נוספות, הוא הזדמנות ייחודית בקנה מידה עולמי לביסוס ביטחון האנרגיה בישראל ולפיתוח כלכלות האנרגיה באזורנו.

מדינת ישראל ראתה עצמה כאי אנרגטי במשך רוב תקופת קיומה ורק לאחרונה ביססה עצמה כבעלת עצמאות באנרגיה וזאת בזכות מאגרי הגז שנמצאו בשטחינו. כיום, המגמה התהפכה ומתלות מוחלטת ביבוא ממדינות זרות הפכנו ליצואנים ובתוך כך ביססנו את תפקידנו האזורי בעידוד המעבר לדלקים פחות מזהמים גם בקרב שכנינו. בראייה ארוכת טווח יש לבחון הקמת תשתיות אזוריות משותפות אשר יבססו את כלכלות האזור כבר היום וכן יישאו הבטחה לטרנספורמציה אנרגטית בעתיד – כך למשל רשתות הגז עשויות להפוך תשתית להזרמת מימן למשל.

צעדי המדיניות שנגזרים מהחזון הם הלכה למעשה תכנית העבודה של משרד האנרגיה וזאת מתוך הסתכלות אסטרטגית על האזור והתהליכים בו. להלן פירוט צעדי המדיניות, הנושאים והפרויקטים בדרך למימוש חזון האנרגיה האזורי.

תשתיות בינלאומיות: חיבורי חשמל אזוריים

פרויקטים של תשתיות חשמל בינלאומיות יכולים לשמש כזרז לאנרגיות מתחדשות וקישוריות בין מדינות. מערכת החשמל האירופאית ומדינות נוספות, המחוברות אליה, מקיימות רשת מסועפת אשר מתפרסת בכל יבשת אירופה ומתחברת הן למדינות הסקנדינביות, מדינות אסיה ומדינות צפון אפריקה. קישוריות זו מאפשרת למדינות לסחור בחשמל מצד אחד ומצד שני לייצב את מערכות הביקוש וההיצע שלהן וכך להגיע למערכת מאוזנת ויעילה יותר שתוכל לאפשר ייצור חשמל מאנרגיה מתחדשת בכמויות גדולות מאוד.

הכבל החשמלי לאירופה

בימים אלו משרד האנרגיה מבצע בחינת התכנות לחיבור רשת החשמל המקומית לאירופאית באמצעות הכבל הקפריסאי. הכבל מתוכנן לחבר בין ישראל, קפריסין, כרתים וחצי האי היווני וכך לחבר את רשת החשמל הישראלית אל הרשת החשמל האירופאית[100]. חיבור של מדינת ישראל למערכת זו בעל חשיבות גבוהה כיוון שיאפשר מכירת עודפי חשמל שייווצרו מהגדלת אחוז המתחדשות בתמהיל הייצור וקניית חשמל נקי בעת מחסור, ייצר מערכת יציבה ויעילה יותר, יעלה את בטחון האנרגיה בעתות חירום ויחסוך בהקמת מתקני ייצור נוספים.

חיבור חשמלי עם ירדן, מצרים ומדינות נוספות ורכישת חשמל ירוק

כאמור על מנת להקים רשת מספיק רחבה שתאפשר להגיע לאיזון ולמקסום היעילות בהיצע וביקוש, וכן להקטין שימוש בקרקעות, יש צורך לקשר את מערכות החשמל שלנו גם למדינות שכנות נוספות כמו ירדן, מצריים ואחרות. בירדן ובמצריים ישנם שטחים מדבריים רחבי היקף, בהם קיימת קרינת שמש במרבית ימות השנה, אשר יכולים להיות מנוצלים לטובת בניית שדות סולאריים לייצור חשמל ומכירתו למדינות שכנות הזקוקות לכך. הדבר יתרום לצמיחה כלכלית אזורית ויוכל לספק לישראל גיבוי בשעות שיא וימים בהם הייצור ממתחדשות נמוך יותר.

אחד האתגרים בייצור אנרגיה באתרים אלו הינו הולכת האנרגיה למרחקים ארוכים אשר גורר עלויות נוספות ומתאפיין באובדן אנרגיה בדרך. אפשרויות נוספת להעברת אנרגיה למרחקים ארוכים הינה שימוש במימן. ניתן להפיק מימן בשדות הסולאריים ולהובילו בצנרת לישראל. באופן זה ניתן להעביר כמויות אנרגיה גבוהות משמעותית מקווי מתח עליון ויתכן אף באופן רווחי יותר. בארץ ניתן יהיה להשתמש במימן כדלק לכלי רכב או לתעשייה, לאגירה או לייצור חשמל.

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[100] הפרויקט מקודם ע"י חברת היזם הקפריסאית Euro –Asia Interconnector

החזון של רשת חשמל אזורית נתמך ע"י פרויקטים אזוריים נוספים בתחום החשמל המקודמים באזורינו:

- הסכם שנחתם לאחרונה בין סעודיה לירדן בנוגע לחיבור רשתות חשמל ביניהן.
- תכנית האו"ם לפיתוח רשתות חשמל בין המדינות: מצרים, ירדן, לבנון, הרשות הפלסטינאית, עיראק, לוב, סוריה וטורקיה (The Eight Countries Electric Interconnection Project).
- הסכם לחיבור בין רשת החשמל של עיראק למערכת GCC (Gulf Cooperation Council - מערכת חשמל משותפת של מדינות המפרץ) בתיווך אמריקני.
- חשמל ליריחו - ירדן מספקת חשמל ליריחו באופן קבוע ולאחרונה אושרה הרחבה של חיבור זה ע"י הקמת קו מתח גבוה נוסף, כך שבפועל גם החיבור לירדן כבר מתקיים בשטחינו.

פרויקטים אלה עשויים להיות הבסיס למערכת חשמל משותפת כמו זו שקיימת ברחבי יבשת אירופה ואזורים נרחבים אחרים בעולם. מערכת משותפת ורחבה, מייעלת את ייצור החשמל, מקדמת תהליכים של מעבר לאנרגיות מתחדשות אשר מפחיתות פליטות ותורמות לשמירה על הסביבה. אם נרצה, במבט חזוני לעתיד, מערכת החשמל הישראלית יכולה להתחבר לזו הירדנית, המצרית ואולי אף ישירות למערכת הסעודית דרך הים האדום. כך, פרויקטים אלו בצירוף לקידום החיבור לרשת החשמל האירופאית דרך קפריסין ויוון, ימצבו את ישראל כגשר חשמלי בין מערכת החשמל הפאן ערבית לזו האירופאית.

תשתיות בינלאומיות: גז טבעי

על אף המעבר למתחדשות, לגז הטבעי יהיה ביקוש לשנים קדימה ברחבי העולם כדלק מעבר מעצם היותו דלק נקי יותר מפחם ומזוט. לכן, לתפיסתנו יש לקדם את פרויקט ה- East Med אשר נחתם עם קפריסין ויוון והמתעתד להיחתם גם עם איטליה ו/ או גם עם מדינות הבלקן. אין ספק שבשלבים הבאים גם מצריים וקפריסין יחלו לפתח את המאגרים שבשטחיהן ויצטרפו לייצוא הגז באמצעות צינור ה- East Med.

בתחילת שנת 2020 ישראל החלה לייצא גז טבעי לירדן ולמצריים, אך על מנת לעודד ייצוא גז טבעי נוסף יש לפעול ולקדם את הפעלתם של מתקני הנזלת הגז במצריים וכן הקמת מתקני הנזלת גז צפים. אפשרות נוספת לקידום ייצוא הגז היא דרך הים האדום: כבר היום צנרת הגז שלנו מחוברת דרך ירדן לצנרת הפן ערבית אשר יכולה להזרים את הגז דרומה ולעודד הקמת מתקני הנזלה בסיני. הדבר יאפשר ייצוא אל מדינות אסיה, בהן הדרישה לגז בטבעי נמצאת במגמת עליה חדה, אשר תמשיך במגמה זו ככל שמדינות ענק אלו עוברות מגמות התפתחות וצמיחה אדירות.

באזורינו קיימות שתי מערכות גז בינלאומיות: מערכת פאן ערבית המחברת כאמור, בין ירדן, מצריים וסוריה, וכן מערכת הגז של מדינות המפרץ אשר מגיעה עד ליאנבו השוכנת במערב סעודיה, לחופי הים האדום. מתוך כך ניתן לקדם מערכת אשר תחבר בין שלושת המערכות הללו ותייצר מערכת מסחר משוכללת ויעילה להובלת הגז ממדינות המפרץ לאירופה בצנרת או באמצעות מתקני הנזלה.

קשרי אנרגיה באיו"ש ועזה

ישנה חשיבות רבה שלשטחי הרשות הפלסטינית ועזה יהיו קשרים עם המדינות השכנות על מנת לסחור בחשמל, למקסם ולייעל את מערכות האנרגיה ולקדם שימוש בחשמל נקי ודלקים פחות מזהמים. עזה כבר היום מתקדמת מאוד בכמות השימוש במתחדשות בשטחה, לא רחוק היום בו עזה תתחיל לייבא גז טבעי באמצעות צנרת משטחי ישראל: פרויקט Gas 4 Gasa המקודם יחד עם האיחוד האירופאי, ומדינות נוספות, מתוכנן להסב ולהרחיב את תחנת הכוח בעזה כך שיתאפשר מעבר לייצור חשמל פחות מזהם. הדבר יוביל לאיכות חיים גבוהה יותר, אספקת חשמל אמינה, יציבה וזולה יותר וקידום צמיחה כלכלית ותעסוקה תוך שימוש בדלקים נקיים יותר והפחתת זיהום האוויר.

שטחי הרשות הפלסטינית, נכון להיום מסתמכים כמעט לחלוטין על רשת החשמל הישראלית, וככל שהצמיחה הכלכלית ברשות תעלה כך גם צרכי החשמל, ועל כן יש לעודד הקמת ייצור חשמל מקומי ברשות. על מנת לעודד הקמת תחנות כח הפועלות על גז טבעי, קידם משרד האנרגיה את מדיניות השר דאז, המאפשרת שימוש ברשת החשמל הישראלית להולכת החשמל בין היצרנים לבין נקודות ביקוש ברשות וכך תומך הדבר בהקמת תחנות כח בשטחי הרשות הפלסטינאית. להערכתנו ככל שצינור הגז יתחבר לתחנת כח ג'נין או אחרות כאשר יקומו, התלות ביצור הישראלי תפחת. אנו צופים שבעתיד, הרשות תפרוס רשת חשמל כך שהחשמל יוזרם ישירות מתחנות הכח אל הצרכנים, ללא הצורך בהולכה דרך הרשת הישראלית. בנוסף, יש לעודד את הרשות להגביר את חיבוריה אל מערכות החשמל הירדניות כפי שקיימים היום כבר באזור יריחו, על מנת לקנות חשמל נקי ולשפר את יציבות המערכת שלהם. קשרים אלו יביאו לצמיחה ועידוד תעשייה ותעסוקה בשני האזורים בד בבד עם אנרגיה נקייה, יעילה וברת השגה לכל.

קידום פרוייקטי תשתית משמעותיים

משרד האנרגיה הישראלי מקדם ביום שני פרויקטים של תשתיות בינלאומית לחיבור לאירופה, דרך קפריסין ויוון, במטרה לקדם קישוריות אנרגיה אזורית. קיים פוטנציאל לא מבוטל של ייצוא חשמל מערבה דרך הרשת הישראלית-אירופית, אך גם קישוריות עתידית מזרחה ודרומה דרך ירדן, מצריים ומדינות נוספות. כיוון התפתחות דומה ניתן לראות גם בתחום הגז הטבעי ובמקביל לצינור ה-East Med קיים פוטנציאל לפיתוח תשתיות גז טבעי ליצוא מזרחה ודרומה.

בנוסף, יש לקחת את השינויים הטכנולוגיים האדירים שמתרחשים בסקטור האנרגיה - מימן ובמיוחד מימן ירוק המיוצר באנרגיה מתחדשת, מזוהה כחלק מתמהיל האנרגיה העתידי והאפשרויות בו עצומות. אך לצורך ייצור רווחי אנו זקוקים לקנה מידה גבוה של אנרגיה מתחדשת. הפוטנציאל של ייצור מימן במדבריות המזרח התיכון כאמור לעיל והעברתו דרך צינור גז טבעי משודרג לאירופה דרך ישראל, עשוי להניב רווח כלכלי וסביבתי משמעותי לכל הצדדים המעורבים.

אין ספק כי ההזדמנויות המפורטות בפרק זה בעולם של תשתיות בינלאומיות הן אדירות ואנו רק מגלים את קצה הקרחון שלהן בזכות ההסכמים שנחתמו לא מכבר וכן בזכות פיתוח מאגרי הגז. כפי שראינו את פורום הגז האזורי (EMGF) קורם עור וגידים במהירות שיא ובשיתוף פעולה מדהים של כל הצדדים המעורבים, כך ברור לנו שככל ששיתופי פעולה אלו עם המדינות השכנות, יגברו ופרוייקטי התשתיות הבינלאומיים יתקדמו לצד פיתוחים טכנולוגיים, כך גם הרצון לפיתוח קשרים חדשים ותשתיות נוספות רק ילך ויגבר.

קידום שיתופי פעולה בתחום הסייבר

שיתוף פעולה אסטרטגי נוסף הוא תחום הגנת הסייבר על תשתיות אנרגיה קריטיות: כמו מדינות אחרות בעולם, ישראל מתמודדת עם הסכנות הטמונות באיומי סייבר, במיוחד בתחום תשתיות האנרגיה. אין ספק שקישוריות ופיתוח שיתוף פעולה בתחום זה יכולים לעזור לכל השותפים בדבר. בחזון של שיתוף פעולה אזורי אסטרטגי, בעולם של הגנת תשתיות, יכולים להיווצר הזדמנויות ויתרונות מדהימים חדשים במגזר הציבורי והפרטי במרחב כולו.

שיתופי פעולה בתחום המחקר והחדשנות

ישראל כידוע היא אומת הסטארט אפ והיא אחת ממוקדי החדשנות העולמית. האתגרים המשותפים שיש למדינות האזור בתחומים טכנולוגיים כמו אגירה, אנרגיה מתחדשת, רכב חשמלי וכיוצא בזה יכולים להיות הבסיס למיזמים משותפים אזוריים כדוגמת שותפות במחקרים, הקמת קרן אזורית ומכוני מחקר משותפים.

עקרונות תכנון, מתווה גיבוש המדיניות ותוצאות המודל

עקרונות תכנון

בפרקים הקודמים סקרנו את המגמות העיקריות במשקי האנרגיה בעולם ובישראל. מגמות אלו הביאו לידי ביטוי את צעדי המדיניות עליהן כבר החליטה הממשלה ואותם כבר מקדם המשרד. כל אלו יוצרים את נקודת המוצא בבואנו לתכנן את יעדי משק האנרגיה לשנת 2050. סקירת המגמות הן אבן הדרך הראשונה בבואנו לתכנן מדיניות במשק האנרגיה. לאחר סקירת המגמות ובחינת מאפייניו הייחודיים של המשק הישראלי, יש לבחון את המדיניות על שלושת הרגליים עליו עומד משק האנרגיה : ביטחון אנרגיה, כלכלה וסביבה.

<u>אמינות אספקה ובטחון אנרגיה</u>

בראש ובראשונה משק האנרגיה הישראלי צריך לספק אנרגיה לצרכי המשק באופן רציף ואמין. אמינות האספקה והביטחון באנרגיה עשויים להיות מופרים ע"י הפרעות חד פעמיות חיצוניות כדוגמת רעידת אדמה או מלחמה או לסבול מהפרעות שוטפות שנובעות בין היתר מתכנון משק ביתירות נמוכה. למשק הישראלי מספר מאפיינים אשר מגדירים את תפיסת הביטחון במשק ביניהם העובדה כי ישראל היא מדינה מאוימת ביטחונית ומוגדרת, נכון להיום, כאי אנרגטי. לאור תפיסת ביטחון האנרגיה קידם המשרד בשנים האחרונות מספר צעדי מדיניות להתמודדות עם מצבי חירום. לצד המדיניות לשעת חירום, המגמות החזויות במשק דווקא צפויות לאתגר את שאלת אמינות האספקה בשגרה, על כן יש לדון בצעדים אשר עשויים להיות רלוונטיים בבחינה עתידית של המשק, בין היתר ניתן למנות את האתגרים הבאים:

א. הבטחת יתירות באספקת גז טבעי למשק ובכלל זה: הבטחת יכולת תפקוד עצמאית של מערכות קבלת הגז הטבעי, הגדלת יתירות צנרת הולכת הגז הטבעי והקמת מאגר גז יבשתי.
ב. הבטחת ביטחון באנרגיה בסקטור התחבורה ובכלל זה: הבטחת יכולת טעינה בעת שיבושים באספקת החשמל, הגדרת מנגנון שיבטיח אספקת גז טבעי להנעת רכבי גט"ד במצב חירום והגדרת מנגנונים להתקנת גיבויים חשמליים בתחנות טעינה מהירה ובתחנות תדלוק גט"ד.
ג. הבטחת ביטחון באנרגיה בסקטור התעשייה ובכלל זה: הגדרת מנגנון שיבטיח העדפה באספקת גז טבעי לתעשייה חיונית במצב חירום ובחינת הצורך לחייב או לתמרץ יכולת דואלית של מפעלים המוגדרים כמפעלים חיוניים.
ד. ביזור מקורות אנרגיה: בתרחיש של שיעור מתחדשות גבוה, יוקמו אלפי מתקנים פוטו-וולטאיים ברחבי הארץ, בחלקם גם תשולב יכולת אגירה. תמהיל המתקנים הפוטו-וולטאיים שיוקמו יכלול מתקנים קרקעיים, מתקני גגות ומתקנים על גבי מאגרי מים. הביזור הגאוגרפי של המתקנים

לאורך ולרוחב הארץ לעומת מספר מצומצם של מתקני ייצור גדולים מהווה חיזוק ומעמיד אתגר למרכיב ביטחון האנרגיה: מחד, הביזור מקטין את הסיכון מפגיעה פיזית בכמות הספק משמעותי, מאידך הביזור מגדיל את התלות של מתקני הייצור ברשתות במתח גבוה ונמוך, בניגוד למתח העליון ורשת ההולכה הארצית.

ה. קריטריון האמינות של משק החשמל: מרכיב מדיניות מרכזי בביטחון האנרגיה הוא קביעת קריטריון האמינות המשקי. קריטריון האמינות משקף את קביעת המדיניות באשר לכמות ההספק התוספתי המתוכנן להקמה, מעבר לצרכי המשק, שיופעל כביטוח בזמנים בהם תקלות/אירועי חירום יפגעו ביכולת לייצר כבשגרה. קריטריון האמינות צריך להיקבע כאיזון של קובע המדיניות בין עלות צפויה של אי-אספקת אנרגיה למול העלות הוודאית שבהקמת מתקני ייצור נוספים. בהיבט זה, יש להבחין בין קריטריון של דקות אי אספקה, המתאר קשיים בצריכת האנרגיה שמקורם ברשת החשמל, לבין אמינות משקית, שהיא היכולת לייצר חשמל בכמות מספקת. בהמשך לצורך בגיבוי, קביעת קריטריון האמינות תשפיע באופן ישיר על כמות הגיבוי המשקי הנדרש.

ו. גיבוי משק החשמל בחירום: בתרחיש של שיעור מתחדשות גבוה (מעל 30%) שרובו צפוי להיות בטכנולוגיה סולארית, התלות של המשק הישראלי בגרמי השמים הופכת לגורם סיכון משמעותי. ימים רבים ו/או רצופים של עננות/ערפל/אובך עשויים לסכן את היכולת של מערכת החשמל לעמוד בביקוש המשקי. לשם כך, יידרש גיבוי מצד מתקנים קונבנציונאליים שיהיו זמינים למנהל המערכת ויוכלו לספק את מלוא הביקוש. מתקנים אלו יפעלו ככל הנראה מספר שעות מצומצם במרבית השנה ויידרשו לרגולציה מתאימה שתבטיח כי הם אכן זמינים ומסוגלים לייצר חשמל לצרכי המשק הישראלי כולו בשעת הצורך.

ז. דלקי הגיבוי של המערכת: כחלק מתפיסת ההיערכות להבטחת יכולת הייצור בתרחישי חירום שונים על בסיס סל דלקים מגוון, נדרשת יכולת פעילות בדלקים חליפיים כדי לספק את צרכי המשק. מרבית מתקני הייצור הקונבנציונאליים המוקמים כיום הינם מתקני ייצור דו-דלקיים הפועלים בגז טבעי כדלק ראשי ובסולר כדלק חליפי. בהיבט זה, ככל והתלות במתקני ייצור קונבנציונאליים פוחתת בשגרה, כך המשק מוגן יותר מפני תרחישים של פגיעה ברציפות האספקה של גז טבעי. עם זאת, לצורך היערכות לתרחישי חירום, יש להבטיח יכולת שימוש גם בדלקים חליפיים כגיבוי. יש לציין כי שיפור ביטחון האנרגיה על פי פרמטר זה, אינו תלוי רק ביכולת הדו-דלקיות של המתקנים, אלא מותנה בשדרוג משמעותי של יכולות פיתוח צנרת דלקי הגיבוי ויכולות המיכול של הדלקים החלופיים.

ח. איומי פגיעה פיזית: תרחישי חירום שונים עשויים להתייחס לפגיעה אפשרית בתשתיות פיזיות של משק החשמל. השקעות לצורך מתן מענה בדמות מיגון פיזי וניטור פסיבי ואקטיבי של האיומים הצפויים, יהיו חלק משמירת ביטחון האנרגיה גם בטווח הרחוק.

ט. איומי סייבר: עד היום, אנרגיה חשמלית הופקה בעיקר בתחנות כוח מרכזיות גדולות. שילוב של טכנולוגיות חדשות לייצור אנרגיה מבוזרת כגון פאנלים סולאריים רוח ועוד, יוצר הכרח להקמת רשתות תקשורת במקביל לרשת החשמל, וזאת עבור ניטור מבוזר של טכנולוגיות אנרגיה מתחדשת ושל ציוד הקצה האלקטרוני המפוזר ברשת כולה, כגון: מוני אנרגיה, בקרים חכמים, מאגדים, חיישנים חכמים ועוד. העברת הנתונים מציוד הקצה אל שרתי היישום דרך אוסף של רשתות תקשורת, חושפת את "רשת החשמל החכמה" לאיומי אבטחה רבים. קביעת תקינה ישראלית (בסיוע של מעבדת הסייבר הלאומית) לרכיבים קריטיים תקטין באופן דרמטי את היכולת לפגוע במשק יצור החשמל.

כלכלה- תחרות ומחירים בני השגה

העיקרון השני לאורו מתוכנן משק האנרגיה הינו העיקרון הכלכלי. ישראל, פועלת רבות כדי לקדם אנרגיה יעילה, חסכונית ובת השגה ולשם כך מקדמת רפורמות, מפתחת תשתיות ומשקיעה רבות במחקר ופיתוח בתחומי האנרגיה. ההחלטות במשק, בראשן החלטות הנוגעות למשק החשמל, מתקבלות בבחינה מעמיקה של העלויות והתועלות הכלכליות. כך למשל מכרזי המתחדשות שהוציאה רשות החשמל בשנים האחרונות, הביאו הלכה למעשה להורדת מחירים דרסטית במחירי האנרגיות המתחדשות בישראל וזאת הודות למערכת מכרזים תחרותית.

בנוסף נציין כי הגז הטבעי הינו מרכיב חשוב בכלכלת ישראל ובביטחון האנרגיה שלה. ישראל היא אי אנרגטי, ולמעט מאגרי הגז הטבעי שנמצאו במימי הים התיכון, היא מדינה עניה יחסית במשאבי טבע. לפיכך, למציאת ופיתוח מאגרי הגז הימיים חשיבות רבה מבחינה כלכלית, ביטחונית, אסטרטגית וסביבתית. הכנסות המדינה מהפקת ומכירת הגז הטבעי לשימוש מקומי וליצוא מאפשרות הגדלת הרווחה של אזרחי המדינה, זאת מלבד תועלות נוספות כגון חיזוק מצבה הפיננסי של ישראל, ותרומת תעשייה זו לתעסוקה ולצריכה בישראל.

כמו כן , המשרד מקדם מספר רפורמות שתכליתן קידום משק יעיל ותחרותי. בחלק מכך, בשנת 2018 הוביל המשרד רפורמה מרחיקת לכת בחברת חשמל שעשויה לתרום לתחרותיות במשק ולקדם את יעילותו על אחת כמה וכמה אל מול האתגרים שצפויים למשק לאור המעבר למשק מבוזר.

מתוך כך, תכנון עתידי, כפי שנפרט בהמשך, צריך לקחת בחשבון את העלויות והתועלות הכלכליות וכן את המשמעויות הרחבות על צמיחת המשק.

סביבה – הפחתת גזי חממה וזיהום אוויר

העיקרון השלישי לאורו מתוכנן משק האנרגיה הינו העיקרון הסביבתי. במהלך השנים האחרונות ביצע משרד האנרגיה שורה ארוכה של מהלכים, אשר מהווים את היסודות הנדרשים לקידום אנרגיה נקייה בשיתוף עם גורמי ממשלה אחרים. שתי ההחלטות הדרמטיות ביותר בתחום הן העלאת יעד המתחדשות ל30% בשנת 2030 וההחלטה על הפסקת הייצור בפחם. לצד החלטות אלה, בשנת 2018, קידם המשרד מהלכים הכרחיים ליצירת התנאים למעבר משקי התחבורה והתעשייה לעולם נטול נפט, לרבות, תמיכה בפרישת תשתיות טעינה לרכב חשמלי ותחנות תדלוק בגז טבעי דחוס והעמקת התמיכה הממשלתית בפרישת רשת חלוקת הגז הטבעי. כמו כן, הכריז שר האנרגיה דאז בתחילת שנת 2018 על יעדי משק האנרגיה לשנת 2030. היעדים כוללים את הפחתת השימוש במוצרי דלק מזהמים ובפרט הפסקת השימוש בפחם והפסקת רובו המכריע של השימוש בתזקיקי נפט, תוך שמירה על אמינות ורציפות אספקת האנרגיה.

מסגרת העבודה לתכנון היעדים לשנת 2050 שתכליתה הפחתת פליטות גזי חממה במשק נכתבה לאור עיקרון זה. יחד עם זאת במבט רחב יותר בקביעת מדיניות יש לנסות להביא בחשבון עלויות סביבתיות נוספות הנוגעת כמובן להפחתת פליטות מזהמים אך גם למה שהולך והופך מאתגר יותר – ההשפעות הסביבתיות והנופיות הרחבות של תפיסת השטח הנדרשת לצורך עמידה ביעדים מאתגרים של אנרגיות מתחדשות.

מתווה גיבוש המדיניות

קביעת מדיניות ארוכת טווח בתחום מורכב כל כך שמשתנה באופן תדיר ומהיר מאופיינת ברמת חוסר וודאות גבוהה. בשל כך, מתווה העבודה הינו חזרתי והמדיניות נבנית בהדרגה, בצורה דו כיוונית, נדבך אחר נדבך וישנה גמישות לשינויים ושיפורים באמצעות מעורבות גבוהה של כלל בעלי העניין לכל אורך התהליך אשר התבצע באופן הבא:

על מנת לקבל החלטות מושכלות מבוססות נתונים, עבודת הצוותים החלה בסקירת הנעשה בעולם - בבחינת מגמות עולמיות ותכניות אסטרטגיות של מדינות שונות. בשלב הבא, כל צוות הגדיר את "תמונת המצב בישראל" והאתגרים בתחומו. במסגרת אפיון זה, הוגדרו "אילוצי המערכת" המשפיעים על הגדרת היעדים הסופיים ובחירת החלופה הטובה ביותר לישראל. את תהליך העבודה ליוותה וועדת היגוי מייעצת שכללה נציגים ממשרדי הממשלה הרלוונטיים, נציגי אקדמיה, המגזר הפרטי וארגונים סביבתיים.

<u>גיבוש המדיניות התבצע במתווה משולב של שני תהליכים משלימים:</u>

1) גישת Top Down – קביעת יעדים שאפתניים בתחום הפחתת פליטות גזי החממה על ידי מובילי המדיניות במשרד. לפי גישה זו, היעדים שיבחרו יחייבו ביצוע פעולות דרמטיות בכדי להשיגם ולמקם את ישראל כאחת המדינות המובילות בתחום.
2) גישת Bottom Up – קביעת יעדים על ידי צוותי העבודה המקצועיים בעלי המומחיות בכל אחד מהתחומים במשק האנרגיה ובהתחשב באילוצי המשק הישראלי.

שילוב שתי הגישות המתוארות לעיל התבצע בעזרת מודל טכנו-כלכלי שנכתב לצורך זה ומתואר בהמשך.

יש לציין כי אנו רואים בכתיבת מפת הדרכים תהליך מתמשך למעבר למשק אנרגיה אמין, יעיל ונקי ועל כן מפת הדרכים תעודכן בפרקי זמן קבועים של 5 שנים.

שימוש במודל לבחינת תרחישים עתידיים אפשריים למשק החשמל

לצורך בחינת תרחישים עתידיים ומשמעויות ליישומם נכתב מודל הכולל שני חלקים – מודל טכני המבצע סימולציה של תפעול רכיבי הייצור השונים במשק מול עקומת הביקוש, ומודל כלכלי המתבסס על ממצאי המודל הטכני ובאמצעותם מעריך את העלויות המשקיות השנתיות למגזר החשמל בהתאם למחירים הצפויים לרכיבים השונים בעתיד.

התהליך כלל חשיבה משותפת של חמישה צוותי עבודה במשרד האנרגיה, צוות רב מגזרי בו השתתפו משרדי הממשלה הרלוונטיים לרבות אך לא רק, משרד הגנת הסביבה, משרד האוצר, מנהל התכנון, המועצה הלאומית לכלכלה, בנק ישראל, משרד התחבורה, משרד הכלכלה, רשות המיסים, כמו גם נציגי אקדמיה והמגזר השלישי.

המודל הטכני

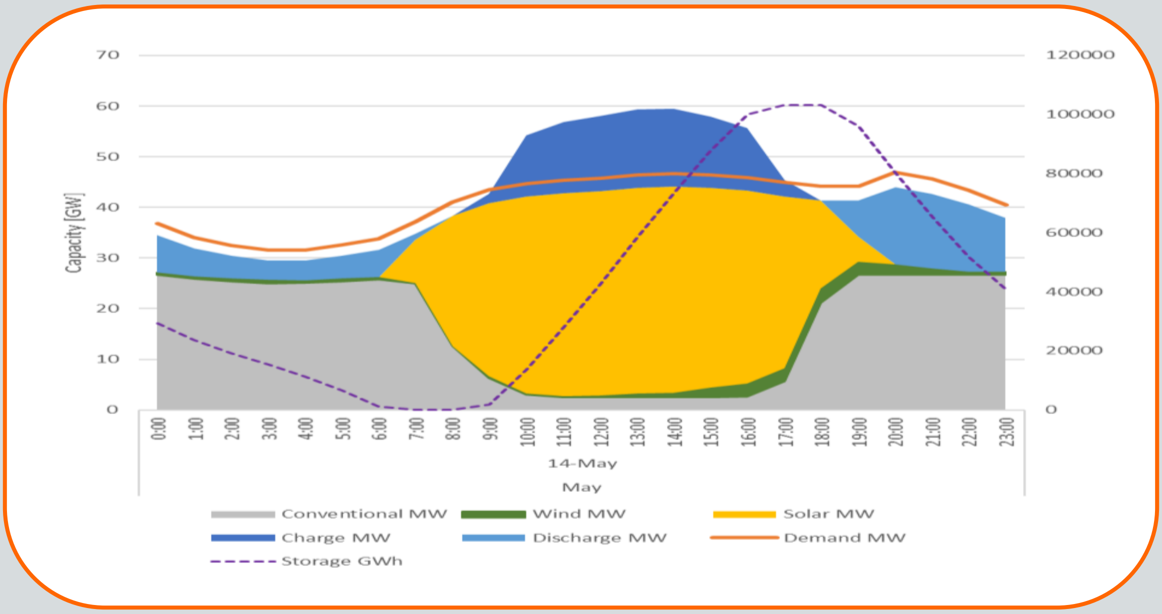
המודל הטכני מבצע ניתוח שעתי, על כלל משק החשמל בישראל, ומתאים בין הביקוש השעתי לתפוקה של מקורות האנרגיה השונים. מקורות האנרגיה המטופלים על ידי המודל הם: ייצור קונבנציונלי – תמהיל של יחידות מחז"מ ופיקריות המוסקות בגז טבעי, אנרגיה סולארית (בעיקר מערכות פוטו-וולטאיות) ורוח. כמו כן המודל מתייחס לרכיב אגירה המאפשר להתאים בין תפוקת המקורות המתחדשים לעקומת הביקוש. המודל הינו מודל מצרפי, דהיינו מבצע הערכה לגבי מגזרים שלמים במשק האנרגיה ללא הפרדה ליחידות ייצור בודדות או לאזורים גאוגרפיים.

להלן פירוט הנתונים המתקבלים בקלט ופלט למודל:

קלט
סך הביקוש השנתי לחשמל החזוי בנקודות זמן בעתיד
אחוז החשמל ממקור סולארי שיידרש לייצור באותן נקודות זמן
ההספק המותקן של טורבינות רוח
כמות האגירה הצפויה בנקודת הזמן
כמות האנרגיה שתיחסך באמצעות התייעלות באנרגיה
אחוז פליטות גזי החממה שיטופלו באמצעות תפיסת פחמן (CCU/CCS)

פלט
עקומת ההפעלה של מערכות האגירה, ממנה ניתן ללמוד על כמות האגירה ששימשה בפועל ואחוז הניצול של המאגרים
האנרגיה הסולארית שנותרה מעבר לצריכה וליכולת הקליטה של מערכות האגירה ולכן הושלכה, אחוז השימוש באנרגיה הסולארית במשק בפועל (ללא האנרגיה שהושלכה).
עקומת ההפעלה של היחידות הקונבנציונליות, ממנה מחושב ההספק המותקן המכסימלי הנדרש ביחידות גזיות, סך ייצור החשמל ביחידות אלו, צריכת גז שעתית ושנתית למשק החשמל, אחוז הניצול של יחידות הגז, הפליטות ממגזר החשמל.

בתרשים 36, ניתן לראות דוגמא לסימולציה עבור יום אופייני. הקו הכתום מציין את עקום הביקוש השעתי, באפור מוצג ההספק של היחידות הקונבנציונליות, בירוק תפוקת טורבינות הרוח, בצהוב אנרגיית שמש שמוזנת לאספקת הביקוש, בכחול כהה עודף אנרגיית שמש שטוען את סוללות האגירה, ובתכלת אנרגיה הנפרקת מהסוללות למילוי הביקוש, הקו המקווקו (סגול) מתאר את מצב טעינת הסוללות – מאפס סביב 8:00 בבוקר, עד למילוי הסוללות סביב 17:00 אחה"צ, ולאחר מכן פריקה במשך הלילה, עד לבוקר שלמחרת.



תרשים 36: דוגמא לסימולציה השעתית במשך יום אופייני, מודל האנרגיה, משרד האנרגיה.

המודל הכלכלי

למודל הטכני צמוד מודל כלכלי המאפשר לחשב את העלויות המשקיות של מגזר החשמל על בסיס הרכיבים הבאים:

- עלות הרכיב הקונבנציונלי על בסיס עלות ההון, עלות התפעול, עלות הגז, ועלויות חיצוניות (פליטת מזהמים ופליטת גזי החממה)
- עלות הרכיב הסולארי, על בסיס עלות ההון ועלות התפעול של ההספק הסולארי המותקן
- עלות רכיב הרוח, על בסיס עלות ההון והתפעול
- עלות רכיב האגירה, המורכב מעלות ההון ועלות התפעול
- עלות תפיסת הפחמן, בהתאם לפליטות מהרכיב הקונבנציונלי ואחוז הטיפול שהוגדר לפליטות אלו

פלט המודל הכלכלי מאפשר לחשב את העלות המשקית השנתית של התרחישים השונים ובכך להשוות בין תמהילי מקורות שונים.

מגבלות המודל

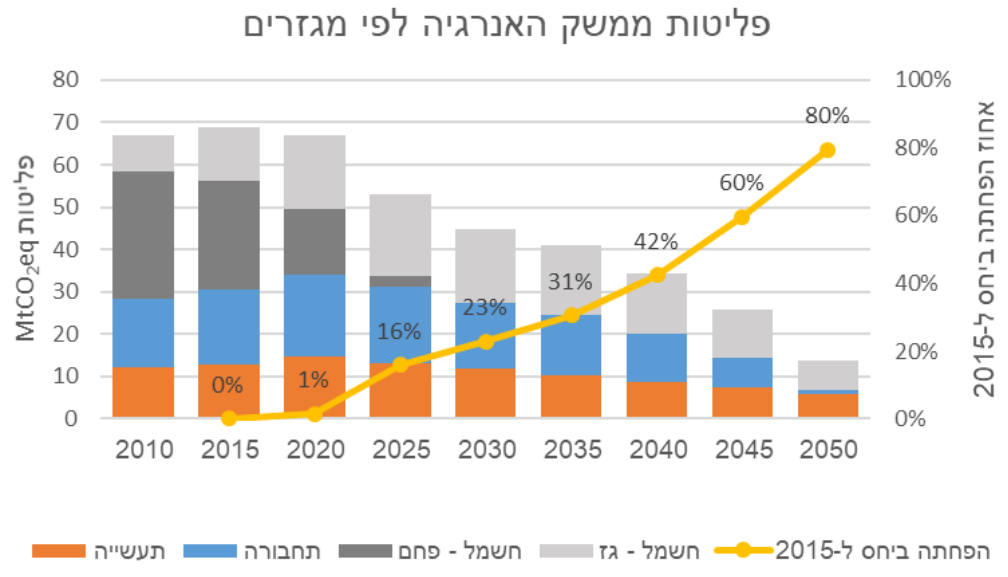
מתוך רצון לשמור את המודל פשוט ומהיר, נעשו מספר הנחות מקלות המאפשרות לקבל תמונה מצרפית על משק החשמל בישראל. להלן המגבלות הנובעות מאופן הפעולה שנבחר:

- המודל הינו מצרפי לכלל משק החשמל בארץ ולכן אינו מספק ניתוח על בסיס מיקום גיאוגרפי. משמעות הדבר היא כי לא ניתן ללמוד ממנו על רשת החשמל – על העומסים במקטעי ההולכה השונים, על צרכי פיתוח הרשת ועל עלויות הרשת בתרחישים השונים.
- המודל מתייחס לכל מגזר הייצור כיחידה אחת – היחידות הקונבנציונליות מחושבות כרכיב יחיד ללא אבחנה בין מחז"מ לפיקר, או בין יחידות ייצור שונות. אשר על כן אין התייחסות למשטר ההפעלה של היחידות השונות; המגזר הסולארי לא מבדיל בין מערכות תרמו-סולאריות לפוטו-וולטאיות, בין מערכות קרקעיות למערכות בשימוש כפול, בין מערכות מרוחקות למערכות קרובות לאתרי הביקוש; בין אגירה שאובה לאגירה בסוללות או אגירה בטכנולוגיה עתידית.
- המודל אינו מתייחס לנושא ההספק הנדרש מהאגירה, ומניח שניתן לספק את האנרגיה הנדרשת מן האגירה בכל מצב.
- המודל אינו מחשב את רזרבת הייצור הנדרשת (קלט) אך מעריך את עלותה.

תוצאות מודל – תרחישים עתידיים

בכדי להעריך את הכיוון המועדף לפיתוח משק האנרגיה לקראת שנת 2050, בשלב הראשון נבחנה האפשרות והמשמעויות של השגת יעד 100% אנרגיה מתחדשת לייצור החשמל. היות ובישראל המקור הכמעט בלעדי לאנרגיה מתחדשת הינו השמש, הפער בין עקומת הייצור הסולארי השנתי לעקומת הביקוש מחייב העברת כמויות אנרגיה אדירות מתקופת האביב לחורף. נמצא כי כיום עדיין לא נראית באופק טכנולוגיה שתאפשר אגירה בסדרי הגודל הנדרשים ובעלות סבירה. בבחינת המודל נמצא כי מעל 95% אנרגיה סולארית בתמהיל הדלקים, תדרוש כמות אגירה שהינה בלתי סבירה (בטכנולוגיות הקיימות) וערכים מעל 90% אנרגיה סולארית יהיו מאוד קשים להשגה גם ברמה התאורטית. מאידך, על פי המודל, <u>בתרחיש האופטימלי כלכלית</u>, הכולל את עלויות המזהמים ומחירי אנרגיה ללא ניכוי מיסים, במחירים הצפויים בשנת 2050 למקורות הסולאריים ולאגירה, עומד הייצור הסולארי בתמהיל על כ-81%. <u>מכאן שהטווח בין הייצור הסולארי האפשרי לזה האופטימלי כלכלית עומד על בין 81-90% אנרגיה סולארית בתמהיל הדלקים</u>.

בבחינת יעדי ההפחתה של המגזרים העיקריים במשק האנרגיה, הכוללים את מגזרי החשמל, התחבורה והתעשייה, נמצא כי מגזר התעשייה יתקשה להשיג הפחתה משמעותית בפליטות, ולכן מגזר החשמל יידרש להפחתה משמעותית יותר בכדי לפצות על הקושי במגזר התעשייה. בתרשים 37 להלן ניתן לראות את פליטת גזי החממה מהמגזרים העיקריים. בכדי להשיג הפחתה של 80% בסך פליטות גזי החממה ממגזר האנרגיה יהיה צורך להשיג הפחתה של כ-86% במגזר החשמל, שיאזן בין הצורך להשגת יעדים שאפתניים התואמים את המגמה העולמית למאבק במשבר האקלים, לבין העלויות המשקיות, השטח שיידרש להקמת המערכות הסולאריות וכמות האגירה הנדרשת.



תרשים 37: פליטות גזי החממה מהמגזרים העיקריים במשק האנרגיה: ייצור החשמל, התחבורה והתעשייה. בתרשים מתואר תרחיש להשגת הפחתה של 80% בפליטות גזי החממה בשנת 2050, ביחס לפליטות בשנת 2015. מודל האנרגיה, משרד האנרגיה.

בשלב הבא, נבחנו שלושה תרחישים מרכזיים ("תרחישי על"); תרחיש "עסקים כרגיל" המייצג את הפחתת הפליטות במשק האנרגיה הישראלי ללא שינוי מדיניות ושני תרחישי קיצון- תרחיש "מבוסס אנרגיה מתחדשת" ותרחיש "מבוסס טכנולוגיות חדשות":

- תרחיש "עסקים כרגיל" המניח השגה של 17% מקורות מתחדשים בתמהיל האנרגיה, 17% התייעלות באנרגיה בשנת 2030 ושמירה על יחס זה עד לשנת 2050, והפסקת השימוש בפחם עד שנת 2025.
- תרחיש "מבוסס אנרגיה מתחדשת" (Solar) המניח הפחתה של פליטות גזי החממה באמצעות שימוש באחוזים גבוהים מאד של אנרגיה סולארית – עד 90% בשנת 2050 והשאר בגז טבעי.
- תרחיש "מבוסס טכנולוגיות חדשות" (Technology) המניח הפחתה של פליטות גזי החממה באמצעות 54% אנרגיה מתחדשת בתמהיל האנרגיה, 34% גז טבעי משולב עם תפיסת פחמן/ טכנולוגיות אחרות ו12% גז טבעי.

המודל מאפשר בחינה של אופני הפיתוח הללו, תוך הערכת ההשלכות של כל תרחיש ומציאת התמהיל האופטימלי (בבחינת העלות המשקית/ הפחתת פליטות גזי חממה) בתרחישים השונים.

ניתוח תרחישי העל בעזרת המודל מאפשר לבחון מספר היבטים:

- ההספק הסולארי המותקן הנדרש לאורך השנים.

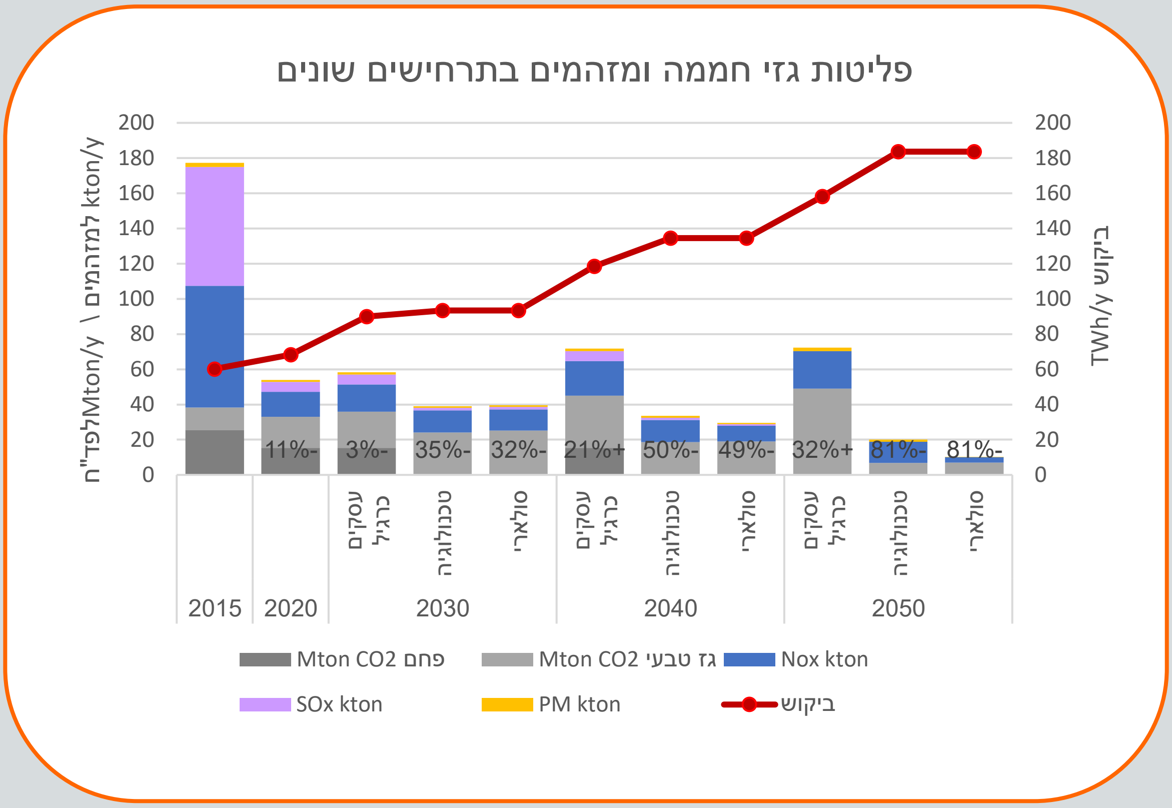
- כמות האגירה המותקנת הנדרשת לאורך השנים.
- אופן תפעול היחידות בגז טבעי. בעתיד מוטה מקורות אנרגיה מתחדשים ידרשו מאפיינים ייחודיים לתפעול יחידות אלו, כגון מספר התנעות גבוה, הדממה למשך פרקי זמן ארוכים (שבועות וחודשים), ודרישה לגמישות גבוהה מאד, הן בהאצה (ramp-up) מהירה מהתנעה להספק מלא והן ביכולת פעולה בהספק נמוך מאד.
- אופטימיזציה כלכלית. תחשיב העלות של התרחישים השונים יאפשר לזהות את הנתיב בו העלויות צפויות להיות הנמוכות ביותר ובכך לבחור את האמצעים בהם כדאי להשקיע כבר כעת בכדי להגיע לנתיב הנבחר.

ניתוח ממצאי המודל

להלן מוצגים תוצאות המודל ביחס לכל אחד מהתרחישים.

ניתן לראות בתרשים 38, כי ללא שינוי במדיניות, הביקוש לחשמל יגדל פי 2.6 כאשר בשני תרחישי ההפחתה- בתרחיש הראשון "מבוסס אנרגיה מתחדשת" (Solar) ובתרחיש השני "מבוסס טכנולוגיות חדשות" (Technology) הביקוש לחשמל גדל פי 3 עקב המעבר לרכב חשמלי.

על אף שהביקוש לחשמל גבוה יותר בתרחישי ההפחתה לעומת תרחיש "עסקים כרגיל", בשני התרחישים פליטות גזי החממה יופחתו ב-81% (מ-37.1 לכ- 7.03 $MtCO_2$) ביחס לשנת הייחוס 2015 לעומת זאת, בתרחיש עסקים כרגיל, פליטות גזי החממה יגדלו ב-33% ביחס לשנת 2015 מ-37.1 לכ- 49 $MtCO_2$). מבחינת מזהמים נוספים, ניתן לראות כי בתרחיש "עסקים כרגיל" החומר החלקיקי (PM) יופחת ב-8% עד לשנת 2050 (2.12 לעומת 2.30 kton), בתרחיש הסולארי יקטנו ב-87% מהערכים בשנת 2015 (0.30 kton). בבחינת מזהמי תחמוצות החנקן (NO_X) רואים כי בתרחיש "עסקים כרגיל" רמת תחמוצת החנקן יורדת ב-69% (21.25 לעומת 69.1 בשנת 2050 לעומת שנת 2015 בהתאמה), בתרחיש הטכנולוגי יורדת ב-83% (11.93 kton) ובתרחיש הסולארי יורדת ב-96% (3.05 kton). כאשר בוחנים את רמת תחמוצות הגופרית (SO_X) רואים כי בכל התרחישים לא נפלטות תחמוצות גופרית בשנת 2050. יש לציין כי תחשיבי פליטות המזהמים השונים בעתיד הינן תחת ההנחה כי הפליטות הסגוליות (פליטת מזהמים ליחידת אנרגיה מיוצרת) יוותרו בערכים הנוכחיים. אך סביר ששיפורים טכנולוגיים בעתיד, יאפשרו את הפחתת פליטות המזהמים אל מתחת לערכים שצוינו לעיל.

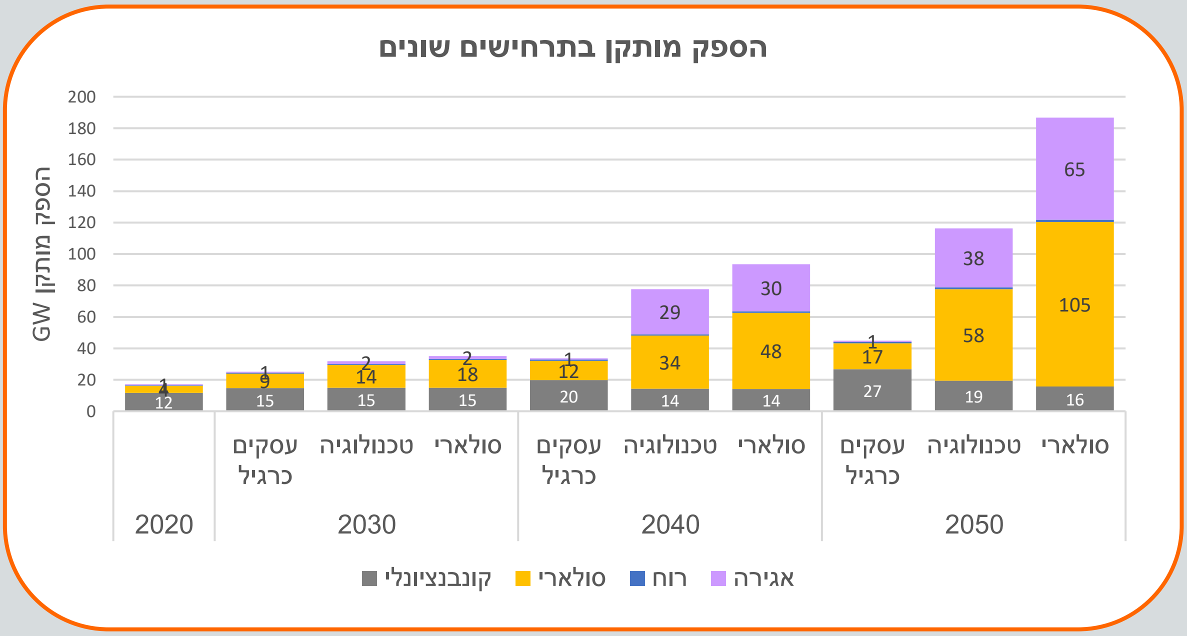


תרשים 38: תוצאות הרצת המודל הטכנו –כלכלי לשלושה תרחישים – תרחיש "עסקים כרגיל" ושני תרחישי קיצון, תרחיש "מבוסס אנרגיה מתחדשת" ותרחיש "מבוסס טכנולוגיות חדשות". משרד האנרגיה 2020.

בתרשים 39 להלן ניתן לראות את ההספק שיידרש ממתקני הייצור השונים עד לשנת 2050 בשלושת התרחישים. ניתן להתרשם מההספק הניכר שיידרש למערכות הסולאריות ולאגירה בתרחיש הסולארי (ובאופן מתון יותר גם בתרחיש הטכנולוגיות). כיוון שמגה-וואט מותקן סולארי מייצר רק כ-30% מסך האנרגיה שמייצר מגה-וואט קונבנציונלי, הרי שנדרש הספק מותקן סולארי גבוה פי שלושה ויותר מהספק קונבנציונלי לצורך אספקת אותה כמות אנרגיה. בנוסף, המערכות הסולאריות דורשות אגירה ניכרת בכדי להעביר את כמויות האנרגיה הגבוהות המיוצרות בצהריים אל הערב והלילה שלאחריהם.

כמו כן, ניתן לראות בתרשים כי גם בתרחיש הסולארי נדרש הספק משמעותי בגז טבעי, וזאת בכדי שזה יהווה גיבוי למערכות הסולאריות בעת תקופות בהן אור השמש מועט, כגון מספר ימים רצופים בחורף עם עננות כבדה על פני רוב הארץ. אם נביט על התרחיש הסולארי בשנת 2050, למשל, הרי ששיא הביקוש לחשמל באותה השנה צפוי להיות כ-32 GW, אולם גם תחת ההנחה שיהיו כ- 105 GW מתקנים סולאריים מותקנים (הספק מותקן), עדין יהיה צורך בכ-16 GW של יחידות גזיות בכדי לספק את הביקוש במשך שבועיים-שלושה מעוננים לאורך השנה. מתוצאות הרצת המודל עולה כי יהיה צורך בהספק בגובה של כ-50% משיא הביקוש בלבד היות ועם כמות האגירה שתתקיים במשך בשנה זו, ניתן יהיה להפעיל את היחידות בגז טבעי במשך 24 שעות רצוף בהספק נומינלי, בעוד

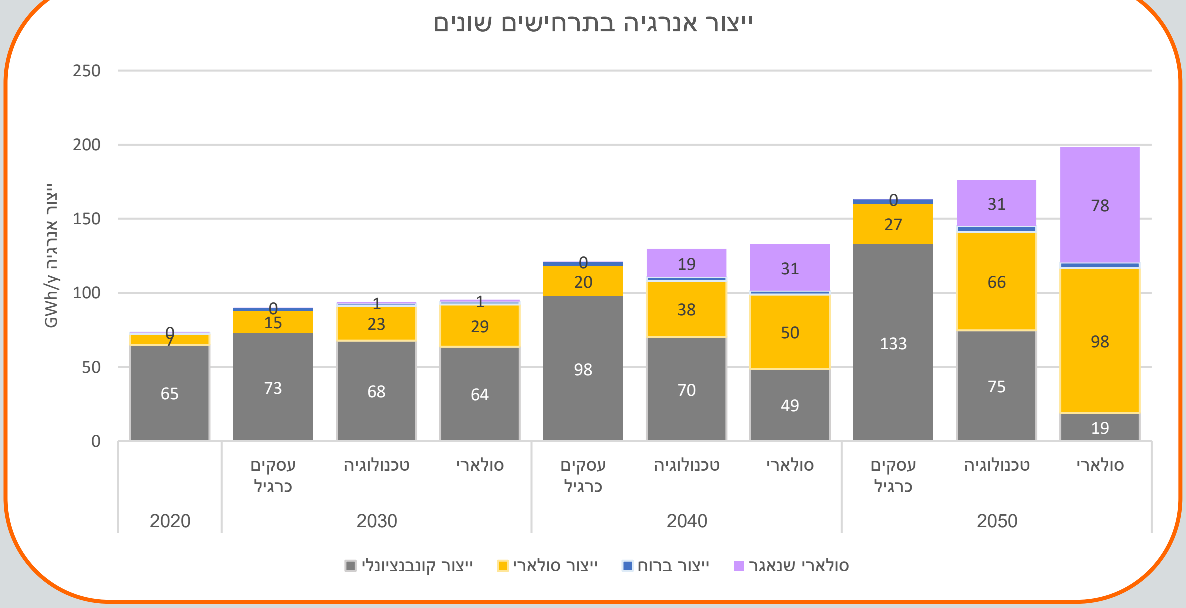
מערכות האגירה יצברו את העודפים בשעות הביקוש הנמוך ויספקו את החוסר בשעות הביקוש הגבוה, יחד עם ההספק הסולארי המועט שייוצר בצהריים ניתן יהיה לשמור על אספקת חשמל רציפה. אולם, יש לזכור שיהיה צורך להוסיף עוד כ-GW 1-2 קונבנציונליים כרזרבה למקרה של תקלה במערך הייצור. לסיכום, ניתן לראות כי בכל תרחיש, ישראל תידרש ליכולת הספק בגז טבעי של כ- GW 18 לכל הפחות בשנת 2050.



תרשים 39: הספק מותקן בתרחישים שונים, מודל האנרגיה, משרד האנרגיה.

כמות האנרגיה שתיוצר מכל אחד מהמקורות מוצגת בתרשים 40 להלן. בתרשים, העמודות הסגולות מבטאות אנרגיה המופקת מהמקורות הסולאריים אך נאגרת בסוללות לשימוש מאוחר יותר, כך שיש לראות בעמודות אלו תוספת על העמודות הצהובות המבטאות אנרגיה סולארית ששימשה ישירות למילוי הביקוש.

ניתן לראות כי הייצור הסולארי (בצהוב) הולך ועולה, בעוד הייצור הקונבנציונלי (באפור) עולה בתרחיש העסקים כרגיל אך יורד בתרחישים הטכנולוגי והסולארי. ובפרט כדאי לשים לב לפער בין ההספק הקונבנציונלי המותקן בתרחיש הסולארי בשנת 2050 (בתרשים הקודם) לייצור המועט במגזר זה באותו התרחיש. משמעות הדבר היא כי יחידות הייצור עלולות לעמוד חודשים ארוכים ללא שימוש בזמן שהייצור הסולארי יספק את כל צרכי המשק. לאופן הפעלה זה של יחידות הייצור תהיינה השלכות על תפעול היחידות משום שהן אינן מתוכננות לתקופות ארוכות של הדממה והשמשה. מאידך, שימוש מועט ביחידות אלה יוכל להעלות את אורך החיים שלהן ובכך להוזיל את עלויות האנרגיה.



תרשים 40: ייצור אנרגיה בתרחישים שונים, מודל האנרגיה, משרד האנרגיה. בעמודות מוצגת כמות האנרגיה שתיוצר בטכנולוגיות השונות, בשלושת התרחישים. שימו לב כי השטח המסומן בסגול מבטא את האנרגיה שתיוצר במגזר הסולארי, אך תיאגר לשימוש מאוחר יותר.

כפי שרואים מניתוח החלופות לעיל, שני תרחישי הקיצון מובילים לאותה תוצאה – הפחתת 80% פליטות גזי החממה במשק האנרגיה בשנת 2050 לעומת שנת הייחוס 2015.

תוצאה זו מדגישה את "מניפת" התרחישים האפשריים להגעה ליעד של 80% הפחתת פליטות במשק האנרגיה בשימוש בכלים קיימים ועתידיים על בסיס קצב הבשלה של כל אחד מהם והכל לצד התייעלות משמעותית בצריכת האנרגיה:

1. העלאת אחוז אנרגית השמש בתמהיל ייצור החשמל
2. שימוש נרחב בטכנולוגיות לתפיסת פחמן והטמנתו או טכנולוגיות דומות אחרות
3. שימוש בטכנולוגיות חדשות שאינן ידועות היום
4. שימוש באנרגיה גרעינית, שימוש במימן ו/או אחרות
5. קישוריות – חיבור רשת החשמל למדינות אחרות ורכישת חשמל נקי

לכל אחד מהכלים לעיל יתרונות וחסרונות אחרים כמו גם רמת הבשלה וקצב התפתחות שונה. אף על פי כן, ניתן לגזור כבר היום משמעויות מיישום שתי חלופות הקיצון – מפורטות בטבלה הבאה:

לוח 7: משמעויות הנגזרות מניתוח שתי חלופות הקיצון במודל הטכנו-כלכלי בכדי להגיע להפחתה של 80% פליטות גזי חממה בשנת 2050:

תנאי הכרחי	2020	יעד 2030	יעד 2050
הערכת השטח הנדרש להקמת מערכות אנרגיה מתחדשת		כ- 160 אלף דונם	500-900 אלף דונם*
אגירה	0.3 GW (2.4 GWh)	3.5 GW (17.2 GWh)	34-57* GW (150-260 GWh)
פיתוח הרשת – הערכה ליכולת הולכת אנרגיה מתחדשת	3-4 GW	11 GW	>30 GW*
עלויות צפויות למשק		23-26 מיליארד ₪ בשנה	49-53 מיליארד ₪ בשנה

* תלוי בכמות האנרגיה הסולארית

יש להדגיש כי הערכת העלות בטבלה מתארת את העלות השנתית המלאה החזויה לייצור החשמל במשק. בבחינה שנערכה ברשות החשמל להגדלת יעדי האנרגיה המתחדשת ל-30% בשנת 2030[101] נמצא כי הפער בין תרחיש ה"עסקים כרגיל" לתרחיש ההפחתה נמצא בתחום ±2% מהעלות המשקית, בבחינה שנערכה לשנת 2050 נמצא כי העלות המשקית בתרחיש ההפחתה הינה זהה או נמוכה בכ-7% מהעלות בתרחיש "עסקים כרגיל". יש לזכור כי אי הוודאות בטכנולוגיות ובעלויות הצפויות בשנת 2050 גבוהה מ-10% ולכן ניתן לומר כי העלויות בתרחישים השונים אינן שונות מהותית. על פי המודל ישנן משמעויות דרסטיות למעבר למשק אנרגיה דל פליטות ותנאי סף בלעדיהם לא נוכל לעמוד ביעד.

סוגיית השטח:

על פי ניתוח המודל, על מנת לאפשר אחוז גבוה (50-85%) של אנרגיה מתחדשת בתמהיל ייצור החשמל העתידי (מתבסס על העלאת אחוז האנרגיה הסולארית בלבד) יש צורך בכ-520-940 אלף דונם לשם הקמת תחנות ייצור סולאריות בשנת 2050- שטח נדרש זה שווה לכעשרת הפעמים שטחה של תל אביב. על מנת לעמוד ביעד של 30% אנרגיה מתחדשת בתמהיל הייצור, יש צורך להקצות כבר

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[101] https://www.gov.il/BlobFolder/reports/2030_final/he/Files_pirsumim_2030_f_10.08.2020_paper.pdf

עד לשנת 2030 שטח של למעלה מ100 אלף דונם. הקצאת שטח בהיקפים כאלו, הלכה למעשה, אינה אפשרית כלל. כבר כיום נתקל משק האנרגיה בקשיים הולכים וגדלים באיתור ותכנון קרקע למיזמי אנרגיה סולארית. המעבר לייצור באנרגיה סולארית מחייב שטחים בהיקף של פי 100-150 מאלו הנדרשים לייצור בגז טבעי. לפיכך, יישום אנרגיה מתחדשת בשיעורים גבוהים מחייב לא רק דו שימוש נרחב בקרקע, אלא גם קיומם של פיתוחים טכנולוגיים הן בשימוש בשטחים נוספים דוגמת קירות מסך, הן בפיתוח דו- שימוש בין חקלאות לבין אנרגית שמש והן בפיתוח טכנולוגיות להגברת נצילות התאים הפוטוולטאים ליחידת שטח. ללא ספק, לאור המגמות העולמיות, טכנולוגיות מסוג זה עשויות להתפתח ועל המשק הישראלי להוות גורם מוביל בפיתוח מגמות אלה.

<u>אגירה:</u>

על פי ניתוח המודל, על מנת לאפשר אחוז גבוה (50-85%) של אנרגיה מתחדשת בתמהיל ייצור החשמל יש צורך ביכולת אגירה של 34-54 GW עד לשנת 2050. לצורך עמידה ביעד של 30% אנרגיה מתחדשת בתמהיל ייצור החשמל בשנת 2030 נזדקק ליכולת אגירה בבמות של 2.7 GW. נכון להיום יכולת האגירה עומדת על 0.3 GW בלבד ומבוססת רובה ככולה על אגירה שאובה.

<u>פיתוח הרשת- הולכה:</u>

על פי ניתוח המודל, על מנת לאפשר אחוז גבוה (50-85%) של אנרגיה מתחדשת בתמהיל ייצור החשמל יש צורך ביכולת הולכת אנרגיה מתחדשת של מעל 30 GW בבדי לתת מענה להתפתחויות הביקוש הצפויות עד לשנת 2050. לצורך עמידה ביעד של 30% אנרגיה מתחדשת בתמהיל ייצור החשמל בשנת 2030 נזדקק ליכולת הולכה בבמות של 11.6 GW, כאשר נכון להיום היכולת עומדת על 3-4 GW בלבד.

<u>עלויות צפויות למשק - השקעות:</u>

בחינת כלל העלויות למשק חושבה על בסיס עבודת רשות החשמל אשר ביצעה כימות של העלויות הכרובות בהגדלת יעד האנרגיה המתחדשת[102]. העלויות מוצגות בעלות עודפת של הגדלת יעד המתחדשות מ- 17% ל 30%. העלויות שתומחרו חולקו לשתי קטגוריות: עלויות הקמה ותפעול של המתקנים הפוטו-וולטאים ועלויות ההשקעה ברשת כדי לקלוט את ההספק הנדרש לצורך עמידה ביעד המתחדשות לשנת 2030. מעבר לעלויות שתומחרו, יש מספר עלויות למשק החשמל שלא תומחרו בשלב זה ובהן:

א. עלויות נוספות הנובעות מהטמעת אמצעים שונים לשם ייצוב הרשת
ב. עלויות הפיתוח הנדרשות ברשת חלוקת החשמל לצורך קליטת האנרגיה המתחדשת

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[102] https://www.gov.il/BlobFolder/reports/2030_final/he/Files_pirsumim_2030_f_10.08.2020_paper.pdf

ג. תרומת האנרגיה המתחדשת לשרידות עקב ביזור מערך הייצור

ד. חיסכון באיבודי חשמל עקב ביזור מערך הייצור והקמת מתקני ייצור בקרבה למוקדי צריכה

ה. הפחתת הריכוזיות במקטע הייצור

הניתוח לוקח בחשבון את עלויות הקמת המתקנים עד שנת 2030 אך מחשב את עלויות הדלקים, התפעול הקבוע והמזהמים, הנובעים מתמהיל ההספק שיוקם על מנת לעמוד ביעד, לאורך תקופה של 20 שנים, קרי עד שנת 2040. כלל העלויות הוונו לשנת 2020 לפי שיעור ריבית היוון בהשקעות חסרות סיכון בגובה של 3%.

בחישוב כלל העלות הנדרשת להקמה ולתפעול של מתקני האנרגיה המתחדשת הנדרשים לצורך עמידה ביעד של 30% בשנת 2030 עולה כי הפער בין יעד מתחדשות של 17% ל 30% נע בין עלות עודפת של כ- 4 מיליארד ₪, לחיסכון של 8 מיליארד ₪, ערכים הנמצאים בתחום ±2% מסך העלות המשקית. בבחינת הפער בשנת 2050 בין יעד מתחדשות של 17% ל-86% נמצא כי העלות בתרחיש ההפחתה הינה זהה או נמוכה בכ-7% מהעלות בתרחיש "עסקים כרגיל".

העלויות הנדרשות לשם פיתוח הרשת תלויות גם הן בסוג ההספק שיוקם. ככל שההספק המוקם הוא בשימוש דואלי כך סביר יותר שהוא יוקם סמוך לאזור צריכה ולכן יצריך פיתוח רשת מופחת. יחד עם זאת, החיסכון ברשת בא לידי ביטוי בעיקר כאשר המתקנים בשימוש דואליים קמים בסמיכות למוקדי הביקוש במרכז הארץ, בעוד מתקנים בשימוש דואלי באזורים בהם הצריכה נמוכה יותר מהייצור אינם מביאים לחסכון משמעותי ברשת. ככל שההספק מוקם בקרקעי גובר הסיכוי שיוקם במרחק גדול יותר מאזורי צריכה ולכן נדרשת השקעה גדולה יותר ברשת.

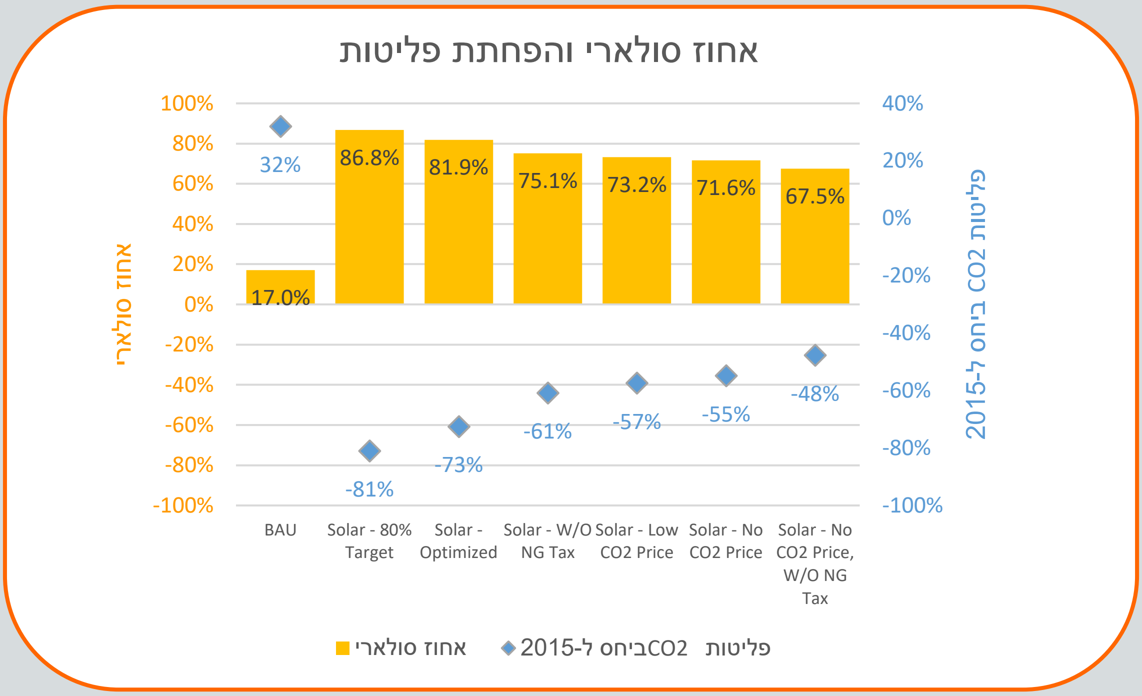
מהבחינה עולה כי פערי העלות בהשקעות ברשת בין יעד מתחדשות של 17% ל- 30% הם כ- 4-5 מיליארד ₪. בנוסף ניתן לראות שבתרחיש המוטה למתקני ייצור קרקעיים, ההשקעה הנדרשת ברשת גבוהה יותר בשל ריחוקם ממוקדי צריכה. כאמור, עלויות ההשקעה ברשת אינן כוללות בשלב זה את עלות ההשקעה ברשת החלוקה.

בתרשים 41 מוצגת בדיקת רגישות שנערכה באמצעות המודל לחישוב אחוז האנרגיה המתחדשת בתמהיל הייצור שיביא לעלויות משקיות מינימליות, תחת הנחות מחיר שונות. בגרף ניתן לראות שבעה תרחישי עלויות, בשנת 2050. התרחיש הראשון משמאל הוא מתווה "עסקים כרגיל" לשם השוואה, בו יותקנו 17% של אנרגיה סולארית ופליטות גזי החממה בשנת 2050 יגדלו ב-32% ביחס לשנת 2015. העמודה השנייה מציגה את התרחיש הסולארי לשנת 2050 ובו 86% אנרגיה סולארית בתמהיל והפחתה של 81% בפליטות גזי החממה. בעמודה השלישית מוצג התרחיש **האופטימלי כלכלית** ביחס למחירים הצפויים בשנת 2050, על פי תרחיש זה המחיר המשקי המינימלי יושג עם כ-82% סולאריים בתמהיל הדלקים ותוך הפחתה של 73% בפליטות. זהו ערך קרוב למדי ליעד

ההפחתה שנקבע לשנת 2050 – משמע העלות המשקית בתרחיש שנקבע אינה גבוהה משמעותית מהאופטימום הכלכלי באותה השנה.

בעמודה הרביעית מוצגות תוצאות תרחיש ללא התחשבות במיסים על הגז הטבעי – מתוך הבנה כי בראייה משקית המיסים אינם עלות אלא העברה של כספים בתוך המשק, בוצע חישוב התרחיש האופטימלי בהנחת מחיר גז ללא רכיב המיסים. התוצאה היא כי בתנאים אלו העלות המשקית המינימאלית תהיה בהשגה של 75% סולאריים והפחתה של 61% בפליטות בלבד. לאחר מכן נבחן תרחיש בו העלות החיצונית של הפחמן הדו-חמצני (פד"ח) נמוכה, לאחר מכן תרחיש ללא כל עלות לפד"ח, ולבסוף תרחיש ללא עלות פד"ח וללא מיסי גז. בתרחיש האחרון האופטימום הינו 67% סולאריים ועם הפחתה של 48% בפליטות בלבד.

מהניתוח ניתן להסיק כי היעד שנקבע אינו יקר בהרבה מהאופטימום הכלכלי בתרחיש המחירים הצפוי לשנת 2050, אך בהנחות מחירים נמוכים יותר לגז ו\או לפד"ח, האופטימום נע לכיוון הפחתה באנרגיה הסולארית והגדלת חלקו של הגז הטבעי בתמהיל. בתרחישים אלו גדל הפער בין האופטימום הכלכלי ליעד העל של הפחתת 80% בפליטות ממשק האנרגיה.



תרשים 41: בדיקת רגישות לבחינת הפחתת פליטות גזי החממה, במצב כלכלי אופטימלי, בתרחישי מחירים שונים לגז טבעי ולפחמן דו-חמצני. מודל אנרגיה, משרד האנרגיה.

לסיכום, תוצאות הרצת המודל בתרחישים השונים הן המפתח לקביעת היעדים לשנת 2050. המודל הטכני מצביע על התרחיש האפשרי והמודל הכלכלי על הכדאיות הכלכלית בהרצות השונות. לאור תוצאות המודל וטווח התכנון הארוך, ניתן לומר כי לא קיימת יכולת של ממש לאמוד את פערי העלות בין התרחישים השונים. לפיכך, הגורמים המרכזיים בעיצוב קבלת ההחלטות בטווח זמן זה הינם ההשפעה על רמת הביטחון באנרגיה המושגת וההשפעה הסביבתית הכוללת, לרבות פלטת מזהמים מקומיים והשפעות סביבתיות הנגרמות לאור שימוש נרחב בקרקע והפרת המרקם האקולוגי. כל אלו באים לידי ביטוי לא רק בקביעת היעדים, אלא קודם כל במדיניות ממשלתית כוללת, דוגמת מדיניות הקצאת הקרקע בישראל, הנכונות התכנונית והמקובלות הציבורית להעברת תשתיות הולכת האנרגיה הנדרשות והיכולת להפחית משמעותית את זיהום האוויר המקומי באמצעים שונים. כל אלו מובילים למסקנה הבלתי נמנעת כי טווח התכנון הארוך מחייב מרחב גמישות משמעותי ואינו תומך בהתמקדות בטכנולוגיה אחת בלבד. לפיכך, הגמישות בקביעת הטכנולוגיות והתרחישים השונים הם כלים קריטיים בקביעת יעדים תפקודיים של הפחתת פליטות וזאת חלף קביעת יעד המקבע טכנולוגיה. בנוסף וכפי שפורט לעיל נגזרות המודל המתייחסות לשטח, אגירה ורשת הן הבסיס לקביעת אבני הדרך של התוכנית והאילוצים להגעה ליעדים.

יעדי התכנית

יעדי התכנית

משק האנרגיה מספק את האנרגיה החיונית לתפקוד תקין של כלל הסקטורים בישראל כמו גם של כל אזרחי ישראל ולכן משפיע באופן ישיר ומהותי הן על כלכלת ישראל והן על איכות חייהם של תושביה. שלושת העקרונות המנחים של תכנון משק האנרגיה הם – ביטחון אנרגיה, כלכלה וסביבה.

למשק הישראלי מאפיינים ייחודיים. ישראל היא אי אנרגטי גאו פוליטי, המאופיינת בצפיפות אוכלוסייה גבוהה יחסית, בקצב גידול אוכלוסייה גבוה, במיעוט שטחים פתוחים במיוחד באזור המרכז, בעתודות גז גדולות, בפוטנציאל לייצור חשמל מאנרגיות השמש אולם במיעוט אפשרויות ליצירת אנרגיה ממקורות מתחדשים אחרים.

תכנון יעדים ארוכי טווח במשק האנרגיה מתכלל את עקרונות המשק ביחד עם מאפיינה הייחודיים של ישראל וזאת על רקע השאיפה להפחית משמעותית את פליטת גזי החממה שמקורם במשק האנרגיה.

על כן, משרד האנרגיה הגדיר ארבעה 'יעדים ראשיים' שישקפו את המטרה האסטרטגית של הפחתת פליטות, ובנוסף לכך יעדים סקטוריאליים תומכים בעזרתם ניתן יהיה להשיגה. 'יעד העל' מוגדר **כהפחתת פליטות גזי חממה ממגזר האנרגיה בשיעור של 80%** ביחס לשנת הייחוס 2015 וזאת עד לשנת 2050.

היעדים והמדדים עבור סקטור האנרגיה מוצגים בלוח הבא:

לוח 8: יעדי תכנית האנרגיה

יעדים ראשיים	מדד	2018	יעד 2030	יעד 2050
הפחתת פליטות גזי חממה במשק האנרגיה	אחוז הפחתת פליטות גזי חממה ביחס לשנת 2015	0%	22%	**80%**
הפחתת פליטות גזי חממה במגזר החשמל	אחוז הפחתת פליטות גזי חממה ביחס לשנת 2015	7.5%	30%	**85%-75%**
יעילות באנרגיה	אחוז שיפור שנתי בעצימות אנרגיה (טרה-וואט/מלש"ח)	0.7%	שיפור שנתי של 1.3% בעצימות האנרגיה	**שיפור שנתי של 1.3% בעצימות האנרגיה**
שימוש בפחם	אחוז פחם בתמהיל ייצור החשמל	30%	0%	**0%**

יעדים אלו נבחרו מכיוון שהם משקפים את המטרות האסטרטגיות של התכנית ובפרט, הפחתת פליטות גזי חממה ומזהמי אוויר.

עמידה ביעדי התוכנית תלויה באבני הדרך להגעה ליעדים ובמפת הדרכים שתלך ותתגבש עם הזמן. מפת הדרכים תלויה במספר אילוצים והחלטות מדיניות. להלן דיון ברכיבים המשמעותיים של מפת הדרכים להגעה ליעדים וקביעת אבני דרך.

מפת הדרכים להגעה ליעדים – אבני הדרך ועמודי המדיניות המרכזיים בדרך להגעה ליעד

כאמור עמידה ביעדים ארוכי טווח חייבת לעבור ביעדי ביניים וכן במספר צמתים אשר יגדירו את העמידה ביעדים ויותר מכך את הדרך או אופן העמידה ביעדים. כך למשל, החלטה בשאלת מדיניות הקצאת הקרקעות הן בשימוש בלעדי והן בשימושים דואליים תשפיע באופן ישיר על אחוז הייצור מאנרגיה סולארית. באופן דומה מדיניות שתביא לחיבור הרשת הישראלית עם רשתות אחרות וייצור אנרגיות מתחדשות במדינות שכנות ורכישת החשמל בישראל יביא לעמידה ביעד מבלי להקים הספק נוסף בישראל. לצד החלטות מדיניות יבחן על פני זמן קצב התקדמות הטכנולוגיה אשר ישפיע על הטמעת טכנולוגיות נוספות ומתוך כך על אופן העמידה ביעדים. להלן אבני הדרך והמאפיינים השונים אשר יקבעו את אופן העמידה ביעדים.

הגדלת אחוז המתחדשות בתמהיל הייצור

תוצאות המודל מציגות שני תרחישים להגעה ליעד הפחתת פליטות במשק החשמל. התרחישים כוללים אחוז מתחדשות הנע בין 50% ל-85%. בשני התרחישים מדובר בקצב חדירה גבוה למשק והוא גוזר משמעויות רבות. על כן, וכפי שמפורט בתוכנית יקבע יעד מתחדשות לטווח הקצר וטווח הביניים, נכון להיום 20% מתחדשות עד שנת 2025 ו-30% עד שנת 2030. יעד זה יעודכן עם הזמן והוא אחד המפתחות המשמעותיים לעמידה ביעדי התוכנית.

אחוז גבוה (מעל 30%) של אנרגיה מתחדשת בתמהיל הייצור כרוך באתגרים רבים הנוגעים בין השאר בהיבטים תכנוניים, סביבתיים, פיננסיים, ובעיקר ביציבות ושרידות מערכת החשמל, קצב התקדמות טכנולוגיות האגירה ומציאת שטחים לצורך הקמת מערכות סולאריות.

בהיעדר פוטנציאל לייצור אנרגיה מתחדשת ממקורות קבועים כגון מקורות הידרו-אלקטריים וגיאותרמיים, ובשל החסמים הרבים הנוגעים לקידום מתקנים בטכנולוגיות אחרות, ההנחה בבסיס העבודה היא שלצורך עמידה ביעד, תוספת ההספק שתידרש תהיה ברובה המוחלט באמצעות מתקני

ייצור סולאריים. כך, עומדת ישראל להפוך לאחת המובילות העולמיות בחלק הייצור הסולארי מתוך סך הייצור. למרות היתרונות הכלכליים של ייצור סולארי ומאפייני האקלים בישראל, קיימת מורכבות רבה בניהול מערכת חשמל המסתמכת באופן כמעט בלעדי על מקור אנרגיה מתחדשת אחד בלבד, בפרט סירוגי (שאינו ניתן לשליטה על ידי מנהלי הרשת ואינו בעל כושר אספקה רציף). לאור האמור, יש חשיבות רבה לשימור ולהרחבת הפעולות שננקטו כדי להקל על שילובם של מתקנים פוטו-וולטאים, לקידום סוגים נוספים של אנרגיות מתחדשות ובפרט טכנולוגיית הרוח, כמו גם לשימוש במתקני אגירה לצורך קליטת עודפי ייצור סולארי והגמשת מערך הייצור.

לישראל מספר מאפיינים נוספים המעצימים את האתגר הנובע משילוב משמעותי של אנרגיות מתחדשות, ובפרט שילוב מתקנים סולאריים. ראשית, לישראל אין חיבור משמעותי עם מדינות שכנות שמאפשר הזרמת עודפי חשמל או גיבוי במקרה של מחסור. בנוסף, ישראל היא מדינה קטנה ובעלת צפיפות אוכלוסין גבוהה. בהשוואה לייצור קונבנציונלי, כמות האנרגיה שמיוצרת לתא שטח באמצעות מתקנים פוטו-וולטאים נמוכה משמעותית. יצוין בהקשר זה כי מוקדי הצריכה העיקריים מרוכזים באזור המרכז, בעוד שפוטנציאל השטחים הפנויים הגדול ביותר להקמת מתקני ייצור קרקעיים נמצא באזור הדרום, בו צריכת החשמל היא נמוכה. כתוצאה מכך, נדרש ניצול מרבי של יכולת הקמת מערכות ייצור בשימוש כפול בשטחים הבנויים במרכז, ופיתוח משמעותי של רשת ההולכה לצורך העברת האנרגיה ממוקדי הייצור למוקדי הצריכה.

מתוך כך, כאמור, נראה כי התמודדות עם האתגרים וכן המדיניות הממשלתית הנושא, שבעלייה באחוז הייצור הסולארי, קרי יעדי המתחדשות בטווח הקצר והבינוני, יקבעו את אופן ההגעה ליעדים ארוכי הטווח.

הטמעה של טכנולוגיות נוספות במשק החשמל

טכנולוגיות הקשורות לעולם תפיסת הפחמן הן טכנולוגיות המימן ה"כחול". מימן כחול הוא מימן המופק מגז טבעי (הכולל פחמן ומימן בלבד). בהליכי ההפקה נוצרות תרכובות פחמן שניתן לתפוס ולנצל בדומה לטכנולוגיות ה-CCU שצוינו לעיל. את המימן ניתן לאגור ולהזין לטורבינות ייעודיות לייצור חשמל (טורבינות הדומות לטורבינות גז עם שינויים מסוימים), לתנורים תעשייתיים כחלופה לדלקים מזהמים, או לתאי דלק, ההופכים מימן וחמצן למים תוך כדי ייצור חשמל.

לצד טכנולוגיות אלה, קיימת האפשרות לייצור חשמל מאנרגיה גרעינית הנפוצה מאוד בעולם, אולם בישראל היא נתקלת בהתנגדויות משמעותיות. תחום קרוב הוא ההיתוך הגרעיני, שהינו בטוח ונקי יותר מתהליך הביקוע הגרעיני שבשימוש כיום. לאחרונה הוצגו מספר פריצות דרך בתחום זה ויתכן כי בעתיד יוכל להוות מקור שופע לאנרגיה נקייה וזולה. גם טכנולוגיות טורבינות הרוח הצפות בעומק הים מתפתחת בימים אלו במהירות וצפוי כי בעוד כעשור תוכל להוות מקור זול וזמין לחשמל נקי.

הטמעת הטכנולוגיות במשק הישראלי כתלות בהבשלתן הן הטכנולוגית והן הציבורית תקבע באופן מהותי את אופן העמידה ביעדים.

הגעה ליעדי הפחתת פליטות בסקטורים משלימים- תעשייה, תחבורה ומבנים

כאמור, המשך הפיתוח הכלכלי בישראל ידרוש גידול מתמשך בביקוש לאנרגיה. הקשר בין תעשייה, תחבורה וסקטור המבנים לאנרגיה הוא קשר ישיר כיוון ששלושת התחומים תלויים באנרגיה לפעילותם השוטפת, עם זאת האתגר והאחריות למעבר לאנרגיה נקייה בסקטורים אלה משותף ותלוי במספר בעלי עניין.

1. מגזר התעשייה

ישנם שלושה מקורות לפליטה במגזר התעשייה: פליטה ישירה מהתהליכים התעשייתיים עצמם, פליטה עקיפה עקב שימוש בחשמל ופליטה ישירה עקב שריפת דלקים וגז. בעולם, משקיעים בתהליכים המנסים לצמצם פליטות אלו וגם בישראל, משרד האנרגיה בשיתוף משרד הכלכלה, רשות החדשנות והתאחדות התעשיינים משתפים פעולה במטרה לקדם תהליכי מחקר, פיתוח ויישום של תהליכים מופחתים פליטות בתעשייה.
התהליכים להסבת התעשייה לתעשייה דלת או מאופסת פליטות גזי חממה הינם ארוכי טווח ודורשים הן בחינה הנדסית עמוקה והן השקעה של סכומים גבוהים. היות וכך יש להתחיל לקדם את התהליכים במהירות האפשרית בכדי לאפשר לתעשייה את הזמן הנדרש למעבר. ללא הסבה לגז טבעי בשלב הראשון במקביל לתהליכי חשמול ומעבר למימן בטווח הארוך, לא נוכל להפחית פליטות בסקטור זה ולעמוד ביעד העל.

להלן יעדי מגזר התעשייה:

יעד	מדד	2018	יעד 2030	יעד 2050
הפחתת פליטות גזי חממה של התעשייה	הפחתת פליטות גזי חממה ביחס לשנת 2015		15%	40%

2. מגזר התחבורה:

כיום קיימת תלות כמעט מוחלטת בנפט כמקור אנרגיה לתחבורה בארץ ובעולם. למעלה מ-90% מצריכת האנרגיה בתחבורה העולמית מקורה בנפט ובישראל התלות אף גדולה יותר. למצב זה ישנן השלכות שליליות ביותר הן מההיבט הסביבתי, כתוצאה מפליטות גזי חממה, הן מההיבט הבריאותי עקב מזהמי האוויר שונים, הן מההיבט הכלכלי, מאחר ומחירי הנפט מתאפיינים בתנודתיות גבוהה, והן מההיבט הגיאופוליטי, מאחר והנפט מצוי בחלקו הגדול במדינות התורמות לחוסר יציבות פוליטית. על מנת להפחית את הפליטות מסקטור זה יש לעודד חדירת רכב חשמלי ע"י חבילת תמריצים הכוללת הטבות מיסים רכישה ומכס, פריסת תשתיות ועמדות טעינה, השקעות ברשת החשמל בבדי שתוכל לספק את הביקוש התוספתי והשקעה במו"פ. בנוסף יש צורך לאמץ את התקנים האירופאים לפליטות ברכבים חדשים ולקבוע יעדי מכירות וייבוא. מבחינת התחבורה הכבדה שלא צפויה לעבור חשמול בעשורים הקרובים, יש צורך באיסור מכירת כלי רכב מונעים בבנזין וסולר ובהשקעה נרחבת בתחליפי דלקים כגון מימן, גז טבעי נוזלי (גט"ן) וביו דלקים.

להלן יעדי מגזר התחבורה:

יעד	מדד	2018	יעד 2030	יעד 2050
רכבים מאופסי פליטה	אחוז רכבים מאופסי פליטה מסך מצבת הרכבים*	0%	25% עבור רכבים קלים מתחת ל-3.5 טון ואוטובוסים - 10% עבור משאיות כבדות	100%
יעילות אנרגטית	צריכת אנרגיה סופית מתחבורה לתושב לשנה (MWh/capita)	7.7	6-7	2-3

3. מגזר המבנים

בישראל, סקטור המבנים אחראי על כשליש מפליטות גזי החממה, בעיקר כתוצאה מצריכת אנרגיה לתאורה, לחימום ולקירור. אימוץ תקני בנייה ירוקה יוביל לחיסכון של עד 30% בצריכת האנרגיה במבנים, אולם, אימוץ של בנייה ירוקה אינו ממצה את פוטנציאל הפחתת פליטות גזי החממה ויש צורך לחיוב בנייה מאופסת אנרגיה, כך שייצור האנרגיה שווה לצריכת האנרגיה ומאזן האנרגיה הינו אפסי ואף חיובי במבנים אלה.

להלן יעדי מגזר המבנים כפי שנקבעו ע"י צוות מבנים וערים:

יעד	מדד	יעד 2030	יעד 2050
בתי מגורים צמודי קרקע	מהתחלות הבנייה	**100%**	**100%**
מבני מגורים בבנייה רוויה 3-5 קומות	מהתחלות הבנייה	**100%**	**100%**
מבני מסחר	מהתחלות הבנייה	**50%**	**100%**
מבני ציבור	מהתחלות הבנייה	**100%**	**100%**
מבני חינוך	מהתחלות הבנייה	**100%**	**100%**
מבני ממשלה בבעלות מנהל הדיור הממשלתי	מהתחלות הבנייה	**100%**	**100%**

- היעדים משקפים את אחוז המבנים שיעברו התעדה למימוש פוטנציאל האיפוס בהתאם למאפייני המבנה.

העובדה כי הגעה ליעדים בתחום האנרגיה תלויה לא מעט ביעדים של המשקים המשלימים, מצריכה שיתוף פעולה בין-משרדי ובין מגזרי, והיא קריטית להגעה למטרה המשותפת של השגת יעדי הפחתת הפליטות הלאומיים של ישראל. האתגרים העומדים בפנינו מורכבים ולכן לטיפול בהן נדרשת גישה משולבת המתבססת על יעילות ניצול המשאבים של כל משרד ותחום ועל חלוקת אחריות. תיאום זה יכול ליצור יתרון לגודל - מהלך של מספר משרדים ובעלי עניין הוא עוצמתי ויעיל יותר. אולם, קיים קושי לסנכרן ולתאם שגרה ונהלים ארגוניים, אשר מייצר חסם משמעותי לשת"פ, ולכל אחד מהגופים משתפי הפעולה יש מטרות ולחצים שונים שיכולים לפגוע במהלך הכולל. סוגיית השטח למשל, הינה דוגמא לאתגר שנוכל להתגבר עליו רק על ידי הבנה הדדית וחתירה למטרה זהה, שילוב נכסים והסכמה על ערך משמעותי שלכל אחד מהמשרדים יש סיבה ערכית אמתית לקדם אותו.

מדיניות הקצאת השטח

על פי ניתוח המודל, על מנת לאפשר אחוז גבוה (50-85%) של אנרגיה מתחדשת בתמהיל ייצור החשמל העתידי (מתבסס על העלאת אחוז האנרגיה הסולארית בלבד) יש צורך בכ-520-940 אלף דונם לשם הקמת תחנות ייצור סולאריות בשנת 2050- שטח נדרש זה שווה לכעשרת הפעמים שטחה של תל אביב. מדובר כאמור בשטח אדיר ועלכן להקצאת השטח השפעה מכרעת על העמידה ביעדי התוכנית.

לשם עמידה ביעד של לפחות 50% אנרגיה מתחדשת בתמהיל האנרגיה בשנת 2050, הערכות המודל המשמש לעבודה זו עומדות על צורך בהקמה של הספק מותקן של 58,000 מגה-וואט סולארי על פני כ-520,000 דונם. העלאת אחוזה מתחדשות לכדי 85% תצריך כ-940,000 דונם. שימוש נרחב כל כך בשטח, גם אם בשימושים דואליים, מציב אתגר חסר תקדים בכל הנוגע לייצור אנרגיה בטכנולוגיית PV ויכולת קליטתו ברשת.

מתוך כך בחינת העלאת יעד מתחדשות עד כדי עמידה ביעד המקסימלי מחייבת בחינה של עתודות השטח. כפי שפורט בעבודת יעדי 2030 סך הפוטנציאל לשטחים אשר נסקרו בתוכנית עומד על כ-180 אלף דונם בלבד. כך עולה הצורך בבחינה של פוטנציאל נוסף. פוטנציאל זה עשוי להגיע מקירוי כבישים ושימוש דואלי בשטחי חקלאות. בכל הקשור לקירוי כבישים מדובר עדיין בטכנולוגיה יקרה יחסית שלא נוסתה באופן רחב אולם בכל הקשור לאגרי-וולטאי נראה שבעולם הולכת ומתפתחת היום, כאמור, טכנולוגיה רלוונטית. לצד הפוטנציאל הגלום הן לחקלאות והן לאנרגיה יש לבחון בקפידה את העלויות הכלכליות ואת העלויות הסביבתיות שבשימוש נרחב כל כך בשטחים חקלאיים לטובת ייצור באנרגיה סולארית.

אגירה

אגירת אנרגיה מחליפה הקמת תוספת ייצור וחוסכת בשטחים. השימוש באגירה הוא אמצעי מפתח לפתרון בעיית הפקת חשמל מאנרגיה סולארית. השימוש באגירה, בין אם אגירה שאובה, בסוללות או בכל טכנולוגיה אחרת, יכול לפתור את בעיית הייצור העודף באמצעות קליטת עודפי הייצור בשעות הצהריים ופריקתה בערב ובלילה. בנוסף, לאמצעי האגירה יכולת תגובה מהירה והם יכולים לתת מענה לחלק מהבעיות הדינמיות המקשות על שמירת יציבות הרשת. לאגירה בסוללות יתרונות נוספים כגון זמני הקמה מהירים יחסית, גודל המתקנים והיכולת לשלב אותם בתשתיות קיימות ויכולת הקמה מודולרית.

יש לציין כי טכנולוגיית האגירה באמצעות סוללות עדיין בחיתוליה ואין ניסיון רב בעולם בתפעול מערכת חשמל הכוללת כמות גדולה מאד של מערכות אגירה באמצעות סוללות. בנוסף, קיימת אי וודאות רבה

לגבי עלויות הטכנולוגיה, מחזורי החיים שלה ואף לגבי היכולות שלה.[103] עם זאת, השימוש בטכנולוגיה זו הולך וגובר ברחבי העולם וקיימת מגמה ברורה של ירידת מחירים כאשר הצפי הוא להמשך המגמה לאורך העשור הקרוב לפחות[104].

על מנת לספק את הביקוש בשנת 2030 כאשר תמהיל האנרגיה יכיל 30% אנרגיה מתחדשת, ובשנת 2050 כאשר תמהיל האנרגיה יכיל מינימום 50% אנרגיה מתחדשת, יהיה צורך בכמות אגירה של כ- 17,200 ו-150,000-260,000 מגה-וואט-שעה בהתאמה[105]. בבחינת העלות העודפת והחיסכון המשקי של הגדלת יעד המתחדשות ל 30% עולה כי הטווח נע בין עלות עודפת של כ-4 מיליארד ₪ לבין חיסכון של כ-8 מיליארד ₪. עד לשנת 2050 צפוי חיסכון של כ-3 מיליארד ₪ בשנה, אך ערך זה הינו נמוך ביחס לאי הוודאות בנוגע לעלויות בטווח הזמן של 30 שנים.

פיתוח הרשת

על פי ניתוח המודל, על מנת לאפשר אחוז גבוה (50-85%) של אנרגיה מתחדשת בתמהיל ייצור החשמל יש צורך ביכולת הולכת אנרגיה מתחדשת של מעל 30 GW על מנת לתת מענה להתפתחויות הביקוש הצפויות עד לשנת 2050. לצורך עמידה ביעד של 30% אנרגיה מתחדשת בתמהיל ייצור החשמל בשנת 2030 נזדקק ליכולת הולכה בכמות של 11.6 GW, כאשר נכון להיום היכולת עומדת על 3-4 GW בלבד.

רשת החשמל מהווה תשתית לאומית עיקרית וחיונית שתפקידה, בין היתר, להעביר את האנרגיה המיוצרת בתחנות הכוח אל מרכזי הצריכה ברמת האמינות והאיכות הנדרשת. פיתוח מערכת ההולכה וההשנאה נדרש על מנת לתת מענה להתפתחות הביקוש הצפוי במשק החשמל, הצורך בשדרוג הרשת לשם הגברת שרידות המערכת, אמינות ויתירות ההספקה ולחיבור של מתקני ייצור ובכללם מתקני ייצור באמצעות אנרגיה מתחדשת הנדרשים למשק החשמל.

יחידת תכנון ופיתוח טכנולוגיות (תפ"ט) בחברת ניהול המערכת אחראית על תכנון מערכת ההולכה בהתייחס לביקוש הצפוי במשק החשמל על פי אזורים גיאוגרפיים וטכנולוגיות הייצור תוך שמירה על שרידות ואמינות האספקה. פרויקטים במקטע ההולכה מקודמים במסגרת תכניות מתאר ארציות במסגרת המועצה הארצית או הוועדה לתשתיות לאומיות (ות"ל). מעבר לקושי המערכתי בפיתוח מקטע ההולכה, הליך התכנון של הפרויקטים כולל חסמים רבים ואורך זמן רב. קושי זה הולך וגובר עם

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[103] ראו גם: NREL – Cost projections for Utility-Scale Battery Storage, June 2019

[104] ראו גם: IRENA – Electricity storage and renewables: Cost and markets to 2030

[105] כמות ההספק המדויקת, תלויה במספר גורמים ובעיקר בתמהיל של סוגי המתקנים, זאת לאור רמות התפוקה הממוצעות השונות

העלייה במגמה של ביזור ייצור החשמל, מאידך העיכובים בפיתוח הרשת מונעים הקמה של מערכות ייצור, ובפרט מערכות סולאריות בדרום.

תוספת של הספק מותקן באנרגיות מתחדשות, בוודאי מסוג סירוגי אחד, עשויה שלא לחסוך כמעט בכלל הספק קונבנציונלי, שנדרש לצורך גיבוי מתקני הייצור באנרגיות מתחדשות בשעות בהן אין ייצור מהם.[106] מכיוון שהרשת צריכה לתת מענה לקליטת האנרגיה מכל מתקני הייצור ולהעברתו ממוקדי הייצור אל מוקדי הצריכה, הוספה של מתקנים פוטו-וולטאים בהיקף של אלפי מגה-וואט מחייבת התאמה של פיתוח הרשת והגדלת היקף ההשקעות במקטעי הרשת.

קושי נוסף נובע מכך שהייצור הסולארי מרוכז בכ-5 שעות ביום, בממוצע, כך שייצור סולארי דורש הספק הולכה מרבי גבוה פי 3 לערך ביחס לייצור דומה ממקורות קונבנציונליים. יוצא מכך שהגדלת הייצור הסולארי מטילה דרישות כבדות על הרשת. שימוש משמעותי באגירה יכול להפחית דרישות אלו ולכן יש לתכנן את הרשת במקביל לתחזיות הייצור הסולארי והאגירה.

תכנון תשתיות אנרגיה באופן כללי היא משימה מורכבת, אחד האתגרים המשמעותיים הוא התחרות על משאב הקרקע. ישראל היא מהמדינות הצפופות בעולם, עם ממוצע של 405 תושבים לקילומטר מרובע[107]. יתרה על כך, תחזית הצמיחה של הלמ"ס מלמדת כי אוכלוסיית ישראל צפויה להכפיל את עצמה עד לשנת 2065, אז יחיו בישראל כ-20 מיליון איש[108]. בהתאם לכך, מקודמות עשרות אלפי יחידות דיור אשר צפויות לתת מענה לתחזיות אלו[109]. לכך יש להוסיף את אספקת התשתיות הדרושות לאותן יחידות דיור ובמקביל יש לשמור ולהבטיח שאספקת התשתיות תהייה באמינות גבוהה וביתירות.

מורכבות תכנון התשתיות מתעצמת, על רקע הרצון להגדיל את חלקן של האנרגיות המתחדשות בתמהיל הייצור, שיתבסס על חשמל סולרי שמאופיין ב: 1) צורך בשטחים נרחבים ביחס לייצור באמצעים אחרים; 2) ייצור חשמל מבוזר; 3) ייצור המחייב רשת חשמל מבוזרת בפריסה רחבה שגם בעבורה יש לאתר שטחים.[110]

מתוך כך וכפי שעולה מניתוח המודל בחינת התאמת הרשת להגדלת יעד המתחדשות וקליטת הטכנולוגיות היא תנאי הכרחי בדרך לעמידה ביעדים.

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[106] שילוב של אמצעי אגירה לצד מתקני האנרגיות המתחדשות יכול כמובן לחסוך בהספק קונבנציונלי.

[107] https://ourworldindata.org/grapher/population-density

[108] https://www.cbs.gov.il/he/mediarelease/pages/2017

[109] לדוגמא, לפי נתוני מנהל התכנון, בשנת 2019 אושרו כ - 140,000 יחידות דיור חדשות.

[110] למשל, בהינתן שרוחב מינימלי של רצועת הולכה הינו 40 מ' – 70 מ', משמע שכל קילומטר רץ - קילומטר אורך, של רצועת חשמל שתוקם תתפוס שטח של כ – 40,000 מ"ר – 70,000 מ"ר.

שיתופי פעולה אזוריים וקישוריות

המשק הישראלי נכון להיום הוא אי אנרגטי. אין ספק שהצורך בשמירה על אמינות האספקה ביחד עם המחסור בשטח, השאיפה לפיתוח כלכלי והרצון להפחית פליטות ומזהמים מסמנים את הדרך לקידום שיתופי פעולה אזוריים. חיבור רשת החשמל הישראלית וכן קידום מיזמים לייצור אנרגיות מתחדשות במדינות השכנות, אשר נבחנו כחלק מהתרחישים במודל, עשויים לאפשר למשק הישראלי את ההגעה ליעד, תוך חיזוק הכלכלה האזורית, ותרומה להפחתת הפליטות גם מחוץ לישראל. מורכבות התהליכים מצריכים הערכות עכשוויות בעניין זה וקידום מדיניות שתבחן את אפשרויות אלה.

אבני הדרך לעמידה ביעדים

כאמור, השגת היעדים המוצגים תלויה בגורמים רבים שפורטו לעיל והם שיקבעו את קצב העמידה ביעדים. חלק מהפרמטרים תלויים בהתפתחות טכנולוגית ואזוריות ואת חלקן לא ניתן להעריך נכון להיום. עם זאת נראה כי קיימים שני פרמטרים עיקריים אשר ישפיעו באופן המשמעותי ביותר על העמידה ביעדים: העלאת אחוז האנרגיה המתחדשת והאגירה באופן משמעותי, בשילוב הטמעת טכנולוגיות חדשות שיובילו להפחתת פליטות. ללא עמידה בפרמטרים אלה לפחות, לא תתאפשר הפחתת פליטות שאפתנית כפי שהוצע בסקטור זה. מתוך כך ניתן לומר כי השגת היעדים תלויה בקיומם של מספר תנאים הכרחיים אשר חלקם יקבעו היום ויתעדכנו וחלקם יקבעו בהמשך:

תנאי הכרחי	2020	יעד 2030	יעד 2050
שטח להקמת מערכות אנרגיה מתחדשת		כ-160 אלף דונם	500-900 אלף דונם (תלוי בבמות האנרגיה הסולארית)
אגירה	0.3 GW	GW 3.5	GW 34-57 (תלוי בבמות האנרגיה הסולארית)
פיתוח הרשת – יכולת הולכת אנרגיה מתחדשת	GW 3-4	11.6 GW	מעל 30 GW (תלוי בבמות האנרגיה הסולארית)

תרחישים שונים לעמידה ביעדים

לרוב, תכנון אסטרטגי הוא תהליך שמתחיל מההווה, ממפה הזדמנויות ואתגרים, מגדיר את המטרה, מהו החזון, היעד המועדף וכיצד להגיע אליו. מאידך, תכנון ארוך טווח יכול שיתחיל מהעתיד, יסתכל קדימה לעתיד הרחוק יותר כדי לראות מה עשוי לקרות ויקבע מהם הצעדים שיש לקדם על מנת להתכונן לעתיד. תכנון לטווח קצר מניע למציאת פתרונות ברי-קיימא, ולהתמודדות עם שינויים דרסטיים או לא מכוונים. עם זאת, פתרונות ברי-קיימא הנלקחים מדאגות לטווח הקצר הם לרוב אבני הדרך התורמות להשגת היעד לטווח הארוך.

על כן, משרד האנרגיה הגדיר ארבעה 'יעדים ראשיים' שישקפו את המטרה האסטרטגית ויעדים סקטוריאליים תומכים בעזרתם ניתן יהיה להשיגה. 'יעד העל' מוגדר כהפחתת פליטות גזי חממה ממגזר האנרגיה בשיעור של 80% ביחס לשנת הייחוס 2015 וזאת עד לשנת 2050.

בחינת השפעת התכנית והעמידה ביעדים נעשית על ידי השוואה בין תרחיש "עסקים כרגיל" לבין תרחיש בו מיושמת התכנית המוצעת. השפעת התכנית מוצגת כאן כטווח בין תרחיש בעל רמת מימוש חלקית של התכנית ובין תרחיש בעל רמת מימוש מלאה של התכנית:

עסקים כרגיל – התרחיש מניח כי הביקוש לאנרגיה ימשיך לגדול שכן הוא מושפע באופן ישיר מקצב גידול האוכלוסייה הגבוה ומרמת חיים הולכת ועולה. מבחינת תמהיל הדלקים לייצור חשמל, נעמוד על 17% ייצור מאנרגיה מתחדשת, 83% ייצור מגז טבעי וללא שימוש בפחם כמו גם 7% התייעלות בחשמל[111] ביחס לשנת 2015. צפיפות האוכלוסין תלך ותגדל- גורם אשר יקשה על הקצרת שטחים לטובת ייצור האנרגיה כמו גם פיתוח הרשת להולכת חשמל מאזורי הייצור לאזורי הביקוש. חשמול סקטור התעשייה והתחבורה יהיה זניח. בתרחיש זה, על מנת לעמוד בביקוש הצפוי של 158 טרה וואט שעה בשנת 2050 (פי 2.6 משנת 2015) יצטרכו לקום עוד תחנות כח גזיות בסדר גודל של MW 10,000 בעוד הקשיים לתכנן ולהקים יחידות אלו הולכים וגוברים.

תרחיש בעל רמת מימוש חלקית - התרחיש מניח השגה חלקית של היעדים ומימוש חלקי של המדיניות התומכת במעבר לאמצעים מקיימים. התרחיש מניח הפסקת שימוש בפחם, 50% ייצור חשמל מאנרגיה מתחדשת ו50% מגז טבעי. תרחיש זה מניח ירידה משמעותית במחירי האגירה וירידה מתונה במחירי הטכנולוגיות לייצור חשמל סולארי כמו גם התפתחות מתונה של יעילות הפאנלים לייצור חשמל סולארי. בתרחיש זה הונח פיתוח איטי וחלקי של רשת החשמל ומיצוי במעט מלא של פוטנציאל השטח לייצור חשמל סולארי. מבחינת משקים משלימים- הונחה עמידה חלקית במעבר לרכבים מאופסי פליטות (הפחתה של

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[111] בשנת 2030. בגלל שאין התייעלות נוספת, וסך הביקוש גדל, אזי חלק ההתייעלות יקטן עד 4.1% בשנת 2050

65% בפליטות במקום 94%) וחשמול חלקי של סקטור התעשייה (הפחתה של 14% בפליטות גזי החממה במקום 43%).

תרחיש בעל רמת מימוש גבוהה- התרחיש מניח שינוי מהותי במשק החשמל, השגה מלאה של היעדים ומימוש מיטבי של המדיניות התומכת. התרחיש מניח משק חשמל מבוזר וחכם, הפסקת שימוש בפחם, 50-85% ייצור חשמל מאנרגיה מתחדשת והשאר מגז טבעי המבוסס ברובו על אמצעים להפחתת פלטות (תפיסת פחמן או הפקת מימן כחול). תרחיש זה מניח ירידה משמעותית במחירי האגירה ובמחירי הטכנולוגיות לייצור חשמל סולארי כמו גם קפיצת התפתחות ביעילות הפאנלים לייצור חשמל סולארי. בתרחיש זה הונח פיתוח מלא של רשת החשמל ומיצוי מלא של פוטנציאל השטח לייצור חשמל סולארי. מבחינת משקים משלימים- הונחה עמידה מלאה ביעדים- 94% מעבר לרכבים מאופסי פליטות ומיצוי פוטנציאל החשמול של סקטור התעשייה.

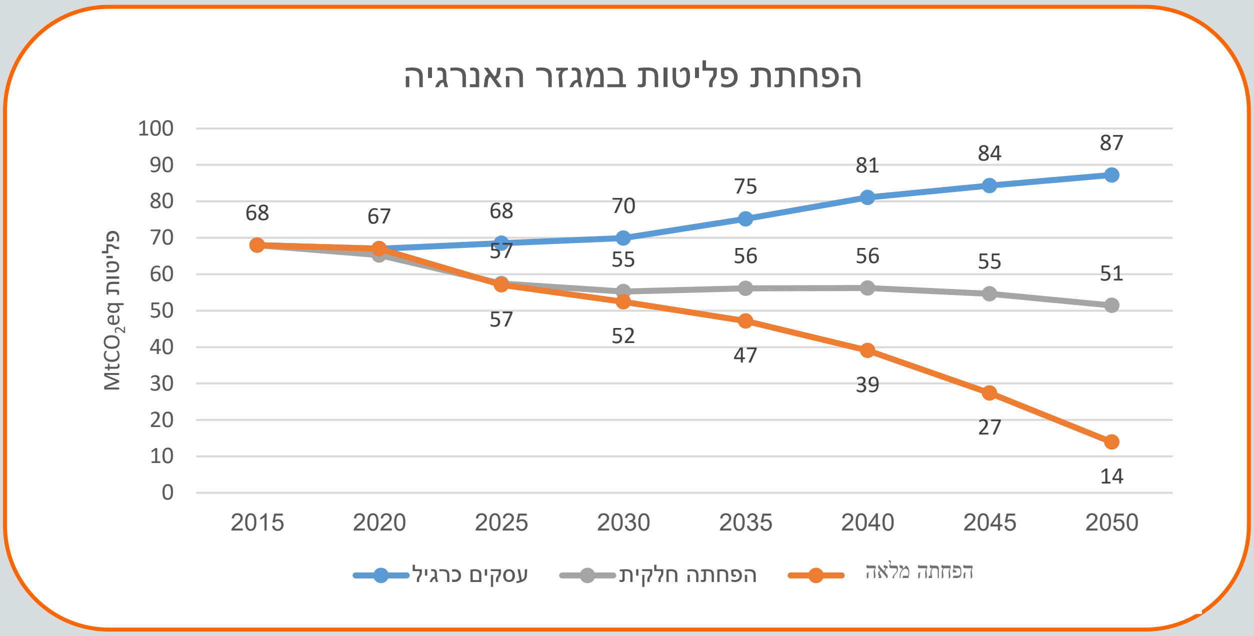
בתרחיש זה ניתן להשיג את יעד ההפחתה של 85%-75% בפליטות ממגזר החשמל באמצעות ייצור ממקורות מתחדשים ואגירה, או עם התקנה מופחתת של מקורות מתחדשים (כ-50%) אך עם שימוש באמצעים טכנולוגיים אחרים כדוגמת תפיסת פחמן לצורך הפחתת הפליטות והשגת היעדים. היעדים הסופיים יקבעו בהתאם להתפתחות הטכנולוגיות ולרמות המחיר והזמינות.

עמידה ביעדים

להלן מוצג הלוח המסכם של העמידה ביעדים בתרחיש הנמוך ובתרחיש הגבוה ביחס לתרחיש הבסיס של עסקים כרגיל, כפי המתואר בפרק התרחישים. היעדים לשנים 2030 ו-2050 נבחרו על בסיס התרחיש הגבוה וזאת מתוך מטרה להביא להפחתה מרבית של פליטות גזי חממה במשק האנרגיה הישראלי לאור הצורך בשמירה על אמינות האספקה, מחירים ברי השגה, המאפיינים הייחודיים של ישראל וקצב התקדמות הטכנולוגיות.

לוח 9: עמידה ביעדי התוכנית בתרחיש הנמוך ובתרחיש הגבוה

יעד	מדד	2030			2050		
		עסקים כרגיל	**הפחתה חלקית**	**הפחתה מלאה**	**עסקים כרגיל**	**הפחתה חלקית**	**הפחתה מלאה**
הפחתת פליטות גזי חממה במשק האנרגיה	אחוז הפחתת פליטות גזי חממה ביחס לשנת 2015	(עלייה של 4%)	20%	כ-30%	- (עלייה של 28%)	הפחתה 24%	הפחתה 80%
הפחתת פליטות גזי חממה במגזר החשמל	אחוז הפחתת פליטות גזי חממה ביחס לשנת 2015	5%	17%	32%	עליה של 21%	32%	81%
יעילות באנרגיה	אחוז שיפור שנתי בעצימות אנרגיה (טרה-וואט/מלש"ח)	-	1%	1.3%	-	1%	1.3%
שימוש בפחם	אחוז פחם בתמהיל ייצור החשמל	19%	0%	0%	0%	0%	0%
תחבורה מאופסת פליטות	אחוז הפחתת פליטות גזי חממה ביחס לשנת 2015	תוספת 33%	תוספת 6%	9% הפחתה	תוספת 76%	13%	94%
חשמול המגזר הביתי והתעשייתי	אחוז הפחתת פליטות גזי חממה ביחס לשנת 2015	תוספת 7.5%	תוספת 5.4%	4.2% הפחתה	תוספת 14%	14%	43%



תרשים 41: תחזית הפחתת פליטות במגזר האנרגיה בתרחיש "עסקים כרגיל", תרחיש יישום נמוך (הפחתה חלקית) ותרחיש יישום גבוה (הפחתה מלאה), מודל האנרגיה, משרד האנרגיה.

בתרשים 41 ניתן לראות את הירידה המשמעותית בפליטות בין שנת 2020 ל-2025 בתרחישי ההפחתה עקב הפסקת השימוש בפחם. בתרחיש עסקים כרגיל, סך פליטות גזי החממה ממגזר האנרגיה צפויות לגדול בכ-28% לעומת שנת הייחוס 2015 ולעמוד על 87 MtCO$_2$e בשנה. לעומת זאת, בתרחיש ההפחתה החלקית, סך פליטות גזי החממה ממגזר האנרגיה צפויות להצטמצם בכ-24% לעומת שנת הייחוס 2015 ולעמוד על 51 MtCO$_2$e בשנה, ובתרחיש הפחתה מלאה, סך פליטות גזי החממה ממגזר האנרגיה צפויות להצטמצם ב-80% לעומת שנת הייחוס 2015 ולעמוד על 14 MtCO$_2$e בשנה.

כפי שנכתב בהרחבה בעבודה זו, האחריות הבסיסית של משרד האנרגיה היא לדאוג לאמינות ורציפות אספקת האנרגיה במחירים ברי השגה ולבצע זו לאור משבר האקלים, המביא בפני עצמו אתגרים משמעותיים למשק האנרגיה ומאפייניה הייחודיים של ישראל. יישום מלא של התכנית יביא לעמידה ביעדים, בעוד יישום חלקי, כפי שמוגדר בתרחיש הנמוך, לא יאפשר את הפחתת הפליטות הרצויה במשק האנרגיה. עמידה מלאה ביעדי התכנית מלווה באתגרים רבים ותלויה באופן ישיר ביכולות שונות וביניהן:

1. השלמת המהלך להפסקת השימוש בפחם בסקטור ייצור החשמל;
2. השלמת המהלך לחיבור התעשייה לרשת הגז הטבעי חלף דלקים מזהמים היום;
3. השקעות לפיתוח מואץ של רשת החשמל והתאמתה לקליטת אנרגיה מתחדשת בכמות גבוהה כמו גם חשמול בתחבורה ובתעשייה;
4. הטמעת מתקני אגירת חשמל בהספק הנדרש;

5. מיצוי פוטנציאל הקרקע להקמת מתקני ייצור סולאריים ובפרט בשימוש כפול;
6. ניהול חכם של מערך ייצור החשמל וניהול ביקושים;
7. השקעות בהתייעלות באנרגיה;
8. השקעות במו"פ של טכנולוגיות להתייעלות באנרגיה, אגירה, אנרגיה מתחדשת וטכנולוגיות להפחתת פליטות (תפיסת פחמן, מימן כחול וכדומה);
9. יכולת לשיתופי פעולה בין בעלי העניין הרלוונטיים;
10. קישוריות – יכולת לחיבור רשת החשמל למדינות שכנות;
11. עמידה ביעדי הפחתת פליטות במשקים משלימים (תחבורה, תעשייה ומבנים);

מימוש יעדי משק האנרגיה לשנת 2050 עתיד להפחית באופן חסר תקדים את פליטות המזהמים שלנזקיהן השלכות בריאותיות וסביבתיות קשות על תושבי ישראל, ולאפשר למדינת ישראל לעמוד בהתחייבויותיה הבינלאומיות בהקשר זה. היעדים כוללים את הפחתת השימוש במוצרי דלק מזהמים ובפרט הפסקת השימוש בפחם והפסקת רובו המכריע של השימוש בתזקיקי נפט והעלאת חלקן של האנרגיות המתחדשות בתמהיל האנרגיה תוך שמירה על אמינות ורציפות אספקת האנרגיה. התכנית מהווה צעד משמעותי לקראת הפחתת התלות של מדינת ישראל בפחם ובתזקיקי נפט וצפויה להוביל לשינויים רחבים במשק האנרגיה הישראלי. זאת, לצד שמירה על אמינות וזמינות אספקת האנרגיה בשגרה ובחירום. בנוסף, תלווה מדיניות הפחתת השימוש במוצרי דלק מזהמים, בצעדים נוספים להשגת יעדי התייעלות באנרגיה.

האתגר העיקרי בתכנון ארוך טווח הינו הסתמכות על משתנים שלמעשה אינם ידועים היום אך בעלי השפעה משמעותית לטווח הארוך (game changers). לדוגמא, המניע המרכזי למדיניות ההשקעה באנרגיות מתחדשות הוא הרצון לצמצם את פליטות גזי החממה והזיהום המקומי והגלובלי. ההוצאה הגבוהה על אנרגיות מתחדשות, ביחס למקורות דלק פוסיליים, מקוזזת עם תועלת חזויה הנובעת מהפנמת העלויות החיצוניות של ייצור האנרגיה. במידה וטכנולוגיות לצמצום זיהום יתפתחו ויגדילו את יעילותן, הן עשויות להיות תחליף להשקעה במתקני ייצור סולאריים ומתקני אגירה ומתקני ייצור גמישים נלווים, מאידך קפיצות דרך טכנולוגיות באמצעי הייצור הסולאריים ובאגירה יוכלו להביא להשגה מהירה יותר של היעדים ובעלויות מופחתות. דוגמא נוספת הינה חיבור חשמלי בין ישראל למדינות אחרות – כיום, לישראל אין כל חיבור חשמלי למדינה אחרת. במדינות רבות במערב, החיבור הבין-מדיני מאפשר מרווח ביטחון במקרים של קשיי ייצור. ייבוא החשמל הוא שימושי במיוחד לישראל עקב פרופיל הייצור הסולארי ומגבלותיו שצוינו בעבודה זו. במידה ובטווח הרחוק יהיה חיבור שכזה, הרי שהוא עשוי לאפשר את הגדלת חלקה של אנרגיית ה-PV בתמהיל הדלקים הישראלי כמו גם יאפשר רכישת חשמל נקי ממדינות שכנות בעת מחסור.

לכן, כאשר מתכננים לטווח ארוך בסביבה משתנה (קפיצות טכנולוגיות, ירידות/תנודתיות מחירים ועוד) קבענו את המטרה (הפחתת פליטות מקסימלית במשק האנרגיה), וסימנו מספר אפשרויות להשגת היעד,

במטרה לעדכן את מפת הדרכים ואבני הדרך בהתאם להתפתחויות העולמיות והטכנולוגיות. כך, בכל עת ההחלטה הטובה ביותר לטווח הקצר והבינוני (עד 10 שנים קדימה) מיושמת, ונוכל להימנע מקבלת החלטות ארוכות טווח מבוססות על מידע חסר שעלולות לקבע את משק האנרגיה הישראלי במסלול שאינו המיטבי.

יעדי הפחתת הפליטות אותם קובע משרד האנרגיה לשנת 2050 במסגרת עבודה זו, יובילו להפחתה דרמטית בפלטות הפד"ח בישראל, יהיו בשורה אחת עם היעדים אותם קובעות מדינות רבות בעולם וזאת חרף מגמת הגידול הטבעי בישראל, אשר חורגת מהמקובל במדינות הOECD. העמידה ביעדים אלו תלויה ראשית בהשגת יעדי הביניים לשנת 2030 אשר נקבעו זה מכבר על ידי המשרד. יעדים אלו לשנת 2030 הינם יעדים פרטניים אשר התכניות למימושם נמצאות בחלקן בביצוע ובחלקן ממתינות עדיין לאימוץ ממשלתי.

בבואנו לקבוע יעדים לשנת 2050 עלינו להבטיח עמידה על עקרונות הרציפות התפקודית, כדאיות כלכלית משקית וראייה סביבתית כוללת. כפי שעולה מעבודה זו אנו סבורים כי אכן ניתן יהיה לעמוד על עקרונות אלו תוך הפחתה של כ- 80% בפלטות בפד"ח במשק האנרגיה. עם זאת, בנקודת הזמן בה אנו נמצאים לא ניתן לקבוע באופן חד משמעי את החלופות העדיפות להשגת היעד מנקודת ראות כלכלית, שכן טווח התכנון הינו ארוך מידי ומשק האנרגיה מתאפיין בתנודתיות חזקה בכל האמור לפיתוחן של טכנולוגיות והשתנותם של מחירים. ייתרה מכך, בהינתן המידע הקיים היום ספק רב אם ניתן לבסס את השגת היעד על שימוש באנרגיית שמש בלבד וזאת לאור המשמעות הנדרשת בעיקר בהיבטי קרקע ורשת, משמעות בעלת השלכות סביבתיות ותכנוניות מורכבות ביותר.

לפיכך, לצד הגדלה משמעותית ויציבה של היקף השימוש באנרגיית שמש ובטכנולוגיית אגירה, עלינו לפתח כמה אופני פעולה שיאפשרו בעתיד התמקדות בחלופה המיטבית. בין אופני פעולה אלו ציינו בעבודה זו את פיתוחן של טכנולוגיות תפיסת פחמן, הפקת מימן, ייצור אנרגיה מתחדשת בהתבסס על מקורות נוספים שזמינותם כיום מוגבלת, כמו גם חיבוריות לרשתות חשמל אזוריות.

צעדי המדיניות המפורטים להלן, הינם האמצעים בהם על המדינה לנקוט על מנת לאפשר זאת.

צעדי מדיניות

צעדי מדיניות

על מנת להשיג את היעדים השאפתניים המוצגים בנייר מדיניות זה, דרושים צעדי מדיניות המיועדים להתאמת התשתית הפיזית והרגולטורית - בעיקר צעדים שראוי לעגן באמצעות הצבת יעד כמותי בטווח הקצר-בינוני (עשר שנים) על מנת שלא לקבע מסלולים שאינם מיטביים לזמן הארוך.

משק החשמל:

1. פיתוח מואץ של רשת החשמל- פיתוח רשת החשמל מהווה תנאי הכרחי ליישום היעדים. על כן, נדרש לגבש בהקדם תכניות פיתוח למערכת ההולכה ולרשת החלוקה שתיתן מענה לקליטת ההספק הנדרש. יש לפתח את רשת ההולכה כך שתאפשר ייצור חשמל סולארי מסיבי בפריפריה ובעיקר בדרום הארץ, ואת רשת החלוקה והאספקה כך שתוכל לנהל ביציבות ייצור כמויות גדולות של חשמל סולארי על גגות הבתים. בנוסף, היות וקיימים חסמים משמעותיים לפיתוח הרשת, נדרש לקדם בהקדם תכנית להסרת חסמים, להאצת פריסת הרשת ולייעול ההליכים התכנוניים למתקני רשת.
2. הטמנת קווי מתח עליון - הטמנת קווי מתח עליון מסירה את המופע העילי והפגיעה הנופית, מונעת פגיעה בבעלי כנף, מצמצמת את פוטנציאל הפגיעה בעקבות הקצנת תופעות מזג אוויר ופגיעות אדם ומצמצמת תפיסת שטחים. לאור הצפיפות ההולכת וגדלה והצורך בהקמת קווי מתח עליון נוספים, לא מן הנמנע שיידרש שילוב מוגבר של קווים מוטמנים באזורים בנויים וגם בשטחים פתוחים.
3. הולכה בזרם ישר (DC) –לזרם ישר מספר יתרונות, ובפרט בקווי מתח מוטמנים. אובדן האנרגיה בהולכה בזרם ישר הינו נמוך מאד והעלויות נמוכות יחסית, וזאת ביחס לאובדן הגבוה בקווי הולכה מוטמנים בזרם חילופין (AC) ועלויות גבוהות פי 5-7 ביחס לקווי מתח עיליים. בנוסף, פליטת הקרינה מקווי זרם ישר נמוכה ומרחקי הביטחון הנדרשים הינם נמוכים משמעותית. משמעות הדבר היא כי ניתן להטמין קווי DC לצד תשתיות קיימות כגון כבישים או קווי מתח עיליים, ובכך לפשט ולזרז את הליכי התכנון וההפקעה המורכבים הנדרשים לצורך הקמת קווי מתח עיליים. אולם, קווי DC מסוגלים להוליך אנרגיה רק מנקודה ונקודה, ובשני קצות הקו יש להקים תחנות המרה גדולות ויקרות. היות וכך, יש לבחון כבלי הולכה בזרם ישר כפתרון לצורך הולכת הספקים גבוהים מאד של אנרגיה מאתרי הייצור הסולארי בפריפריה ישירות לרשת החשמל במרכז הארץ באזורי הצריכה, אך כבלים אלו לא יוכלו להחליף את רשת ההולכה הקיימת על כל מורכבותה.
4. מנהרות תשתית רב מערכתיות - מנהרת תשתיות היא ללא ספק הדרך הטובה ביותר תכנונית וסביבתית להעברת תשתיות "בכפיפה אחת" באזורים בנויים צפופים. על מנת לקדם מנהרות תשתית יש לקדם הקמת גורם מקצועי מתכלל שירכז בידיו את הסמכויות לקידום, ניהול, תפעול וטיפול במנהרות תשתית כמו גם לייצר מנגנונים כלכליים להסדרת מקורות המימון

והתפעול של הקמת המנהרה. בנוסף, יש צורך להטמיע הגדרות וכללים לאיתור מנהרות תשתית רב מערכתיות המתייחסים להיבטי כלכלה, יעילות תפקודית, סביבה ותכנון בהליכי קידום תכניות למנהרות.

5. תכנון אנרגיה נקייה בשטחים המבונים – יש להטמיע הנחיות בתהליך התכנון הכוללות בחינה של שימושי הקרקע בשטחים המבונים בהתייחס לאפשרות למצותם לייצור להפקת אנרגיה ממקורות מתחדשים לצורך ייעול ניצול הקרקע בתוכנית. לרבות, אך לא רק: הנחיות למקסום פוטנציאל ייצור אנרגיה בשטחים מבונים קיימים ובתוכניות חדשות; שמירת שטחים למערכות חשמל וחדרי ההשנאה הנדרשים לקליטת חשמל ממקורות ייצור מרובים ומבוזרים; תכנון ושמירת אתרים להטענת רכבים חשמליים בשטחים הפרטיים והציבוריים; קביעת הנחיות ברורות ופשוטות להתקנת מערכות ייצור אנרגיה נקייה המיועדות לרשות המקומית ולאזרח, כמו גם הנחיות ומנגנוני גמישות שיאפשרו שילוב ועדכון חידושים טכנולוגיים בהתאם להתפתחויות ולצרכים המשתנים; ניצול והפקת חשמל נקי ביעילות ובטכנולוגיה המיטבית במירב השטח המבונה על כל שימושיו (למשל בבבישים). גופים מקצועיים תכנוניים מנהלים ומתכללים יסייעו לקדם וללוות את הליך הפקת החשמל ממקורות מתחדשים בשטחים מבונים, במסגרת זאת יש לכלול: א) מדריך להליכי הקמת אנרגיה מתחדשת בשטחים מבונים. ב) הכשרת אנשי מקצוע לליווי ההליך וסיוע בהסרת חסמים. ג) מעקב אחר פוטנציאל הייצור החזוי מהשטח המבונה אל מול המימוש בפועל וניתוח החסמים והפערים. ד) הסקת מסקנות והמלצות להמשך מיצוי הפוטנציאל. ה) קידום הסרת החסמים ויצירת מנגנוני עידוד על בסיס הלמידה והניסיון. ו) הנגשת המידע ופרסומו לציבור בעזרת מאגרי מידע ונתונים מקוונים.

6. ביזור מערכת האנרגיה בישראל - הקמת אמצעי ייצור ואגירה מקומיים בסמיכות למוקדי הביקוש כמו גם יצירת מערכות כלכליות שיביאו למקסום פוטנציאל זה, תחסוך משאבי קרקע של הולכת רשת למרחקים, הגדלת הניצולת של ייצור החשמל המקומי והפחתת אובדן, כל זאת תוך הגדלת אמינות אספקה ושירות ליישובים מרוחקים ו/או מבודדים. קידום והטמעת רשת חכמה לניהול מערכות החשמל כחלק מתוכניות פיתוח הרשת– קביעת לו"ז להטמעה ואימוץ רשת חכמה לניהול מערכת החשמל לפי שלבים ואבני דרך. שינוי תפיסת הרשת על ידי הרגולטור וקידום אמצעים חוקיים ורגולטורים שיאפשרו הקמת מערות כאמור ושילובן לתוך משק החשמל הישראלי.

7. אגירת חשמל – בחינת אופן ההטמעה של מתקני אגירה באופן מיטבי בהתאם להתפתחות הטכנולוגית, מחירי האגירה וצרכי המשק. עוד מוצע לבחון את התועלות משילוב טכנולוגיות אחרות ובפרט אנרגיית רוח. יש לקדם מגוון מערכות אגירה- מגוון טכנולוגיות אגירה מתפתחות במקביל ויש להניח שיהיו פתרונות מגוונים לאגירת אנרגיה ברמה ארצית ומקומית. יש לשמור על אפשרות הקמה והטמעת הטכנולוגיות בעתיד לרבות שיחלופן ככל

שיתקדמו ופיזור גיאוגרפי של מתקני האגירה בהתאם למיקום אופטימלי. מתקני אגירת אנרגיה בליווי מערכות קצה חכמות, יכולות לתת מענה לגיבוי ולניהול יעיל יותר של הרשת כך שניתן יהיה לנתב ולתעל את האנרגיה לצרכנים לפי הביקוש.

8. קרקע – הקרקע היא משאב מוגבל ויש להתייחס אליה בזהירות הראויה, בעיקר במדינה צפופה וקטנה כמו שלנו, "שנושאת על גבה" אתגרים רבים כגון הקצאת קרקעות רבות לנושאי דיור, ביטחון ועוד. לאור מגבלת הקרקע, נדרש להגדיל ולמצות את פוטנציאל השטח כחלק ממטרות תכנון משק האנרגיה. צעדי מדיניות שיכללו עקרונות לתכנון והקצאת הקרקעות, תוך ניצול מקסימלי של מימושן יאפשר לייצר פתרון מאוזן ומשולב לאתגרים של הפחתת פליטות גזי חממה ולאתגרים אחרים שניצבים בפני המתכנן כאמור. דוגמאות לכך הן: הגדרת הנחיות בתוכניות להטמעה של מתקנים פוטו-וולטאים כשימוש נלווה בתכניות, חיוב התקנת מתקנים פוטו-וולטאים בבניה חדשה, מיצוי פוטנציאל השטחים הדואליים (גגות, כבישים ומחלפים, חניונים, מאגרי מים וייעודים נוספים), תכנון מערכות חשמל מובנות ומוטמנות בתוכניות השטחים המבונים וכמובן הנחיות לשילוב אגירת אנרגיה. שימוש בקרקע באופן מושכל וממצה בשטחים המבונים, יכול לחסוך שטחים נרחבים לא רק לטובת הייצור, אלא גם לטובת מערכת הולכת החשמל אל השטחים המבונים. בנוסף לשימוש יעיל ומושכל, יש לייצר ודאות, מנגנונים ברורים וגנריים לתנאי השימוש בקרקע והקצאתה על מנת למנוע את ההליכים הארוכים והדיונים הנדרשים לכל פרויקט אד – הוק.
9. אסדרות - יש לוודא קיומם של פתרונות אסדרתיים לטווח ארוך על מנת ליצור אופק לתעשייה הסולארית. בכלל זה, יש להמשיך ולקיים באופן סדיר הליכים תחרותיים ובנוסף לתת מענה רציף בדמות אסדרות בסיסיות. האסדרות ייקבעו ללא תלות במכסה, או באמצעות אפשרות להשתלב בממסחר הסיטונאי הכללי בשוק החשמל. בנוסף, יש לבחון אילו התאמות נדרשות באסדרות הרלוונטיות של מתקני ייצור קונבנציונליים, על מנת לאפשר התאמה שלהם למשטרי הפעלה שיידרשו.
10. ניהול מערך הייצור - לשם התמודדות עם האתגרים בניהול מערך הייצור, יש צורך להטמיע ולהפעיל מגוון כלים אשר יסייעו בהיערכות מערך הייצור ובהם הוספת אגירה בהיקפים משמעותיים, הוספת גמישות למערך הייצור באמצעות שינוי התמהיל הקונבנציונלי, שינוי משטר ההפעלה של היחידות הקונבנציונליות הקיימות במערכת, ניהול ביקושים, ואף קיטום של הייצור הסולארי בשעות שיא הייצור. הטמעה והפעלה של כלים כאמור, בהיקפים גדולים, עשויה להיות מורכבת ולדרוש שינויים הנדסיים ורגולטוריים שתהיה להם השפעה נרחבת על מערך הייצור ועל אופן ניהול הייצור והביקוש.
11. ניהול ביקושים – כלי ראשון במעלה להגדלת הגמישות ברשת הינו ניהול הביקוש. עם העלייה בחדירת האנרגיה הסולארית לרשת יש להכניס את ניהול הביקושים כחלק אינטגרלי מניהול

המערכת, גם ברמת רשת החלוקה. יש להרחיב את הסדרי ניהול הביקוש, לאסדר את הפעלת חברות האגרגציה, חברות המאגדות ומנהלות צרכנים רבים לכדי "תחנות כוח וירטואליות" המסוגלות להגיב לדרישות מנהל המערכת ולתרום ליציבות הרשת.

12. שיתוף פעולה רב מגזרי - מעבר לכך, על אף צעדים רבים שכבר קודמו והמאמצים הרבים שהושקעו מצד משרדי הממשלה ושחקנים נוספים בשילוב אנרגיות מתחדשות, קיימים עדיין מגוון חסמים ואתגרים. הגדלת היעד תחייב מאמץ ושיתוף פעולה חוצה מערכות לטובת מגוון צעדים של ייעול הליכים, צמצום חסמים ויצירת תמריצים.
13. תמריצי מימון - הקמת קרן הלוואות בערבות המדינה לרשויות לטובת הקמת PV ואגירת אנרגיה. במטרה להגדיל את היקף ייצור החשמל ממקור סולארי על גבי מבנים ציבוריים, לפתור את חסמי המימון ולייצר תמריץ לרשויות המקומיות, בינואר 2020 הושקה קרן הלוואות להאצת הטמעת אנרגיות מתחדשות ברשויות המקומיות בישראל. הקרן תספק הלוואות בהיקף של כ-500 מיליון ₪. לאור הצלחת הקרן והביקוש הגבוה מצד הרשויות המקומיות, נכון יהיה להקצות משאבים נוספים בהיקף של 500 מלש"ח למימון ותמיכה בהתקנת מערכות נוספות לייצור חשמל מקומי ובפרט באמצעות מנגנוני סיוע לרשויות המקומיות.

התייעלות באנרגיה:

14. יש לבצע עדכון תקנות מקורות אנרגיה (בתחום מיזוג האוויר, מכשירי חשמל ביתיים ועוד) ועדכון המפרט של סקר אנרגיה המחויב לפי חוק באופן שוטף ועל פי ההתקדמות הטכנולוגית. בנוסף לכל אלו, תחויב הטמעה של ת"י ISO 50001 למערכות ניהול אנרגיה בקרב גופים המחויבים בהיתר פליטה ותצא לפועל רפורמה ביבוא מוצרי חשמל.
15. תמריצים, מענקים והלוואות - לצורך עמידה ביעדים שפורטו לעיל, יש צורך בתקציב חמש שנתי בסך כמיליארד ש"ח (עבור השנים 2021-2025), להרחבת התמיכה בפרויקטים להתייעלות באנרגיה והפחתת פליטות גזי חממה.
16. חיוב מבני ממשלה ויחידות סמך ביעדי אנרגיה מתחדשת ויעילות באנרגיה- קידום החלטת ממשלה במשרדי ממשלה ויחידות סמך שתכלול שני רכיבים עיקריים שייושמו במשרדי הממשלה ויחידות הסמך: התקנת מערכות לייצור אנרגיה סולארית על גבי גגות מבני המשרדים והתייעלות בצריכת האנרגיה.
17. חינוך, הכשרה והסברה- על מנת להגביר מודעות ולשנות את הרגלי הצריכה בתחום האנרגיה יש צורך להרחיב את היקף פעילות החינוך, ההכשרה וההסברה. על מנת לממש את הפעילות הדרושה יש צורך בתקציב של 40 מלש"ח למשך 5 השנים הבאות.
18. חשמול המגזר הביתי- בחינת תיקון תקנות התכנון והבנייה כך שתבוטל החובה לפרישת תשתית גפ"מ בבנייה חדשה למגורים.

19. בנייה מאופסת אנרגיה – חיוב תקן בנייה בת-קיימא (בנייה ירוקה) במסגרת בקשות להיתרי בנייה למבנים חדשים הנבנים במשק.

20. פתיחת מגזר אספקת החשמל לתחרות צפויה ליצור מערך תמריצים תעריפיים מקומיים לניהול ביקושים והתייעלות. מספקים מקומיים יוכלו אף לתמוך בהתקנת אמצעי התייעלות בקרב הצרכנים – בגלל שחיסכון באנרגיה עולה פחות מייצור אותה כמות אנרגיה, הרי שיש כדאיות לספקים לשלם לצרכנים ליישם צעדי התייעלות מאשר לרכוש חשמל. עם פתיחת השוק לספקים פרטיים ניתן יהיה גם לחייב אותם ביישום צעדי התייעלות באחוז מסוים מסך הביקוש שהם מנהלים, מודל הנקרא Energy Efficiency Portfolio Standard (EEPS).

תחבורה מאופסת ודלת פליטות:

28. הערכות תשתיות – לאור הצפי לחדירה של מאות אלפים ואף מיליוני רכבים חשמליים, יש לוודא כי מערכת החשמל ערובה לספק את החשמל הנוסף שיידרש למשק, בייחוד בשעות העומס. יש להכין בתוך שנתיים תכנית להתאמת הרשת ופיתוחה לקליטת עמדות לטעינת כלי תחבורה חשמליים (רכבים, אוטובוסים, ודו-גלגליים) במרחב הציבורי והפרטי. יש לקדם טעינה מנוהלת ("טעינה חכמה") לשם הסטת הטעינה לשעות השפל, על מנת שהשפעת הרכב החשמלי על שיא ביקוש החשמל תהיה מצומצמת ככל הניתן. התכנית תתייחס בין היתר לאפשרות להזין את רשת החשמל באמצעות הרכבים החשמליים (זרימה דו כיוונית V2G).

29. הטבת מס רכישה ומכס – בשנת 2019 האריכה הממשלה את הטבת המיסוי על רכבים חשמליים מלאים עד לשנת 2024. עד שנת 2022 המיסוי על רכב חשמלי יעמוד על 10% ולאחר מכן יעלה בהדרגה עד ל-35% בשנת 2024. התחזית מראה כי עלות רכב חשמלי תהיה גבוהה מעלות רכב קונבנציונלי עד שנת 2026, ולכן יש לבחון בשנת 2022 את הארכת הטבת המיסוי, ככל והפער בין הרכבים לא הצטמצם באופן מלא לאחר הטבת המס. בנוסף, יש לבטל כל מכס המוטל על רכבים חשמליים עד שנת 2026 לפחות.

30. יעד מכירות – יש לאמץ יעדים של מדינות מובילות בעולם ולקבוע יעד של 100% מכירות רכבי אפס פליטות פרטיים (Zero Emission Vehicles) בשנת 2030.

31. מנגנון הפחתת פליטות לרכבים קלים- לצורך הגעה ליעד כאמור בסעיף 30 לעיל – מוצע, כפי שמקובל באיחוד האירופי, לבחון הטלת חובה על יבואנים לעמוד ביעדי פליטות ממוצעות או לחילופין חיוב שילוב של מכסות מינימאליות להנעה חלופית במסגרת מצאי הרכבים אותן הם מייבאים לארץ. יש להחיל מנגנון זה על רכבים פרטיים ולבחון הרחבת המנגנון – בשינויים מתחייבים, גם למשאיות קלות.

32. פריסת רשת עמדות טעינה – עד שנת 2030 תידרשנה בישראל כ-60 אלף נקודות טעינה איטיות ציבוריות וכ-1,000 נקודות טעינה מהירות בעלות של 1 מיליארד ש"ח. עד היום

השקיעה הממשלה כ-30 מלש"ח בהקמה של 2,500 נקודות טעינה (איטיות ומהירות). נקודות אלו יספקו מענה מלא לרכבים שיעלו על הכביש ב-2-3 השנים הקרובות. לאחר מכן יש לבחון תמיכה נוספת בהקמת עמדות טעינה, בתלות בהתפתחות שוק הרכב החשמלי בישראל.

33. תשתיות טעינה בבניה חדשה – יש לפעול בתוך שנה לתיקון תקנות התכנון והבנייה ולהחלת חובה להקמת תשתית חשמל מקדמית בבנייני מגורים חדשים לחיבור עמדות טעינה עתידיות, בהתבסס על ממצאי עבודת משרד הבינוי והשיכון. יש לפעול לניסוח והחלת הנחיות דומות במבני צבור, מסחר, ותעסוקה.
34. הקמת עמדות טעינה בבתים משותפים – יש לפעול בתוך שנה לתיקון חוק המקרקעין על מנת לאפשר הקמת עמדת טעינה בחניונים פרטיים במבני מגורים משותפים ללא הצורך בהסכמת כלל דיירי בבניין.
35. כלי רכב ממשלתיים – יש לקבוע מעבר הדרגתי של רכבי ממשלה להנעות חלופיות כך שהחל משנת 2025, ירכשו או יוחכרו ע"י הממשלה רכבים חשמליים בלבד. יש לקבוע יעדי ביניים בתוך שנה, ולהחיל הנחיה דומה על חברות ממשלתיות.
36. שווי שימוש ואגרת רישוי – יש לפעול להארכת הטבת שווי שימוש לרכבים חשמליים עד שנת 2026 וכן להעניק הנחה באגרת הרישוי עבור רכב חשמלי בסך של 50% לפחות בייחס לרכב בעירה פנימית.
37. מוניות חשמליות – יש לפעול בתוך שנה ליישום החלטת ממשלה מספר 529 מיום 6.9.2015 בדבר הקניית זכות ציבורית באגרה מופחתת למוניות המונעות בהנעה חשמלית (יש להקנות זכות זו לכלל ציבור נהגי המוניות בישראל).
38. חניה מועדפת לכלי רכב חשמליים – יש לקבוע בתוך שנה על מנגנון להקצאת חניות ייעודיות ומוזלות לכלי רכב חשמליים בחניוני תחנות רכבת ובחניונים של פרויקטים תחבורתיים לאומיים המתכוננים כיום ובעתיד.
39. איסור כניסת רכבים למרכזי ערים – יש לפעול בתוך שנתיים, בשיתוף הרשויות המקומיות, להכנת תכנית לקביעת יעדים לאיסור כניסת רכבים מונעי סולר למרכזי הערים או לאזורים מתוחמים החל משנת יעד.
40. הסברה – יש לצאת בפרסום לפי סקטורים וציבור המשתמשים, ולמקד את הציבור ביתרונות התחבורה החשמלית בתוך שנה. הפרסום יכלול ימי עיון וסדנאות, בשיתוף הסקטור הפרטי והרשויות המקומיות, בהם הציבור יוכל להתנסות ולהכיר מקרוב רכבים חשמליים.
41. רכבי מימן – יש לפעול בתוך שלוש שנים לאימוץ תקינה בינלאומית והכנת תשתית רגולטורית שתאפשר שימוש ברכבי מימן בישראל, ככל ותהיה פריצת דרך בטכנולוגיה זו בשנים הבאות.

עד פריצת הדרך, יש לפעול לביצוע הדגמות לשימוש ברכבי מימן באמצעות תקציבי מחקר ופיתוח במשרד האנרגיה.

42. דו-גלגליים חשמליים –דו-גלגליים פועלים בחלק גדול מהזמן במרחב העירוני ועל כן הנזקים שהם מסבים לסביבה, הן מבחינת זיהום האוויר והן מבחינת הרעש הנם משמעותיים ביותר. יש לפעול להכנת תכנית להאצת המעבר לדו-גלגליים חשמליים בתוך שנה.

43. מערך תמריצים ברור- מערך התמריצים הנדרש לעמוד בפני בעלי העניין השונים במשק צריך להיות מקיף וכוללני. מערך התמריצים צריך לכוון את כל שרשרת האספקה של צ״י הרכב לחלופות דלות פחמן. התמריצים צריכים להתייחס לכל בעלי העניין (צ״י רכב, יבואני רכב כבד, ספקי תשתית תדלוק, ספקי דלק/חברות דלק וכיוצ"ב) ולטווח ארוך המייצר וודאות רגולטורית.

44. רגולציה בינלאומית מחייבת- הפחתת פליטות בתחום התעופה אינה יכולה להתבצע מיוזמה מקומית וחייבת להיות משולבת עם רגולציה גלובלית. כמו לדוגמה, חובה לשילוב של דלקים מתחדשים בתחבורה אווירית, הטלת מיסוי על דס"ל בטיסות בינלאומיות וכיוצ"ב.

45. תכנית להעברת סקטור הספנות לדלקים נקיים- מידת ההשפעה של התעבורה הימית על היקף פליטות גזי החממה ותרומתה לזיהום האוויר בערי נמל הינה משמעותית. תקנות של ארגון הספנות הבינלאומי מחייב ספינות להפחתת הפליטות באמצעים שונים. אחד האמצעים שלאחרונה צוברים תאוצה הוא החלפת הדלק המשמש לספינות (מזוט) בסוגים אחרים של הנעה וביניהם גז טבעי נוזלי. השימוש בגט"ן הינו כלכלי ובעל פוטנציאל להפחתה דרמטית בהיקף הפליטות של כל המזהמים וגם גזי חממה. אולם, הוא מחייב השקעה ניכרת בהתאמת מנועי הספינות ויצירת תשתית תדלוק בנמלים. בנוסף, קיים אתגר משמעותי בהפחתה של דליפות מתאן שעשויות לקזז חלק מהתועלת האקלימית בשימוש בדלק מסוג זה. התכנית המוצעת כוללת שיתוף פעולה אזורי בינלאומי (מדינות הים התיכון) ליצירת תשתית תדלוק מתאימה משולב עם מערך תמריצים להסבת הספינות. התכנית בשלבי הכנה במסגרת פעילות קבוצת עבודה ייעודית לנושא במסגרת פורום הגז של מזרח הים התיכון (EMGF)

46. העברת מערך האוטובוסים העירוניים לחשמל- העברת מערך האוטובוסים העירוניים לחשמל, כך שהחל משנת 2026 לא יכנסו אוטובוסים חדשים מונעי סולר לשירות. ההעברה תתבצע דרך שילוב חובה במכרזי הפעלת אשכולות תחבורה ציבורית. בנוסף, עשויה להינתן תמיכה להעברת יתרת צ״י התחבורה הציבורית לגז טבעי.

47. תמיכה בהקמת תשתית תדלוק גט"ד בתחנות ציבוריות- מתן מענקים פיננסיים.

48. העברת משק הפסולת להנעה חלופית – מתן תמריצים להקמת תחנות תדלוק, הסבת צ״י משאיות, מתן תמריצים רגולטוריים וכיוצ"ב.

49. פיילוט ותקינה של תחנת תדלוק במימן והסדרה של גט"ן- מימון פרוייקט חלוץ של תקינה לתחנת מימן ושל שימוש בגט"ן במשאיות כבדות/כבדות מאד.

50. קידום רגולציית על סקטור המשאיות הקלות – כפי שמקובל באיחוד האירופי וכפי שמוצע גם לגבי מכוניות פרטיות, יש לבחון הטלת חובה על יבואנים לעמוד ביעדי פליטות ממוצעות או חיוב שילוב הנעה חלופית במסגרת מצאי המשאיות אותן הם מייבאים לארץ.

51. קידום רגולציה המחייבת חברות דלק לשלב דלקים מתחדשים/ירוקים ממקור מקומי- רגולציה זו, בשונה מ"חובת המהילה" הקיימת במדינות אירופה לשילוב ביודלקים, שאינה רלוונטית לישראל בה אין ייצור ביודלקים מדור ראשון, עשויה להוביל לחובה הדרגתית ומידתית לשילוב דלקים מתחדשים ונקיים במסגרת סה"כ הדלקים הנמכרים על ידי חברות הדלק/בתי הזיקוק וכו'.

סקטור התעשייה

52. מימוש החזון יחייב ביצוע השקעות ברשת החלוקה בהיקף של כ-900 מיליון ₪. לפני מתן המענקים, ייבחנו המקטעים והצריכות הפוטנציאליות על רקע הצעדים הנעשים לקידום הרשת.

53. הקמת בסיס נתונים של צריכת אנרגיה בתעשייה שיאפשר לנתח את פוטנציאל הצריכה בהתאם למאפייני צריכת האנרגיה, מיקום גיאוגרפי ומאפייני הצרכן ופעילותו.

54. יש לבצע עבודה כלכלית המנתחת את ההשפעה של שינויים במחירי הדלקים ביחס למחיר הגז טבעי על כדאיות ההסבה לגז טבעי.

55. יש לבחון בכל תקופת זמן, חסמים רגולטורים של צרכנים להסבות לגז טבעי, ולהציע צעדים לטיפול בהם.

סקטור הגז הטבעי

56. בחינת מדיניות הייצוא - כבכל פרויקט, האפשרות להקדים את התקבולים מפרויקט מגדילה את כדאיותו. ככל שבעלי החזקות יפיקו את הגז הטבעי מוקדם יותר, כך תגדל כדאיותו של הפרויקט, ובמשק מוגבל ביקוש כמו המשק המקומי, יצוא הוא הנתיב המרכזי המאפשר הקדמת ההכנסות מהפרויקט, ומשכך מוצע להרחיב את אפשרויות הייצוא.

57. עידוד המשך פיתוח והפקה - בשל תרומתו של הגז הטבעי למשק הישראלי מבחינה כלכלית, סביבתית ואסטרטגית, ישנה חשיבות להמשיך ולעודד חיפוש והפקה של גז טבעי בטווח הקרוב, ולקדם מיצוי חכם ואופטימלי של עתודות האנרגיה הקיימות בישראל.

58. מדיניות בנושא לכידת ואגירת פחמן: ללכידת ואגירת פחמן תפקיד משמעותי ביותר בהפחתת הפליטות בארץ ובעולם. פרויקטים עתידיים והמשך השימוש בגז לצרכים מקומיים ייתכן ויותנו

בפרויקטים של אגירת פחמן. לצורך כך יש להסדיר את הנושא מבחינה רגולטורית ולבצע: סקירה עולמית כלכלית, הנדסית ורגולטורית בנושא אגירת פחמן ושימוש בפחמן בתעשייה (CCS ו- CCU).

59. החלפת גז טבעי במימן/ביוגז - האירופאים מתירים להחדיר לרשת הגז הטבעי מימן בשיעור של עד 20% מהכמות ברשת הגז הטבעי – מבלי שהדבר ישפיע על בטיחות הרשת ועל צורת השימוש[112]. מכיוון שרשתות ההולכה והחלוקה בישראל נבנים בסטנדרטים מחמירים מאוד, מבחינת הבטיחות ככל הנראה הרשת בישראל יכולה לעמוד בשיעור זה[113]. על כן מומלץ בשנים הקרובות לצאת לפיילוט שיבחן שילוב מימן ברשת ולהרחיבו בשלב מאוחר יותר בהתאם לממצאים.

60. חיבור רשת החשמל הישראלית לרשתות שכנות- לאחרונה, עקב חתימת הסכמי נורמליזציה עם איחוד האמירויות הערביות ובחריין, יש לבחון חיבור הרשת הישראלית למדינות השכנות לרבות לאירופה ולמזרח התיכון. החיבור של מדינת ישראל למערכת כזו יספק בטחון אנרגיה במקרי חירום ומצד שני יאפשר גם לישראל למכור את העודפים שייווצרו מהגדלת המתחדשות וכן לקנות חשמל נקי משכנותיה וכך לייצר מערכת יציבה ויעילה יותר. לאחרונה מקודם חיבור כבל תת ימי לקפריסין ואל יבשת אירופה. קידום הכבל מתוכנן לחבר בין ישראל, קפריסין, כרתים וחצי האי היווני וכך בעצם לחבר את רשת החשמל הישראלית אל הרשת החשמל האירופאית.

61. תחזיות ומדיניות גז טבעי ודלקים - יש לבצע עבודה מעמיקה לבחינת הצרכים של המשק בתקופת הביניים למעבר למשק אנרגיה מאופס פליטות והדרכים להשגתם. העבודה תכלול, בין השאר, תחזית ישראלית לשימוש בדלקים נוזליים בהתאם למדיניות המעבר לתחבורה נקייה.

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[112] https://hydeploy.co.uk/faqs/hydrogen-level-set-maximum-20/

[113] בהתבסס על שיחה עם מהנדסי נגב גז

62. יש להקצות תקציב ייעודי למשרד האנרגיה, למשך עשור, לצרכי השקעות במחקר ופיתוח בתחום האנרגיה הנקייה ובפרט תחבורה נקייה ותפיסת פחמן. התקציב יאפשר לממן חוקרים באקדמיה, חברות ומיזמים פורצי דרך בתחום האנרגיה הנקייה, ויתרום למיצובה של ישראל כאומת סטארט-אפ גם בתחומי האנרגיה.
63. יש לאפשר למשרד בשיתוף משרד הכלכלה לסייע בהקמת תעשייה מתקדמת בתחומי האנרגיה (לדוגמא מפעלי לייצור סוללות, מפעל לייצור אמצעי אגירת חום, מפעל לייצור פאנלים סולאריים מתקדמים), על ידי הקצאת תקציב ייעודי לתחום זה במשרד הכלכלה, ושיתוף משרד האנרגיה בתהליכי קבלת ההחלטות. יש לייצר מסלול מואץ לאישורים בתחום זה.
64. יש להקים מכונים לאומיים לאנרגיה בתחום אגירת האנרגיה, מימן, רשת החשמל ואנרגיית השמש.
65. יש לעבות את הפעילות המחקרית של המכונים (המכון הגיאולוגי וחקר ימים ואגמים לישראל) וביצוע מחקרים בינתחומיים בשת"פ עם חוקרים מתחומים נוספים (הנדסה, כלכלה).
66. קולות קוראים: המשרד תומך במו"פ דרך קולות קוראים הפתוחים לאקדמיה ולתעשייה. ניתן להרחיב את היקפי המימון ולהיכנס לתחומים חדשים רלוונטיים.

נספח 17

העתק ממסמך העקרונות

עמ' 800

מדינת ישראל
משרד האנרגיה
מינהל אוצרות טבע

נפט וגז
ל׳ בחשון התשפ״ג
24 בנובמבר 2022

לכבוד:
חברי מועצת הנפט

הנדון: עקרונות ההליך התחרותי הרביעי 2022

מצורפים בזאת העקרונות המרכזיים של ההליך התחרותי הרביעי למתן רישיונות לחיפוש גז ונפט בים.

בדומה להליכים התחרותיים הקודמים, תנאי סף להשתתפות להליך הינו עמידת הקבוצה כולה ובפרט המפעיל בדרישות המפורטות ב״תקנות הנפט (עקרונות פעולה לחיפושי נפט והפקתו בים), תשע״ז-2016״ (מצ״ב).

א. משך זמן הרישיון וחובת קדיחה

סעיף 18 (א) לחוק הנפט, קובע כי רישיון לחיפוש נפט ניתן לתקופה של 3 שנים, וסעיף 18 (ב) קובע כי הממונה רשאי להאריך את תוקף רישיון החיפוש עד לתקופה של 7 שנים. על פי סעיף 21 לחוק הנפט בעל רישיון חיפוש חייב להתחיל לקדוח תוך 24 חודשים מיום קבלת הרישיון. יחד עם זאת, סעיף 51 לחוק קובע הממונה רשאי להאריך את מועד הביצוע של פעולה שיש לבצעה לפי זכות נפט. כלומר, לממונה קיימת סמכות להאריך את התקופה בה חובה על בעל רישיון לקדוח בשטח רישיון, לתקופה של מעבר ל- 24 חודשים.
ההליך התחרותי נסוב על הזכות לקבל רישיון חיפוש לתקופה של 3 שנים, בהתאם לתכנית עבודה שתוגש עם ההצעה. הדרישות לתוכנית העבודה אינן כוללות חובה לבצע קידוח חיפוש בתקופה זו של 3 השנים הראשונות.
עם זאת, כפי שיוסבר בהמשך, התחייבות בתכנית עבודה של מציע, לביצוע קידוח חיפוש במהלך 3 השנים הראשונות תעניק משקל משמעותי בהערכת ההצעה ובניקודה, וממילא לסיכוי לזכייה ברישיון החיפוש.
בהליך התחרותי נקבע, כי קבוצה אשר תבצע את תכנית העבודה לה היא התחייבה, רישיון החיפוש שלה יוארך בשנתיים נוספות, וככל שתעמוד בכל הדרישות, רישיון החיפוש יוארך בשנתיים נוספות עד למקסימום 7 השנים האפשריות להחזקה ברישיון חיפוש.
מי שיקבל במסגרת ההליך רישיון החיפוש, מבלי שהתחייב לקדיחה ב-3 שנים הראשונות, יחליט לקראת סיומה של תכנית העבודה של ה-3 שנים הראשונות, האם לאור הסקרים אשר ביצע קיימת מטרה מבטיחה לקדיחה. היה ויחליט בעל הרישיון כי אין מטרה כאמור, יחזיר את רישיון החיפוש למדינה וזאת ללא נקיטת סנקציות מאת המדינה. היה וימצא כי ישנה מטרה ראויה ומתאימה לקדיחה יגיש לממונה תכנית עבודה הכוללת התחייבות לקדיחה במשך השנתיים הבאות ותכנית עבודה לשאר הרישיונות.

הרעיון העומד מאחורי תקופות רישיון אלו של 3+2+2, הוא שב-3 השנים הראשונות בעל הרישיון לומד את שטח הרישיון שקיבל, ולאחר מכן, בהתאם לבדיקות שיבצע על פי תכנית העבודה, מחליט האם יש מטרה המצדיקה קידוח. מעבר לכך, כיוון שמדובר רק על מבנה שבעל הרישיון טרם קדח בו עומדת בפני בעל הרישיון אפשרות ללימוד שטח הרישיון באופן הדוק ומעמיק על ידי קידוח, אשר כתוצאה ממנו יידע האם גם בשאר הרישיונות המצויים ברשותו מצויות מטרות גז או שמא מדובר על מטרות "יבשות".

חשוב להדגיש כי במקרה בו זוכה בשטח בהליך התחרותי אשר במהלך הצעת תכנית העבודה התחייב לבצע קידוח במהלך 3 השנים הראשונות, יחליט שלא לבצע קידוח לאחר שהגיע למסקנה כי אין מטרת גז/נפט בשטח הרישיון, או מכל סיבה שהיא, הערבויות אשר העמיד יחולטו.

ב. סעיפי ניקוד

אזור G

נושא התיחור			יחידת מדידה	ניקוד	משקל
תכנית עבודה מחייבת במהלך 3 השנים הראשונות	ביצוע קידוח חיפוש (במהלך 3 השנים הראשונות)		מספר קידוחים	70	85
	ביצוע סקר סייסמי 3D		שטח (קמ"ר)	20	
	ביצוע סקר סייסמי 2D		אורך כולל (ק"מ)	0	
	עיבוד חוזר של סקרים סייסמיים קיימים	עיבוד חוזר של סקר סייסמי 3D	שטח (קמ"ר)	7	
		עיבוד חוזר של סקר סייסמי 2D	אורך כולל (ק"מ)	0	
	סקרים גיאופיסיים נוספים או מחקרים גיאולוגים שונים		סכום התחייבות להשקעה כספית	3	
מענק חתימה			סכום מענק	100	15
סה"כ					100

אזורים H+E

נושא התיחור			יחידת מדידה	ניקוד	משקל
תכנית עבודה מחייבת במהלך 3 השנים הראשונות	ביצוע קידוח חיפוש (במהלך 3 השנים הראשונות)		מספר קידוחים	50	85
	ביצוע סקר סייסמי 3D		שטח (קמ״ר)	30	
	ביצוע סקר סייסמי 2D		אורך כולל (ק״מ)	5	
	עיבוד חוזר של סקרים סייסמיים קיימים	עיבוד חוזר של סקר סייסמי 3D	שטח (קמ״ר)	10	
		עיבוד חוזר של סקר סייסמי 2D	אורך כולל (ק״מ)	2	
	סקרים גיאופיסיים נוספים או מחקרים גיאולוגים שונים		סכום התחייבות להשקעה כספית	3	
מענק חתימה			סכום מענק	100	15
סה״כ					100

אזור I

נושא התיחור			יחידת מדידה	ניקוד	משקל
תכנית עבודה מחייבת במהלך 3 השנים הראשונות	ביצוע קידוח חיפוש (במהלך 3 השנים הראשונות)		מספר קידוחים	0	85
	ביצוע סקר סייסמי 3D		שטח (קמ״ר)	65	
	ביצוע סקר סייסמי 2D		אורך כולל (ק״מ)	25	
	עיבוד חוזר של סקרים סייסמיים קיימים	עיבוד חוזר של סקר סייסמי 3D	שטח (קמ״ר)	0	
		עיבוד חוזר של סקר סייסמי 2D	אורך כולל (ק״מ)	6	
	סקרים גיאופיסיים נוספים או מחקרים גיאולוגים שונים		סכום התחייבות להשקעה כספית	4	
מענק חתימה			סכום מענק	100	15
סה״כ					100

תכנית עבודה – 85%

העיקרון המנחה של הניקוד הוא שקבוצות אשר יעברו את תנאי הסף כאמור לעיל, ראויות לקבל זכויות נפט בישראל מבחינה מקצועית ומבחינה כלכלית.

התחרות היא בעיקרה על תכנית העבודה אשר הקבוצה מתחייבת לבצע ברישיון החיפוש, ולכן נקבע כי תכנית העבודה תקבל 85 נקודות מתוך 100.

הניקוד בתוך 85 הנקודות מתחלק בהתאמה להשקעה הכספית המשוערת אשר בעל רישיון החיפוש צריך להשקיע. עלותו של קידוח חיפוש מוערכת בכ -80-100 מיליון דולר, עלות סקר סייסמי 3D מוערכת בכ- 5-10 מיליון דולר, עלות סקר 2D מוערכת בכ 1-5 מיליון דולר, עלותו של עיבוד חוזר של סקר D3 מוערכת בכ 1-2 מיליון דולר ועלותו של עיבוד חוזר סקר D2 מוערכת בכ- 0.5-1 מיליון דולר.

בכל מקבץ בלוקים התיחור שנקבע הוא שונה, בהתאם למידע הגאולוגי הקיים ביחס לאותו מקבץ, ולכן המשקל של כל רכיב שונה בהתאם לבשלות המידע הקיים במקבץ זה. במקבץ בו לא קיים עדיין סקר D3 יינתן ניקוד גבוה יותר לביצוע סקר חדש D3 מאשר במקבץ בו כבר קיים סקר D3. וכן בהתאמה לגבי שאר הסקרים המתוחרים בטבלה.

מענק חתימה- 15%

עיקר ההכנסות של המדינה מגז ונפט הינו בשלב ההפקה. לצורך כך נחקק חוק מס רווחי יתר (חוק ששינסקי) אשר מתווסף למס חברות/מס הכנסה ולתמלוגים על פי חוק הנפט. מטרתו של סעיף זה היא הכנסת רכיב נוסף, כלכלי, בתחרות אשר לגביו יתחרו קבוצות המבקשות לקבל זכות נפט. משקלו של פרמטר זה קטן יחסית במטרה שלא להרתיע חברות אשר לא יהיו מוכנות להשקיע כספים רבים בשלב המקדמי של כניסה לרישיון.

סיבה נוספת למשקל הנמוך יחסית של מענק החתימה היא הסיכון הגבוה של שלב הרישיון בו קיים חוסר וודאות משמעותי ביחס לכלכליות ההשקעה. מצב זה שונה מהמצב בענפים אחרים כגון הקמת תחנת כוח, הקמת בניין משרדים, תפעול רשת סלולארית וכיו״ב, כאשר בענף חיפושי הנפט והגז שיעור ההצלחות באתרים בהם כבר הוחלט על ביצוע קידוח הינו כ-20% בלבד.

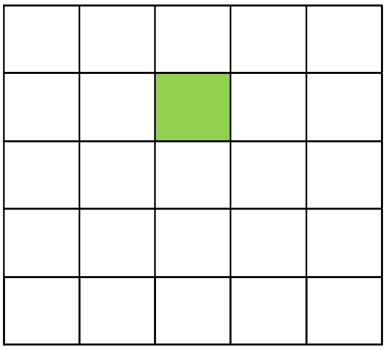
ג. ערבויות ועידוד חבילות בלוקים

ע״פ חוק הנפט, השטח המקסימלי שניתן לתת לגביו רישיון חיפוש הוא 400 קמ״ר, וזאת לעומת שטחים נרחבים וגדולים בהרבה, הקבועים במדינות הגובלות עם ישראל.

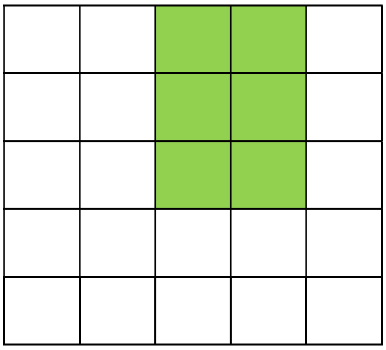
ישנה עדיפות וקיים יתרון לכך שקבוצה תקבל רישיון חיפוש בכמה בלוקים גובלים וזאת משתי סיבות עיקריות. הראשונה, היא שמבנה המאגרים בדרך כלל לא תואם לגבולות רישיון ועשויים להיות מאגרים גדולים אשר משתרעים על פני מספר שטחי רישיונות. לכן ישנה עדיפות כי מבנה אחד יוחזק ע״י קבוצה אחת, על מנת לצמצם את הצורך בביצוע איחוד פעולות בין מספר קבוצות שונות המחזיקות ומפיקות נפט/גז מאותו המאגר. קבלה של מספר רישיונות בשטחים סמוכים מגדילה את הסיכויים לכך. בנוסף, ביצוע סקרים סייסמיים גדולים על פני שטחי מספר בלוקים הינו כלכלי יותר לעומת ביצוע סקרים סייסמיים קטנים על ידי מספר קבוצות, כל אחת בבלוק בודד שברשותה.

לאור ההבנה כי נכון יותר להעניק רישיונות חיפוש בשטחים רציפים וגדולים יותר לקבוצה אחת, הוחלט גם לתמרץ זאת באמצעות הדרישות להפקדת ערבויות. הערבויות משמשות בעיקר כערבות ביצוע, על מנת לוודא כי בעל רישיון החיפוש אשר קיבל מהמדינה את השטח לטובת חיפוש אכן מבצע את המוטל עליו בשקידה ראויה לטובת חיפוש נפט וגז. חשוב להבין כי מטרת הערבות אינה תשלום ובטחון למקרה של אסון. לצורך זאת קיים מערך ביטוחים אשר בעל רישיון החיפוש מעמיד לפי דרישות הממונה.

גובה הערבות הבסיסית לכל רישיון הינה 2.5 מיליון דולר. כאשר יזם מבקש זכות לקבל מספר רישיונות בשטחים רציפים, אזי גובה הערבות על השטח הנוסף הינו תוספת של 0.5 מיליון דולר לכל רישיון נוסף במקום 2.5 מיליון דולר, כך עד גובה ערבות מרבי של 5 מיליון דולר (לערבות בגין 6 רישיונות השטחים רציפים שהיא הכמות המירבית במסגרת ההליך התחרותי הנוכחי).
בשלב השני, כאשר בעל רישיון חיפוש יבקש לבצע קידוח ב-3 השנים השניות לפני ביצוע הקידוח עליו יהיה להעמיד בנוסף לערבות הבסיס שהעמיד (2.5 מיליון דולר), עוד ערבות בנקאית בגובה 5 מיליון דולר לקידוח, כפי שנקבע בהנחיות הערבויות המפורסמות באתר המשרד. דוגמאות:



בקשת רישיון בודד – 2.5 מיליון דולר.



בקשת רישיון ב-6 שטחים צמודים, ערבות - 5 מיליון דולר.

ד. <u>אגרות ותשלומים</u>

לצורך השתתפות בהליך התחרותי, מוצע למשתתפים להירשם תחילה באתר האינטרנט המיוחד שהוקם לצורך ההליך, וזאת לצורך קבלת אפשרות להגשת וקבלת מידע רציף- שאלות, תשובות והבהרות אשר יעלו במהלך התקופה בה מסמכי ההליך יפורסמו.
בנוסף לכך כל קבוצה מחויבת, כתנאי להשתתפות בתהליך התחרותי והגשת הצעות ומסמכי ההליך, בתשלום עבור אגרת בקשה הכוללת רכישת חבילת המידע שהוכנה על ידי הצוות המקצועי במשרד. חבילה זו כוללת דוחות ונתונים גיאולוגיים וגיאופסיים מקידוחים וסקרים, בכלל זה תוצאת המחקר האגני והערכת העתודות שבוצעה על ידי המשרד, וכן מידע סביבתי על האזורים המוצעים המצוי בידי המשרד. מטרת החבילה היא לספק מידע על כלל השטח העומד לתחרות וזאת כדי לאפשר ליזמים לזהות את הבלוקים אשר מעניינים אותם במיוחד ולגביהם ירצו להגיש הצעות. עלות הרכישה של אגרת הבקשה וחבילת המידע היא 50,000$ וזאת לצורך כיסוי עלויות אחסון, טיפול והכנת חבילת המידע.

ה. שיקולי תחרות

בתהליכים שקדמו להכנת מסמכי ההליך ניתנה חשיבות רבה לנושא התחרות. המשרד מעוניין לעודד את התחרות והשתתפות של מספר חברות גבוה ככל האפשר, על מנת לפתח את המשאבים הנמצאים בשטח הימי של ישראל, באופן אופטימאלי. בהתאם, להערכת היועצים הבינלאומיים המלווים את ההליך התחרותי, יש קושי לא מבוטל לעניין חברות באקספלורציה בהשתתפות. בנוסף, אירוע של כניסה למדינה חדשה הוא משמעותי עבור חברה ולכן, על אף המאמצים המשרד משקיע וישקיע לעידוד כניסת שחקנים חדשים, ייתכן ועיקר התחרות תהיה בין חברות הפעילות כבר בישראל. לאור זאת המשרד מעוניין שלא להגביל חברות הפעילות בישראל מההשתתפות בהליך התחרותי אך עם זאת מבקש לקבוע הוראות שונות בנושא התחרות כדי למקסם את התחרות על הרשיונות החדשים.

לאור חוות דעת שהתקבלה מטעם רשות התחרות, מסמכי ההליך מחילים את המגבלות הבאות על בעלי חזקות קיימות:

- המחזיק ביותר מחזקה מפיקה אחת (=שברון) רשאי להגיש הצעה לכל אזור, אולם היא תתקבל רק במקרה שמדובר בהצעה יחידה לאזור זה, וכי קיים הסדר למכר בנפרד של הגז ע"י כל אחד מבעלי הרשיון שיתקבל.
- המחזיק בחזקה מפיקה אחת (=ניו מד, רציו) רשאי להגיש הצעה לכל אזור, אולם ההצעה תתקבל רק בהתקיים **אחד** מהתנאים הבאים:
    - ○ המחזיק הקיים חובר לשחקן חדש מחזיק לפחות ב-50% מההצעה.
    - ○ המחזיק הקיים חובר לשחקן חדש המוגדר כמפעיל עבור ההצעה.
    - ○ אין הצעות נוספות לאזור זה, או שההצעה היחידה הנוספת היא של מחזיק ביותר מחזקה אחת, **ובנוסף** קיים הסדר למכר בנפרד.
- מספר שחקנים המחזיקים כיום באותה חזקה אינם רשאים להגיש הצעה משותפת.

ו. עקרונות סביבתיים

שינויי האקלים הינם שינויים גלובליים ויש להתבונן בראיה גלובלית ולא מקומית. הפקת גז טבעי שייעודו להחליף דלקים מזהמים הרבה יותר, אם במצריים וירדן ואם באירופה, הינו תהליך מבורך שיסייע למדינות אלו לשמור על אספקת אנרגיה אמינה תוך שימוש בגז טבעי כאנרגיית מעבר. החלפת הדלקים המזהמים בתקופת המעבר תפחית את זיהום האוויר במדינות אלו, תשפר את בריאות האדם והסביבה ואף תפחית את פליטות גזי החממה שלהן בעקבות הקרבה לאזורי ביקוש סמוכים, אזורי ביקוש ל- LNG ובשל הפקת הגז הטבעי בשיטות קונבנציונאליות ושיטות הטיפול הישראליות הנקיות באופן משמעותי מהנעשה במדינות אחרות.

אין בתהליך החיפוש במים הכלכליים לפגוע בייעדי הפחתת הפליטות של מדינת ישראל, ואף לא בהחלטות הממשלה וביעדיה. הגז הטבעי כאמור, מחליף את השימוש בדלקים מזהמים יותר, ומהווה דלק מעבר עד אשר תמהיל מקורות האנרגיה בישראל יכלול מקורות אנרגיה נקייה בלבד, מה שלא צפוי בשנים הקרובות.

העקרונות הסביבתיים בהליך התחרותי הרביעי מבוססים על העקרונות הסביבתיים שאומצו בהליכים תחרותיים קודמים שנקבעו לאחר סיומו המוצלח של הסקר האסטרטגי הסביבתי, עדכוניו ואימוץ המלצותיו.

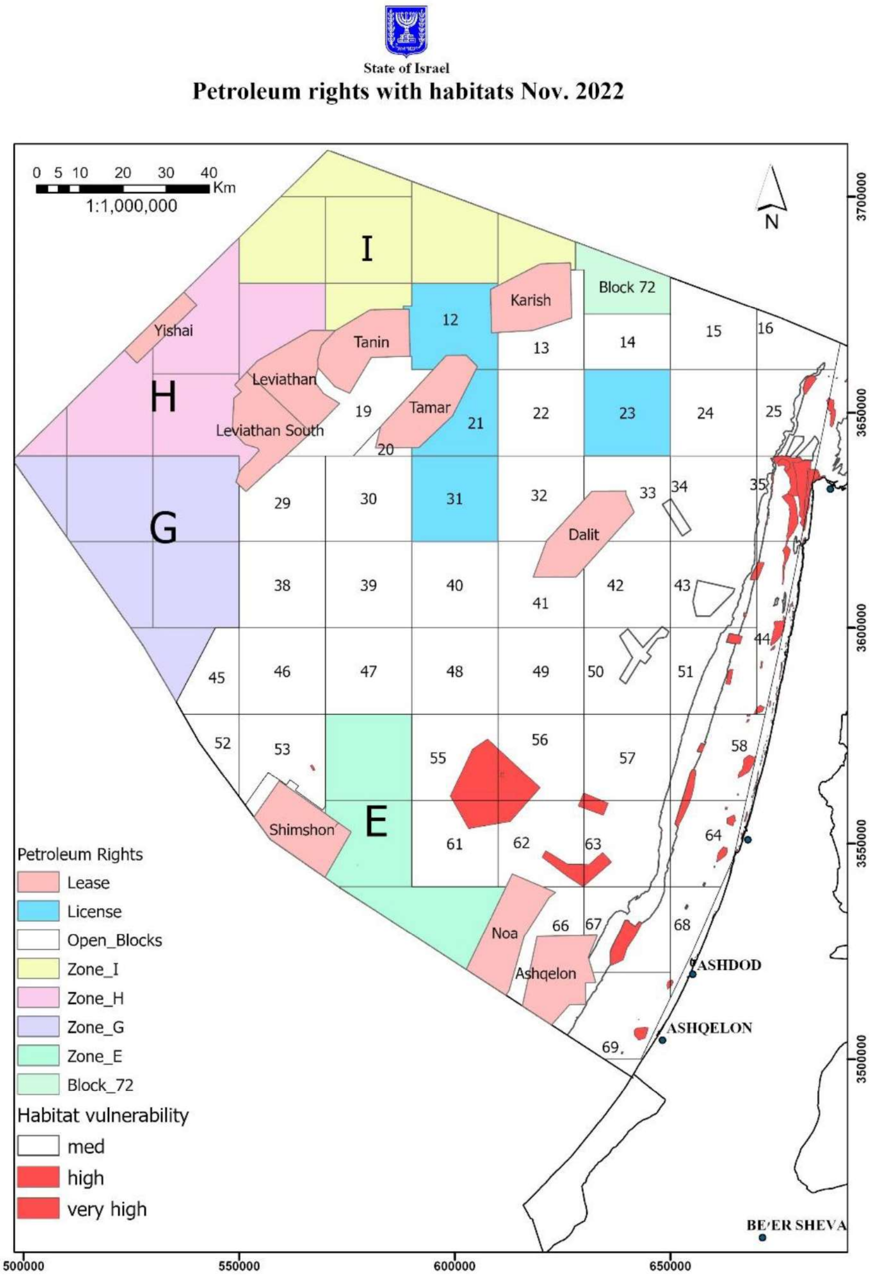
להלן פירוט העקרונות:

1. מניתוח המרחב הימי שנסקר בסא״ס עולה, כי יש הצדקה להתייחסות שונה לאזור הקרוב לחוף לעומת זה המרוחק ממנו. לפיכך, ההמלצה הכללית לעת הזאת היא לתת רישיונות על-פי חוק הנפט בשטחים המרוחקים מהחוף בלמעלה מ-7 ק״מ.
2. בתחום בתי הגידול ברמת רגישות 4 בשטחים המרוחקים מהחוף, מומלץ להגביל פעולות קדיחה או הנחת צנרת, תשתיות ומתקנים אחרים בתחומם ולהגביל ביצוע קידוחים במרחק של 1 ק״מ מהם כדי להימנע מפגיעה באותם בתי גידול.
3. ביחס לבתי גידול ברמת רגישות 3, מוצע להגביל את הפעילות בהם ובסמיכות להם בדומה למוצע עבור בתי גידול ברמת רגישות 4, וזאת עד להשלמת מידע נוסף, שיאפשר עדכון המדיניות ביחס לבתי גידול אלו.
4. בתחום בתי גידול בעלי רגישות גבוהה מאוד לפעולות בעלות הפרעה של קול מומלץ שלא לבצע סקרים סיסמיים.
5. בנוסף להמלצות אלו, מומלץ לתת עדיפות למתן זכויות באזורים בעלי רגישות אקולוגית נמוכה במסגרת מכלול השיקולים של הממונה בבואו להעניק זכויות.

לפיכך:

6. במסגרת ההליך התחרותי אליו אנו יוצאים יינתנו רישיונות חיפוש רק בשטחים המרוחקים מהחוף (במרחק העולה על 30 ק״מ מהחוף), הואיל וברצועה הקרובה לחוף מתרכזים מירב השימושים הימיים הקיימים והמתוכננים, וברצועה הרחוקה יותר מהחוף השימושים הימיים מועטים.
7. המידע על בתי הגידול במרחב הימי נכלל בחבילת המידע של ההליך התחרותי (מפת בתי הגידול ורגישותם – עדכון דצמבר 2021 מצורפת בהמשך).
8. יש לציין, כי בהענקת רישיון החיפוש ולאחריו במתן אישורים לסקרים, לקדיחה ולהקמת תשתיות אנו מיידעים את מבקשי רישיון החיפוש בדבר רגישות בתי הגידול המצויים בתחום הרישיון, על המגבלות האפשריות על רמת הפיתוח שתתאפשר, על אמצעים והפעולות שיידרשו ועל המגבלות שיוטלו לצורך שימור בתי הגידול.
9. במסגרת התנאים לאישור קדיחה נדרש מבעל רישיון לבצע סקר רקע מקדים, שמטרתו לוודא שאין בתי גידול רגישים במרחב המתוכנן לקידוח החיפוש, להכין מסמך סביבתי שאישורו נסמך על חוות דעת היחידה להגנת הסביבה הימית במשרד להגנת הסביבה, וכן לקבל היתר הזרמה לים, היתר רעלים ולקבל אישור לתכנית חירום מפעלית. אישורים והיתרים אלה נמצאים בסמכות הבלעדית של המשרד להגנת הסביבה.

יוער, כי במסגרת בחינת מפעיל על ידי הממונה נדרש ממבקשי הזכות להציג את הנאותות הסביבתית (Environmental Appropriateness Report) של מבקש הזכות ונאותות זו נבחנת טרם מתן הרישיון.



איור 1. מפת בתי הגידול הרגישים והבלוקים המיועדים לשיווק במסגרת ההליך התחרותי הרביעי.

בכבוד רב

חן בר יוסף
הממונה על ענייני הנפט

נספח 18

העתק מתקציר דו״ח מבקר המדינה

עמ׳ 809

נספח 18

משרד מבקר המדינה
ונציב תלונות הציבור

פרק | 1

מיטיגציה
פעולות להפחתת פליטות גזי חממה

פרק 1 | מיטיגציה - פעולות להפחתת פליטות גזי חממה

רקע

כמות גזי החממה (גז"ח) המצרפית של כל המדינות הנפלטת לאטמוספרה קובעת את ריכוזם באוויר. ככל שריכוזם גבוה יותר, צפויה עלייה גדולה יותר בטמפרטורה בכדור הארץ, וכתוצאה מכך החמרה של תופעות שינויי האקלים בעולם. מאז התרחשותה של המהפכה התעשייתית ותחילת השימוש בפחם ובנפט בתעשייה, בתחבורה ולייצור חשמל, החלו להיפלט לאטמוספרה גזי חממה בכמויות הולכות וגדלות, ובעשורים האחרונים גדלו הכמויות בהיקפים נרחבים במיוחד. עיקר הזינוק בפליטות העולמיות של גז"ח התרחש ב-70 השנים האחרונות והן ממשיכות לעלות גם כיום, כשהגידול בשיעור הפליטות נאמד באלפי אחוזים לעומת התקופה שקדמה למהפכה התעשייתית - וההערכה היא כי פליטות גז"ח העולמיות טרם הגיעו לשיאן. משמעות הדבר היא עלייה חדה בריכוז גז"ח באוויר.

ההתחממות הגלובלית, הנובעת מפליטת גזי חממה מעשה ידי אדם, מוכרת בעשרות השנים האחרונות כאחת הבעיות החמורות שעימן צריכה להתמודד הקהילה הבין-לאומית, זאת באמצעות שני כלים מרכזיים: (א) ייצור אנרגייה נטולת פליטות גז"ח, כלומר שאינה מדלקים פוסיליים; (ב) צמצום בצריכת האנרגייה באמצעות התייעלות בצריכתה. בניגוד לפליטות מזהמים לאוויר, שהשפעתם מוגבלת בעיקר לאזור הגיאוגרפי שבו מצויים מקורות הפליטה של המזהמים, ההשפעה של פליטות גז"ח אינה מקומית, וכל מדינה מושפעת מהיקף הפליטות של יתר המדינות. על כן, כדי להקטין את כמות הפליטות העולמית נדרש שיתוף פעולה הדוק של הקהילה הבין-לאומית. הצטברותן של עדויות מדעיות בנושא שינויי האקלים וההבנה כי נדרש שיתוף פעולה גלובלי אפקטיבי כדי לצמצם את פליטות גזי החממה העולמיות הניעו את הקהילה הבין-לאומית לגבש בשנת 1992 את אמנת המסגרת של האו"ם (ה-UNFCCC), שעליה חתומה ישראל.

נתוני מפתח

2 °C

הגבלת עליית הטמפרטורה העולמית לפי הסכם פריז, ושאיפה להגבלה ל-1.5 °C

2050

שנת היעד לאיפוס פחמני לפי הסכם פריז, עם יעדי ביניים שאפתניים לשנת 2030

10
מתוך 29

מיקום ישראל ברשימת 29 מדינות ה-OECD הפולטות הכי הרבה גז"ח לנפש בשנת 2016. בשנת 2019 פלטה ישראל 8.8 טונות לנפש

103% -
203%

העלייה (אבסולוטית) הצפויה בהיקף הפליטה בישראל בשנת 2030 בהשוואה לשנת 1990, לעומת הפחתה של 32% בממוצע הפליטות של שווייץ האיחוד האירופי, קנדה, ארצות הברית, יפן, מקסיקו ודרום קוריאה

2%

שיעור ההשקעה בתשתיות בישראל בשנת 2016, לעומת שיעור ממוצע ה-OECD - כ-3.4% עד 3.5% מהתמ"ג (כ-75% יותר מבישראל)

+0.9%

שיעור העלייה בביקוש לאנרגייה מתחדשת בעולם בשנת 2020, ואילו הביקוש לפחם פחת ב-6.7%, לגז טבעי ב-3.3% ולנפט ב-8.5%

30%

יעד האנרגייה המתחדשת של ישראל לשנת 2030, לעומת יעדים שנעים בין 55% ל-100% במדינות OECD שנסקרו. נכון לשנת 2020 שיעור האנרגייה המתחדשת הוא 6.1%

49.2
מיליארד ש"ח

אומדן העלויות למשק האנרגייה להפחתת גז"ח לשנת 2050 שעלה ממודל של משרד האנרגייה בתרחיש מוטה אנרגייה מתחדשת, אומדן שהוא גם הכלכלי ביותר מבין כל התרחישים

תמונת המצב העולה מן הביקורת

הפליטות לנפש בישראל גבוהות בהשוואה למדינות אחרות: מגמת הפליטות לנפש נמצאת בעיקרה במגמת ירידה (ירידה לא רציפה מכ-10.7 טונות CO_{2eq} לנפש בשנת 2000 לכ-8.8 טונות CO_{2eq} לנפש בשנת 2018). אולם בהשוואה ל-29 מדינות ה-OECD שנסקרו, ישראל דורגה בשנת 2016 עשירית (בשליש העליון) ברשימת המדינות עם שיעור הפליטות הכי גבוה לנפש. ערכי הפליטה לקמ"ר הגבוהים יחסית של ישראל (3.6 טונה לקמ"ר נכון לשנת 2018), בשילוב עם היותה מדינת בעלת אוכלוסייה המונה כ-9.3 מיליון איש, מביאים לכך שישראל פולטת גזי חממה בהיקף דומה למדינה בגודל בינוני.

פעולות ממשלת ישראל להפחתת גז"ח עד שנת 2020

מיטיגציה (פעולות להפחתת פליטות גז"ח) בשנים 1996 - 2009: אף שישראל הצטרפה לאמנת ה-UNFCCC ואשררה אותה בשנת 1996, עלה כי כעבור 13 שנים היא קיבלה החלטות אופרטיביות הנוגעות לגיבוש מדיניות בנושא הפחתת פליטות גז"ח. גם אז לא ננקטו הפעולות שנדרשו ליישום ההמלצות וההחלטות בעניין ולהשגת הישגים ממשיים בתחום הפחתת פליטות גז"ח, אף שבחינות עלות-תועלת שבוצעו העלו כי קיימות תועלות מובהקות ביישום אמצעים להפחתת גז"ח.

קביעת יעדי הפחתת פליטות גזי חממה:

1. יותר מ-20 שנה לאחר הצטרפותה לאמנת ה-UNFCCC אימצה ממשלת ישראל באפריל 2016 תוכנית לאומית עם יעדי הפחתת פליטות גז"ח (כלליים וסקטוריאליים) נמוכים מההמלצה השמרנית שגיבשה ועדת היגוי בין-משרדית (במקום 7.2 טונה CO_{2eq} לנפש, נקבע יעד של 7.7 טונה CO_{2eq} לנפש).

2. ישראל קבעה יעד הפחתת פליטות גז"ח לנפש בלבד, אף שעל מדינות מפותחות לקבוע יעדים בערכים מוחלטים ושאפתניים. קביעת יעדים לנפש מאפשרת לישראל להעלות את כמות הפליטות האבסולוטית כל עוד יש גידול אוכלוסין, זאת בניגוד למגמה (השלילית) ביתר מדינות ה-OECD.

3. ישראל קבעה יעד הפחתת פליטות גז"ח אשר היה צפוי להוביל לעלייה אבסולוטית של 103% בפליטות ביחס לשנת 1990 ושל 12% ביחס לשנת 2005, ואילו יעדי יתר המדינות שנסקרו (שווייץ, האיחוד האירופי, קנדה, ארצות הברית, מקסיקו ודרום קוריאה) היו צפויים להוביל אצלן לירידה ממוצעת של 32% ושל 33%, בהתאמה.

לפיכך, ישראל אינה מדינה "מובילה" (taking the lead) בקביעת יעדי הפחתת גז"ח כנדרש בהסכם פריז.

מיצוי פוטנציאל ההפחתה לעומת היעד של 7.7 טונה פליטות גז"ח לנפש: בחינות עלות-תועלת מקיפות שבוצעו במשך השנים העלו כי קיימות תועלות כלכליות משמעותיות באימוץ עשרות אמצעי הפחתת גז"ח שונים שנבחנו (לעיתים עד כ-80%). בפועל, אומצו פחות אמצעים, ולכן השגת היעד שנקבע, גם אם יינקטו כל אמצעי ההפחתה שבתוכנית הלאומית להפחתת פליטות גז"ח, צפויה להביא למימוש חלקי בלבד (תועלת של 50 מיליארד ש"ח במקום כ-217 מיליארד ש"ח, פחות מרבע) של הפוטנציאל הסביבתי והכלכלי הטמון ביישום אמצעים אלו. כמו כן החלטת ממשלה 542 משנת 2015 בעניין יעדי ישראל להפחתת פליטות, והתוכנית הלאומית להפחתת פליטות גז"ח משנת 2016 שגובשה בעקבותיה, אינן מורות על הפנמת העלויות הכלכליות של פליטות גז"ח, בין באמצעות מס פחמן ובין בדרך אחרת.

הפליטות לנפש וכמות הפליטות האבסולוטית: בשנים 2015 - 2020 נרשמה עלייה בפליטות האבסולוטיות של ישראל. כך למשל, בשנת 2018 היה גידול של 2.3 ובשנת 2019 גידול של 0.3 מיליון טונות CO_{2eq} בהשוואה לפליטות בשנת 2015. לעניין נתוני הפליטות לנפש - הערך של 8.5 טונה פליטות גז"ח לנפש הקיים נכון ל-2020 משקף ירידה למול 2015 ועמידה ביעד שנקבע ל-2025 בזכות מגמת הפחתת השימוש בפחם שהחלה בשנת

2012. עם זאת, דוח ועדת היגוי ומעקב לעניין הפחתת פליטות גזי חממה בראשות המשרד להג"ס ציין בנוגע לשנת 2020 כי בעקבות משבר הקורונה הייתה ירידה משמעותית בפעילות הכלכלית במשק, וכי "למשבר הקורונה היתה תרומה לרמת הפליטות הנמוכה יחסית בשנת 2020". זאת לפי הדוח כתוצאה, בין השאר, מירידה בצריכת הדלקים לתחבורה (כ-10% הפחתה בצריכה בהשוואה לשנת 2019), ירידה בצריכת החשמל במשק (כ-1.4% הפחתה בצריכה בהשוואה לשנת 2019) וירידה בצריכה המשקית.

מידת ההתקדמות בהשגת היעדים הסקטוריאליים: ההתקדמות בהשגת כל היעדים הסקטוריאליים נעה בטווח שבין ב"פיגור" לאפס.

הנחיות שונות בהחלטות ממשלה 542 משנת 2015 ו-1403 משנת 2016 (בתחומים כמו: כלים כלכליים נוספים להמלצות ועדת מיסוי ירוק; מנגנונים לעידוד התייעלות אנרגטית במשרדי ממשלה; עידוד תחבורה ציבורית; חסמים להקמת מתקני אנרגיות מתחדשות; ושימוש בחשבונות החשמל כמסלקה), שכללו היבטים תקציביים ורגולטוריים כאחד - לא בוצעו מאז התקבלו ההחלטות. לפיכך לא הושגו היעדים הסקטוריאליים של ממשלת ישראל בהפחתת פליטות גז"ח. כך:

1. **יעד צמצום הנסועה הפרטית ב-20%:** הנסועה הפרטית עלתה מ-42 מיליארד ק"מ בשנת 2015 לכ-50 מיליארד ק"מ בשנת 2019. לפי דוח המעקב השנתי של המשרד להג"ס ממאי 2021 "הממשלה אינה צפויה לעמוד ביעד לסקטור התחבורה של צמצום נסועה פרטית". כמו כן משרד התחבורה לא הכין תוכנית פרטנית לצמצום הנסועה הפרטית כנדרש החלטת ממשלה 1403 משנת 2016 בעניין.

2. **יעד התייעלות של 20% באנרגייה:** ישראל לא עמדה ביעדים שקבעה לעצמה לשנת 2020, ובפועל ההתייעלות האנרגטית הייתה כ-62% פחות מהיעד שנקבע. כמו כן מתוך 800 מיליון ש"ח שהוקצו בהחלטות הממשלה לטובת הפחתת פליטות גז"ח באמצעות התייעלות, לא נוצלו 500 מיליון ש"ח לפחות.

3. **יעד ייצור חשמל מאנרגיות מתחדשות:** ישראל לא עמדה ביעד של 10% שקבעה לעצמה לשנת 2020 (בפועל - שיעור של 35% - 40% פחות מהיעד שנקבע), וההתקדמות להשגת יעד של 17% אנרגיות מתחדשות לשנת 2030 מועטה (ובפרט למול היעד המתהווה של 30%), והגיעה נכון לסוף שנת 2020 ל-6.1% בלבד.

השקעה בתשתיות: לפי ה-OECD, משנת 1997 בקירוב ההשקעה בתשתיות בישראל הייתה נמוכה מההשקעה הממוצעת במדינות ה-OECD. נכון לשנת 2016, ההשקעה בתשתיות בישראל מוערכת בכ-2% מהתמ"ג, ואילו ממוצע ה-OECD הוא כ-3.4% - 3.5% מהתמ"ג (כ-75% יותר מבישראל).

גיבוש יעדי הפחתת גז"ח סקטוריאליים לישראל

גיבוש האסטרטגיה של ישראל למעבר לכלכלה דלת פחמן עד שנת 2050: בתהליך המעבר לכלכלה דלת פחמן 2050 שמוביל המשרד להג"ס נמצאו עיכובים בגיבוש היעדים בעיקר בתחום האנרגייה בשל היעדר הסכמות לגבי היעדים בין משרד האנרגייה ובין המשרד להג"ס. כתוצאה מכך התעכב שלב האינטגרציה של כל חלקי המשק בתהליך, ונכון ליוני 2021 ישראל טרם הציגה תוכנית להפחתת פליטות גז"ח כמצופה בהסכם פריז.

מאפייני הטיפול בנושא האקלים: ריבוי סמכויות חקיקה ומינהל, קונפליקט בין יעדים של משרדי ממשלה ופער מובנה בין אחריות וסמכות יוצרים קושי מובנה בקידום הפחתת פליטות גז"ח. במצב של קונפליקט או פוטנציאל לקונפליקט בין היעדים המרכזיים של משרדי הממשלה ובין היעד של הפחתת פליטות גז"ח, המשרדים מתעדפים את קידום היעדים שמצויים בליבת אחריותם המיניסטריאלית על פני הפחתת פליטות (למעט במשרד להג"ס). התוצאה היא דחיקה לאורך השנים של משבר האקלים ושל יעדי הפחתת הפליטות בסדר העדיפויות המיניסטריאלי לטובת יעדים אחרים - בשלב גיבוש היעדים, בעת תקצובם ובדרך להשגתם.

סקטור האנרגייה

היעד החדש לאנרגיות מתחדשות לשנת 2030 בהשוואה למדינות ה-OECD ומדינות אחרות: מדינות שנסקרו, לרבות מדינות ה-OECD, מציגות יעדים מעודכנים לאנרגייה מתחדשת לשנת 2030 שנעים בין 40% ל-100%, ואילו ישראל מציגה יעד חדש של 30% - הנמוך ביותר ממדינות ה-OECD אשר לפי הסכם פריז אמורות להציג יעדים בערכים מוחלטים ושאפתניים ולהוביל את הליך האיפוס הפחמני (דה-קרבוניזציה) העולמי. קביעת יעדים שיגדילו את ההשקעה בתשתיות אנרגיות פוסיליות עד שנת 2030 עלולה לסכן את הליך המעבר לכלכלה דלת פחמן עד שנת 2050.

שיתוף בהחלטת הממשלה 465 בדבר יעד של 30% לאנרגייה מתחדשת לשנת 2030: ההכרעה בסוגיות כמו היקף השטחים הזמינים למתקני PV (פתוחים ודואליים), בשלות טכנולוגית של אגירת חשמל ממתקני PV וניתוחי עלות תועלת שעל בסיסם התקבלה החלטת שר האנרגייה (אשר נרשמה כהחלטת ממשלה 465 משנת 2020 ולפיה "הממשלה רושמת לפניה את החלטת שר האנרגייה על עקרונות המדיניות שלפיהם עד שנת 2030 30% מייצור החשמל יהיה מאנרגייה מתחדשת") התבצעו על ידי משרד האנרגייה ורשות החשמל, ללא שיתוף מוקדם של משרדי ממשלה וגורמים רלוונטיים נוספים (כגון רשות מקרקעי ישראל [רמ"י], מינהל התכנון במשרד הפנים, משרד הבינוי והשיכון והמשרד להג"ס) כגורמים מכריעים. כמו כן בדיקת רשות החשמל הוגבלה להיתכנות שיעור של 30% אנרגיות מתחדשות; היא לא בחנה את הפוטנציאל המלא להפחתת גז"ח לשנת 2030 ולא כללה משמעויות של שיפורים טכנולוגיים הצפויים להשפיע בשנים הקרובות על פוטנציאל זה.

גיבוש יעדים לשנת 2050 לסקטור האנרגייה: ממשלת ישראל גיבשה החלטת ממשלה 171 משנת 2021 יעד פליטות גז"ח לסקטור האנרגייה אשר מלמד על מדיניות של מעבר לכלכלה דלת פחמן ולא מאופסת פחמן כפי שמתכננות מדינות OECD רבות. משרד האנרגייה לא קבע יעד לאנרגיות מתחדשות לשנת 2050 בשל החסמים שאותם מנה ובשל אי-הוודאות בקביעת יעדים לטווח ארוך. המשרד קבע יעד הפחתת פליטות לסקטור האנרגייה, אך לא פירט במפת הדרכים שפרסם בשנת 2021 להערות הציבור ובמסמכי המדיניות של המשרד כיצד בכוונתו להשיגו ללא יעדים שאפתניים לאנרגיות מתחדשות וללא טכנולוגיות חלופיות בשלות או טכנולוגיות בשימוש (כגון טכנולוגיות CCS לתפיסת פחמן, גרעין, מימן וטכנולוגיות עתידיות), וגם לא כיצד בכוונתו לפעול לקידום השימוש בטכנולוגיות החלופיות האמורות או לפעול להסרת החסמים שמנה במסמכיו.

התרחישים שהציג משרד האנרגייה מלמדים כי הוא סבור שיישום מלא של יעד הפחתת פליטות של 85% מושג באמצעות ייצור חשמל בשיעור של 54% עד 90% מאנרגייה מתחדשת, שהוא טווח רחב שמקנה לו גמישות. המשרד לא הציע טווח זה של אנרגיות מתחדשות כיעד משנה ליעד-העל של הפחתת פליטות. השארת תמהיל של 70% אנרגיית גז טבעי לאחר שנת 2030 ללא קביעת יעדי אנרגיות מתחדשות לשנת 2050 מניחה בסיס לתכנון, פיתוח והשקעות להמשך הפיתוח של משק הגז בישראל, ועלולה לפגוע במעבר עתידי לכלכלה דלת-פחמן.

אומדני עלויות למעבר לכלכלה דלת פחמן: אומדן עלויות שבוצע העלה כי בכל אחת מהשנים 2030, 2040, 2050 התרחיש מוטה הטכנולוגיות שאינן סולריות (כמו תפיסת פחמן) הוא היקר ביותר, ואילו התרחיש מוטה אנרגייה סולרית בשנת 2050 - שנת היעד הרלוונטית לאסטרטגית מעבר לכלכלה דלת פחמן - הוא בעל העלויות הנמוכות ביותר מבין כל התרחישים ומוערך בכ-49.2 מיליארד ש"ח, בהשוואה לתרחיש מוטה הטכנולוגיות שאינן סולריות שמוערך בכ-56.9 מיליארד ש"ח. משרד האנרגייה לא בחן מחדש את התרחישים, זאת אף שמהנתונים ניתן היה להסיק שאין היתכנות כלכלית לתרחיש מוטה טכנולוגיות, וכי יש להתמקד בתרחיש הסולרי שהוא בעל מנעד גמישות נרחב בפני עצמו (בעל שיעור של עד 90% אנרגיות מתחדשות) ולבחון את הדרכים להוצאתו לפועל. כמו כן אומדני יישום התרחישים השונים לא הוצגו במפת הדרכים למשק האנרגייה 2050, אשר פורסמה להערות הציבור באפריל 2021.

מדיניות הפחתת פליטות גז"ח מול הפקת דלקים פוסיליים: קידום הפקת דלקים פוסיליים אינו מתיישב עם המדיניות המוצהרת של הממשלה, זה יותר מעשור, לצמצם פליטות גז"ח ומזהמי אוויר. בעוד הממשלה מקדמת מאבק בשינויי האקלים ולמען אוויר נקי, היא גם מקדמת מדיניות של "מיצוי פוטנציאל" משאבים[1] שנדרש להתאימו למאמץ הלאומי להפחתת פליטות גז"ח.

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[1] לישראל תוכניות להפקת דלקים משדות גז שהיא מפתחת באמצעות חברות אנרגייה; תוכניות לפיתוח והקמה של תשתיות ותחנות כוח של אלפי מגוואטים; וכן תוכניות לכרייה, הפקה וזיקוק של דלקים פוסיליים שונים, לרבות פצלי שמן שמהם ניתן להפיק אנרגייה, נפט וגז.

סקטור התחבורה

👎 **רכבים חשמליים:** נכון לשנת 2020 שיעור הרכבים החשמליים בישראל הוא 0.05% מכלל הרכבים, והפעולות להגדלת שיעורם נמצאות בראשיתן. בעקבות מגפת הקורונה העולמית החליט משרד האנרגייה לדחות את היעד שנקבע בשנת 2019 - לאסור ייבוא רכבים עם מנועי בערה החל בשנת 2030 - בחמש שנים נוספות (עד שנת 2035) אף על פי שלא הראה כי מדינות אחרות פעלו באופן דומה.

👎 **התוכנית להפחתת גז"ח לסקטור התחבורה:** חלקים משמעותיים מהתוכנית להפחתת פליטות גז"ח מסקטור התחבורה שאותה מקדמים משרדי התחבורה, הג"ס והאנרגייה נותרים בגדר המלצות או הצעות לנקיטת פעולות וכלי מדיניות, ומשרד התחבורה טרם גיבש תוכנית מפורטת להפחתת גז"ח מסקטור זה אשר משתלבת עם יתר התוכניות האסטרטגיות במשרד התחבורה. כמו כן לא הובהר הקשר בין כל אמצעי ועד כמה נקיטתו תתרום להפחתת גז"ח. דוגמאות להמלצות (שטרם אומצו או תוקצבו) הן למשל הגדלת ההשקעה בתשתיות התחבורה הציבורית ובפרט במערכות הסעת המונים; חבילת מדיניות מותאמת לניהול חנייה; תמחור הנסיעה בכביש לפי סוג הרכב; סגירת רחובות לתנועה ויצירת תשתית לעידוד רכיבת אופניים והליכה; תוכנית לאומית לעידוד עבודה, לימודים וקניות מרחוק.

👎 **חסמים:** קיימים חסמים למימוש האמצעים שמנו המשרדים, והסרתם דורשת מעורבות של משרדים ויחידות סמך ממשלתיות רבות (ובהם רמ"י, מינהל התכנון, משרד הפנים והרשויות המקומיות). דוגמאות לחסמים הן היעדר תשתית טעינה יעילה לרכבים חשמליים; קושי בהתקנת נקודות טעינה בבתים משותפים מסיבות משפטיות; היעדר ידע מספיק בתחום הטעינה ברשויות המקומיות; והיעדר תוכנית לעידוד השימוש בתחבורה ציבורית.

סקטור המבנים והערים

👎 **יעדי ישראל שגובשו לאיפוס האנרגייה במבנים חדשים:** רוב המדינות שנסקרו קבעו כי מבני מגורים יחויבו באיפוס אנרגטי עד 2020, ובישראל חובה כזו צפויה לחול משנת 2025 ובאופן חלקי ביותר. כך למשל מבנים גבוהים יותר מחמש קומות, אשר שיעורם צפוי להיות כ-80% מהמבנים למגורים, ומבני תעשייה כלל אינם כלולים בחובת איפוס אנרגטי. התוכנית אינה כוללת יעדים חדשים לשנת 2050, למעט מבני מסחר. כמו כן טרם גובשו תוכנית ליישום היעדים לאיפוס האנרגייה והפחתת פליטות גזי חממה מסקטור מבנים והמנגנון שיפעל להשגתם.

התייעלות באנרגייה במבנים קיימים: לא נקבעו יעדים לחיוב התייעלות אנרגטית במבנים קיימים אשר בשנת 2050 (לפי משרד האנרגייה) צפויים להיות כ-50% מכלל המבנים.

סקטור הפסולת

יעדים בתחום הפסולת: המשרד להג"ס לא קבע יעדי הפחתת פליטות גז"ח לסקטור הפסולת במסגרת החלטת ממשלה 542 (בהמשך להסכם פריז) ואף שהטיפול בנוגע לצמצום היקפי הפסולת ואופן הטיפול המיטבי בה נמצאו, לפי מסמך האסטרטגיה בנושא של המשרד להג"ס, חסרים.

צמצום הפליטות לנפש: כמות הפליטות לנפש נמצאת בעיקרה במגמת ירידה (ירידה לא רציפה מכ-10.7 טונות CO_{2eq} לנפש בשנת 2000 לכ-8.8 טונות CO_{2eq} לנפש בשנת 2018). הערך נכון ל-2020 משקף ירידה למול הערך בשנת 2015 ועמידה ביעד שנקבע לשנת 2025.

הפחתת ייצור חשמל מפחם: משנת 2012 עבר סקטור ייצור האנרגייה בישראל מייצור חשמל מוטה פחם לייצור מופחת פחם ומוטה גז (כמקור עיקרי) - משנת 2012 עד שנת 2018 חלה ירידה בשימוש בפחם לייצור חשמל בשיעור של 29%, ובשנים 2018 עד 2020 הייתה ירידה של עוד 4%. הדבר הביא לירידה בפליטות מזהמים לאוויר ולירידה מסוימת בפליטות פחמן. הפחתה זו היא הגורם העיקרי להפחתת פליטות CO_2 לנפש. המשך יישום מדיניות זו תוביל להפחתה מוערכת של כ-9 מיליון טונות גז"ח עד לשנת 2025 ושל כ-17 מיליון טונות גז"ח עד לשנת 2030.

ייזום הליך מעבר לכלכלה דלת פחמן 2050: המשרד להג"ס יזם את תהליך המעבר לכלכלה דלת פחמן 2050, הליך בין-משרדי ורב-מגזרי במטרה לגבש חזון, אסטרטגיה ותוכנית ארוכת טווח להפיכת כלכלת ישראל לדלה עד מאופסת פליטות עד שנת 2050, וזאת בשיתוף משרדי ממשלה מרכזיים כמו משרד האנרגייה, מינהל התכנון, משרד התחבורה, ובסיועם של ארגונים וגורמים מחוץ לממשלה.

הכנת תוכניות סקטוריאליות להפחתת פליטות גזי חממה: משרד האנרגייה הכין תוכנית "מפת דרכים" להפחתת פליטות גזי חממה בסקטור האנרגייה, שאותה פרסם להערות הציבור בשנת 2021.

עיקרי המלצות הביקורת

מומלץ כי המשרד להג"ס יבחן את יעדי ישראל לפליטות גז"ח למול מדינות מפותחות אחרות ומדינות ה-OECD ויגבש יעדים אבסולוטיים לצד יעדי הפחתה לנפש. עוד מומלץ לבחון את יעדי ישראל בעניין זה למול נתוני 2020 ו-2005 לצד השוואה ל-BAU לקראת 2030. בדרך זו ישראל תוכל לממש את מלוא התועלות הכלכליות הנגזרות, ולצד זאת למצב את מעמדה כמובילה בתחום כנדרש בהסכם פריז.

סגירת הפערים במצב התשתיות הלאומיות באמצעות שיפור התשתיות הקיימות ובניית תשתיות חדשות חיונית ליכולתה של ישראל להפחית פליטות גז"ח. מומלץ שמשרד האוצר

יוביל בחינה של הפערים שהוצגו בדוח, וישלב, בשיתוף משרדי הממשלה הרלוונטיים, יעדים לפיתוח וקידום תשתיות, וזאת בדגש על תשתיות אשר יאיצו את הפחתת פליטות גזי החממה ויתמכו במעבר לכלכלה דלת פחמן.

- מומלץ כי בבואה לבחון את המלצות דוח צוות מדיניות הגז ("ועדת אדירי 2") ולקבל החלטה סופית בנושא, הממשלה תעשה כן בהמשך להחלטה 171 בעניין המעבר לכלכלה דלת פחמן, תוך שהיא מביאה בחשבון את ההשפעות של ההמלצות האמורות על יכולתה של ישראל להשיג את יעדה לכלכלה דלת פחמן עד שנת 2050.

- מומלץ שהממשלה תכיר בהפחתת פליטות גז"ח כיעד לאומי ותתרגם הכרה זו לתיעדוף של כלים אופרטיביים שיקדמו את השגתו, ובכללם מתן עדיפות ליעדים כמו הרחבת תשתיות PV בשטחים שבשימוש נוסף (דואלי), קידום מערכת הסעת המונים ותחנות טעינה לרכבים חשמליים במרחב הציבורי בדרך של הקלות רוחביות לצורך השגתם - בין היתר, בכל הקשור לכללי התכנון והבנייה של מתקנים אלו, הקצאת שטחים דואליים וקרקעות עבורם, מתן הקלות במיסוי או תמריצים כלכליים אחרים ועוד.

אנרגייה

- מומלץ שמשרדי האנרגייה והגה"ס יגבשו מדיניות מוסכמת בעניין משאבים פוסיליים שתהא בהתאמה למאמץ הלאומי להפחתת פליטות גז"ח ומזהמי אוויר, המבוססת על ניתוח כלכלי המביא את מכלול התועלות והעלויות (לרבות החיצוניות) של החלופות השונות ועל ניתוח סביבתי-אקלימי, ובמידת הצורך יביאו אותה לדיון בממשלה.

- יש חשיבות לכך שהליך גיבוש יעדי אנרגיות מתחדשות לשנים 2030 ו-2050, ובפרט ביצוע ההערכות העומדות בבסיס היעדים שייקבעו, יתבצעו במתכונת שיתופית ועל דעת כל המשרדים שתחומי אחריותם רלוונטיים לנושא, לרבות משרד האנרגייה, רשות החשמל, המשרד להג"ס, מינהל התכנון, רמ"י, משרד החקלאות, רשות המיסים ומשרד האוצר. ההחלטה בדבר היעדים מבוססת על אומדנים והערכות שבתחומי האחריות של כל הגורמים האלו, ועל כן יש חשיבות לחתור להסכמה בין-משרדית בין היתר בעניין: פוטנציאל השטחים הדואליים והקרקעות הזמינים, מיקום השטחים הפנויים, זיהוי החסמים להגדלת פוטנציאל זה והדרכים להסרתם, התמריצים הכלכליים ומידת הבשלות הטכנולוגית.

- מומלץ כי לצד דיון בהסרת החסמים להגדלת האנרגייה המתחדשת יתקיים דיון בקרב כל הגורמים הרלוונטים, לרבות משרד האנרגייה, המשרד להג"ס, מינהל התכנון, רמ"י, משרד האוצר וגורמי מטה ממשלתיים בדבר ההגדלה המרבית האפשרית של יעד האנרגיות המתחדשות לשנת 2030. שכן קביעת יעדים שיגדילו את ההשקעה בתשתיות אנרגיות פוסיליות עלולה לסכן את הליך המעבר לכלכלה דלת פחמן עד שנת 2050.

- מומלץ כי משרד האנרגייה יקבע יעדים לסקטור האנרגייה לשנת 2050, לרבות בתחום האנרגיות המתחדשות כפי שעשו מדינות אחרות. כדי לאפשר גמישות מסוימת והתאמה להתפתחויות טכנולוגיות וכלכליות שונות, ניתן לקבוע טווח יעדים לאנרגיות מתחדשות לשנת 2050 או לקבוע יעד אנרגיות מתחדשות הנדרש כדי לעמוד בהפחתת הפליטות

שקבע, תוך ציון במסמכי המדיניות כי השגת היעדים תלויה בפתרונות לקשיים טכנולוגיים ובהסרת חסמים, וכן כי ייתכנו שינויים בתמהיל הפתרונות המיושמים בהתאם להתפתחויות הטכנולוגיות, זאת לצד פעילות להסרת חסמים אלו.

- היעדר הגיוון בסוגי האנרגיות המתחדשות (שאינן סולריות) ומגבלת משאבי הקרקע בישראל המקשים על משרד האנרגייה לבחור ב"תרחיש הסולרי", מצריכים גיבוש תוכנית פעולה ממשלתית ופתרונות למגבלות אלו, גם על ידי פיתוח וקידום של אמצעים ופעולות שאותם העלו משרדי הממשלה השונים ואשר טרם קודמו דיים, ובהם: תיעדוף של מתקני PV בשטחים דואליים; יישום הנחיות בהחלטת ממשלה 208 להסרת חסמים למתקני PV; מיצוי הייצור של אנרגיות ממקורות מאופסי פליטות נוספים; מיצוי האפשרות לקישור מערכת החשמל של ישראל למדינות שכנות ולרשת החשמל האירופית; וקידום חדשנות ופיתוחים טכנולוגיים.

- היכולת לקבוע יעדים שאפתניים לשנת 2030 תשפיע על יכולתה של ישראל לבצע את המעבר לכלכלה מאופסת פחמן, או לכל הפחות דלת פחמן, עד שנת 2050. לפיכך מוצע כי משרד האנרגייה יחתור למיצוי פוטנציאל הפחתת הפליטות בעשור הקרוב עד שנת 2030. קביעת יעד נמוך לשנת 2030 והקמת תשתיות לייצור חשמל מגז עשויות להשפיע על הכדאיות הכלכלית של המעבר לכלכלה דלת פחמן עד שנת 2050. בשל ההשפעות הרוחביות ארוכות הטווח על המשק ובשל הצורך לקדם את הנושא שהוא יעד לאומי, מומלץ כי הדרג המדיני יהיה מעורב בגיבוש ההסכמות הממשלתיות של היעדים. עוד מוצע לבחון כיצד היעד של 30% אנרגייה מתחדשת עד 2030 יאפשר לישראל להשלים את המעבר לכלכלה דלת פחמן עד שנת 2050 בשים לב ליעדיהן של יתר מדינות ה-OECD, ובהתאם לממצאי הבחינה את הצורך בעדכונו.

- מומלץ כי משרד האנרגייה ישלים את הליך אישור התוכנית החדשה להתייעלות באנרגייה 2030 בממשלה, בשים לב ליעדים שאימצו מדינות העולם. בהתאם, יפעל כל אחד מהגורמים הרלוונטיים (לרבות משרדי האנרגייה, הג"ס, האוצר, הבינוי והשיכון, רשות החשמל, מינהל התכנון, רמ"י ורשות המיסים) להשגת מטרות התוכנית בכל הסקטורים, ושרי הממשלה האמונים על גורמים אלו ידווחו לממשלה על פעילותם בנושא כנדרש בחוק.

תחבורה

- מומלץ כי משרד התחבורה, ובמידת הנדרש בשיתוף משרד האנרגייה והמשרד להג"ס, יגבש תוכנית עם יעדים מדידים ולוחות זמנים לשם גיבוש תוכנית מעבר לרכבים חשמליים בישראל.

- סקטור התחבורה עומד בפני שינויים אשר יעצבו מחדש את פניו. פיתוח מערכת תחבורתית מקיימת, יעילה, מהירה ותדירה הוא הכרחי במדינת ישראל, הדלה במשאבי קרקע ובעלת קצב גידול אוכלוסייה מהיר. שינויי עומק כאלו מחייבים התבוננות מחודשת על האופן שבו ישראל מתכננת את המרחב ואת הקרקעות, מאסדרת את תחום התחבורה, מתמרצת ומסירה חסמים - זאת כדי לאפשר את השינויים הנדרשים בסקטור זה להפחתת פליטות גז"ח ומזהמים. כדי להגשים חזון זה ראוי כי הוא ייתמך בתוכנית אסטרטגית ממשלתית

הכוללת יעדים מפורטים, לוחות זמנים, טיפול בחסמים, חלוקת תפקידים ותחומי אחריות לרוחב הממשלה, תקציבים, מדדים ואמצעי בקרה על יישומה של התוכנית. מומלץ כי כל הגורמים הנוגעים בדבר, ובהם משרד התחבורה, משרד האנרגייה, המשרד להג"ס, מינהל התכנון, רמ"י, משרד האוצר, רשות המיסים ויתר הגורמים הרלוונטיים ישלימו במשותף את גיבושה של תוכנית כזו ויפעלו למימושה.

- מומלץ כי משרדי הממשלה הרלוונטיים, ובהם משרדי התחבורה, הג"ס והאנרגייה, יגבשו תוכנית עבודה רב-שנתית פרטנית, מתוקפת ומתוקצבת אשר תתווה את הדרך להשגת יעד הפחתת הפליטות בסקטור התחבורה כדי למצות את התועלות הכלכליות, הסביבתיות והבריאותיות הניכרות שבהשגת היעדים אלו.

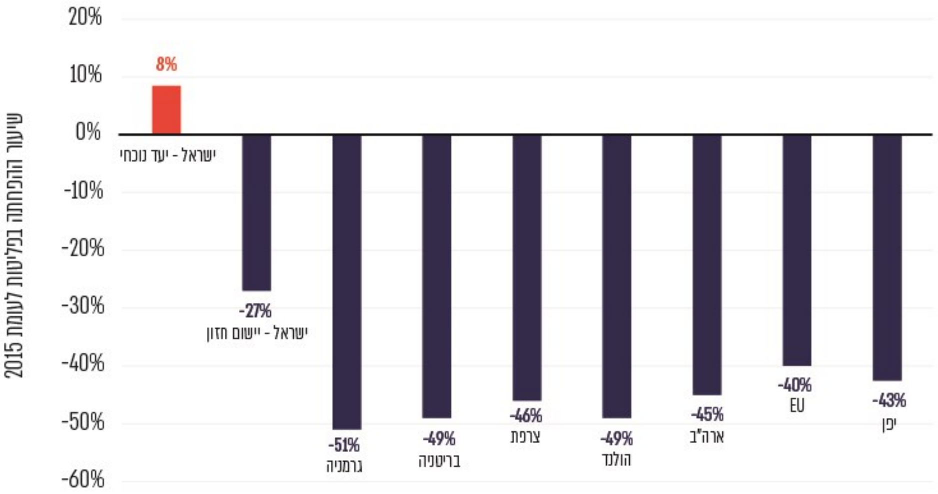
מבנים וערים

- מומלץ שמינהל התכנון (בסיוע המשרדים הרלוונטיים ובהם משרדי האנרגייה, הג"ס והאוצר) ישלים את עדכון היעדים לשנת 2050 ויגבש תוכנית מפורטת להשגתם - כך שתקיף את מלוא הפוטנציאל להפחתת פליטות ולחיסכון כלכלי בסקטור זה עד שנת 2050. עוד מוצע לשלב בתוכנית מנגנון לעדכון היעדים בהתאם להתפתחויות טכנולוגיות עתידיות.

- מומלץ כי כל הגורמים הרלוונטיים לרבות משרדי האנרגייה, הג"ס, האוצר, הבינוי והשיכון, רשות החשמל, מינהל התכנון, רמ"י ורשות המיסים יפעלו לקידום יעדי ההתייעלות באנרגייה ובאיפוס אנרגייה במבנים וערים, זאת על ידי קביעת תמהיל של תמריצים מתאימים, עיגון תקינה וגיבוש רגולציה מתאימה המלווה באכיפה בשים לב להמלצות דוח פוטנציאל הפחתה במבנים 2017 ולתוכנית החדשה להתייעלות באנרגייה 2030 - ויפעלו ליישומה.

האינטרסים הציבוריים שמקדמים משרדי הממשלה מול הפחתת פליטות גז"ח

הפחתת הפליטות הצפויה עד 2030 לפי יעדים לאומיים במדינות נבחרות – למול שנת 2015



המקור: המשרד להג"ס, מתוך UNFCCC GHG emissions database; UNFCCC 2020 ,INDCs, בעיבוד משרד מבקר המדינה.

* ההפחתה הצפויה בארצות הברית על פי הצהרת נשיא ארצות הברית הנבחר, מאפריל 2021.

** יעד נוכחי של ישראל משנת 2015 של 7.7 טונה פליטות גז"ח לנפש.

*** יעד חזון של ישראל המתבסס על הגדלת שיעור האנרגיות המתחדשות ל-40% עד שנת 2030.

סיכום

13 שנים חלפו מאז הצטרפה ישראל ל-UNFCCC והיא החלה בפעולות אופרטיביות להפחתת פליטות גז"ח, אולם נכון לשנת 2021, אף שנרשמה ירידה בפליטות לנפש, הייתה עלייה בפליטות האבסולוטיות של ישראל. אשר לכל היעדים הסקטוריאליים שנקבעו בשנת 2015, ההתקדמות בהשגתם נעה בטווח שבין ב"פיגור" לאפס. בנוגע לקביעת יעדי הפחתה חדשים, הביקורת העלתה כי קיימים חסמים אשר מקשים על משרדי הממשלה לגבש תוכנית אסטרטגית למעבר לכלכלה דלת פחמן.

ההשפעות של המעבר לכלכלה מאופסת או דלת פחמן הן מרחיקות לכת עבור משק החשמל, התחבורה, הערים וכלכלת ישראל. מעבר לכלכלה כזו, אם יבוצע, ישפיע באופן רחב על הצורך בהשקעה ובפיתוח רשת חשמל בישראל לעשרות השנים הבאות, על תכנון מלאי קרקעות המדינה, על תכנון המרחב העירוני, על ההוצאה התקציבית למימון המעבר לכלכלה דלת פחמן ועוד. מדובר ברצף של רפורמות מתמשכות וקשורות זו בזו - על פני 30 שנים לפחות - ועל כן הן מחייבות תכנון מיטבי. לשם המעבר לכלכלה דלת פחמן נדרשת הירתמות של גורמים רבים

בממשלה לצורך: הקצאת משאבים שיתמכו בתהליך ובפיתוח רשת החשמל; הכללת טכנולוגיות חדשות לתמיכה בשינוי פרופיל ייצור החשמל; הסרת חסמים (חסמים תכנוניים, רגולטוריים, טכנולוגיים ואחרים) וקידום רגולציה תומכת; הטמעת שינויים בתפיסת ההפעלה של משק החשמל; וטיפול במכלול סיכונים חדש שלא קיים במתכונת המשק הפועלת כיום.

מומלץ לקיים מאמץ ממשלתי בהכרעת סוגיות אלו ובהובלת ישראל אל עבר כלכלה דלת פחמן או אף מאופסת פחמן.

<u>נספח 19</u>

העתק מפניית העותרת מיום 29.12.21

עמ' 826

מתן גרפינקל
משרד עורכי דין

29 בדצמבר 2021

לכבוד
גב׳ קארין אלהרר
שרת האנרגיה
רח׳ בנק ישראל 7
ירושלים

בדוא״ל: sara@energy.gov.il

נכבדתי,

הנדון: **המשך חיפושי גז ונפט בים התיכון**

בשם מרשתי, גרינפיס ים תיכון בע״מ, הריני לפנות אליך בעניין שבנדון, כדלקמן:

1. כפי שידוע לך, הפקת גז מאובנים במדינת ישראל מתבצעת, נכון להיום, באמצעות שתי אסדות המצויות בסמוך לחופי ישראל - אסדת ״לוויתן״ ואסדת ״תמר״, המופעלות שתיהן על ידי חברת שברון. בנוסף, מאגר ״כריש צפון״, המפותח בימים אלה על ידי חברת אנרג׳יאן, צפוי להתחיל בהפעלה מסחרית בשנת 2023 או קודם לכן.

2. לא למותר לציין כי כיום, וביתר שאת עם השלמת פיתוחו של מאגר כריש צפון, חלק משמעותי מן הגז המופק במימיה הכלכליים של ישראל ייועד לייצוא ולא לצריכה מקומית.

3. לא ניתן להפריז בנזקים הנגרמים כיום, והעלולים להיגרם בעתיד, כתוצאה מהפקת הגז בסמוך לחופי ישראל. די אם נציין את פליטת גזי החממה המהווה חלק מהליך הפקת הגז ושינועו, זיהום האוויר, הסכנה לים ולחופים כתוצאה מאירועי שפך חלילה, הסכנות הביטחוניות לאסדות הקידוח ומתקני ההפקה, ועוד ועוד – השפעות שליליות שלכולן השפעה מקומית בישראל בשעה שהגז המופק בים מיועד בחלקו דווקא לייצוא.

4. נראה כי סכנות אלה לא נעלמו מעינייך, והודעתך מיום 15.12.2021, לפיה שנת 2022 תהיה שנת האנרגיות המתחדשות, ובהתאם לכך - משרד האנרגיה לא יאמץ את מסקנות דו״ח בחינת מדיניות הגז הטבעי ולא יצא להליך הרביעי למתן רישיונות לחיפושי גז טבעי, עולות בקנה אחד עם הרצון לפתח אנרגיות מתחדשות על פני דלקים פוסילים.

5. מרשתי מברכת כמובן על הצהרתך זו, וסבורה כי יש בה כדי להטיב עם משק האנרגיה והגנת הסביבה בישראל. יחד עם זאת סבורה מרשתי, כי בהצהרה זו יש כדי לעמוד באופן חלקי בלבד **עם מלוא המאמצים העולמים בכלל, ועם אלה הנדרשים מישראל בפרט, להביא לצמצום בפליטת גזי החממה ולהפחתת הסיכון מפיתוח של שדות הגז**, בייחוד לאור ההשפעות השליליות שבניצול דלק פוסילי בעת הזו, וזאת משני טעמים עיקריים שיפורטו להלן.

6. ראשית, על פי הודעתך, פיתוח שדות הגז הנוספים לא יבוטל, אלא רק יושהה לתקופה קצרה בת שנה. מובן כי להשהיה זמנית זו אין כל משמעות מעשית כמעט ביחס לצמצום ההשפעות השליליות הנובעות מהרחבת פיתוח מאגרי הגז בישראל, שכן לדחייה כאמור השפעה שולית אם בכלל על האפשרות כי מאגרי גז נוספים יתגלו ויפותחו בישראל בעתיד הנראה לעין.

7. שנית, ועל פי נוסח הודעתך, אין בכוונת המשרד לעצור את פיתוחם האפשרי של שדות גז שרישיונות עבורם כבר הוענקו על ידי הממונה על ענייני הנפט במשרד האנרגיה. למיטב ידיעתה של מרשתי, נכון להיום, עומדים בתוקפם 15 רישיונות שונים לחיפושי גז ונפט בים התיכון, הניתנים למימוש בזמן הקרוב, או שכבר ממומשים בימים אלה.

8. ודוק. המשך הפיתוח בפועל של שדות הגז במימי הים התיכון יחבל במאמצים להביא לצמצום בפליטת גזי החממה ויביא בהכרח להגברת הסיכון הנשקף לסביבה ולבריאות הציבור כתוצאה מהרחבת פיתוח שדות הגז שלחופי ישראל.

9. בהתאם לכך וביחס למסקנות הביניים של "ועדת אדירי 2", שעסקה בהמשך פיתוחו של משק הגז בישראל בכלל וביחס לייצואו בפרט, התייחס המשרד להגנת הסביבה וציין, כי "התועלת הכלכלית הישירה בטווח הקצר מחתימה על עסקאות למכירת גז לאירופה ברורה. עם זאת, היא לא מביאה בחשבון את הסיכונים הסביבתיים והכלכליים כתוצאה מפיתוח תעשייה מזהמת בתחומי ישראל, כמו גם את ההיבט המוסרי והערכי הכרוך בכך".

10. זאת ועוד. כפי שבוודאי ידוע לך, ממשלת ישראל אישרה לפני כשנה וחצי את הצעת משרד האנרגיה להעלות את היעד לייצור חשמל מאנרגיות מתחדשות לשיעור של 30% עד שנת 2030. מבלי להתייחס לשיעור הנמוך של יעד זה, הרי שהמשך פיתוח בפועל של מאגרי הגז בים עלול לסכל את העמידה גם ביעד בלתי שאפתני זה.

11. מכאן, שהן מטעם זה והן מן הסיכונים הסביבתיים והאחרים הנשקפים לסביבה ולבריאות הציבור כתוצאה מפיתוחם של מאגרי גז נוספים, דומה שהמשך פיתוחם של מאגרי הגז מכוח הרישיונות הקיימים, ומתן דחייה קצרה ומוגבלת בזמן ביחס לחלוקת רישיונות חדשים, לא יביא לשינוי הרצוי במשק האנרגיה הישראלי.

12. נוכח האמור, חשיבות הדברים, והעניין הציבורי בעניין, נבקש לקבל את עמדתך ביחס לאפשרות כי משרד האנרגיה יאסור לחלוטין את המשך פיתוחם של מאגרי הגז בים, לרבות בדרך של ביטול הרישיונות הקיימים שכבר הוצאו על ידי הממונה מכוח חוק הנפט, ויודיע כי לא יוענקו יותר רישיונות חדשים.

13. נודה לקבלת עמדה זו בהקדם, לאורה תוכל מרשתי לכלכל את המשך צעדיה.

בכבוד רב,

מתן גרפינקל, עו"ד

<u>נספח 20</u>

העתק מן הפנייה מיום 19.9.22

עמ' 829

נספח 20

מתן גרפינקל
משרד עורכי דין

19 בספטמבר 2022

לכבוד
גב׳ קארין אלהרר
שרת האנרגיה
רח׳ בנק ישראל 7
<u>ירושלים</u>

בדוא״ל: sara@energy.gov.il

נכבדתי,

הנדון: <u>פיתוח נוסף של קידוחי גז ונפט בישראל ועמידה ביעדי הפחתת פליטות גזי החממה – התראה בטרם נקיטת הליכים משפטיים</u>

בשם מרשתי, גרינפיס ים תיכון בע״מ (חל״צ), אני מתכבד לפנות אליך בעניין שבנדון, כדלקמן:

א. <u>כללי</u>

1. כפי שבוודאי ידוע לך, משבר האקלים הוא המשבר החריף ביותר איתו מתמודדת האנושות בעת הזו. למרבה הצער, אזהרותיהם של מומחי האקלים שנשמעו בשנים האחרונות בדבר ההשלכות של משבר זה התממשו והתסריטים הפסימיים ביותר שנחזו קורמים עור וגידים.

2. לפי הארגון המטארולוגי הבינלאומי,[1] שבע השנים החולפות היו החמות ביותר שנמדדו אי פעם. לעוצמה ולתדירות של אירועים קיצוניים אלו ישנו קשר ישיר לשינוי האקלים מעשה ידי אדם אשר צפויים להחריף.[2]

3. הגורם המרכזי להגברת אפקט החממה הוא פליטות פחמן מעשה ידי אדם, שמקורן בשריפה של דלק מאובנים - נפט, גז מחצבי ופחם המשחררים גזי חממה בכמות שתורמת ל-2/3 מהתחממות כדור הארץ מבחינה היסטורית וכ-85% בעשור האחרון.[3] גלי חום אמנם היו בעבר, אבל לא בתדירות ובעוצמה אליה אנו עדים. לא מדובר רק בגלי חום אלא בטמפרטורת האוויר, הקרקע והים, היקף כיסוי הקרח וגודלם של קרחונים, שטחי יערות־עד, חומציות האוקיינוסים, עוצמת זרם הגולף ועוד, אשר חווים שינויים הרי גורל בשנים האחרונות.[4]

4. העדויות המדעיות בעניין משבר האקלים הן חד משמעיות: כל עיכוב בפעולה גלובלית צפוי להביא להחמצת חלון ההזדמנויות המצטמצם, לטובת הבטחת עתיד בר קיימא של חיים על פני כדור הארץ.

5. נוכח חשיבות העניין ובמסגרת ועידת האקלים ה- 21 של האו״ם בשנת 2015, נחתם הסכם פריז במטרה להביא להפחתת פליטות גזי חממה ברמה הגלובלית, והגבלת ההתחממות הגלובלית לפחות מ – 2 מעלות צלזיוס ביחס לתקופה הטרום תעשייתית עד לשנת 2050 (להלן: ״**הסכם פריז**״). 195 מדינות חתמו על הסכם פריז, ביניהן גם ישראל, שחתמה על ההסכם ביום 22.4.2016.

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[1] https://public.wmo.int/en/media/press-release/united-science-we-are-heading-wrong-direction

[2] United in Science: We are heading in the wrong direction

[3] https://www.ipcc.ch/report/ar6/wg1/#FullReport עמוד 222

[4]

ב. <u>התחייבויות מדינת ישראל להפחתת פליטות גזי חממה</u>

.6 בהתאם לparagraph 4, Article 12 בהסכם פריז, המדינות החתומות על ההסכם מחויבות לדווח למזכירות ה-UNFCC (United Nations Framework Convention on Climate Change) את מלאי פליטות גזי החממה השנתיות במדינה, וכן להעביר למזכירות אחת ל-5 שנים יעדי הפחתת הפליטות, שאפתניים יותר מהיעדים שקדמו להם.

.7 בדיווח האחרון של מדינת ישראל ל-UNFCC משנת 2019, דווח על כמות פליטות גזי חממה שנתית אשר עומדת על כ-79 מיליון טון שווה ערך פחמן דו חמצני (MtCO2eq).[5]

.8 לקראת ועידת האקלים בגלזגו (26COP) בנובמבר 2021, העבירה מדינת ישראל את יעדי הפחתת הפליטות המעודכנים לשנת 2021. היעדים שהוגשו התבססו על החלטת ממשלה מספר 171 של הממשלה מיום 25.07.2021 ("כלכלה דלת פחמן"), בה נקבעו הצעדים הבאים[6]:

8.1. עדכון היעד הלאומי להפחתת פליטת גזי חממה לשנת 2030, כך שהכמות השנתית של פליטות גזי חממה בשנת 2030 תפחת ב-27% לפחות מהכמות השנתית שנמדדה בשנת 2015, אשר עמדה על 79 מיליון טון. בהתאם לאמור, תעמוד הכמות השנתית של פליטות גזי חממה בשנת 2030 על כ-58 מיליון טון.

8.2. קביעת יעד לאומי להפחתת פליטות גזי חממה לשנת 2050, כך שהכמות השנתית של פליטות גזי חממה בשנת 2050 תפחת ב-85% לפחות מהכמות השנתית שנמדדה בשנת 2015. בהתאם לאמור, תעמוד הכמות השנתית של פליטות גזי חממה בשנת 2050 על כ-12 מיליון טון.

.9 היעדים שלעיל נקבעו ועוגנו בהחלטת ממשלה מס' 171 מיום 25.7.2021 והוגשו למזכירות האו"ם (NDC Registry). – (להלן: "יעדי ההפחתה")

.10 כאן המקום לציין, כי יעדי ההפחתה הם יעדים אבסולוטיים (ולא פר נפש, כפי שנקבע בעבר) והם נקבעו על ידי ממשלת ישראל על אף הגידול הצפוי באוכלוסיות ישראל בשיעור צפוי של בין 1.4% ל 2% בכל שנה.

.11 עוד נבהיר כי לצורך עמידה ביעדים של 2030 נדרש קצב הפחתת פליטות גזי חממה של כ-4% בשנה. עמידה ביעדים של 2050 לעומת זאת דורשת הפחתה בקצב של 7.5% לשנה בין 2030 ל-2050.

.12 כפי שיפורט לעיל, עקב הערכת חסר מהותית בחישוב פליטות המתאן של ישראל, קיים חשש כבד כי המשך פיתוח הליכי האקספלורציה של גז ונפט בישראל יסכל את אפשרותה של מדינת ישראל לעמוד ביעדי ההפחתה לרבות ביחס להפחתה ההדרגתית הנדרשת לשם העמידה ביעדים אלה. ונפרט.

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[5] United nation Framework convention on climate change https://di.unfccc.int/ghg_profiles/nonAnnexOne/ISR/ISR_ghg_profile.pdf

[6] משרד ראש הממשלה (2021) מעבר לכלכלה דלת פחמן https://www.gov.il/he/departments/policies/dec171_2021

ג. הערת החסר בחישוב פליטות המתאן של ישראל

13. המתאן הוא אחד מגזי החממה ומהווה את המרכיב המרכזי בגז המחצבים. בעוד שריכוז המתאן באטמוספירה נמוך בהרבה מזה של פחמן דו חמצני, הרכבו הכימי של המתאן הופך אותו ליעיל במיוחד בכליאת חום, ועל פי החישובים העדכניים, על פני 20 שנה הוא יוצר אפקט חממה גבוה פי 84-86 מזה של פחמן דו חמצני.[7] המתאן אחראי, על פי הדוח האחרון של הפאנל הבין ממשלתי לשינויי האקלים (IPCC), לכשליש מהתחממות כדור הארץ עד כה.[8]

14. על פי דוח האו"ם שפורסם במאי 2021,[9] התעשיות הפוסיליות אחראיות על 35% מכלל פליטות המתאן האנושיות. לכל אורך הדרך – החל מהקידוח, שאיבה, זיקוק, שינוע ושריפה – פחם, גז ונפט פולטים לא רק פחמן דו חמצני אלא גם מתאן, והרבה ממנו: מוערך כי 3% מכלל הגז הטבעי שמופק אובד בכל שנה עקב דליפות, תקלות ובעירה בשלבי הייצור.[10]

15. במהלך תהליך הפקת הגז, נוצרות פליטות בלתי מוקדיות. מדובר בדליפות גז בלתי מכוונות שמקורן בייצור ועיבוד במתקני הגז והנפט השונים (בין היתר דרך פעולות או תקלות של נישוב ופליירינג), ובמערך ההולכה והחלוקה. אלו הם הפסדי אנרגיה ממושכים בשיעור נמוך - פליטות לאוויר של גז אגרסיבי חסר צבע או ריח, מכל מרכיבי המערכת, דבר שמקשה מאוד על זיהוי שלהם באופן רציף ומקיף. על פי ההערכות המדעיות המקובלות, פליטות המתאן המדווחות מכל השלבים בשימוש בגז מחצבי נמוכות בכ-70% ממספרן האמיתי.[11]

16. בישראל הפער בין הדיווח למציאות לאין שיעור גדול יותר. מחישוב שערכה מרשתי, על פי המתודולוגיה המקובלת של הפאנל הבין-ממשלתי לשינויי אקלים (IPCC) להערכת פליטות גזי חממה בעת פעילות שגרתית של מערכות ייצור והולכת הגז, ובהתאם להמלצות דוח מוסד שמואל נאמן[12] בנושא, עולה כי בחישוב השמרני ביותר[13], בשנת 2019 נוצרו במשק הגז בישראל פליטות כוללות שנעות בין 42.74 ל-55.84 קילו טון מתאן מכל שרשרת הייצור. זהו פער העומד על פי 40-50 מההערכות אותן פרסם משרד האנרגיה[14]. למיטב ידיעתה של מרשתי, בעתיד הקרוב צפוי המשרד להגנת הסביבה לפרסם עבודה מקצועית הנעשית בימים אלו בעניין שיעור פליטות המתאן בישראל שיש בה לאשש ולו באופן חלקי את טענתה של מרשתי כי שיעור פליטות המתאן בישראל מדווח בחסר רב.

17. כך או כך וכפי שיפורט להלן, אם יוגדל ייצור הגז הטבעי בישראל ובהתחשב בשיעורה בפועל של פליטת המתאן בישראל, יביא הדבר בהכרח לכך, כי מדינת ישראל לא תוכל לעמוד ביעדי הפליטה שנטלה על עצמה לרבות בהפחתה ההדרגתית הנדרשת של פליטות גזי החממה בתקופה הצפויה עד למועד העמידה ביעד.

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[7] UNECE, Methange management https://unece.org/challenge

[8] https://www.haaretz.co.il/nature/climate/.premium-MAGAZINE-1.10100465

[9] https://wedocs.unep.org/bitstream/handle/20.500.11822/35917/GMA_ES.pdf

[10] https://www.unep.org/news-and-stories/press-release/global-assessment-urgent-steps-must-be-taken-reduce-methane

[11] https://www.iea.org/news/methane-emissions-from-the-energy-sector-are-70-higher-than-official-figures

[12] לב-און, מ., לב-און, פרי., אילון, א. (2016) פליטות מתאן ממגזר הנפט והגז הטבעי ושיטות מיטביות לכימות. מוסד שמואל נאמן.

[13] חישוב זה שמרני מכיוון שאינו כולל פליטות בבארות או בקרקעית הים, ואיננו מתייחס לגז המיוצא אחרי שלב ההפקה.

[14] מסמכי החישוב המלאים של צוות "זיקוק" בנוגע לפליטות מתאן בישראל https://www.zikuk.org.il/

18. ודוק. בשנת 2020, הופקו ממקורות הגז הטבעי בישראל 16 BCM (12 BCM לצריכה מקומית, 4 BCM לייצוא). חישוב פליטות המתאן לפי מתודולוגיית ה-IPCC שהוצגה לעיל, מציג טווח אפשרי של 62-76 קילו טון מתאן, שהם שווי ערך ל5.24-6.38 מיליון טון שווה ערך פחמן דו חמצני (MtCO2eq).[15]

19. כלומר, סך פליטות גזי החממה של ישראל לשנת 2019 עומד בפועל על כ-85 מיליון טונה, ולא 79 מיליון טונה, כפי שדיווחה ישראל לUNFCC. על רקע זה, יש לבחון האם ביכולתה של מדינת ישראל לעמוד ביעדי ההפחתה בכלל וביחס לשנת 2050 (לרבות בהפחתה ההדרגתית הנדרשת עד לשנה זו) בפרט אם יוגדל שיעור ייצור והפקת הגז בישראל, כפי שמבקש משרד האנרגיה לעשות.[16]

ד. הגדלת ייצור הגז הטבעי בישראל לא תאפשר לישראל לעמוד בהתחייבויות שנטלה על עצמה ליעדי הפליטה בשנת 2050

ד.1 היעדים לשנת 2050

20. נכון להיום, מופק בישראל גז ממאגרי תמר ו-לוויתן ובסוף שנה זו, צפויה להחל הפקת גז ממאגר כריש. בהתבסס על המתודולוגיה שהוזכרה לעיל, שיעור פליטות המתאן (ק״ט CH_4) משלושת המאגרים שהוזכרו יעמוד על 85.5-99.5 קילו טון ויביא את סך פליטות גזי החממה לשיעור שבין 7.24 – 8.38 מיליון טון שווי ערך פחמן דו חמצני.

21. על פי הערכותיו השמרניות של משרד האנרגיה, מצויים במאגרי הגז במים הכלכליים של ישראל כ- BCM500 נוספים או 36 BCM בשנה. על פי החישוב שבוצע על ידי מרשתי, תוספת פליטות המתאן השנתית ממאגרים חדשים אלה, ככל שאכן ינוצלו, תעמוד על כ- 35.3 ק״ט CH_4 ותביא את סך הפליטה הכוללת מכלל המאגרים (הנוכחיים ואלה החדשים) ל 120-135 ק״ט CH_4 המגלמים פליטות גזי חממה בשיעור של 11.38-10.24 MtCO2eq:

<u>גידול בפליטות גזי חממה בהינתן ייצוא – לפי ניצול **500 BCM**:</u>

	הפקה בשנת 2020	סה״כ בתוספת הפקה מאסדת כריש	סה״כ בתוספת הפקה מאגרים חדשים	תרומת המאגרים החדשים
כמות הגז המופקת (BCM)	16	24	36	12
פליטות מתאן (ק״ט CH_4)	62 -76	85.5 -99.5	120 – 135	35.3

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[15] עם GWP של 84 למתאן, שהוא ה-GWP לתקופה של 20 שנה, תקופת הזמן הרלוונטית ליעד ה-NET ZERO עד 2050

[16] https://www.globes.co.il/news/article.aspx?did=1001413504

פליטות גזי חממה **(MtCO2eq)**	**5.24 -6.38**	**7.24- 8.38**	**10.24 -11.38**	**3**

בהתאם לכך, ואם תתממש ההנחה "האופטימית" לפיה במים הכלכליים של ישראל יתגלו עתודות גז בשיעור של 1000 bcm, יעמדו פליטות המתאן ותוספת פליטות גזי החממה על שיעורים אלה:

גידול בפליטות גזי חממה בהינתן ייצוא – לפי ניצול BCM 1000:

	הפקה בשנת 2020	סה"כ בתוספת הפקה מאסדת כריש	סה"כ בתוספת הפקה מאגרים חדשים	תרומת המאגרים החדשים
כמות הגז המופקת (BCM)	16	24	48	24
פליטות מתאן (ק"ט CH_4)	62 -76	85.5 -99.5	170-156	70.5
פליטות גזי חממה **(MtCO2eq)**	**5.24 -6.38**	**7.24- 8.38**	**13.1- 14.2**	**5.8**

22. הנה כי כן, גם בהתבסס על ההנחה השמרנית, לפיה במימיה הכלכליים של ישראל מצוי גז בהיקף של BCM500 "בלבד", יביא ניצולם, יחד עם ניצול המאגרים הקיימים -ובהתחשב בהערכת אמת של שיעור פליטות המתאן הנובע מניצול כלל המאגרים- לפליטת גזי חממה בשיעור שנתי של 10.24-11.38 MtCO2eq. שיעור זה יגדל ל- MtCO2eq 13.1-14.2 בהינתן ניצול מאגרים של BCM1000.

23. במילים אחרות, על פי ההערכה השמרנית, המשך פיתוחו של משק הגז יביא לשיעור של פליטות גזי חממה של 10.24-11.38 MtCO2eq, ממשק זה בלבד, כלומר שיעור השווה כמעט בגודלו לשיעור סך הפליטות של גזי חממה שישראל התחייבה שתעמוד בה בשנת 2050.

24. ודוק. בהתחשב בכך כי משק הגז הישראלי אינו הגורם היחידי הגורם לפליטות של גזי חממה ונוכח העובדה כי קיימים מקורות משמעותיים נוספים של פליטות גזי חממה בישראל, **מובן כי המשך פיתוחו של משק הגז הישראלי יביא בהכרח לכך כי מדינת ישראל לא תוכל לעמוד ביעדי ההפחתה שנטלה על עצמה**.

25. כך למשל, שיעור פליטות גזי החממה מתעשיית המלט, התחבורה הימית והתעופה בישראל לבדם הגיע לסך של כ –7 מיליון טון בשנת 2021 המתווספים (יחד עם מקורות נוספים) לפליטות גזי חממה שמקורם ממשק הגז והנפט. תחום נוסף אשר לא זוכה לטיפול נאות הינו הפסולת שפולט כמויות הולכות וגדלות של גזי חממה.

26. דברים אלה רק מקבלים משנה תוקף נוכח העובדה כי על מיטב ההערכה והידוע כיום, היכולת להביא בעתיד להפחתה משמעותית (אם בכלל) של פליטות גזי חממה ממגזרים אלה נמוכה ביותר כך שבמידה גבוהה מאוד של ודאות ניתן להניח שגם בשנת 2050 שיעור פליטות גזי החממה ממגזרים אלה יהיה משמעותי ביותר ויעלה באופן משמעותי את סך פליטות גזי החממה בישראל בשנה זו. כל זאת, עוד לפני שנלקחה בחשבון האפשרות כי שיעור הפליטות ממגזר המלט, התחבורה הימית והתעופה יעלה בהתאם לעלייה ברמת החיים וגידול האוכלוסין בישראל.

27. האמור לעיל מוביל אפוא למסקנה כי המשך פיתוחו של משק הגז והנפט הישראלי יביא בהכרח להפרת התחייבויותיה של ישראל לעמיד ביעדי הפליטה ולפגיעה בסביבה, על כל המשתמע מכך.

ה. יעדי ההפחתה כוללים גם התחייבות להפחתה הדרגתית עד לשנת היעד

28. כאמור לעיל, הראנו כי המשך פיתוחו של משק הגז והנפט הישראלי יביא בהכרח לכך כי ישראל לא תעמוד ביעדי ההפחתה שנטלה על עצמה. ואולם, הפרה צפויה זו אינה ההפרה היחידה של יעדי ההפחתה.

29. גזי חממה נפלטים לאטמוספירה ונותרים בה לעשרות עד מאות שנים. התחקות אחר קצב ההצטברות והפירוק של גזי החממה מאפשר למדעני האקלים להעריך תקציב פחמן אשר משקף באופן מהימן את כמות הפליטות המצטברות עד לחציית רף טמפרטורה מסוים. קיים, אפוא, תקציב אשר משקף חציית התחממות של מעלה וחצי לעומת העידן הטרום תעשייתי, תקציב גבוה יותר לחציית קו השתי מעלות וכן הלאה.

30. דו"ח הפאנל הבינממשלתי לשינויי אקלים של האו"ם (IPCC) משנת 2020 בנושא "מעלה וחצי" מעריך שתקציב הפחמן שעומד לראשות האנושות לחציית קו המעלה וחצי עומד על 580-420 מיליארד טון שווי ערך פחמן דו-חמצני. עמידה במסגרת התקציב של 420 מיליארד טון נותן סיכוי של 66% להגביל את התחממות כדור הארץ במעלה וחצי. עמידה בתקציב של 580 נותן סיכוי של 50%. כדי להמחיש את המשמעות של מספרים אלה, מספיק להזכיר שפליטות הפחמן של האנושות עומדות מדי שנה על כ-42 מיליארד טון. במילים אחרות, יש לנו פחות מעשר שנים של "עסקים כרגיל" כדי להגביל את ההתחממות מתחת לרף טמפרטורה של מעלה וחצי. [17]

31. אשר על כן, ה-IPCC מדגיש כי "נתיבים להגבלת ההתחממות למעלה ללא פעילות ספיחת פחמן או במידה מועטה דורשת מעבר מהיר ושאפתני בתחומי האנרגיה, אדמה, עירוניות.." יתירה מזו, מדגיש הדוח כי "ככל שהפליטות ב-2030 תהינה נמוכות, כך יקטן האתגר להגבלת ההתחממות הגלובאלית למעלה וחצי אחרי 2030".[18]

32. הרוח והכוונה של הסכם פריז, אשר יונק מעבודותיו של ה-IPCC הינה כי המאבק במשבר האקלים מושתת על שתי רגליים כל אחת חשובה בפני עצמה: יעדים שאפתניים דרך הפחתה מתמדת ומהירה. היעדים והשנים שמתייחסים אליהם, וכמו כן רף טמפרטורה מסוים, באים להמחיש באופן פשוט את קיומו של תקציב פחמן

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[17] SR15_Full_Report_High_Res.pdf (ipcc.ch) עמוד 12

[18] SR15_Full_Report_High_Res.pdf (ipcc.ch) עמוד 18;

מוגבל, כאשר כל פעילות, גם באמצע הדרך, שמגבירה פליטות גזי חממה, פוגעת בסיכויים להגביל את התחממות כדור הארץ. ובשפה המובנת של דו״ח ה-IPCC: ״פחות הפחתת פליטות פחמן דו-חמצני בעתיד הקרוב תדרוש צמצומים דרסטיים ומעמיקים יותר בטווח הארוך כדי לעמוד ביעדים.[19]

.33 יתירה מזו, בתחשיבי התקציב האלה, תרומתו הייחודית של גז המתאן להתחממות במיוחד לטווח הקצר מחייבת תעדוף הפחתת פליטות המתאן על פני הפחתת פליטות המפחמן הדו חמצני. היא אשר יכולה לסייע יותר מכל צעד אחר לבלימת משבר האקלים בשנים הקרובות, כפי שגם יוצא מדו״ח ה-[20].IPCC

ו. **המשך פיתוח משק הגז והנפט מנוגד להחלטת הממשלה בעניין ולהחייבויות שנטלה על עצמה ישראל**

.34 כפי שצוין בהרחבה לעיל, אם ימשיך הליך פיתוחו של משק הגז והנפט בישראל הדבר יהיה מנוגד באופן חזיתי להתחייבויות שנטלה על עצמה ישראל בעניין ובכלל זה בניגוד להחלטת הממשלה מס׳ 171.

.35 כידוע, חובתו של שר בממשלת ישראל לקבל ולקיים את עמדת הממשלה בעניין מסוים הנתון לסמכותו. בהנחיית היועץ המשפטי לממשלה 1.1001 (21.484) ניתנה לכך התייחסות:

״כיוון שעדיין לא נפסקה הלכה בשאלה אם שר חייב לקבל את עמדת הממשלה בנוגע להפעלת סמכות שהחוק הקנה לו, כאשר עמדת הממשלה נוגדת את עמדתו, מן הראוי לברר שאלה זאת לגופה. הבירור מוביל למסקנה כי אכן חובה כזאת מוטלת על השר. נראה כי מסקנה זאת מקובלת על רוב המשפטנים שהביעו את דעתם בשאלה זו״

.36 דומה כי דברים אלה מדברים בעד עצמם, בייחוד כאשר עסקינו בהחלטת ממשלה משמעותית שיש בה כדי להשליך על יעדים שנטלה על עצמה מדינת ישראל במסגרת מחויבויותיה הבין לאומיות. יתרה מכך יש להזכיר, כי קיים חשש כבד כי הבסיס העובדתי עליו מתבסס משרד האנרגיה עת הוא מבקש להרחיב ולפתח עוד את משק הגז והנפט בישראל הוא שגוי, עת שיעור פליטות המתאן המשוער ממשק זה נמוך בסדרי גודל מזה שבפועל.

.37 אשר על כן, נבקש לקבל את עמדתך בהקדם ביחס להמשך פיתוח משק הגז והנפט בישראל לרבות ביחס לאפשרות קידומו של ההליך התחרותי הרביעי בזמן הקרוב. ככל שעמדה זו תעמוד על כך כי יש להמשיך בהליכי

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[19] Ibid p. 126
Less CO2 emission reductions in the near term would require steeper and deeper reductions in the longer term in order to meet specific warming targets afterwards (Riahi et al., 2015; Luderer et al., 2016a). This is a direct consequence of the quasi-linear relationship between the total cumulative amount of CO2 emitted into the atmosphere and global mean temperature rise (Matthews et al., 2009; Zickfeld et al., 2009; Collins et al., 2013; Knutti and Rogelj, 2015). Besides this clear geophysical trade-off over time, delaying GHG emissions reductions over the coming years also leads to economic and institutional lock-in into carbon-intensive infrastructure, that is, the continued investment in and use of carbon-intensive technologies that are difficult or costly to phase-out once deployed

[20] IBID עמ 126
Though CO2 dominates long-term warming, the reduction of warming short-lived climate forcers (SLCFs), such as methane and black carbon, can in the short term contribute significantly to limiting warming to 1.5°C above pre-industrial levels.

הפיתוח, בין אם באמצעות מתן רשיונות אקספלורציה חדשים במימי הים התיכון או בכל דרך רלוונטית אחרת, בכוונת מרשתי לפנות בעניין לערכאות על מנת לעצור מהלכים אלה.

38. אודה לתשובתך המהירה לאורה תוכל מרשתי לכלכל את המשך צעדיה.

בכבוד רב,

מתן גרפינקל, עו״ד

העתק: גב׳ תמר זנדברג, השרה להגנת הסביבה

נספח 21

העתק מן הפנייה מיום 1.2.23

עמ׳ 838

נספח 21

מתן גרפינקל
משרד עורכי דין

1 בפברואר 2023

לכבוד
מר שגיא גנות
מנהל תחום סחר ביני"ל בגז
משרד האנרגיה

מר חן בר יוסף
הממונה על ענייני הנפט
משרד האנרגיה

בדוא"ל: sagig@energy.gov.il
cbaryoseph@energy.gov.il

א.נ.,

הנדון: **ההליך התחרותי הרביעי – התראה בטרם נקיטת הליכים משפטיים**

בשם מרשתי, גרינפיס ים תיכון בע"מ (חל"צ), הריני לפנות אליכם בעניין שבנדון, כדלקמן:

א. כללי

1. כפי שבוודאי ידוע לך, ביום 13.12.22 פרסם משרד האנרגיה את מסמכי ההליך התחרותי הרביעי לקבלת רשיונות לחיפושי גז טבעי במימי ישראל (להלן: "**ההליך התחרותי**").

2. מרשתי סבורה, כי המשך פיתוחו של משק הגז בעת הזו שגוי ויהיה בו כדי לפגוע ביכולתה של מדינת ישראל לעמוד ביעדי הפחתת פליטות גזי חממה אשר נטלה על עצמה כמו גם באיכות הסביבה ובריאות הציבור. זאת, כאשר סביר להניח כי מרבית אם לא כל הגז שיופק כתוצאה מהליך זה (אם אכן יימצאו מקורות גז חדשים) ייועד לייצוא ולא לצריכה מקומית.

3. כך או כך, עיון במסמכי ההליך התחרותי מגלה כי נפל בהם פגם של ממש המצדיק, לכל הפחות את השהיית ההליך עד אשר יושלמו ויעודכנו מסמכי הסקר האסטרטגי הסביבתי ביחס לאזורי החיפוש העומדים כעת על הפרק במסגרת הליך זה.

ב. הסקר האסטרטגי הסביבתי לא עודכן כנדרש ביחס להליך התחרותי

4. על פי האמור באתר[1] משרד האנרגיה, הסקר האסטרטגי הסביבתי (להלן: "**סא"ס**") הוא:

> **"כלי עזר מרכזי לקבלת החלטות ולקביעת מדיניות בהתייחס לניצול משאבים, המקובל במדינות מפותחות לצורך בחינת השפעות סביבתיות של אופן ניצול המשאבים. לשם כך יזם והוביל משרד האנרגיה הכנת סקר אסטרטגי סביבתי המתייחס לכל המרחב הימי של מדינת ישראל, ומסייע לתכלל שיקולים סביבתיים במסגרת פיתוח משאבי נפט וגט טבעי בים ולאזן בין הצורך בפיתוח המשאב לצמצום פגיעה אפשרי בסביבה. מסקנות והמלצות הסקר אומצו על ידי הממונה על ענייני הנפט והוטמעו בהליך התחרותי למתן רישיונות לחיפושים במרחב הימי של ישראל, על פי העקרונות המקובלים לפיתוח משאבים תוך שמירה על הסביבה במדינות ה – OECD."**

5. בהתאם לכך, נערך בשנת 2016 הסא"ס הראשון שבחן בקווים כללים את המים הכלכליים בישראל. סא"ס נוסף נערך בשנת 2018 ושימש הליך תחרותי אחר שפורסם באותה העת. סא"ס שלישי נערך בשנת 2020.

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[1] https://www.gov.il/he/departments/guides/enviromental_info?chapterIndex=3

החשיבות שבעדכון מסמך הסא״ס מעת לעת בכלל ובתדירות של אחת לשנתיים בפרט הוזכרו בסא״ס משנת 2020 שם צוין[2]:

> **״בסא״ס הומלץ על ביצוע סא״ס נוסף לאחר 5 שנים...חשוב לעדכן את הסא״ס כתהליך נושם ולהמשיך בעדכון הדו שנתי המקיף כפי שהתבצע עד כה״**

6. למרות האמור לעיל, הרי שנכון להיום טרם בוצע סא״ס נוסף מקיף או אף עדכון בלבד של הסא״ס, למרות שחלפו כשבע שנים מאז ביצוע הסא״ס המלא וכשלוש שנים מן המועד האחרון בו עודכן הסא״ס.

7. ודוק. הסא״ס שעל פי עמדת משרד הארגיה מהווה נדבך חשוב הדרוש לפיתוח וחיפוש של גז ונפט בים לא רק שלא עודכן כנדרש, אלא שהלכה למעשה אין בו כמעט כל מידע הרלוונטי להליך התחרותי הנוכחי. מסמכי הסא״ס הקיימים אינם עוסקים בשטח נשוא הליך זה או שהמידע המצוי בהם ביחס אליו אינו מעודכן די הצורך נוכח ההתפתחויות הרבות בסביבה הימית בשנים האחרונות.

8. על רקע זה, עולה חשש כבד שמא עצם ההחלטה לצאת להליך התחרותי הרביעי נתקבלה על בסיס עובדתי חלקי ובניגוד לעמדת משרד האנרגיה עצמו המבקשת לפתח את קידוחי הגז והנפט בים על בסיס מסמך סביבתי מקיף, רלוונטי ומעודכן.

9. נוכח האמור עמדת מרשתי היא כי אין מקום להמשיך בהליך התחרותי הרביעי עד לעדכון כנדרש של מסמך הסא״ס. לחילופין ומטעמי זהירות בלבד מבקשת מרשתי להביע בפניכם את עמדתה ביחס לפגמים שנפלו בהליך עצמו.

ג. <u>ההליך התחרותי אינו משקלל כנדרש את כישורי המציעים בפן הסביבתי</u>

10. כל עוד נמשך ההליך התחרותי זה יש להבטיח כי הוא ייעשה באופן שיצמצם ככל הניתן כל פגיעה אפשרית עתידית בסביבה ובבריאות הציבור. ביתר פירוט, מרשתי סבורה כי על משרד האנרגיה להבטיח כי רק גופים להם עבר נקי בכל הקשור לקיום הוראות בתחום איכות הסביבה יוכלו להשתתף בהליך התחרותי וכי מבין גופים אלה תינתן העדפה, במסגרת ניקודם בהליך, למי שפועל באופן מוגבר לטובת שמירה על הסביבה ובריאות הציבור. נפרט.

11. עיון במסמכי ההליך התחרותי מלמד כי בעוד ביחס לאיתנות הפיננסית הנדרשת ממי שיוכל להגיש את הצעתו להליך התחרותי נדרשה עמידה ביעדים כספיים כאלו ואחרים, לא הועלתה דרישה דומה ביחס לעמידה בדרישות סביבתיות.

12. כך למשל, בעוד שבמסגרת תנאי הסף להשתתפות בהליך התחרותי נדרש המציע להציג כי ברשותו הון בסך של 50 מיליון דולר, הרי שאין דרישה מקבילה הנוגעת לעברו הסביבתי של המציע. כל שנדרש בהיבט הסביבתי מן המציע כדי שיוכל להגיש את הצעתו למכרז הוא:

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[2] https://www.gov.il/BlobFolder/guide/enviromental_info/he/SEA_2020_update.pdf

> "Experience in HSE activities and maintenance of a safety and environmental management system for petroleum operations, including preparation of safety programs, conduction of HSE risk assessment, preparation of environmental documents and environmental monitoring programs relating to petroleum rights activities, all in accordance with internationally accepted standards."

13. כלומר על המציע להראות כי הוא בעל ניסיון כללי בעריכת תוכניות בטיחות, תוכניות ניטור, הערכת סיכונים וכיו״ב על מנת שיוכל להגיש את הצעתו להליך התחרותי. למרות חשיבותה, אין בדרישה זו כדי להבטיח כי מציע שבמסגרת פעילותו להפקת גז או נפט בים פעל בהתאם לכל ההוראות והכללים שחלו עליו בתחומי איכות הסביבה וכי במסגרת פעילות זו לא נגרמו נזקים לסביבה ולציבור בניגוד לדין.

14. ודוק. על פי תנאי ההליך התחרותי כיום, ייתכן כי מציע שהיה אחראי למשל לאירוע שפך גדול בים כתוצאה ממעשה או מחדל שבתחום אחריותו יוכל לגשת להליך התחרותי הרביעי. מצב זה אין לקבל. כפי שבמסגרת מסמכי ההליך התחרותי הובטח כי רק מציעים בעלי איתנות פיננסית מסוימת יוכלו להשתתף בו, כך יש להבטיח כי רק מציעים להם עבר סביבתי ללא רבב יוכלו לעסוק בפעילות לה השפעה שלילית אפשרית על הסביבה בתחומי המים הכלכליים של ישראל. די בהקשר זה להזכיר את האסון הסביבתי העלול להתרחש אם יקרה חלילה אירוע שפך במימיה הכלכליים של ישראל.

15. זאת ועוד. עיון במסמכי ההליך התחרותי מלמד כי במסגרת המשקולות שנקבעו להערכת ההצעות וניקודן, לא ניתנה כל התייחסות שהיא לנושאים סביבתיים הרלוונטים לפעילותו של המציע ואין הם לוקחות בחשבון, במסגרת הערכת המציעים, את מסמכי הנאותות הסביבתית האמורים להיות מוגשים על ידם. כך למשל, ניתנת העדפה למציע שמתחייב לקדוח מספר גדול של בארות בשטח גדול, למי שיציע מענק חתימה גדול יותר וכו׳ אך כאמור מיקומם של הנושאים הסביבתיים במסגרת הערכת המציעים נעדר.

16. לטעמנו ונוכח ההשפעה האפשרית הגדולה של קידוחי גז ונפט בלב ים על הסביבה ובריאות הציבור, ראוי להעדיף מציעים להם, למשל, עבר סביבתי ללא רבב על פני כאלו שבמסגרת פעילותם גרמו בעבר לנזקים סביבתיים משמעותיים. בכך יהיה להקטין את הסיכוי כי כתוצאה מפעולות הקידוח ייגרמו נזקים חמורים לסביבה ובריאות הציבור.

ד. __סיכום__

17. מן האמור עולה אפוא כי בהליך התחרותי נפלו 2 פגמים. האחד, העובדה כי ההליך פורסם בטרם עודכן כנדרש מסמך הסא״ס והשני כי ההליך אינו לוקח בחשבון די הצורך את כישורי המציעים בפן הסביבתי.

18. נוכח האמור, סבורה מרשתי כי יש לדחות את ההליך התחרותי עד למתן מענה לסוגיות אלו. בהתחשב בלוחות הזמנים של ההליך התחרותי, מועד פנייה זו במסגרת לוחות הזמנים של ההליך למתן התייחסות לשאלות ההבהרה, מבקשת מרשתי מענה לפנייתה זו בהקדם, לאורה תוכל לכלכל את המשך צעדיה.

בכבוד רב,

מתן גרפינקל, עו״ד

נספח 22

העתק מן הפנייה מיום 29.3.23

עמ׳ 842

נספח 22

מתן גרפינקל
משרד עורכי דין

29 במרץ 2023

לכבוד
מר ישראל כץ
שר האנרגיה
רח' בנק ישראל 7
ירושלים

מר חן בר יוסף
מנהל מינהל אוצרות טבע, הממונה על ענייני הנפט, משרד האנרגיה
רח' בנק ישראל 7
ירושלים

בדוא״ל: sar@energy.gov.il

cbaryoseph@energy.gov.il

נכבדי,

הנדון: ההליך התחרותי הרביעי ועמידה ביעדי הפחתת פליטות גזי החממה – התראה בטרם נקיטת הליכים משפטיים

בשם מרשתי, גרינפיס ים תיכון בע״מ (חל״צ), אני מתכבד לפנות אליכם בעניין שבנדון, כדלקמן:

א. כללי

1. כפי שבוודאי ידוע לכם, משבר האקלים הוא המשבר החריף ביותר איתו מתמודדת האנושות בעת הזו. למרבה הצער, אזהרותיהם של מומחי האקלים שנשמעו בשנים האחרונות בדבר ההשלכות של משבר זה התממשו והתסריטים הפסימיים ביותר שנחזו קורמים עור וגידים.

2. לפי הארגון המטאורולוגי הבינלאומי[1], שבע השנים החולפות היו החמות ביותר שנמדדו אי פעם. לעוצמה ולתדירות של אירועים קיצוניים אלו ישנו קשר ישיר לשינוי האקלים מעשה ידי אדם אשר צפויים להחריף[2].

3. הגורם המרכזי להגברת אפקט החממה הוא פליטות פחמן מעשה ידי אדם, שמקורן בשריפה של דלקי מאובנים - נפט, גז מחצבי ופחם המשחררים גזי חממה בכמות שתורמת ל-2/3 מהתחממות כדור הארץ מבחינה היסטורית וכ-85% בעשור האחרון. גלי חום אמנם היו בעבר, אבל לא בתדירות ובעוצמה אליה אנו עדים. לא מדובר רק בגלי חום אלא בטמפרטורת האוויר, הקרקע והים, היקף כיסוי הקרח וגודלם של קרחונים, שטחי יערות־עד, חומציות האוקיינוסים, עוצמת זרם הגולף ועוד, אשר חווים שינויים הרי גורל בשנים האחרונות[3].

4. העדויות המדעיות בעניין משבר האקלים הן חד משמעיות: כל עיכוב בפעולה גלובלית צפוי להביא להחמצת חלון ההזדמנויות המצטמצם, לטובת הבטחת עתיד בר קיימא של חיים על פני כדור הארץ.

5. נוכח חשיבות העניין ובמסגרת ועידת האקלים ה- 21 של האו״ם בשנת 2015, נחתם הסכם פריז במטרה להביא להפחתת פליטות גזי חממה ברמה הגלובלית, והגבלת ההתחממות הגלובלית לפחות מ – 2 מעלות צלזיוס ביחס לתקופה הטרום תעשייתית עד לשנת 2050 (להלן: **״הסכם פריז״**). 195 מדינות חתמו על הסכם פריז, ביניהן גם ישראל, שחתמה על ההסכם ביום 22.4.2016. מאז נחתם ההסכם, הצטברו הראיות המדעיות המעידות על הצורך בהגבלת ההתחממות הגלובלית לפחות מ – 1.5 מעלות צלזיוס, על מנת למתן את ההשלכות

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[1] https://public.wmo.int/en/media/press-release/united-science-we-are-heading-wrong-direction
[2] United in Science: We are heading in the wrong direction
[3] https://www.ipcc.ch/report/ar6/wg1/#FullReport

הבלתי הפיכות של שינוי האקלים. לצורך כך, ובהתאם לפרסומים של הפאנל הבין-ממשלתי לשינויי האקלים (IPCC)[4], נדרשת הפחתת פליטות גלובלית של 50% עד לשנת 2030, ואיפוס פליטות נטו עד לשנת 2050 (ביחס לשנת הבסיס 2015).

ב. **<u>התחייבויות מדינת ישראל להפחתת פליטות גזי חממה</u>**

6. בהתאם ל-Article 4, paragraph 12 בהסכם פריז, המדינות החתומות על ההסכם מחויבות לדווח למזכירות ה-UNFCC (United Nations Framework Convention on Climate Change) את מלאי פליטות גזי החממה השנתיות במדינה, וכן להעביר למזכירות אחת ל-5 שנים יעדי הפחתת הפליטות, שאפתניים יותר מהיעדים שקדמו להם.

7. בדיווח האחרון של מדינת ישראל ל-UNFCC משנת 2019, דווח על כמות פליטות גזי חממה שנתית אשר עומדת על כ-79 מיליון טון שווה ערך פחמן דו חמצני (MtCO2eq).[5]

8. לקראת ועידת האקלים בגלזגו (26COP) בנובמבר 2021, העבירה מדינת ישראל את יעדי הפחתת הפליטות המעודכנים לשנת 2021. היעדים שהוגשו התבססו על החלטת ממשלה מספר 171 של הממשלה מיום 25.07.2021 ("כלכלה דלת פחמן"), בה נקבעו הצעדים הבאים[6]:

8.1. עדכון היעד הלאומי להפחתת פליטת גזי חממה לשנת 2030, כך שהכמות השנתית של פליטות גזי חממה בשנת 2030 תפחת ב-27% לפחות מהכמות השנתית שנמדדה בשנת 2015, אשר עמדה על 79 מיליון טון. בהתאם לאמור, תעמוד הכמות השנתית של פליטות גזי חממה בשנת 2030 על כ-58 מיליון טון.

8.2. קביעת יעד לאומי להפחתת פליטות גזי חממה לשנת 2050, כך שהכמות השנתית של פליטות גזי חממה בשנת 2050 תפחת ב-85% לפחות מהכמות השנתית שנמדדה בשנת 2015. בהתאם לאמור, תעמוד הכמות השנתית של פליטות גזי חממה בשנת 2050 על כ-12 מיליון טון.

9. היעדים שלעיל נקבעו ועוגנו בהחלטת ממשלה מס' 171 מיום 25.7.2021 והוגשו למזכירות האו"ם (NDC Registry). – (להלן: "**יעדי ההפחתה**") .

10. כאן המקום לציין, כי יעדי ההפחתה הם יעדים אבסולוטיים (ולא פר נפש, כפי שנקבע בעבר) והם נקבעו על ידי ממשלת ישראל על אף הגידול הצפוי באוכלוסיות ישראל בשיעור צפוי של בין 1.4% ל 2% בכל שנה.

11. עוד נבהיר כי על מנת להבטיח עמידה ביעדי הפחתת פליטות, נדרש קצב הפחתה הדרגתי אך עקבי. כך למשל, עבור עמידה ביעדי הפחתת פליטות עד שנת 2030, נדרש קצב הפחתה של כ-4% בשנה. עמידה ביעדים של 2050 לעומות זאת דורשת הפחתה בקצב של 7.5% לשנה בין 2030 ל-2050.

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[4] IPCC. (2021). Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou (eds.)]. Cambridge University Press. In Press.

[5] United nation Framework convention on climate change https://di.unfccc.int/ghg_profiles/nonAnnexOne/ISR/ISR_ghg_profile.pdf

[6] משרד ראש הממשלה (2021) מעבר לכלכלה דלת פחמן https://www.gov.il/he/departments/policies/dec171_2021

12. יש לציין כי על פי דו"ח שביצעה חברת BDO, שהוצג בכנס סביבה 2050, נמצא כי בשנת 2022, נרשם גידול של 5% בפליטות גזי החממה של ישראל מכלל המגזרים, כאשר פליטות גזי החממה של ישראל עמדו על 81 מיליון טון[7]. גידול זה מלמד על מגמה הפוכה למגמה הנדרשת להפחתת פליטות.

13. כפי שיפורט לעיל, עקב הערכת חסר מהותית בחישוב פליטות המתאן של ישראל, ובשל העובדה כי ההחלטה על פרסום ההליך התחרותי הרביעי לא התבססה על בסיס עובדתי בכל הנוגע לתוספת פליטות גזי חממה, קיים חשש כבד כי קידומו של ההליך יסכל את אפשרותה של מדינת ישראל לעמוד ביעדי ההפחתה לרבות ביחס להפחתה ההדרגתית הנדרשת לשם העמידה ביעדים אלה. ונפרט.

ג. ההליך התחרותי הרביעי והערכת החסר בחישוב פליטות המתאן של ישראל

14. כפי שבוודאי ידוע לך, ביום 13.12.22 פרסם משרד האנרגיה את מסמכי ההליך התחרותי הרביעי לקבלת רישיונות לחיפושי גז טבעי במימי ישראל (להלן: "**ההליך התחרותי**"). במסגרת ההליך, יוצעו ארבעה מקבצים של רישיונות חיפוש במימי הים התיכון. לפי ההערכה שהוצגה בדו"ח ועדת אדירי 2, יש לפעול לעידוד מציאות BCM500-1000 נוספים של גז.[8]

15. בשלב זה, לא ניתן כמובן לדעת מה יהיו תוצאותיו של הליך זה וביתר פירוט אילו (ואם בכלל) מאגרי דלק פוסילי יתגלו במימי הים התיכון. יחד עם זאת וכפי שיפורט להלן, אין כל ספק כי ככל שיתגלו מאגרים שכאלה, פיתוחם יפגע פגיעה אנושה ביכולתה של ישראל לעמוד ביעדי הפחתת פליטות גזי החממה שמדינת ישראל נטלה על עצמה. נסביר.

16. המתאן הוא אחד מגזי החממה ומהווה את המרכיב המרכזי בגז המחצבים. בעוד שריכוז המתאן באטמוספירה נמוך בהרבה מזה של פחמן דו חמצני, הרכבו הכימי של המתאן הופך אותו ליעיל במיוחד בכליאת חום, ועל פי החישובים העדכניים, על פני 20 שנה הוא יוצר אפקט חממה גבוה פי 84-86 מזה של פחמן דו חמצני.[9] המתאן אחראי, על פי הדוח האחרון של הפאנל הבין ממשלתי לשינויי האקלים (IPCC), לכשליש מהתחממות כדור הארץ עד כה.[10]

17. על פי דוח האו"ם שפורסם במאי 2021,[11] התעשיות הפוסיליות אחראיות על 35% מכלל פליטות המתאן האנושיות. לכל אורך הדרך – החל מהקידוח, שאיבה, זיקוק, שינוע ושריפה – פחם, גז ונפט פולטים לא רק פחמן דו חמצני אלא גם מתאן, והרבה ממנו: מוערך כי 3% מכלל הגז הטבעי שמופק אובד בכל שנה עקב דליפות, תקלות ובעירה בשלבי הייצור.[12]

18. במהלך תהליך הפקת הגז, נוצרות פליטות בלתי מוקדיות. מדובר בדליפות גז בלתי מכוונות שמקורן בייצור ועיבוד במתקני הגז והנפט השונים (בין היתר דרך פעולות או תקלות של נישוב ופליירינג), ובמערך ההולכה והחלוקה. אלו הם הפסדי אנרגיה ממושכים בשיעור נמוך - פליטות לאוויר של גז אגרסיבי חסר צבע או ריח,

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[7] https://www.youtube.com/watch?v=zmJ1WiHV3Gw

[8] https://www.gov.il/BlobFolder/rfp/ng_210621/he/ng_report_2_draft.pdf

[9] UNECE, Methange management https://unece.org/challenge

[10] https://www.haaretz.co.il/nature/climate/.premium-MAGAZINE-1.10100465

[11] https://wedocs.unep.org/bitstream/handle/20.500.11822/35917/GMA_ES.pdf

[12] https://www.unep.org/news-and-stories/press-release/global-assessment-urgent-steps-must-be-taken-reduce-methane

מכל מרכיבי המערכת, דבר שמקשה מאוד על זיהוי שלהם באופן רציף ומקיף. על פי ההערכות המדעיות המקובלות, פליטות המתאן המדווחות מכל השלבים בשימוש בגז מחצבי נמוכות בכ-70% ממספרן האמיתי.[13]

19. מספר עבודות נעשו בישראל לטובת כימות והערכת שיעור פליטות המתאן ממשק הגז בישראל. לאחר שנלקח בחשבון הגידול בכמות הגז המופקת לאורך השנים, נמצא פער של פי 5.7 בין העבודה האחרונה שבוצעה עבור המשרד להגנת הסביבה בשנת 2022, לבין העבודה שבוצעה במשרד האנרגיה בשנת 2019. להשלמת התמונה, לפי הצהרות משרד האנרגיה, עבודה מחודשת הייתה אמורה להתפרסם לקראת סוף 2022, אך טרם פורסמה. זאת ועוד, נציין כי בכלל העבודות שצוינו לעיל החישובים מבוססים על מידע שהתקבל מהחברות המפעילות, ולא נאסף באופן עצמאי.

20. במצב דברים זה יש בו כדי לאשש ולו באופן חלקי את טענתה של מרשתי כי שיעור פליטות המתאן בישראל מדווח בחסר רב.

21. על רקע נתונים אלו, יש לבחון האם ביכולתה של מדינת ישראל לעמוד ביעדי ההפחתה בכלל וביחס לשנים 2030 ו-2050 (לרבות בהפחתה ההדרגתית הנדרשת עד לשנים אלו) בפרט אם יוגדל שיעור חיפוש והפקת הגז בישראל כתוצאה מקידום ההליך הרביעי, כפי שמבקש משרד האנרגיה לעשות. [14]

ד. <u>הגדלת ייצור הגז הטבעי בישראל כתוצאה מן ההליך התחרותי הרביעי תפגע ביכולת של ישראל לעמוד בהתחייבויות שנטלה על עצמה להפחתת פליטות</u>

22. בנסיבות שתוארו, קידום ההליך הרביעי, שתכליתו הרחבת משק הגז בהיקף משוער של כBCM500 (בהתבסס על הערכות שמרניות של משרד האנרגיה), לרבות הפליטות הצפויות בשלב הקידוחים; בשלבי ההפקה וההולכה; פליטות ממתקן הנזלה FLNG ו/או שינוע הגז באמצעות צינורות; יחד עם הרחבת התפוקה במשק הגז הישראלי כפי שדווח לאחרונה על ידי החברות המפעילות את האסדות הקיימו בישראל, והתייחסות ל Scope 3 emissions (פליטות בלתי ישירות הכרוכות בתהליך חיפוש והפקת הגז) – יביאו להגדלה משמעותית של מצאי פליטות גזי החממה הצפויות של ישראל, ויפגעו ביכולת של מדינת ישראל לעמוד ביעדי הפחתת הפליטות אליהן היא מחויבת במסגרת הסכמי האקלים.

23. לטובת כימות מספרי של תוספת הפליטות הצפויה ממהלכים אלו, הוזמנה על ידי מרשתי חוות דעת מומחה, אשר מבקשת להעריך במדויק את תוספת פליטות גזי החממה, ביחס ליעדי ההפחתה של ישראל ישראל לשנים 2030, 2040 ו2050, ובהתאם ל"תקציב פחמן".

24. כך או כך וכפי שיפורט להלן, אם יוגדל ייצור הגז הטבעי בישראל ובהתחשב בשיעורן בפועל של פליטות המתאן בישראל, יביא הדבר בהכרח לפגיעה ביכולתה של מדינת ישראל לעמוד ביעדי הפליטה שנטלה על עצמה, לרבות בהפחתה ההדרגתית הנדרשת של פליטות גזי החממה בתקופה הצפויה עד למועד העמידה ביעד. בחוות דעתו הראשונית התייחס לכך המומחה מטעמה של מרשתי בציינו:

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[13] https: //www.iea.org/news/methane-emissions-from-the-energy-sector-are-70-higher-than-official-figures

[14] https: //www.globes.co.il/news/article.aspx?did=1001413504

"מבחינה ראשונית עולה כבר עתה, כי בהתחשב בקצב הגידול הטבעי הצפוי באוכלוסיית ישראל... הרחבת משק הגז, שעיקרה באפשרות לגילויים והפקתם של בארות גז טבעי נוספים מכוח ההליך התחרותי הרביעי לחיפושי גז בים התיכון, תביא להגדלה משמעותית של מצאי פליטות גזי החממה הצפויות של ישראל, וייתכן שאף תסכל את יכולתה של מדינת ישראל לעמוד ביעדי הפחתת הפליטות אליהן היא מחויבת במסגרת הסכמי האקלים והתחייבויות אחרות, לרבות הפחתת פליטות הדרגתית לאורך השנים, עד להגעה לשנות היעד 2030 ו-2050."

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.25 ודוק. בהתחשב בכך כי משק הגז הישראלי אינו הגורם היחידי הגורם לפליטות של גזי חממה ונוכח העובדה כי קיימים מקורות משמעותיים נוספים של פליטות גזי חממה בישראל, **מובן כי קידום ההליך התחרותי הרביעי והמשך פיתוחו של משק הגז הישראלי יביא בהכרח לכך כי מדינת ישראל לא תוכל לעמוד ביעדי ההפחתה שנטלה על עצמה**.

.26 כך למשל, שיעור פליטות גזי החממה מתעשיית המלט, התחבורה הימית והתעופה בישראל לבדם הגיע לסך של כ – 7 מיליון טון בשנת 2021 המתווספים (יחד עם מקורות נוספים) לפליטות גזי חממה שמקורם ממשק הגז והנפט. תחום נוסף אשר לא זוכה לטיפול נאות הינו הפסולת שפולט כמויות הולכות וגדלות של גזי חממה.

.27 דברים אלה רק מקבלים משנה תוקף נוכח העובדה כי על פי מיטב ההערכה והידוע כיום, היכולת להביא בעתיד להפחתה משמעותית (אם בכלל) של פליטות גזי חממה ממגזרים אלה נמוכה ביותר כך שבמידה גבוהה מאוד של ודאות ניתן להניח שגם בשנת 2050 שיעור פליטות גזי החממה ממגזרים אלה יהיה משמעותי ביותר ויעלה באופן משמעותי את סך פליטות גזי החממה בישראל בשנה זו. כל זאת, עוד לפני שנלקחה בחשבון האפשרות כי שיעור הפליטות ממגזר המלט, התחבורה הימית והתעופה יעלה בהתאם לעלייה ברמת החיים וגידול האוכלוסין בישראל.

.28 האמור לעיל מוביל אפוא למסקנה כי המשך פיתוחו של משק הגז והנפט הישראלי יביא בהכרח להפרת התחייבויותיה של ישראל לעמידה ביעדי הפחתת פליטות ולפגיעה בסביבה, על כל המשתמע מכך.

ה. קידום ההליך התחרותי הרביעי נעשתה ללא בסיס מקצועי איתן ובהתבסס על תשתית עובדתית חסרה

.29 כפי שצוין בהרחבה לעיל, אם ימשיך הליך פיתוחו של משק הגז והנפט בישראל הדבר יהיה מנוגד באופן חזיתי להתחייבויות שנטלה על עצמה ישראל בעניין ובכלל זה בניגוד להחלטת הממשלה מס' 171.

.30 כידוע, החלטתה של הרשות המנהלית צריכה להתבסס על בסיס עובדתי איתן ולאחר שנשקלו כל השיקולים הרלוונטיים לעניין. הדברים מקבלים משנה תוקף, נוכח ההשפעה העצומה של הליך זה, כפי שתואר בהרחבה לעיל, על יכולתה של ישראל לעמוד ביעדי הפחתת הפליטות שנטלה על עצמה.

31. למיטב ידיעתה של מרשתי, במסגרת הדיונים של הגורמים הנוגעים בדבר במשרד האנרגיה ובמועצת הנפט טרם ניתנה ההחלטה לקדם את ההליך התחרותי הרביעי, לא הובאו וממילא לא נשקלו השיקולים הרלוונטיים ביחס להשפעתו של הליך זה על יכולתה של ישראל לעמוד ביעדי ההפחתה.

32. למעשה, הגורמים הנוגעים בדבר כלל לא לקחו בחשבון את השפעותיו האפשרויות של ההליך התחרותי הרביעי על יכולתה של מדינת ישראל לעמוד ביעדי ההפחתה, ואת השלכות המהלך בכל הנוגע לתוספת פליטות גזי חממה של מדינת ישראל. מדובר בפגם מנהלי חמור היורד לשורשו של עניין המטיל צל כבד על ההחלטה לפרסם את ההליך התחרותי הרביעי.

33. אשר על כן, בנסיבות שנוצרו ונוכח האמור לעיל נבקשכם להורות על ביטולו של ההליך התחרותי הרביעי לאלתר.

34. אודה לתשובתכם המהירה לאורה תוכל מרשתי לכלכל את המשך צעדיה.

בכבוד רב,

מתן גרפינקל, עו״ד

העתק: גב׳ עידית סילמן, השרה להגנת הסביבה
מר שגיא גנות, משרד האנרגיה

א'

תמצית חוות דעת – גידול צפוי בפליטות גזי החממה הנובעות מהרחבת משק הגז

לאחרונה, מדינות רבות מתחייבות לאפס את פליטות גזי החממה נטו שלהן עד 2050/60 וחלקן אף מיישמות אסטרטגיות שונות תוך התמקדות בפליטות המתאן, בשל היותו גז חממה בעל פוטנציאל חימום גבוה בהרבה מפחמן דו חמצני. אחד התורמים העיקריים לפליטת גזי חממה הוא מגזר הפקת הנפט והגז, וככל שהביקוש וההפקה של גז טבעי עולה, חשוב להבין מהי השפעת מגזר זה על האקלים. מתאן הנפלט מרשתות אספקת הגז הטבעי הוא מקור משמעותי לפליטת גזי חממה ברחבי העולם, אך קיימת אי ודאות לגבי שיעור הפליטות בגלל בעיית המדידה במיוחד במאגרי גז בים (בהשוואה למאגרי גז יבשתיים). בהתאם לכך, מושקעים מאמצים רבים לכימות פליטת מתאן מתהליכי הפקה וייצור של גז טבעי באופן מדויק. עם זאת, אזורים רבים בעולם חסרים ידע ויכולות לכמת את פליטת המתאן שלהם באמצעות שיטות מדידה ישירות (IEA, 2021) וכתוצאה מכך, רבים מסתמכים על גורמי פליטה בפועל כדי להעריך את פליטותיהם.

בנובמבר 2021, לקראת ועידת האקלים בגלזגו, העבירה מדינת ישראל למזכירות UNFCCC יעדי הפחתת פליטות מעודכנים. במסגרת יעדים אלו התחייבה ישראל להפחתת פליטות גזי חממה עד שנת 2030 ב27% פחות מהכמות השנתית שנמדדה בשנת 2015, אשר עמדה על 79 מיליון טון. כלומר, בשנת 2030 אמורה לעמוד הכמות השנתית של פליטות גזי חממה על כ- 58 מיליון טון. בנוסף, מדינת ישראל התחייבה להפחתת פליטות גזי חממה עד שנת 2050 ב-85% מהכמות השנתית שנמדדה בשנת 2015. כלומר, בשנת 2050 אמורה לעמוד הכמות השנתית של פליטות גזי חממה בישראל על כ- 12 מיליון טון. עוד יובהר כי על מנת להבטיח עמידה ביעדי הפחתת פליטות, נדרש קצב הפחתה הדרגתי אך עקבי. כך למשל, עבור עמידה ביעדי הפחתת פליטות עד שנת 2030, נדרש קצב הפחתה של כ-4% בכל שנה. עמידה ביעדים של 2050 דורשת הפחתה בקצב של 7.5% לשנה בין 2030 ל- 2050, על פי תרחיש עסקים כרגיל.

לבקשת ארגון גרינפיס ישראל, נתבקשתי לכתוב חוות דעת אשר בוחנת את צפי תוספת פליטות גזי החממה בישראל מפיתוח אפשרי של מאגרי גז חדשים בהיקף של BCM 1000-500. עבודה זו תבחן את הפליטות המוקדיות והבלתי מוקדיות ממאגרי גז חדשים, אלה שפיתוחם עומד על הפרק במסגרת ההליך התחרותי הרביעי ומהתשתיות הנלוות להם. פליטות אלו יצטרפו למצאי הפליטות הקיים היום והצפי להרחבת השימוש במאגרי הגז הקיימים ברשותה של מדינת ישראל ובכללם : מאגר תמר, לוויתן וכריש-תנין.

חוות הדעת מבקשת להראות את התרומה של תוספת הפליטות שצוינה לעיל, לאורך השנים, ועד הגעה לשנת היעד 2050. תוספת זו תוצג גרפית ביחס לקצב ההפחתה השנתי הנדרש עבור עמידה ביעדי הפחתת פליטות אליהם התחייבה מדינת ישראל בהסכמי האקלים.

מבחינה ראשונית עולה כבר עתה, כי בהתחשב בקצב הגידול הטבעי הצפוי באוכלוסיית ישראל, בין 1.4% ל 2% בכל שנה, אשר כרוך בתוספת פליטות, ובהתחשב בתוספת הפליטות אשר תוצג בעבודה, הרחבת משק הגז, שעיקרה באפשרות לגילויים והפקתם של בארות גז טבעי נוספים מכוח ההליך התחרותי הרביעי לחיפושי גז בים התיכון, תביא להגדלה משמעותית של מצאי פליטות גזי החממה הצפויות של ישראל, וייתכן שאף תסכל את יכולתה של מדינת ישראל לעמוד ביעדי הפחתת הפליטות אליהן היא מחויבת במסגרת הסכמי האקלים והתחייבויות אחרות, לרבות הפחתת פליטות הדרגתית לאורך השנים, עד להגעה לשנות היעד 2030 ו2050.

תכולת העבודה:

1. סקירת ספרות - פרק זה יבחן את השיטות הקיימות למדידת פליטות גזי חממה ובדגש רב על פליטות מתאן (CH_4). מיפוי ואפיון מקורות הפליטה הפוטנציאליים של מתאן לאוויר מחולק למקטעים שונים בהתבסס על הפירוט במדריך של IPCC ובמצאי פליטות גזי החממה הלאומיים של המדינות האחרות שנסקרו. הטכנולוגיות והאמצעים השונים הקיימים בתעשיית הגז והנפט, ובהתאם לכך גם הפליטות, עשויות להשתנות מאוד בין מדינות שונות ולאורך זמן.
2. מתודולוגיה - פרק זה יבחן את שיטות החישוב למדידת פליטות גזי חממה ממאגרי גז והתשתיות הנלוות להם, ויציג את היתרונות והחסרונות של כל שיטה מדידה. לאחר בחינת השיטות הרלוונטיות תבחר שיטת מדידה מיטבית עבור אזור ים התיכון וחישוב פליטות גזי החממה ייבחן על ידי שיטה זו. בנוסף פרק זה ישווה את התוצאות עם מדידות קודמות שנעשו בארץ על ידי גופים שונים. במידה ואכן ימצאו שינויים בין החישובים שנעשו עד כה לבין תוצאות המודל והחישובים החדשים, הם יוצגו בעבודה.
3. הצגת התוצאות - פרק זה יציג את תוצאות המחקר עם הסבר מורחב על שיטות החישוב ומידת דיוקם לעומת שיטות אחרות.
4. מסקנות - פרק זה יסיק את המסקנות העולות מעבודת המחקר, ויבחן את תוספת פליטות גזי החממה ביחס לקצב ההפחתה הנדרש לעמידה ביעדים אליהם התחייבה ישראל, בין השנים 2015-2050. אלו הן השנים הקריטיות להפחתת פליטות גזי חממה, בהתאם לדוחות מדעיים וכן למחויבות ישראל בהסכמי האקלים.

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