# A radical transformation of mobility in Europe: Exploring the decarbonisation of the transport sector by 2040

## Explorative scenario and related policy packages

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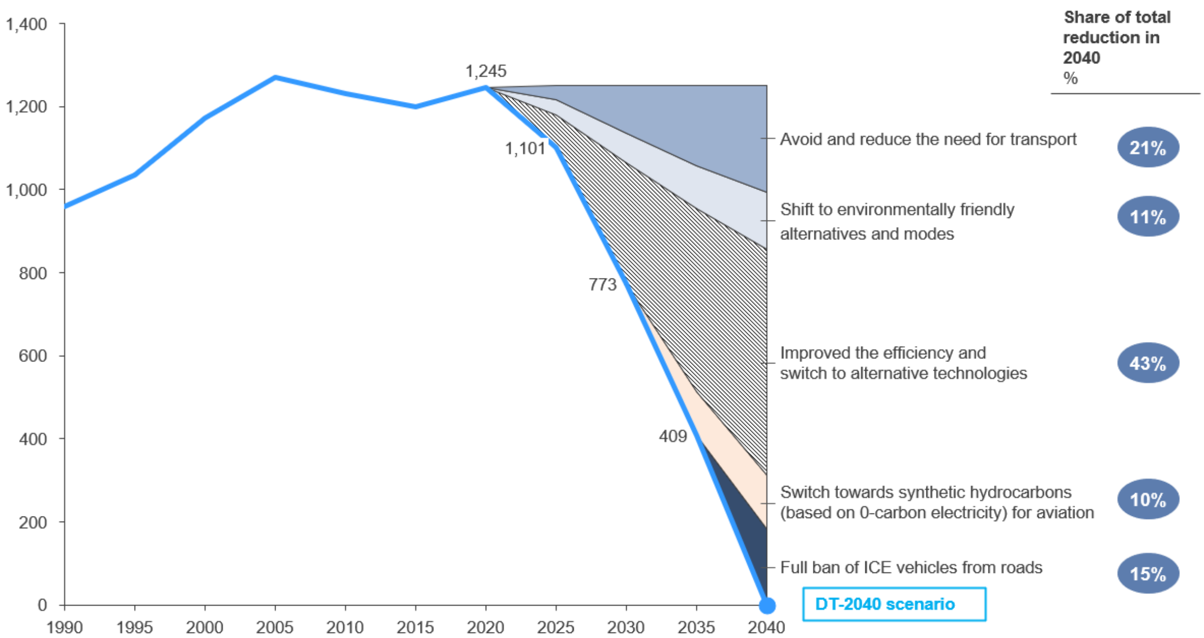
# Executive summary

Potential threats linked to climate change compel us to drastically reduce greenhouse gas (GHG) emissions. To even have a chance of limiting the global temperature rise to 1.5°C requires that global emissions reach net-zero as soon as possible. The EU can play a leading role in this transition with ambitious targets and policies. **The transport sector accounted for 27% of EU emissions in 2017** and is the only sector that has seen emissions increase since 1990. Reversing this trend is as essential as it is complex. The hurdles for changes lie in the scale of the societal, technological and economic shifts needed: our mobility accounts for 26% of total EU energy consumption, using a fleet of ~260 million cars that are primarily powered by oil. (EEA, 2019)

This study explores **a future in which the EU effectively targets zero emissions by 2040 for the transport sector** without relying on biofuels (further information on the position on biofuels in footnote 8). This explicit objective would enable a transition consistent with the magnitude and speed prescribed by the scientific community. It examines the intermediary targets required; it highlights and discusses some of the key economic risks, challenges and benefits associated with these profound efforts (e.g. the yearly production of cars); it recommends a set of policy packages that need to be implemented.

The global **Covid-19 pandemic** has brought with it widespread disruption including a drastic drop in mobility demand as well as global behavioural changes such as remote working that were not conceivable before. Due to its scale and impact, the pandemic is a key moment for society to reflect on its priorities and an unprecedented opportunity to consider the future of certain sectors, including transport. It is not the aim here to contribute to the recent – albeit speculative – body of literature on the impact of Covid-19. While we acknowledge the fact that Covid-19 will have an impact on transport demand, this work primarily aims to highlight a pathway and policy options that exist to reach full decarbonisation by 2040.

Figure 1:Yearly emissions - DT-2040 scenario (million tonnes of $CO_2$).



The scenario detailed in this study ("DT-2040", short for "Decarbonisation of European Transport by 2040") highlights the fact that if the EU hopes to complete decarbonisation of the transport sector by 2040, concerted and ambitious policy actions are required in all areas (see Figure 1). While supply-side measures are undeniably essential to reducing emissions, this study illustrates how **demand-side measures** such as demand reduction and a modal shift facilitate the transition by reducing the scale of deployment of new technologies to challenging but plausible levels. To date, policies to improve the vehicle fleet, such as emission standards and electric vehicle incentives and policies, have been at the core of European and Member State policy developments, with mixed impact on the transport sector. However, the scenario shows that to improve the technical feasibility of the transition, passenger vehicles not only need to shift to lower-emission alternatives, but transport demand and private vehicle use also need to be reduced significantly. The decarbonisation scenario assumes a reduction in total passenger transport demand of -12% as well as a -33% reduction specifically for air transport, both by 2040 (versus 2020 – the box below gives more explanation on taking 2020 as benchmark year). Private vehicle use is assumed to decrease to an average mode share of 43% in urban areas by 2040 (from 62% in 2015), with some urban centres going much below this figure, and 68% in rural areas (from 79% in 2015) by 2040. Hence efforts to reduce transport demand and shift to sustainable transport modes beyond current good practice will be crucial to achieving full decarbonisation by 2040.

In order for the **supply side** to contribute at the scale needed, current efforts also need to be scaled up quickly. Supporting innovation and enabling the massive deployment of new technologies will be key to achieving zero emissions. The shift to electric mobility must be accelerated: DT-2040 describes a future in which all new light-duty vehicles (LDVs) sold by 2028 are zero emission. This means emission standards need to be on a path to reach zero emissions by 2028, or policies with a similar effect need to be implemented, effectively ending the sales of new internal combustion engines. Concerted policy packages, such as those currently found in Norway, need to be implemented across the board in Member States to accelerate the uptake of electric vehicles. Policy makers and car manufacturers need to collaborate closely to ensure this can be done with as little friction as possible, without losing the ambition levels required.

But even these ambitious measures will not be sufficient to achieve a zero-emission fleet by 2040: the "natural" renewal rate still results in a fleet composed of ~39 million internal combustion engine (ICE) LDVs in 2040 (or 28% of the remaining fleet of 137 million passenger vehicles, which is down almost -50% compared with 260 million in 2015). To achieve decarbonisation by 2040 without biofuels, these cars would need to be powered by synthetic hydrocarbons, or banned entirely. However, synthetic hydrocarbons are not considered for road transport in the DT-2040 scenario, but only for modes where alternatives do not seem feasible, such as aviation. Indeed, our analysis shows that the volume of synthetic hydrocarbons needed for the remaining ICE LDVs requires unrealistic levels of electricity production. This is mainly due to the very low efficiency of producing these fuels. Therefore, synthetic hydrocarbons based on zero-emission electricity are one piece of the puzzle, but must always be considered as a last resort. And many other concerns remain in addition to low efficiency: their development is still in its infancy, they would need to rely on direct air capture to be fully decarbonised, and their deployment only makes sense if the electricity itself is clean, which would require massive deployments of zero emission electricity capacity. Therefore, **a ban on the use of all ICE passenger vehicles by 2040** is considered the only plausible option to decarbonise road transport. Such a ban could be progressive, and requires support for alternative modes of transport and the uptake of electric vehicles, with cities able to play a pioneering role by imposing bans earlier. The box below highlights some of the key assumptions and technical results of the DT-2040 scenario.

On the demand side, **policies to avoid and reduce the need for transport** and to shift to more environmentally friendly transport modes have received much less attention, and lack coordination at EU level. Lower passenger transport demand is key since this will directly reduce the technological efforts required, both for direct and indirect electricity demand as well as for e-fuels in air transport. The efficiency gain and the demand reduction will indeed bring energy consumption down by 54% in 2040 compared with 2015. It is important to note that these numbers are based on the assumption that sufficient zero emission based synthetic aircraft fuel can be produced at commercial scale. If such technological development does not follow, a more stringent reduction in transport demand will be needed. To achieve transport demand reduction at such a scale, new and innovative policy solutions will be needed that go beyond existing policies, such as a straight-forward ban of short-to-medium distance flights. Passenger road and air transport needs to shift to rail, public transport and non-motorised transport where applicable.

**Freight transport** needs to shift from road transport to rail and inland waterways. The DT-2040 scenario assumes a decrease from 6 to 3 million trucks on the road by 2050 (3.6 million by 2040). Policies to develop sustainable – especially rail – infrastructure need to be scaled up significantly, and intermodal freight transport should be incentivised more proactively. It is also important to keep in mind that the shift to electrified transport and synthetic fuels requires a simultaneous transition in the power sector: the shift to zero emission energy sources must be accelerated and deepened.

**Large investments in transport infrastructure** are required to enable the transition to zero-emission mobility. This is particularly relevant since today's decisions on investments oriented towards medium to long-term transport solutions (freight logistics, railways, bus fleets and more) will shape the transport infrastructure of 2040 and beyond. Thus, it is essential to avoid any further lock-ins into carbon intensive infrastructure – such as highways or airport expansions – as soon as possible. This requires immediate policy action.

The transition to a zero-emission transport sector requires **ambitious actions by all stakeholders**, on all fronts, and needs to start now. To remain consistent with the Intergovernmental Panel for Climate Change (IPCC) scenarios in line with global warming of 1.5°C, additional and more ambitious measures to quicken the reduction of fossil fuel consumption need to be put in place. Active support will be needed from all actors: policy makers, businesses and civil society, an implicit yet central assumption in the scenario. Some policies are context-dependent (e.g. population density) and some will work in some constituencies and not in others. As such, some policies will inevitably fail, thus only a concerted effort at all levels of policy-making and of the economy can lead to success. The limited time horizon and the ambition level needed to decarbonise the European transport sector by 2040 require stringent action and ambitious policies on all fronts and on all levels.

## Key results and assumptions of the Decarbonised scenario (DT-2040):

**Some key assumptions** (all the assumptions are detailed in Appendix):

- **Base year:** this report often uses 2020 as a benchmark. Naturally, there is currently no data available for this year. 2020 in this report is thus an estimation made by extrapolating data from the past (the latest available). This will obviously be affected by the distortion in mobility caused by the COVID lockdown. 2020 figures have hence to be understood as an estimation of the data underlying current behaviours under "normal" circumstances.
- **Demand reduction in passengers transport** (excluding aviation): -15% of demand (in passengers.km) between 2020 and 2050. This means a reduction of -12% between 2020 and 2040.
- **Aviation** (international (from and to Europe) included): Linear -33% reduction of demand (in passengers.km) between 2020 and 2040 and -50% between 2020 and 2050.
- **Slight increase of demand in freight transport:** +15% between 2020 and 2050 (+10% between 2020 and 2040) (vs +48% in the REF scenario).
- **Modal share shift**: from 62% of passengers transport by cars towards 43% in urban areas (in 2040). From 79% to 68% in non-urban areas between 2015 and 2040.
- **Occupancy and utilisation rate for passenger transport:** respectively +25% and +20% for LDVs between 2020 and 2050. This means that cars will be increasingly shared – decreasing the number of vehicles needed to perform a given demand.
- **Load factors and utilisation rate for freight transport:** respectively +5% and +3% between 2020 and 2050.
- **Technology share of new vehicles**: for LDVs – only electric and hydrogen vehicles are sold as of 2028.
- **Biofuels**: no biofuels modelled in the transport energy consumption (for more information see footnote 9).
- **ICE vehicles circulation ban (all vehicles - not only sales):** Complete ban as of 2040.
- **Phase-in of alternative synthetic fuels (e.g. e-fuels):** starts in 2030, completely replacing the remaining fossil fuels by 2040 in aviation and maritime.

**Some of the key results**

- The transport sector is fully decarbonised in 2040 (aviation included) and emissions are reduced by -38 % in 2030 (vs 2020).
- Efficiency gains & demand reduction will bring energy consumption down by -54% between 2015 and 2040.
- The passenger vehicle fleet is reduced by -27% in 2030 (compared to 2015).
- The amount of High Duty Vehicles is stabilized from 6 million to around 3 million vehicles by 2050.
- For freight (excluding maritime transport), inland waterways and rail double their share up to 58% in 2040, with the modal share of rail going from 15 to 36% in 2040 and the modal share of IWW from 14 to 22% in 2040.
- The use of synthetic hydrocarbons is focused on aviation and is rising to 620 TWh (final energy consumption) in 2040.
- Altogether power demand for transport rises to ~3,300 TWh (which is roughly similar to the total EU production in 2015).

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# Abbreviations

| | |
|---|---|
| **BEV** | Battery Electric Vehicles |
| **$CO_2$** | Carbon Dioxide |
| **$CO_2e$** | Carbon Dioxide Equivalent |
| **DT-2040** | Decarbonisation of European Transport by 2040 |
| **EU** | European Union |
| **EUCalc** | European Calculator |
| **EU-REF16** | Reference scenario (baseline) developed by the EU in 2016 |
| **EV** | Electric Vehicles |
| **FCEV** | Fuel Cell Electric Vehicles |
| **GHG** | Greenhouse Gases |
| **HDV** | High Duty Vehicles (Trucks) |
| **ICE** | Internal Combustion Engine |
| **IPCC** | Intergovernmental Panel on Climate Change |
| **IWW** | Inland Water Ways |
| **LDV** | Light Duty Vehicles (cars and vans) |
| **LTS** | Long-Term Strategy (of EU Commission, 2018) |
| **MS** | Member States |
| **RES** | Renewable Energy Source |
| **PHEV** | Plug-in Hybrid Electric Vehicles |
| **ZEV** | Zero-Emission Vehicles |

# 1 Introduction

## 1.1 Purpose of the report: Climate technical implications of decarbonising transport by 2040 and the associated policy packages needed

**The scenario describes the implications of achieving decarbonisation of the EU transport sector by 2040 and explores the consequences for other sectors (power and industry).** The explicit objective (see Box 1 below) is to describe a transition characterised by bold action that strives for consistency at the magnitude and speed prescribed by the scientific community. The IPCC made clear that drastically reducing emissions to achieve net zero emissions by 2050 is necessary to limit global warming to 1.5°C. The present study's goal is to define and analyse a "what-if" scenario where Europe decarbonises the transport sector by 2040 instead of 2050 to preserve the carbon budget and gives more time to less advanced regions[1]. To this end, the study shows the intermediary targets to be set, the policy packages to be implemented, and the associated economic risks, challenges and opportunities.

All transport modes are covered: surface transport (cars, trucks, trains, buses, bicycles, walking), air transport and water-based transport. Both freight and passenger transport are considered, and distinct assumptions are made for urban/non-urban geographies[2].

**This decarbonisation scenario serves as a quantitative basis to list different packages of policies** that would consistently support achieving the targets for GHG and local pollutants emissions, as well as the energy consumption, technology shift and behavioural changes prescribed.

### Box 1: Transparency on the approach

Theoretically, an infinite number of trajectories exist to reach zero-emission by 2040. How did the authors shape and select one single trajectory? A scenario consists of a narrative that helps define a set of constraints and initial assumptions that can feed a quantitative model, eventually resulting in a set of output indicators. These output indicators are either predetermined by the initial constraints (for example, in this case, the GHG emissions), or a consequence of these constraints (for example, the size of the vehicle fleet). This report's initial constraints and narrative were essentially rooted in scientifically based assumptions supported by Greenpeace (i.e. swift decarbonisation of the transport sector) and EuCalc parameters (see 2.1.3. for more details). Many of the final assumptions are the results of an iterative process (described in section 2.1) between Greenpeace, NewClimate Institute, Climact and external experts, in particular Transport & Environment, based on intermediary results of the model provided by Climact.

[1] A 2040 target would also be more in line with an equitable or "fair" contribution by Europe, see for example the Climate Action Tracker analysis for the EU at https://climateactiontracker.org/countries/eu/.

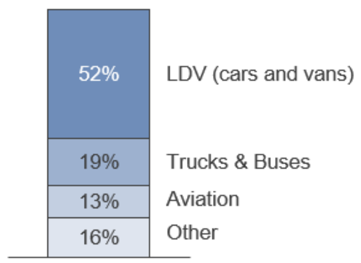
[2] The distinction between "urban" and "non-urban" is based on TRACCS data (EMISIA, INFRAS, IVL, 2013) – itself based on the data received from each EU Member State. Unfortunately there is no common definition of what constitutes an "urban area": each country defines it differently. More details and an explanation can be found on page 75 of the TRACCS report.

## 1.2 Current situation: Transport is a major contributor to EU emissions

**In many ways transport is one of the most challenging sectors in the EU. Transport accounted for ~27% of total EU GHG emissions in 2017, and these emissions have grown by 27% between 1990 and 2016** (European Environment Agency (EEA), 2019)[3]**. It is the only sector in the EU whose emissions have increased.** More than half of these emissions come from cars and vans (or Light Duty Vehicles/LDVs), almost a fifth from Trucks (HDVs) and buses[4], and 13% from aviation (including international transport but excluding any non-$CO_2$ effects which have been estimated to double the impact of aviation emissions[5]). Transport emissions decreased between 2007 and 2013 but have not stopped rising since then.

Figure 2: Total historical emissions in European Union (million tonnes of $CO_2e$) (Source: EEA)


Figure 3: Share of emissions per mode[6] (%)




**While there is talk of net zero GHG ambitions for Europe, the latest targets and the most recent official scenarios do not aim for full decarbonisation of transport.** The two most ambitious scenarios developed by the EU Commission (1.5 LIFE and 1.5 TECH) assume ~90% in 2050 in EU's Long-Term Strategy 'A clean planet for all'[7]. This means that a significant part of direct emissions has to be captured and sequestrated, even in the EU's most ambitious scenarios.

As part of the European Green Deal, new targets are being suggested based on the above-mentioned scenarios: the European Commission has set an aspirational target of 90% reduction in transport emissions by 2050 in order to achieve overall climate neutrality. Whilst this is a significant improvement compared to previous commitments, more ambition is needed when analysing carbon budget concerns (see (Transport & Environment, 2018)). Indeed, both the target (aiming at full decarbonisation instead of a 90% reduction) and the timing (from a carbon budget perspective, 2040 is more appropriate than 2050) can be improved although this would require bold actions and far-reaching policies. Since most of the concrete measures and legislation changes are still to be defined within the above mentioned Green Deal, this study also recommends policy packages to support these targets.

[3] Excluding LULUCF and considering bunkers (international aviation and shipping) as part of transport emissions.
[4] In this study, HDVs do not include buses but only trucks (split into 3 categories)
[5] See https://www.transportenvironment.org/sites/te/files/publications/2017_06_non-CO2_aviation_briefing_final_0.pdf
[6] In 2015.
[7] (European Commission, 2018)

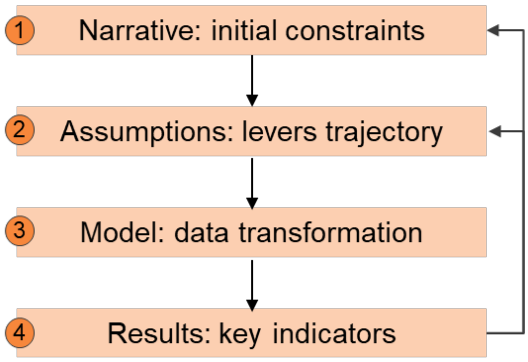
# 2 Decarbonisation of the transport sector by 2040 scenario ("DT-2040")

## 2.1 Scope and approach

This study covers all transport modes within the EU-28 and Switzerland. Land, air and water-based passenger and freight transport are considered. Indicators such as emissions, energy consumption and total number of kilometres (for passengers or tonnes of freight) are computed from 1990 until 2050 for each transportation mode (LDVs, buses, airplanes, etc.), technology (ICE, BEV, etc.) and type of fuels (petrol, diesel, jet fuel or kerosene, etc.). In addition, the study leverages the capabilities of the European Calculator (EUCalc) model and describes the impact of this transformative scenario on the power and industry sectors.

The scenario described in this report is the result of a 1 year process consisting of several iterations around its key components: high-level narrative, key underlying assumptions, model logic and key results[8]. The iterative aspect of the process is key to understand how a single trajectory was eventually selected. This iterative process is illustrated in figure 4 and explained in the next section (2.1.2). The authors developed the scenario using a combination of a normative and explorative approaches. It is "normative" since some elements of a "preferable future" are pre-defined (e.g. the level of yearly emissions to reach by 2040), and "exploratory" since other indicators are the consequences of those assumptions and hence not predefined (e.g. total energy consumption). Other assumptions are not part of the "preferable future" described but have to be predefined. The following sections describe each of these elements.

Figure 4: inspired by "Energy & Climate Scenarios" (The Shift Project, 2019)




### 2.1.1 Narrative – desirable future and necessary enablers

Initial determinants are listed below. Together, they make up the main elements defining the "preferable future" to be explored.

- **Environmental determinants**: the scenario must illustrate full decarbonisation of transport by 2040 without relying on the use of biofuels.
- **Political determinants**: the social acceptability (or the potential to overcome socio-economic hurdles) of new policies should be considered as high – allowing the implementation of approaches such as banning the sales of new ICE vehicles or supporting ambitious policies to reduce demand (e.g. increasing taxes on air transport). The political will to make the transition happen is considered high.

[8] See "Energy & Climate Scenarios: Evaluation and Guidance" from The Shift Project for more details. (The Shift Project, 2019)

- **Economic determinants**: macro-economic indicators (e.g. the evolution of GDP) are not a constraint. Techno-economic indicators (such as car fleet size or yearly sales of cars) resulting from the scenarios have been assessed to refine the scenarios.
- **Technological determinants**: the use of new technologies should not be avoided but the evolution of indicators such as the size of vehicle fleets or the deployment of new power capacity should be limited to what is necessary in order to reduce to a minimum high material use and the resulting indirect emissions.
- **Societal and behavioural determinants**: the potential for societal, social and lifestyle changes can be considered high. Pathways to ambitious demand reduction should be explored if they help reduce the technological burden.

Although desirable, the authors note that at the time of writing, the combination of these enablers has a low probability. This takes nothing away from the value of defining in detail a significantly transformative scenario based on such boundary conditions, particularly in light of the dire consequences of climate change in the case of inaction.

### 2.1.2 Assumptions used to feed the narrative and resulting indicators

Two different sets of inputs are used to feed the model. Historical data and parameters of “levers”. Levers are the main components of the EUCalc model (described in the next section). They consist of trajectories of key drivers of activities (e.g. how will the occupancy rate evolve from 2020 to 2050), energy consumption (e.g. how will the efficiency of combustion engines improve over time) and hence emissions.

The EUCalc model allows the user to define the value of key levers and evaluate the impact on, for example, emissions. The value of these levers is predefined in the tool based on experts’ indications or literature reviews. The modeller can select a level for each of these levers: from “business-as-usual” to “transformational”.

This scenario’s lever levels are either based on initial assumptions (when they are explicit, for example the absence of biofuels), or derived by the authors (based on the pre-filled value within EUCalc) to reach the preferable future goals (when they are not explicit, for example the modal share shift in passenger transport).

The question of feasibility is of course central when authors need to derive the assumptions listed in box 2. To do so, the authors - together with the group of experts listed in box 1 - followed the iterative process described in figure 4. A first selection of level is done, then the model is run, then resulting key indicators are assessed to conclude whether or not the trajectory is consistent with the initial narrative, plausible and minimizing the economic externalities. Based on this assessment, a new iteration is done. The trajectory presented in this study is the result of more than a year of this systematic looping process.

The resulting key indicators are extensively described in the section 2.2. They mainly consist of emissions per mode, energy consumption per mode and vector, size of fleet per mode and technology and yearly production of vehicles per mode and technology.

The assessment described in the previous paragraph is not automated nor were boundaries precisely defined per key indicator. It relied on the knowledge of experts (listed in box 1) and literature/database reviews (a simple example of this is the comparison of the transport sector electricity consumption to the current level of total electricity production in Europe). It is also important to note that several EuCalc parameters were adapted in this process: the list and the changes made can be found in appendix 1.

### 2.1.3 Model

This section briefly describes the EUCalc model and its transport module. More detailed documentation is provided in the Appendix.

EUCalc[9] is an economy-wide simulation model covering all 28 countries of the EU and Switzerland. It models the implications of lifestyle and technological choices on energy, GHG emissions, environment and resources up to 2050. Unlike optimisation models based on costs (e.g. computed general equilibrium models), EUCalc takes a bottom-up, lever-based approach. The demand for goods and services (e.g. transport, food or manufactured goods) drives the use of materials and energy and, eventually, GHG emissions. Furthermore, users can construct their own pathway by selecting the decarbonisation ambition level for the most important drivers, called levers in the model, such as building heating, appliance use, road travel by car, or freight demand. **EUCalc is not a forecasting model, in the sense that it does not attribute any probability to a given scenario, but rather a prospective model that aims to explore possible pathways to decarbonise Europe by 2050.**

In the present study, the EUCalc transport module is used to investigate a pathway to decarbonise transport in Europe by 2040 and to explore its implications. The sequence of transport levers is illustrated in Figure 5 for passenger transport (a similar rationale applies to freight). The total demand for passenger transport is split between urban and non-urban environments, depending on demographic and territorial trends. The model then determines the size of the fleet needed for all modes to satisfy this demand. Fleet and demand will depend on occupancy rate, utilisation rate and is split between the different modes (e.g. cars, buses or trains) for each type of geographic zone (urban and non-urban).

## Box 2: Some of the key assumptions made in this scenario

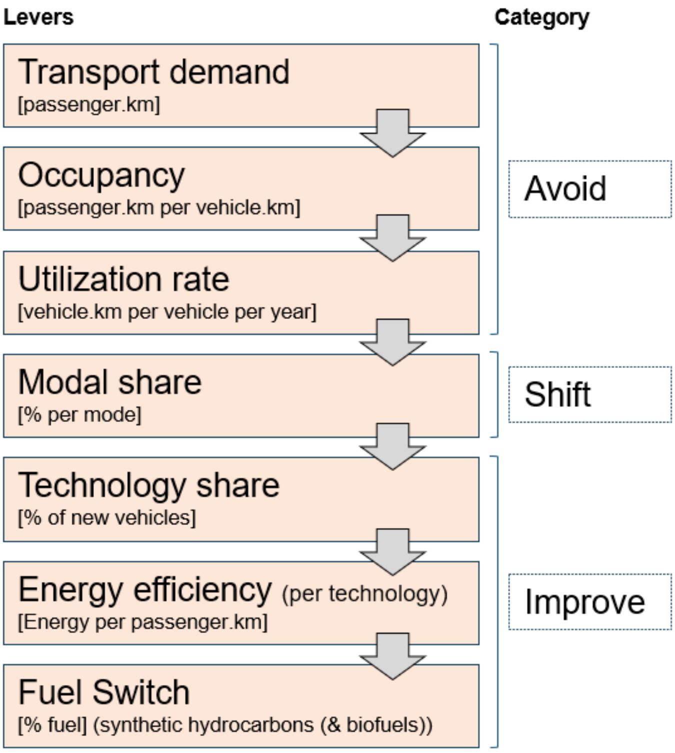
EuCalc standards assumptions usually use 2050 as target year. When useful, the derived value for 2040 is also listed below (all the assumptions are detailed in Appendix):

- **Aviation**: -50% of demand (in passengers.km) between 2020 and 2050. This translates into -33% between 2020 and 2040.
- **Demand reduction in passengers transport (excluding aviation)**: -15% of demand (in passengers.km) between 2020 and 2050. This means a reduction of -12% between 2020 and 2040.
- **Slight increase of demand in freight transport:** +15% between 2020 and 2050 (+10% between 2020 and 2040).
- **Modal share shift**: from 62% of passengers transport by cars towards 34% in urban areas and from 79% to 64% in non-urban areas, between 2020 and 2050. This means 43% in urban areas in 2040 and 68% in non-urban areas in 2040.
- **Occupancy and utilisation rate for passenger transport:** respectively +25% and 20% for LDVs between 2020 and 2050. This means that cars will be increasingly shared – decreasing the number of vehicles needed to perform a given demand.
- **Load factors and utilisation rate for freight transport:** respectively +5% and +3% between 2020 and 2050.
- **Technology share of new vehicles**: for LDVs – only electric and hydrogen vehicles are sold as of 2028.
- **Biofuels**: no biofuels modelled in the transport energy consumption[1].
- **ICE vehicles circulation ban (all - not only sales):** complete ban as of 2040.
- **Phase-in of alternative synthetic fuels** (e.g. e-fuels): starts in 2030, completely replacing the remaining fossil fuels in aviation and maritime by 2040.

[9] See www.european-calculator.eu.
Detailed documentation on EuCalc can be found using the following link: http://www.european-calculator.eu/wp-content/uploads/2019/09/EUCalc_Cross-Sectoral_description_September2019.pdf.
Detailed documentation on the Transport module can found using the following link: http://www.european-calculator.eu/wp-content/uploads/2019/09/EUCalc_Transport_documentation.pdf.

Finally, the efficiency of the different types of vehicles, the powertrain technologies and the fuel mix are used to determine total energy use and the related GHG emissions for the various transportation modes. The categories Avoid, Shift and Improve have been defined to facilitate presentation of the results. They are described in the following section.

Figure 5: Calculation sequence of levers for computing energy and emissions in transport




## 2.2 Results and selected comparison scenarios

The indicators and their results are described in detail in the following sections. The challenges and potential opportunities as well as their plausibility and consistency are the main dimensions that will be discussed. As explained above, this exercise shows what needs to be done to reach zero-emissions by 2040 assuming high political will, not what is likely to happen based on current trends.

### Avoid, Shift and Improve levers: Description

The results are illustrated using the Avoid-Shift-Improve framework – aligned with the policy analysis (Chapter 4) framework. '**Avoid'** levers aim to avoid and reduce transport activity and needs. They cover actions that reduce kilometre demand as well as the number of vehicles needed to meet such demand. '**Shift**' levers aim to shift to more efficient modes such as public transport. '**Improve'** levers concern making vehicles or fuel more energy efficient and less carbon intensive.

### Scenarios used as benchmark

The scenario developed in this report is compared with baseline scenarios. The main baseline is the REF16 scenario of the European Commission (EU-REF16) since it is the scenario with the most publicly available data [10]. However, it is less ambitious than the latest current development scenario (since new policies have been introduced in the meantime). Hence other scenarios are used to enrich the

[10] The data used to build the figures of this study are outputs from EuCalc. This is also the case for the EU-REF scenario that is directly available in the EuCalc tool. The data is thus not directly extracted from EU-REF. As a consequence, some indicators in this study can slightly differ from the exact EU-REF figures.

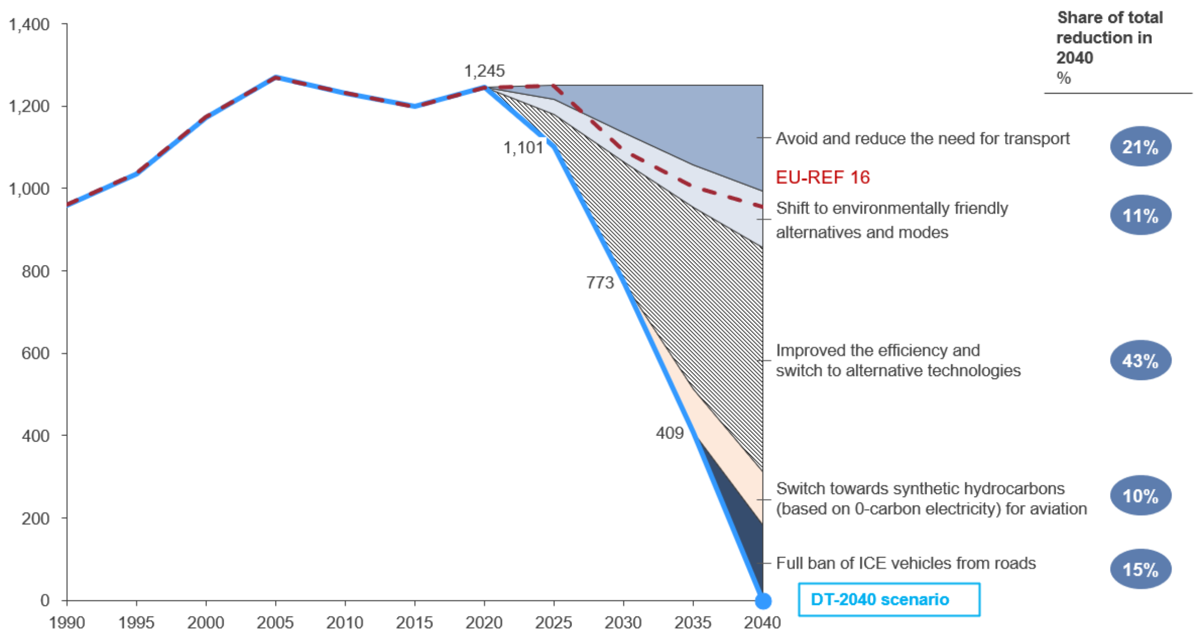
comparison when deemed helpful. The two main scenarios used are those of full decarbonisation of Transport & Environment[11], and the EU-LTS scenario LIFE1.5 of the EU Commission that achieves net-zero in 2050 – although emissions from transport are compensated with capture or sequestration in other sectors.

## 2.2.1 Global sectoral results

### *2.2.1.1 Overall emissions reduction and potential of mitigation levers*

The DT-2040 scenario reaches zero emissions by 2040 with a reduction of -38% by 2030 compared with 2020. Figure 6 highlights the contribution of 5 different groups of levers – labelled using the Avoid-Shift-Improve categories. Given their importance and their disruptive character, the impact of the switch to synthetic hydrocarbons[12] and the ban on all ICE vehicles are illustrated separately. Both demand-side (Avoid and Shift) and supply-side (Improve) measures have significant impact.

Figure 6: Yearly emissions: (i) Comparison between DT-2040 and EU-REF16 and (ii) mitigation potential of lever category (million tonnes of $CO_2$)




Computing cumulated emissions allows a better understanding of the underlying ambition of the scenario, a comparison of it to other scenarios, and connecting this to the overall carbon budgets. The DT-2040 scenario accumulates a carbon budget of ~17 gigatonnes of $CO_2$ until emissions come down

[11] See "How to decarbonise European transport by 2050" (Transport & Environment, 2018).

[12] Electro-fuels are often referred as outputs from "Power-to-Liquids" technologies. Synthetic hydrocarbons are a sub-category of electro-fuels. They replace diesel and gasoline with similar but manufactured fuels. Only synthetic hydrocarbons and manufactured hydrogen are available in EuCalc. Although not formally modeled, Ammonia ($NH_3$) is discussed in next sections. From an efficiency perspective (the total TWh of electricity needed to produce one TWh of the electro-fuel), ammonia and hydrogen are relatively similar. For this reason, they are considered jointly in the hydrogen category. Also note that the reduction potential of hydrogen and ammonia are not part of the category described in this footnote but the "Improve" one.

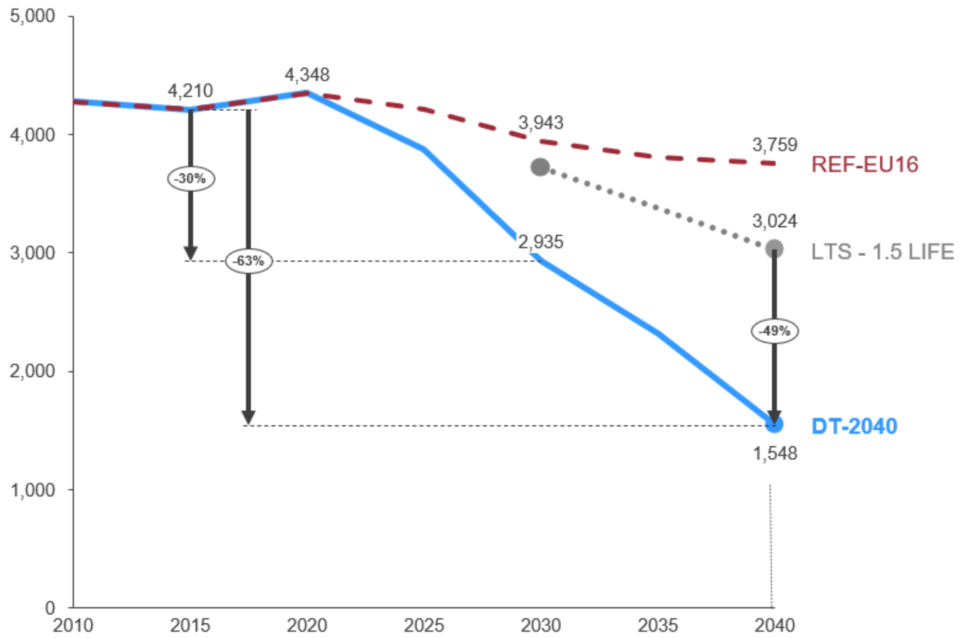
to zero in 2040[13]. This results in 50% less cumulated $CO_2$ emissions (between 2018 and 2050) for EU Transport compared with the EU-REF16 scenario.

### *2.2.1.2 Total energy consumption*

The decarbonisation of the transport sector is mainly driven by a complete phase-out of fossil fuel consumption and a drastic reduction of energy consumption (-26% of final energy consumption in 2030 and -55% in 2040 compared with 2015). This reduction is depicted in Figure 8 and include international shipping – Figure 7 does not include international shipping, for benchmarking purpose, as this sector is usually discussed but excluded from the EU final projections and scenarios.

In contrast, by 2040 the energy consumption from transport in the EU-REF16 scenario is more than three times higher than in DT-2040. DT-2040 also significantly differs from the EU LTS scenarios (approximately -12% in 2030 and -29% in 2040 compared with 2015 for EU LTS, versus respectively -30% and -63% for DT-2040)(European Commission, 2018)[14].

Figure 7: Yearly energy consumption: Comparison between baseline scenario (EU-REF16), EU LTS[15] and DT-2040 scenario (international shipping excluded)[14] (TWh)




[13] If one assigns the EU's transport sector a share of the global carbon budget based on its current share of global emissions for the EU transport sector carbon budget, the result for a 66% likelihood of staying below 1.5°C amounts to 9 gigatons. And for a 66% probability of remaining below 2°C, the budget amounts to 22.9 gigatons. Acknowledging the limitations of calculating carbon budgets for specific regions and even more so for specific sectors, this still signals that higher ambitions need to come from other sectors or that additional and even more ambitious measures to quicken the reduction in energy demand in the transport sector need to be put in place in order to remain in line with the 1.5°C carbon budget.

[14] International shipping is excluded from both comparisons since this sector is usually discussed but excluded from the EU final projections and scenarios.

[15] The energy consumption shown for the LTS-1.5 LIFE is the consumption in 2050. No data was found for 2040.

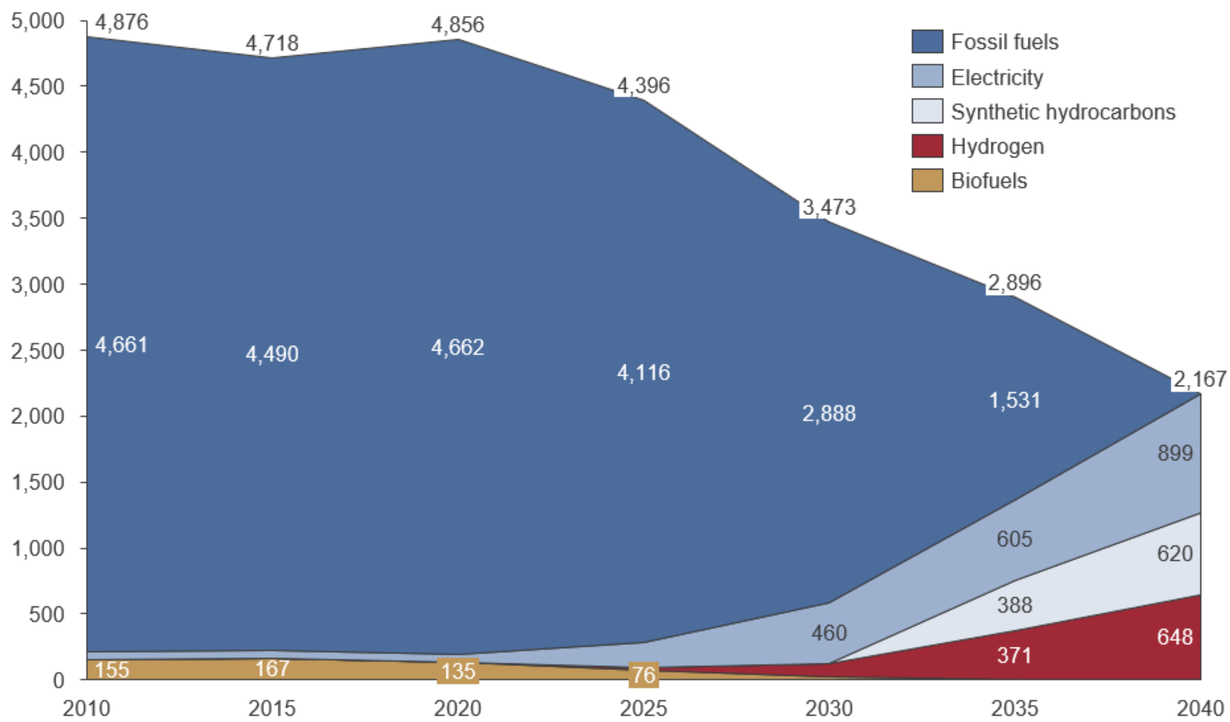
### *2.2.1.3 Energy mix*

Fossil fuel consumption is reduced by ~38% in 2030 (compared with 2015) in the DT-2040 scenario, and represents a share of 84% of total energy consumption in 2030 (2,888 TWh out of 3,472 TWh). It was 95% in 2015 and declines to 0% in 2040 in the DT-2040 scenario.

While energy demand reduction is mainly driven by the reduction in passenger transport demand (-15% for surface passenger demand by 2050), modal shift and utilisation rate, the switch to electricity also spurs significant improvements in efficiency, in turn lowering energy needs. In addition to this decrease in energy consumption, the full substitution in the energy mix results from a massive technological switch to electricity (significantly starting in 2020 in the model for LDVs) and electro-fuels (starting in 2030). It is important to remind the reader that the model tests the consequences of limiting the level of biofuel consumption to 0.

Switching to electricity-based transport (directly or indirectly) will lead to a massive increase in electricity demand and must go hand in hand with a shift to zero-emission based electricity production. The impact on the power sector and the need for electro-fuels will be discussed in Sections 2.2.2 (Box 3) and 3.3.

Figure 8: Evolution of the final energy consumption mix (including both passenger and freight across all modes and vehicle types) - DT-2040 scenario (TWh)



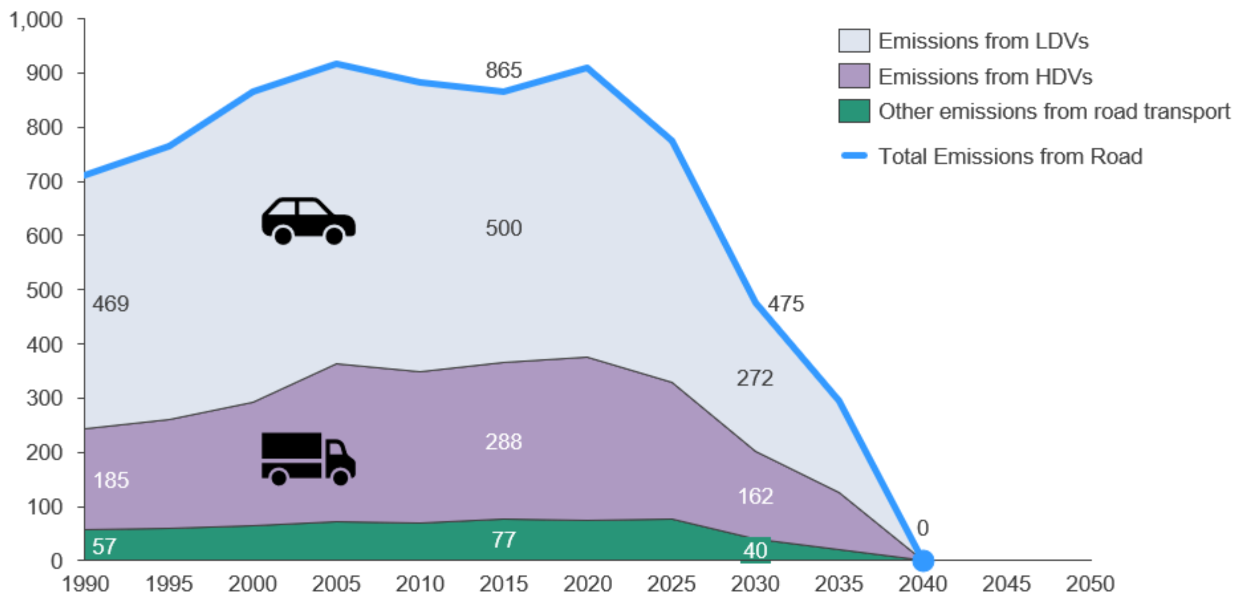
### 2.2.2 Land transport

This section focuses on land (or surface) transport. It starts by focusing on road emissions (and especially LDVs and trucks since they represent the major share of emissions), then enlarges the perimeters to discuss a potential shift to low-carbon and zero-emission modes such as bicycle, walking, rail, etc.

#### *2.2.2.1 Road emissions reduction and comparison with current targets*

Our analysis suggests a required $CO_2$ reduction of 15% by 2025 and 48% by 2030 (compared with current emissions) to reach full decarbonisation in 2040. The potential for mitigation comes from different categories of levers described in the following section. One key lever is the ban on sales of new ICE in 2028 for LDVs. On the one hand, this implies a strong increase in BEV production capacity in the coming years (described in Section 3.1). On the other hand, it also calls for an improvement in the current EU targets for emissions standards of new car sales, currently set at a 37.5% reduction of new ICE vehicles by 2030 (compared with 100% by 2028 in this study's scenario).

Figure 9: DT-2040 scenario: Road transport emissions in the EU - details for LDVs (passengers) and HDVs[16] (freight) (million tonnes of $CO_2$)



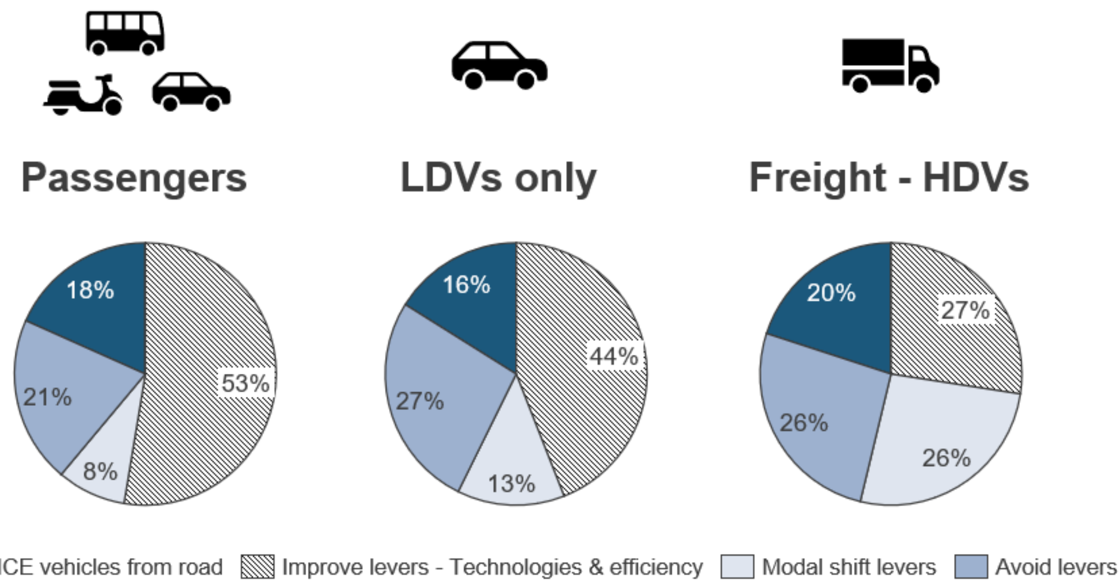

16 Only trucks – buses not included.

### *2.2.2.2 Mitigation potential of each category of levers*

Figure 10 below illustrates the fact that land transport requires the use of all lever families: demand-side measures (avoid and shift) as well as supply-side measures (improve and ban). The following sections define and discuss each of these in detail.

Figure 10: Contribution of the various lever groups to reducing emissions in road transport[17]

(% of total mitigation in 2040 vs 2020)




### *2.2.2.3 "Avoid" levers: Assuming a drastic reduction in demand for passengers and only a slight increase for freight*

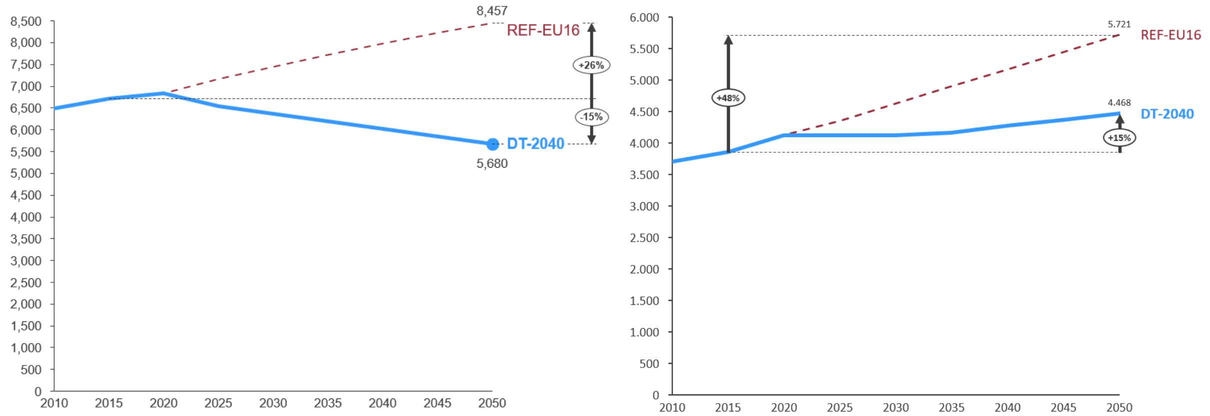
'Avoid' levers decrease the demand for passenger kilometres and limit the increase of freight transport kilometres. They also contribute to reducing the number of vehicles needed to satisfy a given demand, through higher vehicle utilisation and passenger occupancy rates, as well as higher load factors for freight. Policies and measures to cut passenger demand can be found in Section 4.5. These are assumed to result in a significant decrease in demand for passenger transport (-15% between 2015 and 2050) and a slight increase in freight demand as an input to the model (+15% compared with a +48% increase in the REF scenario). These evolutions are described in Figure 11.

Such measures will eventually contribute to a reduction of 124 million tonnes of $CO_2e$ (yearly) by 2040 for passenger transport and 54 million tonnes for freight.

[17] This percentage is the yearly potential for mitigation by each lever category in 2040 compared with 2020 modelled emissions.

Figure 11: Yearly demand for road transport[18]: Comparison between baseline scenario (REF-EU16) and DT-2040

**Passengers** (billions of passenger km) **Freight** (excluding international shipping) (billions of tonne km)




## 2.2.2.4 *“Shift” levers: Significant reduction in the share of LDVs and HDVs*

‘Shift’ levers are those linked to the modal shift[19]. Policies and measures to promote active and low-carbon modes instead of cars can be found in Section 4.5. These result in a decreased share for cars in the total demand: from 72% in 2020 to 55% of passenger kilometres in 2050. This implies shifting a share of passenger transport to public transport such as rail and bus, and an increase in the use of bicycles – especially in urban areas.[20] For freight transport, the model targets a share for rail that increases from 15% to 36% in 2040[21] and from 14% to 22% for inland waterway (IWW) transport.

The study finds that such measures will eventually account for 88 million tonnes of $CO_2$ saved by 2040 in freight transport and 51 million tonnes of passenger transport, contributing 11% to the total reduction in emissions in 2040.

[18] This includes LDVs, 2-wheelers, buses, rail, metro, walking, bicycling, and excludes aviation and maritime transport.

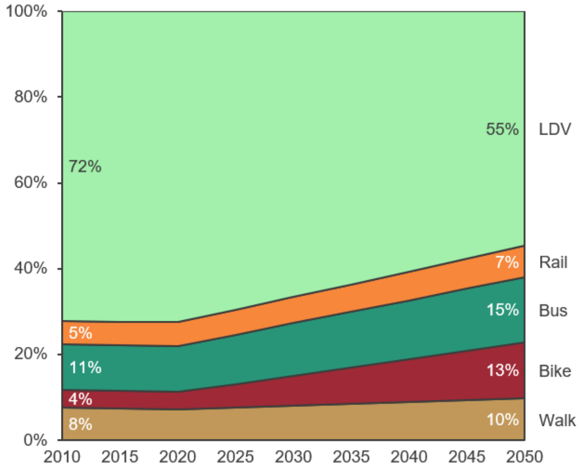
[19] The technology shift (from internal combustion engine to battery) is considered an “Improve” measure.

[20] The model makes a distinction between targets for urban and non-urban areas: it assumes a lower target share for LDVs in urban areas (34% in 2050) compared with non-urban areas (64% in 2050). See footnote 2 for more details on urban and non-urban categories.

[21] See https://www.railfreightforward.eu/about-rail-freight-forward.

Figure 12: Modal share shift in passenger transport[22]

**Modal share evolution in DT-2040 scenario for passenger transport** (% of passenger kilometres)




**Modal share evolution in REF-EU16 scenario for passenger transport** (% of passenger kilometres)

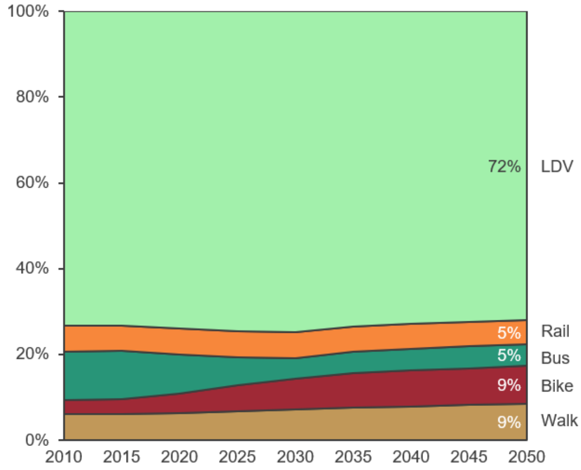
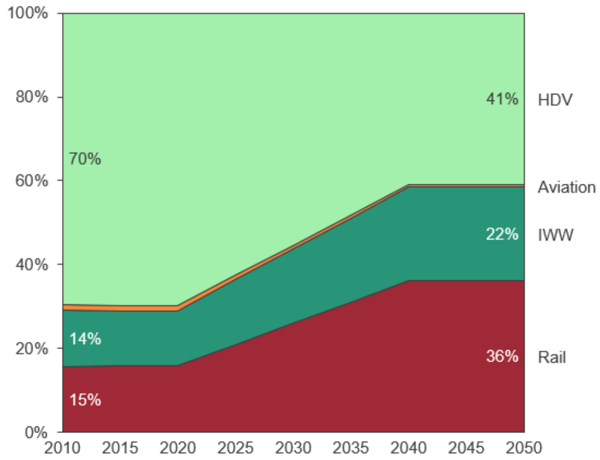
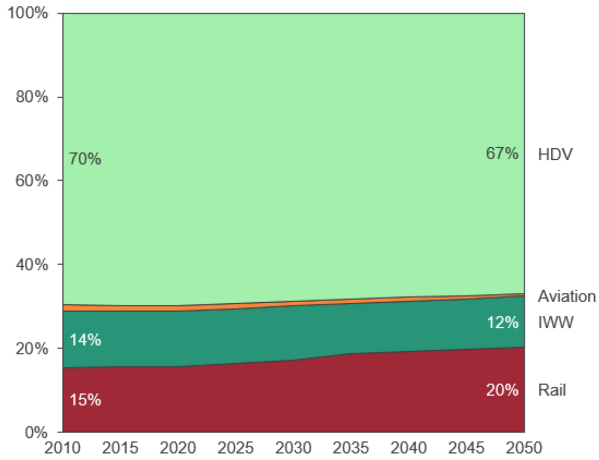



Figure 13: Modal share shift in freight transport

**Modal share evolution in DT-2040 scenario for freight transport** (% of tonne-kilometres)




**Modal share evolution in REF-EU16 scenario for passenger transport** (% of tonne-kilometres)




[22] The model distinguishes between urban and non-urban passengers.

### *2.2.2.5 "Improve" levers: Electric vehicles prevail*

"Improve" levers consist of mitigating actions that expand the deployment of existing technologies not yet scaled up as well as technological innovations. Practically, three types of alternatives are considered: improvements in vehicle efficiency, the technology shift to zero-emission vehicles (BEV and FCEV), and the switch from fossil fuel to synthetic hydrocarbons. Although important, the efficiency of ICE vehicles will not result in full decarbonisation. In addition, since biofuels are dismissed initially, two major zero-emission pathways based on zero emission energy remain: synthetic fuels (hydrogen or synthetic hydrocarbons) and battery electric vehicles.

A massive switch to BEV is assumed in the model: 95% of new sales need to be BEV in 2028 (the rest being hydrogen vehicles), which implies that the market alone is unlikely to drive this change: enhanced targets, strong regulation, infrastructure investments and adequate support are necessary to facilitate this massive shift.

The study finds that such measures will eventually account for 366 million tonnes of $CO_2$ by 2040 for passengers and 91 million tonnes for freight (both yearly).

A quantitative discussion on the limits of technology levers is key to understanding the need for avoid measures and, ultimately, bans. Indeed, for LDVs, decarbonisation will require a massive shift: of the 260 million vehicles in the EU, only 2% are currently EV[23]. The transport sector consumed 4192 TWh of energy in 2015, 95% of which is powered by fossil fuels[24]. Since tremendous efforts are still needed to achieve a fully decarbonised electricity mix, it is important that energy demand from transport is minimised. This is discussed in the following paragraphs.

- ***Are synthetic hydrocarbons a valid substitute for fossil fuels? (More details in Box 3)***

A partial renewal of the fleet means that the remaining ICE vehicles would need to be powered by synthetic hydrocarbons. Sensitivity analysis (illustrated in Box 3) shows that even a reduction of 85% in the ICE fleet compared with current levels would still result in a total demand for synthetic hydrocarbons of ~1,100 TWh. Assuming a 44% electricity-to-synthetic hydrocarbons conversion efficiency[25], this would require 2,500 TWh of electricity. This additional electricity demand is unlikely to be met given that the total power production in the EU amounted to ~3,300 TWh in 2015. Hence, in order to limit the consumption of synthetic hydrocarbons to transport modes in which alternatives seem less feasible, a complete renewal of the fleet to battery electric vehicles and fuel-cell vehicles is considered the most plausible option to decarbonise road transport.

- ***How then to bring about a complete renewal of the fleet?***

Our analysis shows that a "natural" renewal rate (with a fixed vehicle lifetime and an increased utilisation rate) and a ban on **new** ICE vehicles by 2028 still results in a fleet composed of ~39 million ICE LDVs in 2040. In order to avoid an overconsumption of synthetic hydrocarbons, a complete renewal of the fleet is only feasible with a complete ban on **all** ICE vehicles by 2040. This ban was modelled as such in the DT-2040 scenario. Although corresponding measures have already been taken in some cities, these would need to be significantly broadened to reach the scale prescribed in this study. Hence the synthetic hydrocarbons produced using zero-emission electricity will not be used for road transport but only for aviation and maritime transport for which technological alternatives do not yet exist, and for rail (for the share that will not be electrified).

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[23] This figure includes both PHEV and BEV. See https://www.eea.europa.eu/data-and-maps/indicators/proportion-of-vehicle-fleet-meeting-4/assessment-4 (consulted on 11 December 2019)

[24] Source: EuCalc - Eurostat.

[25] (Transport & Environment, 2018)

## Box 3: Road transport: Are synthetic hydrocarbons valid substitutes for fossil fuels?

**Testing the impact on synthetic hydrocarbon consumption in the DT-2040 scenario without a ban on ICE vehicles**

Quantifying the consumption of alternative fuels is key to assessing the plausibility of scenarios. This box discusses the results of a scenario in which the consumption of synthetic hydrocarbons is needed (since it would still represent a significant share of the fleet – see Figure 14) and be allowed for LDVs and HDVs.

Synthetic hydrocarbons are a subcategory of electro-fuels – a more detailed definition can be found in footnote 12. Hydrogen and ammonia production are also key (particularly for the maritime sector). These challenges are discussed in the water-based transport and power sections, whilst this box focuses only on synthetic hydrocarbons.

Figure 14: LDV fleet/DT-2040 scenario without ban

DT-2040 assumptions but without a ban on ICE LDVs fully effective by 2040 (million LDVs - fleet)

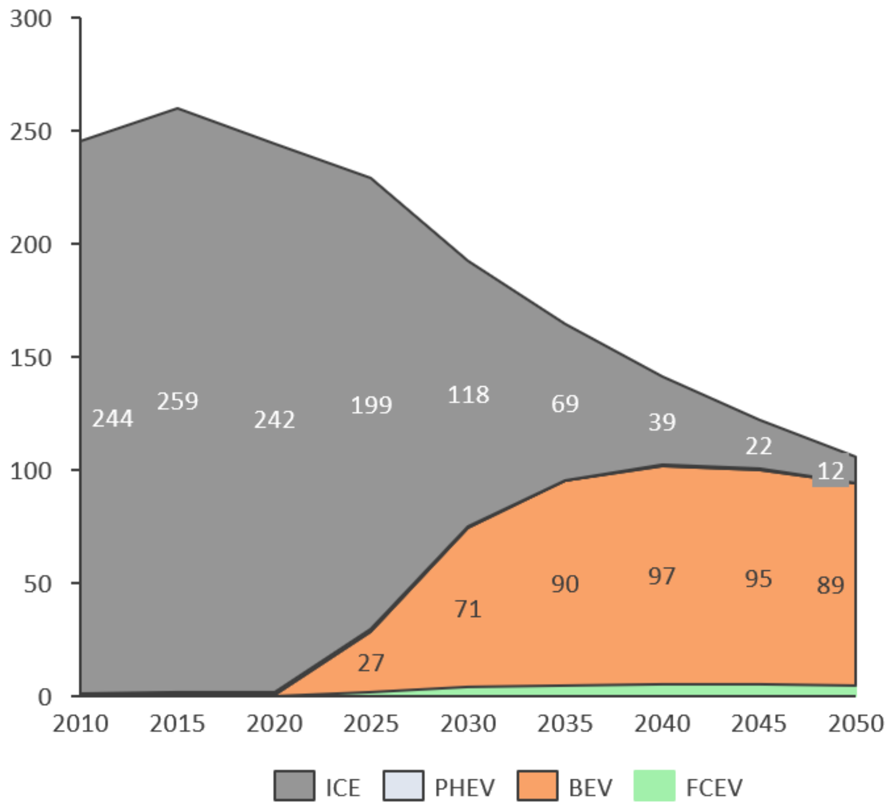


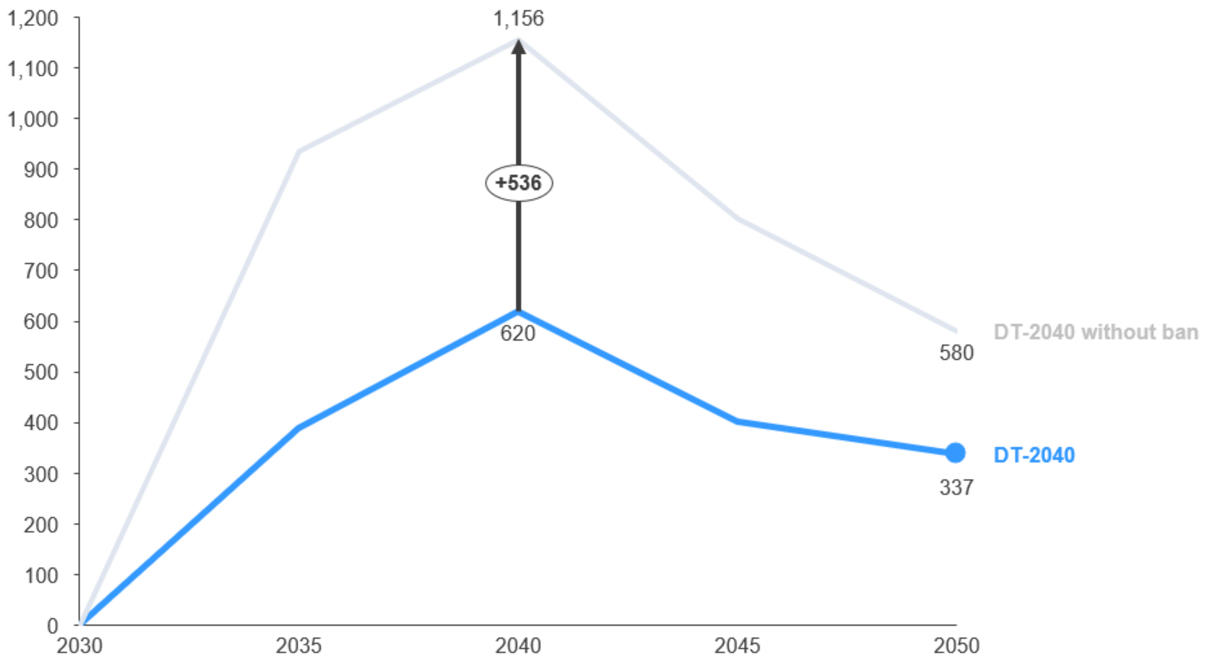

**Figure 14 description**. This scenario uses the same assumptions as those used in the DT-2040 scenario but does not include the ban. It reveals that there would still be ~39 million LDVs by 2040 using “natural” renewal rates (a reduction of 85% compared with 2015). Reaching the decarbonisation target without biofuels will require a significant amount of synthetic hydrocarbons (see Figure 15).

## Box 3 (continued): Road transport: Are synthetic hydrocarbons valid substitutes for fossil fuels?

**Testing the impact on synthetic hydrocarbon consumption in the DT-2040 scenario without a ban on ICE vehicles**

Figure 15 below illustrates the total quantity of synthetic hydrocarbons needed for each scenario. In a situation without a ban, the need for synthetic hydrocarbons would increase by ~546 TWh and reach almost 1,100 TWh. This does not even take into account the efficiency rate (around 44%[26]) for computing the actual electricity needed to produce these fuels, resulting in more than 2,700 TWh of electricity demand just for synthetic hydrocarbons, with about one-third (852 TWh) of this for LDVs alone, for which clear alternatives already exist today in the form of electric vehicles. Given total electricity production of ~3,300 TWh in 2015, the massive efforts needed to make the current capacity clean, the current low efficiency rates, and the fact that they rely on direct air capture to be 100% decarbonised, applying a ban rather deploying technological solutions seems more clear-sighted, especially since clear alternatives exist already today with electric vehicles.

Figure 15: **Total consumption of synthetic hydrocarbons** (e-diesel, e-petrol, e-gas, e-jet fuel and marine e-fuel) (TWh of consumption)



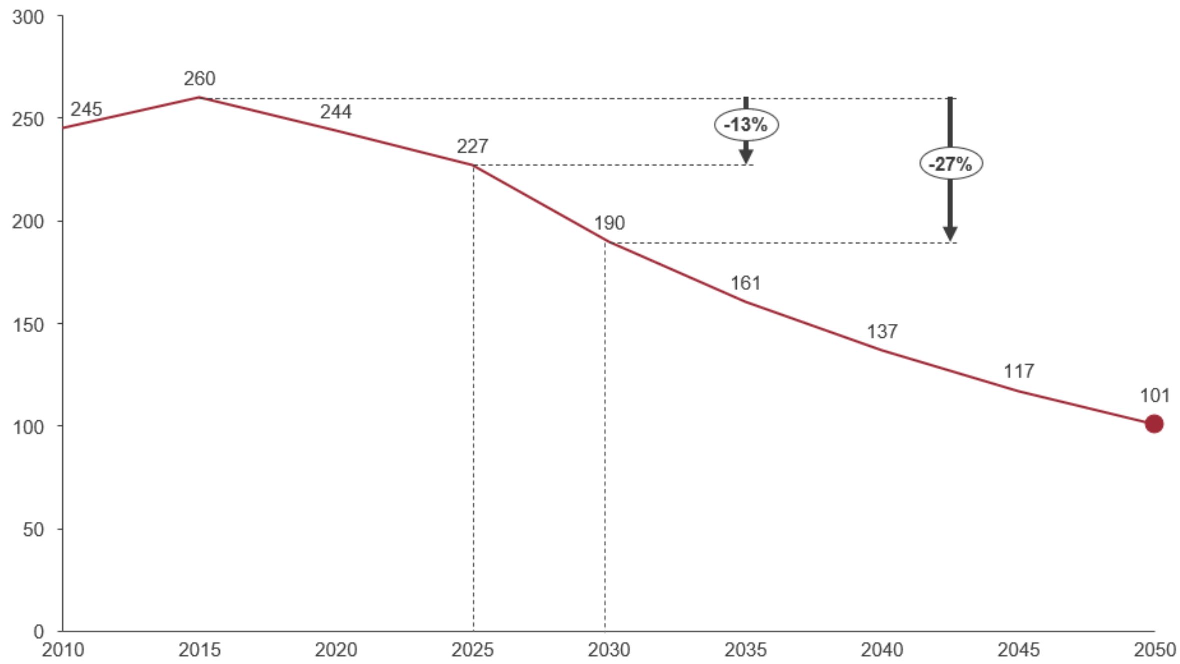

[26] (Transport & Environment, 2018)

### 2.2.2.6 Review of other key underlying indicators: The car fleet

This study makes it possible to identify the direct challenges and opportunities linked to the transition envisaged in the scenario developed. This section briefly discusses the expected evolution of the LDV fleet. Sales of LDVs will be reviewed in the sections on industry, and energy demand in the section on power.

In addition to a shift to zero-emission vehicles, the fleet of LDVs will be reduced by 27% from 260 million in 2015 to 190 million in 2030. The main driver for reduction is a combination of decreased demand for car transport and higher occupancy and utilisation rates. Both encapsulate the notion that changes in habits linked to car ownership as well as the need for innovation in carpooling and car sharing (which typically would be boosted by technologies such as autonomous cars and innovations in areas such as Transport-as-a-Service (TaaS)[27], coupled with automated vehicles, have the potential to significantly increase the utilisation rate of vehicles, hence the need for a smaller fleet).

Figure 16: Total LDV fleet evolution: DT-2040 scenario (millions of vehicles)




[27] These need to be managed carefully, however, as described in "Less (cars) is more: how to go from new to sustainable mobility" (Transport & Environment, 2019)

## 2.2.3 Air and water-based transport

### *2.2.3.1 Air transport*

This model explores a future in which passenger demand for aviation is considerably reduced (the model targets -50% in passenger km by 2050 compared with 2020, which means a 33% reduction by 2040). It has to be noted that this reduction goes hand in hand with the assumption that sufficient e-fuels based on zero-emission electricity can be produced. Given the availability of this type of e-fuel, one might want to reconsider the reduction level.

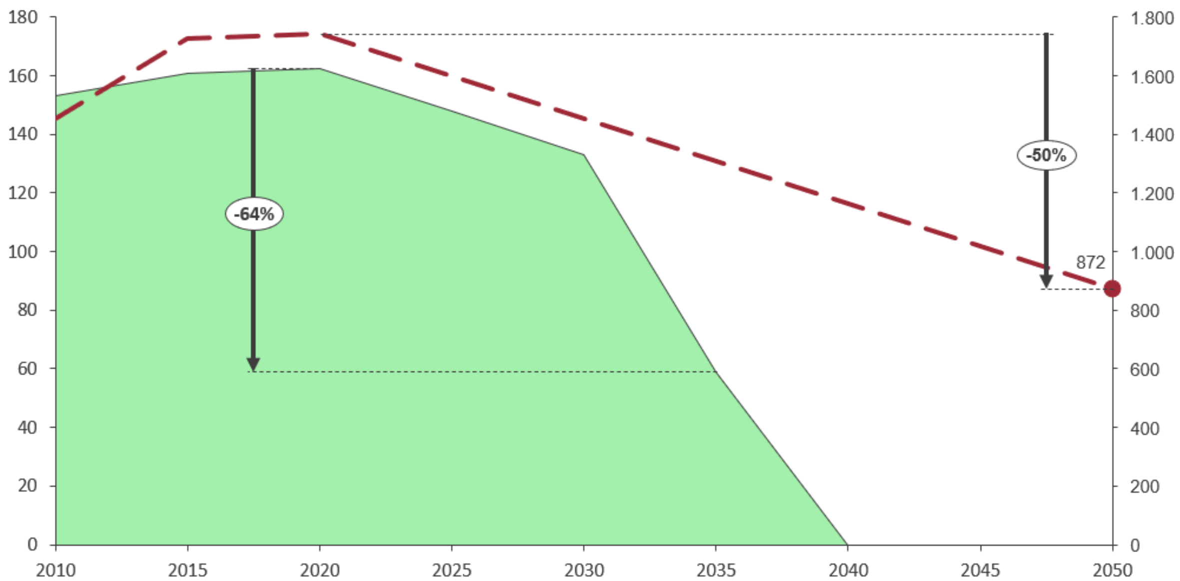
The 50% reduction is in stark contrast to mainstream models, and it implies a strong political will, the need to reduce the amount of long-haul flights, the need for competitive alternatives such as trains for short-to-medium distances, and the necessity of fair restrictions applicable to all citizens in order to generate the needed support. Such measures are detailed in Section 4.5. Another key assumption is improving efficiency and decreasing the energy needs per kilometre by 30% in 2050 (compared with 2015). But the combination of both levers will not be sufficient to reach zero emissions.

**Developing alternative fuels to decarbonise aviation.** In this model, synthetic kerosene (or synthetic jet fuel) is considered the only viable energy vector available (since biofuels were removed from consideration from the start)[28]. As illustrated in the previous section, synthetic kerosene has its limitations (efficiency, direct air capture and the need for upstream clean electricity): hence, energy demand has to be reduced to limit the increase in electricity demand to plausible levels.

It is also important to note that this study does not quantify non-$CO_2$ emissions (nitrogen and sulphur oxides, water vapour, etc.) from aviation which are not (or only to a limited degree) affected by a switch to synthetic kerosene, but are partially addressed by the 50% cut in aviation transport demand.

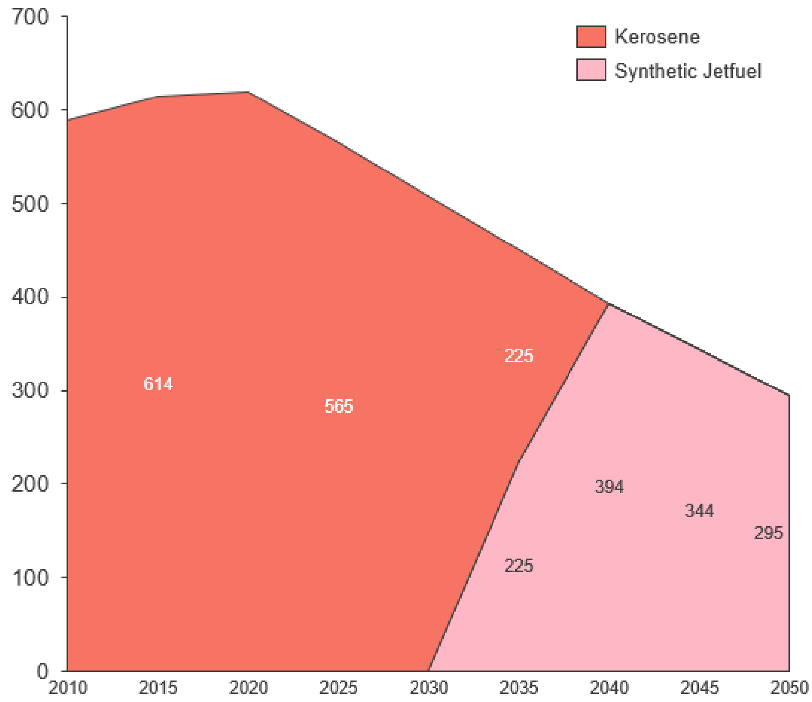
Figure 17: Passenger aviation: Demand and Emissions reduction - DT-2040 scenario

(Green surface: million tonnes of $CO_2$ - left axis. Red dotted line: billion passenger km - right axis)




[28] It is also assumed that electricity will play a role, but with very limited potential (by 2050, 10% of *new* aircraft will be BEV (90% remains ICE)).

Figure 18: Aviation: Energy consumption - DT-2040 scenario (TWh)




### 2.2.3.2 *Water-based transport*

The model encompasses maritime transport (intra and extra-Europe) as well as internal waterways (IWW), which includes coastal transport. Since only freight is modelled – water-based transport is also referred to as shipping in the context of this study.

Water-based transport is expected to grow by 17% between 2015 and 2050. This is driven by the 15% growth for freight (as stated in the box describing initial assumptions) and the shift from HDVs to maritime transport and inland waterways. In EuCalc, the phase-out of fossil fuel consumption (and hence the decarbonisation of the sector) is then driven by an increase in efficiency (of 30% compared with 2020), an accelerated switch to battery-electric, hydrogen and synthetic fuels based on zero-emission electricity. Details of the assumptions can be found in the Appendix.

It is important to note here that with respect to alternative electro-fuels, only synthetic hydrocarbons and hydrogen are fully integrated in EuCalc. However, other technological options – such as the use of ammonia – are under development that are not presently included in the modelling. Scaling up these other options will be essential. Given the total projected fuel consumption of international maritime transport by 2040 (see Figure 19), powering this sector using synthetic hydrocarbons does not seem a realistic option. Alternative and more efficient fuels will have to be scaled up to reach full decarbonisation by 2040. One example is ammonia, which if produced with zero-emission electricity could be a zero-carbon fuel to be used with fuel cells or in internal combustion engines. Since the efficiency rates for hydrogen and ammonia are similar, when calculating ammonia's reduction potential, the model considers them jointly when computing the electricity and final energy needs.

Figure 19: Water-based transport: Energy consumption - DT-2040 scenario (TWh)

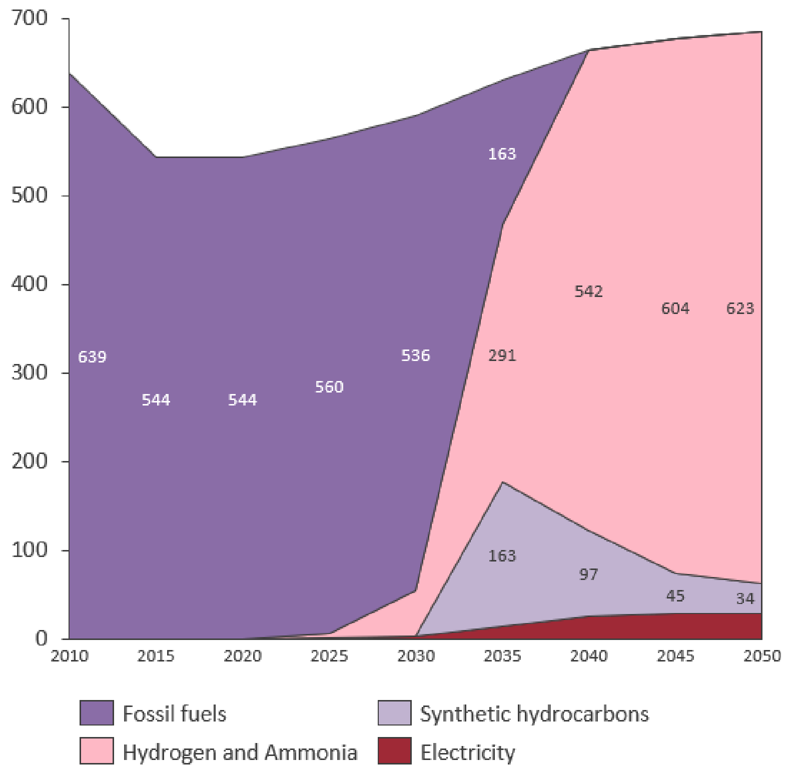
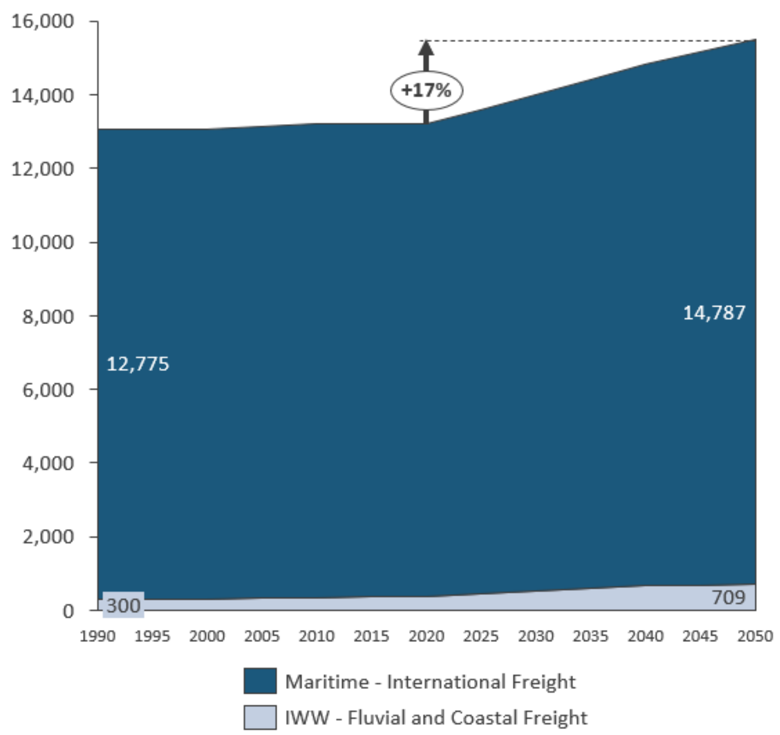



Figure 20: Water-based transport: Activity - DT-2040 scenario (billion tonnes kilometre)



### 2.2.4 Conclusions

**The developed scenario highlights the importance of deploying all available mitigating actions.** Achieving zero emissions will require massive investments to enable the shift to zero-emission vehicles (to develop the manufacturing capacity, infrastructure, zero-emission power capacity and transmission grids). Demand-side measures (categorised as "avoid" and "shift" levers in this report) are certainly as critical as new technologies: they reduce the above-mentioned investments by alleviating the pressure to deploy new technology[29].

**New policies and businesses must reshape the way EU citizens consume mobility in order to reduce demand, deepen the shift to more sustainable modes, and increase fleet utilisation.** Technologies linked to Transport-as-a-Service (TaaS) must be carefully supported to help reach these targets[30].

**The technology shift to electricity must be accelerated:** ensuring that all LDVs sold are zero-emission by 2028 is necessary but not sufficient to realise a zero-emission fleet by 2040. **However, the projected volume of zero-emission vehicles sold in 2025 under the DT-2040 scenario exceeds current market trends and announcements[31]. Hence, additional policies and close collaboration between policy makers and car makers is required.**

**Synthetic hydrocarbons (power-to-liquids) based on zero-emission electricity are one piece of the puzzle, but must always be considered as a last resort, and targeted only at transport modes that do not have alternatives**. Indeed, many concerns remain: their development is still in its infancy, they would need to rely on direct air capture to be fully decarbonised, their deployment only makes sense if the electricity itself is zero-emission based, which requires massive deployments in the power sector, and most importantly, their efficiency is extremely low, especially compared to using electricity in electric vehicles. Consequently, synthetic hydrocarbons should only be considered for modes such as aviation where alternatives are not immediately apparent.

**Therefore, a strong reduction of the fleet combined with a complete shift to battery electric vehicles (and fuel-cell vehicles) is considered the only plausible option to decarbonise road transport, in addition to a modal shift and reduced mobility demand.** A "natural" renewal rate (with increased utilisation rate) and a ban on the sale of **new** ICE vehicles by 2028 still results in a fleet composed of ~39 million ICE LDVs[32] in 2040. Thus, in order to avoid an overconsumption of synthetic hydrocarbons, a phase-out of **all** ICE vehicles by 2040 is necessary.

**Actions need to start now, and a commitment is required from all.** The DT-2040 scenario accumulates a carbon budget of ~17 gigatonnes of $CO_2$ until emissions come down to zero in 2040**.** This results in 51% less cumulated $CO_2$ emissions (between 2018 and 2050) for EU transport compared with the EUREF16 scenario. Which represents a difference of ~18 gigatonnes of $CO_2$. Carbon budget computations are highly complex (see footnote 13 for some estimates), but it is clear that there is very little room for manoeuvring if EU transport is to do its fair share in contributing to limiting global warming to 2°C, let alone 1.5°C. To remain consistent with the +1.5°C scenario from the IPCC, additional and more ambitious measures to quicken the reduction of fossil fuel consumption need to be put in place. In any case, active support will be needed from all actors: policy makers, businesses and citizens.

[29] These measures, for example, reduce the volume of vehicles being sold and therefore the scale-up required in the industry and power sectors to electrify the fleet.
[30] See "Less (cars) is more: how to go from new to sustainable mobility" (Transport & Environment, 2019).
[31] According to Transport & Environment (based on IHS Markit data), the yearly production of EV could reach ~4 million cars and vans by 2025 (Transport & Environment, 2019).
[32] See DT-2040 Scenario "No-Ban" described in Box 3.

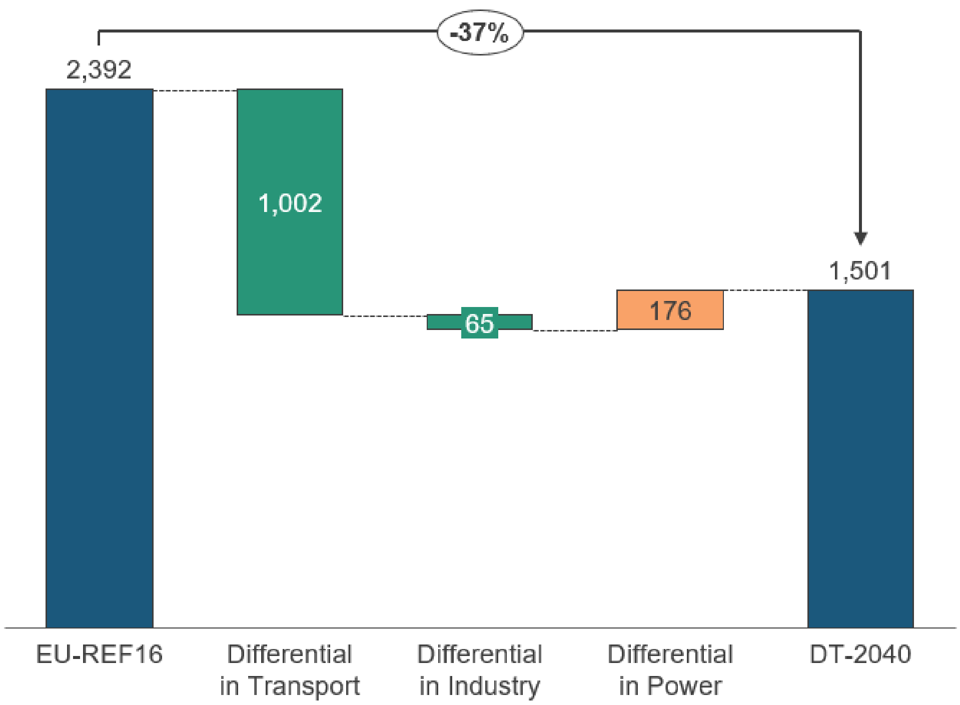
# 3 Impact on industry and power

## 3.1 Approach to estimating the impacts on power and industry

In this section, we investigate the indirect emissions of the DT-2040 Transport scenario for two related sectors: industry and power. They are expressed relative to the EU-REF16 scenario. The methodology used to compute these impacts is the following: **all transport levers are set to their corresponding level in the DT-2040 scenario, while the industry and power levers are set to their EU-REF16 settings.** This means that the industry and power sectors do not have ambitious transition goals – which results in very conservative (or even unrealistically negative) estimations of indirect emissions linked to a radical transformation of transport.

Before exploring sector-specific implications, Figure 21 illustrates the impact of the DT-2040 scenario in terms of GHG emissions across the transport, industry and power sectors. DT-2040 achieves an overall 37% reduction of GHG emissions across these three sectors in 2040 compared with the EU-REF16 projections. This reduction is mainly due to the complete decarbonisation of the transport sector by 2040 in DT-2040. It can be observed that this scenario also allows reducing emissions in the industry sector. However, power sector GHG emissions are increasing due to growing electricity demand from a steadily electrified vehicle fleet as well as a massive demand to produce alternative fuels (electro-fuels), as shown in Section 3.2. Again, this is due to the unambitious assumptions used in the power sector. As may be expected, emissions would be lower with a synchronous decarbonisation of both sectors, and sector integration also clearly needs to happen between the transport and the power sector (e.g. vehicle-to-grid).

Figure 21: Total GHG emissions from transport, industry and power in 2040 for EU-REF16 and DT-2040(million tonnes of $CO_2$ equivalent)



## 3.2 Industry: LDVs sales and production

Emissions from industry are driven by material production, which itself is driven by the production and demand of equipment, goods, vehicles, infrastructure, etc. Figure 21 shows that the indirect emissions of a transition in transport are relatively similar to the emissions without a transition. Although not exhaustive, two major drivers can be highlighted: the shrinking yearly demand for new LDVs (see Figure 22) compensated by the strong modal shift to public transportation, increasing the demand for vehicles such as buses and trains (as explained in Section 2.3.4).

Figure 22: LDV yearly sales: DT-2040 and EU-REF16 scenarios (millions of vehicles)

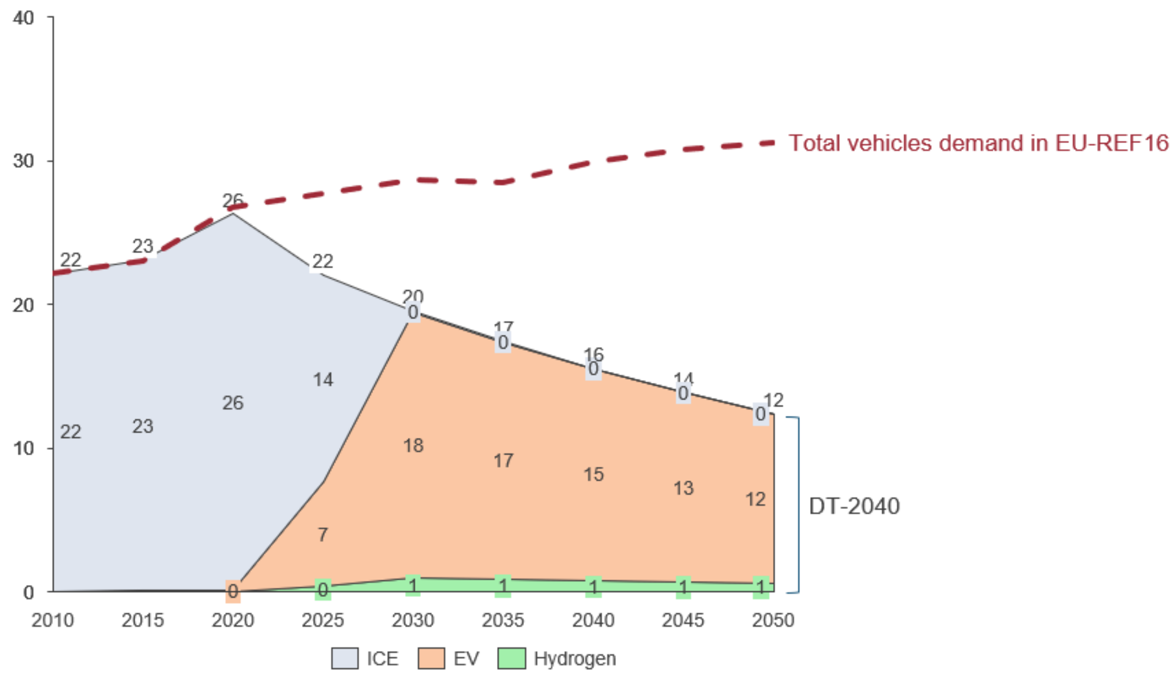



Figure 22 shows that DT-2040 results in a shrinking market for LDVs in Europe, starting in 2020. This figure is the result of the combined effects of the Avoid, Shift and Improve levers described in the previous sections.

Without downplaying the obvious direct impact on major industrial players (mainly on the jobs and financials income they represent), there is potentially a silver lining to this and several ways to compensate for the losses. First, the shift to electric vehicles obviously represents a promising window of opportunity for car makers[33]. Second, although not reflected in the model, as electric vehicles become the norm globally, if Europe manages to lead technologically and to locate the production locally, the decrease in volumes could be compensated for by an increase in EV exports. Third, if automation technologies and car sharing services are already under high scrutiny, the fact that they lead to a higher utilisation rate for cars means more opportunities for both recycling facilities and maintenance services (as much as it calls for more supports from authorities). In addition to the business opportunities at stake, developing the two latter elements will be key to limiting the environmental impact (due for example to the extraction of rare earth elements) of the transition suggested in DT-2040.

[33] See https://www.mckinsey.com/industries/oil-and-gas/our-insights/recharging-economies-the-ev-battery-manufacturing-outlook-for-europe

While this report considers the implications for material consumption under DT-2040, it does not examine it closely. Besides, the modelling exercise was made for Europe but the resources available and the speed at which they can become available for global decarbonisation need to be considered globally. For these reasons, a further assessment of material availability needs to be done to complement this study. Despite technological improvement in the production and recycling of batteries, constraints on resources can potentially hinder the reductions enabled by technological innovation, and hence change the assumptions of the scenario in question.

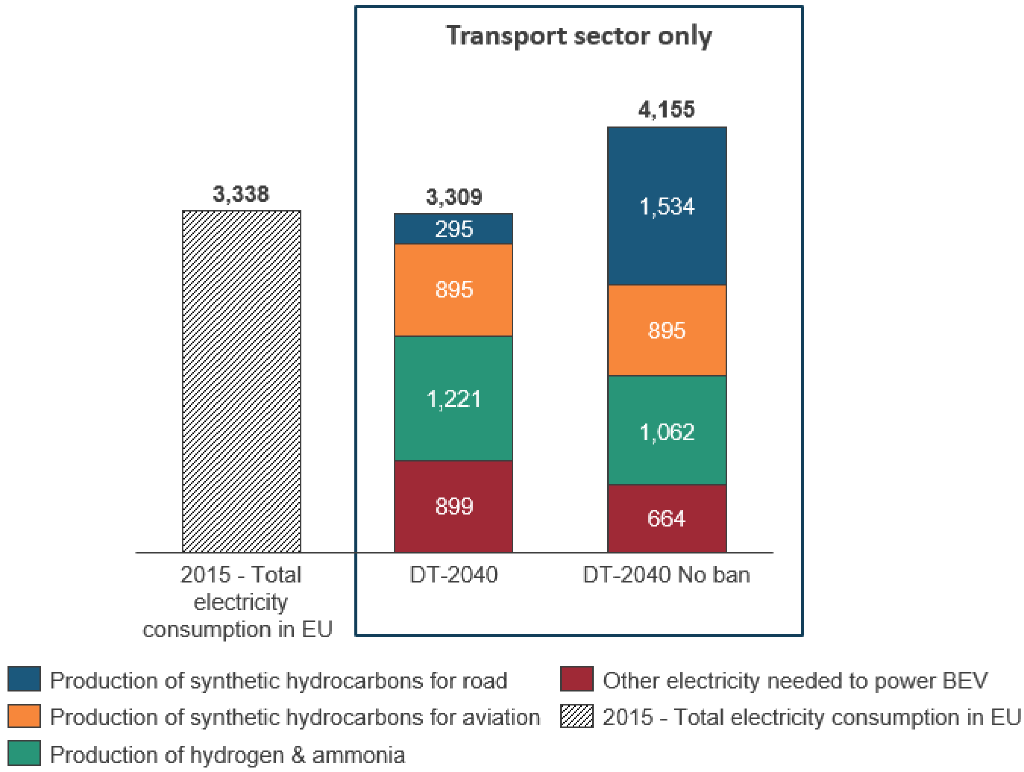
## 3.3 Power: Production increase and production mix

Figure 21 shows a growth of emissions from power generation due to the suggested transport transition. This is linked to two factors:

- The complete electrification of the transport sector. As explained, this electrification is both direct (through BEV for example) and indirect (via synthetic hydrocarbons or hydrogen).
- This electrification is combined with high emission factors in EU-REF16 in 2040 (used to compute indirect emissions under DT-2040). This is due to a limited switch to zero-emission sources in the power sector under EU-REF16.

Figure 23 illustrates the magnitude of the impact on power of a radical transition in transport. Whilst the EU produced ~3300 TWh in 2015, the expected demand from the transport sector alone is estimated at ~3309 TWh in 2040 under the DT-2040 scenario. Without a ban, this demand rises to ~4155 TWh (see the description of a “no-ban” scenario in Box 3).

Figure 23: Electricity demand for transport under three scenarios compared to total EU electricity consumption in 2015[34] (TWh)




[34] This estimation considers the electricity needed to produce alternative fuels using an efficiency rate of 44% for synthetic hydrocarbons and 61% for hydrogen (Transport & Environment, 2018).

From these results, the following can be concluded:

- Even with drastic reductions in mobility demand (as described in DT-2040), electrification of the fleet will swiftly place considerable pressure on the grid. At the moment of writing this report, scenarios promoting decarbonisation through electrification without curbing demand do not seem plausible in the light of the technological deployments needed.
- For the same reason, limiting the use of synthetic hydrocarbons to transport modes without plausible alternatives is necessary. Banning ICE LDVs by 2040 therefore seems inevitable.
- Since it would not make sense to produce synthetic diesel fuel using coal, for example, a simultaneous transition in power and transport is required. Hence, the shift to zero-emission energy sources must be accelerated and deepened. This is another argument in favour of demand reduction measures: they ease the shift by decreasing the clean electricity capacity needed.

# 4 Enabling policies to reach full decarbonisation by 2040

In Chapter 4 we explore enabling policies to fully decarbonise the European (EU-28 and Switzerland) transport sector by 2040. We use key characteristics (called modelling levers) of the DT-2040 scenario as modelled in the previous chapters as a basis to define the required enabling policies. Based on the analysis, we propose policy packages using the Avoid-Shift-Improve framework for passenger and freight transport.

## 4.1 Choosing the right policies

Policies will be a key enabling factor in the transition of the transport sector, but these need to be designed right to be effective. In view of the scale of the change that is needed to achieve decarbonisation of the transport sector by 2040, several key requirements need to be fulfilled:

- **Policies need to consider the full relevant mitigation potential** – As the scenario analysis indicated, a large set of levers need to be pulled to achieve the needed emission reductions. While some lever areas have seen significant policy action (especially in the improve area, see below), others have largely lacked action, namely the avoid/reduce and shift transport areas. Policy solutions will also need to be identified for these areas.
- **Policies need to be ambitious enough to achieve the emission reductions required** – Many of the policies that exist to date in the EU might already achieve emission reductions. However the level is often far from sufficient when compared with what is needed to fully decarbonise the transport sector. The scenario modelled in this report and its levers indicate the level of ambition needed: the policies need to be adapted to achieve this.
- **Policies need to avoid carbon lock-in in the sector** – Effective policy implementation takes time, and getting it right from the beginning is essential, especially given the urgency of action needed. If not designed right, or with the wrong ambition level, they can result in a carbon lock-in. The long lifetime of some of the measures, especially related to infrastructure investments, makes them especially prone to such carbon lock-in.
- **Policies need to support technologies at all stages of development.** While some low carbon technologies are already market ready (e.g. electric trains) or are quickly nearing market readiness (e.g. electric passenger vehicles), others are still in the very early development stages (e.g. electric heavy-duty vehicles) or have barely even started their development (e.g. low carbon airplanes). Policies today need to be able to support the technologies in whatever stage of development they are in, particularly since technology development can take time. Especially research and development, which has a limited immediate impact on emission reductions, play an important role (see Box 7).
- **Policies need to be adapted to the national (local) context.** While some policies work in one context, they might not work in another. Then again, many policies have proven to be effective in multiple contexts, after policy makers have made appropriate adjustments to fit the national context (such as feed-in tariffs or auctioning schemes for renewable energy).
- **Policies need to be designed as policy packages, to account for interaction between policies.** Achieving the scale of the transformation needed is often only possible through the interaction of multiple policy instruments. A prime example is the EV policy package (see Box 6), which includes financial support policies but also behavioural and charging station support policies. Even in cases where a dominant policy exists that can be considered the major driver (such as vehicle emission standards), other policies often exist in parallel that aim at the same reduction potential (e.g. the above mentioned EV support policies). Hence the interaction of a package with these policies needs to be considered.

Seen against this background, policy packages need to be designed carefully. To avoid design errors, they should build on the success of existing policies as much as possible. Identifying good-practice policies in each of the mitigation areas and analysing their scaling potential offers a powerful approach in this respect. This makes it possible to identify policy areas that realistically scale up current policy efforts. By replicating existing policies across new geographic and/or temporal scales, emissions can already be reduced significantly (Roelfsema et al., 2018). Yet, given the magnitude of the challenge, good-practice policies are often not sufficient to achieve emission reductions at the scale and speed needed. We therefore complement such policies with policies from literature.

## 4.2 Conceptual framing and analytical framework

### 4.2.1 Two-step approach to proposing an overarching policy package

This document lays out a two-step approach to identifying the appropriate policy mix/framework needed to decarbonise the transport sector by 2040. To ensure that all relevant emission reduction options are covered, we identify policy areas in the sector along different policy dimensions (see Section 4.2.2). At the highest level, we structure our analysis using the Avoid-Shift-Improve framework.

- **Intermediate Step 1: Review of existing good-practice policies.** In a first step we review existing good-practice policies in the transport sector and analyse their scalability based on their level of maturity, their potential impact and the extent to which they can be replicated. Our review draws from existing good-practice policies across all EU Member States (MS). Where we find good practice polices in jurisdictions outside the EU that would go beyond good practice in the EU, and where we think that these could also be replicated in the EU, we try to include these to the extent possible. A more detailed overview of how we evaluate the good-practice policies is included in Section 4.2.3. Section  includes the results of the analysis.
- **Intermediate Step 2: Identification of the policy gap and how to fill it (lever by lever).** In a second step we analyse the ambition level of current EU policies, estimate the potential impact of scaled good-practice policies (based on intermediate step 1), and identify the remaining gaps to decarbonising the transport sector by 2040. We scale the impact of the good practice analysis to all Member States lever by lever[35]. This enables us to identify where we are, what can be done based on existing experiences, and what needs to be done in addition to achieving decarbonisation by 2040. For the remaining gap we propose a set of additional policies. These policies are often speculative in nature since no or limited pre-existing examples exist. Where possible, we nevertheless try to build on existing policies and propose how their ambition level could be further increased beyond good practice levels. When we propose completely new policies, we try to base them on the literature or apply our expert judgement. To identify how ambitious the policies are compared to the levers, we conduct a literature-informed qualitative analysis that involves, where necessary, our expert judgement. Section 4.2.4 provides a more detailed explanation of how these levers are linked, and Section 4.5 presents the results of the analysis.
- **Results: Drafting a policy package using the Avoid-Shift-Improve framework.** Based on the previous two steps, we propose a policy package, divided into passenger and freight oriented policies, with the ambition level required to decarbonise the transport sector by 2040 following the pathway identified in DT-2040. The policy package builds on existing EU and good-practice policies and additional policies required as identified in step 2. We present the proposed policy package in Section 4.3.

For the sake of reader-friendliness, we present the results, i.e. the policy package, first (Section 4.3), followed by the two intermediate steps 1 and 2 (Section 4.4 and Section 4.5).

The above described analysis of current EU policy focuses only on EU directives and regulations. In this we acknowledge that a large share of effective transport policies works at different governance scales, including EU Member States, regions within the Member States, or even at municipal or city level. These are missing from the evaluation. Focusing only on existing policies at the EU level is a conservative approach to identifying what has already been done and hence will likely underestimate the impact of current policies implemented across all Member States. The actual ambition level of all policies across

[35] Those levers used to model DT-2040.

the EU Member States thereby lies somewhere between the EU policy level and the good practice policy level, whereby good practice policy can be regarded as an upper limit since we have reviewed good-practice policies comprehensively at MS and city level. The actual level of ambition for most levers will therefore be a lot closer to the EU policy level than to the good practice policy level.

While we try to categorise the policies identified for existing and good-practice policies along the defined set of policy dimensions for the transport sector (Section 4.2.2), this is not always straightforward. The impact of policies is often not limited to a single policy area, but spans multiple areas, even if only indirectly. In addition, the scenario modelling exercise has levers at its core that are not always aligned with the policy dimension proposed here. This leads to a situation in which especially the good-practice policies identified in this study impact more than one modelling lever.

The policy analysis presented here focuses on transport sector policies. Cross-sectoral policies are not considered (e.g. a cross-sectoral emission trading scheme or carbon tax). Given that policy impact is hard to grasp, our analysis has a strong focus on “hard” measures. We recognise the need for soft measures in the transport sector transition (education, information sharing, capacity-building, research and more), but due to the difficulty of assessing the impact of such measures, and due to their overarching nature, such measures are beyond the scope of this analysis. Nevertheless, Box 7 discusses the need for research and development.

### 4.2.2 The Avoid-Shift-Improve framework and other policy dimensions

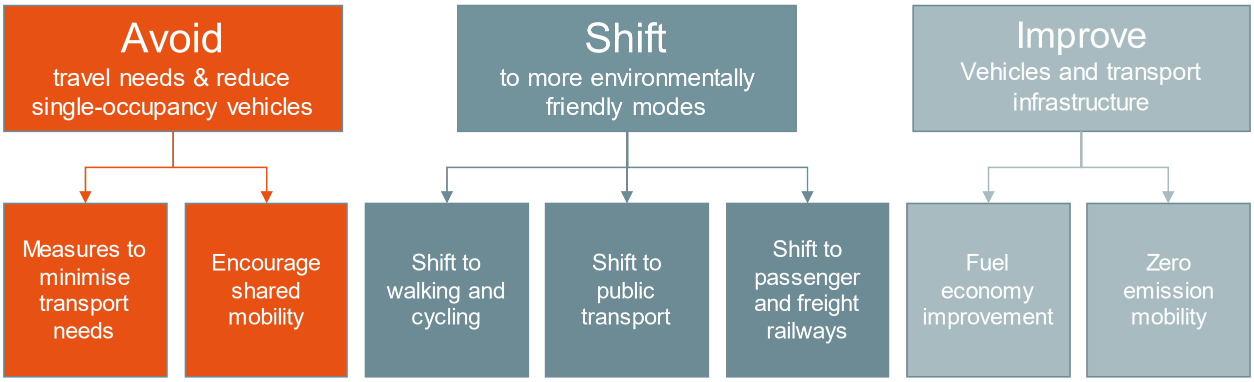
Transforming the transport sector will require a set of policies that tackle multiple dimensions. The most important dimensions of transport sector policies include the nature of the impact, temporal scope, transport demand type, geographic scope, transport type and governance level.

**Nature of the impact**: A policy can have multiple impacts (e.g. low-emission zones can reduce transport demand, enable a shift to environmentally friendly modes of transport, and lead to improved emission intensity of vehicles) and several policies can have the same impact (e.g. urban planning, financial incentives and emission standards may all result in a shift from individual cars to public transport). For the purposes of simplification, we follow the Avoid-Shift-Improve framework and allocate policies in each of the three impact categories based on the policy’s strongest link.

- **Avoid/reduce**: these policies aim to avoid and reduce transport activity and needs by changing behaviours, improving logistics, modifying urban planning, and encouraging shared mobility.
- **Shift**: these policies aim to shift to more efficient modes such as public transport by improving public infrastructures, changing behaviours, making public transport more attractive.
- **Improve**: these policies make vehicles more energy efficient and less carbon intensive.

From a sustainability and cost-efficiency perspective, **policies should first aim to avoid transport needs; if the needs cannot be avoided, aim to shift to more environmentally friendly modes of transport; if the needs cannot be shifted, aim to improve the mode of transport.** While it may be argued that avoid and shift policies tend to be more socially just than improve policies, since they focus on support for non-motorised and public transport, transport policies will not compensate for existing social inequalities. Social equality is a larger socio-economic issue that can only be marginally addressed by the transport policies proposed here. In this report we highlight justice-related transition challenges or opportunities for certain policies when relevant. This aspect of policy design needs to be further investigated, but falls outside the scope of this work. Due to the complexity and overarching nature of policies around 1. new mobility services, also known as Mobility-as-a-Service (MaaS), 2. electric vehicle (EV) uptake and 3. policies supporting research and development, we dedicate a discussion box to each of these policies areas (see Box 5, 6 and 7).

Figure 24: Avoid-Shift-Improve Framework. Adapted from: SLoCaT (2018, p. 3)




**Temporal scope**: the policy analysis is based on current technologies, societal trends and policy developments. For the good practice analysis, we rely solely on implemented policies or concretely planned policies that will likely be implemented soon.

**Transport demand type**: The two types of transport demand that are commonly distinguished are passenger and freight transport. They are distinct in nature and address separate stakeholders, thus they differ in their policy needs.

**Geographic scope:** Depending on the travel distance and the population density of the area, different solutions are needed, e.g. short, medium and long-distance travel. This dimension is addressed when relevant on a policy-by-policy basis.

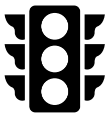
**Transport type**: The four major types of transport used in the analysis are road, rail, air and maritime (including inland waterways). Each transport type encompasses a different set of available technologies and thus results in different policies.

**Governance level**: The above-mentioned dimensions are linked to different policy-making and implementation levels. While overlaps are inevitable, we differentiate between EU, national, and city level policies, but focus here mainly on the EU level, given the scope of the project.

### 4.2.3 Scaling up existing good-practice policies

Figure 24 shows the shell analysis structure used for each policy or policy area. Each policy or policy area is reviewed with the same analytical framework. We (1) define the scope of a given policy and (2) explain what it entails based on the literature. We explain the policy's (3) potential emission mitigation impact, and frame the policy in the aforementioned (4) dimensions. More specifically, we also list the (5) modelling levers influenced by the given policy or policy area.

Figure 25: Shell analysis of a given policy or policy area.

| **Policies** | ***(4)* Dimensions** | *(5)* **Modelling lever(s)** |
|---|---|---|
| ***(1)* Title of policy or policy area** | | |
| ***(2)* What is it?**<br><br>***(3)* Policy impact** | • | • |
| ***(6)* Good practice example** | | |
| *(8)*<br> | • *(7)* **Maturity assessment**<br>• **Replicability assessment**<br>• **Impact assessment.** | |

For each identified policy or policy area, we introduce (6) one good practice example and (7) analyse its maturity level, replicability potential and impact on decarbonising the transport sector, resulting in a (8) traffic light assessment based on equal weighting of the three indicators.

The ***maturity indicator*** assesses how long a policy or set of policies has been in place, in which stage of policy making they are (e.g. planned or in force), and investigates whether the policy is having the intended effect. Essentially, the indicator assesses the degree of certainty a policy will do what it is intended to do. The ***replicability indicator*** assesses the extent to which the identified policy could be replicated in theory and whether it has been replicated in practice. The ***impact indicator*** assesses the emission mitigation potential the policy or set of policies have or could have. The indicator is also informed by the historic performance of the policy, when such information is available.

The assessment shows the scale of performance for each of the three indicators, from low to medium to high. If a policy cannot clearly be allocated to low, medium or high, we give it an intermediary score of low to medium, or medium to high, essentially resulting in a 5-scale assessment. Based on equal weighting of the three indicators, we allocate an overall three-coloured “traffic light” score to the policy or set of policies.

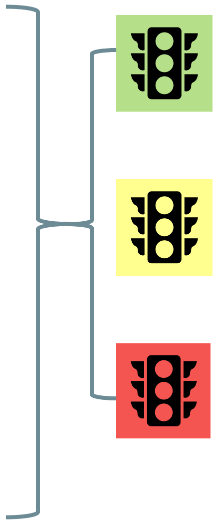
| Indicators | Low | Medium | High | Final score |
|---|---|---|---|---|
| **Maturity/ degree of certainty** | The policy is in the planning phase and there is no certainty concerning its outcome | The policy is implemented, well-established and has an initial track record | The policy is well-established and incorporated in decision-making processes. It is “up and running” and does what is was intended to do. | Equal weight  |
| **Replicability** | The policy cannot be replicated. It has failed before in other contexts or is designed for a very local context. | The policy has been replicated in some cases and shows good potential for even greater replication. | The policy has been replicated several times with success and/or is very easy to replicate. | |
| **Mitigation impact** | The policy has a very low impact on mitigating emissions in the transport sector. | The policy has a medium (potential) impact on mitigating emissions in the transport sector. | The policy has a high (potential) impact on mitigating emissions in the transport sector. | |

Table 1: Good practice policy rating indicators.

Where possible we focus on the policy area and avoid judging/evaluating the concrete policies that are implemented. In the power sector for instance, several different policies have been implemented by Member States to enable the growth of renewables: feed-in tariffs, quota and tender schemes. While all effectively lead to the same ultimate outcome, i.e. the deployment of renewable energy generation, they have different ways of achieving this. This has stirred a lengthy debate about which policy is the most appropriate. It is not the aim here to contribute to such a potential debate in the transport sector. Hence, even if concrete policies are proposed, they should be considered as substitutes for other policies that fit the national context better but achieve the same goal.

### 4.2.4 Linking the ambition levels of DT-2040 and policies

In the modelling exercise of this study, each modelling lever is categorised into four levels of ambition. The level of ambition of policies builds on these four levels. Each level of ambition for modelling levers and the required policies to achieve the lever are explained in Section 2.1.3.

| **Level of ambition** | **Level 1** | **Level 2** | **Level 3** | **Level 4** |
|---|---|---|---|---|
| **of levers** | This level contains projections that are aligned and coherent with the observed trends | This level is an intermediate scenario, more ambitious than business as usual, but not achieving the full potential of available solutions. | This level is considered very ambitious but realistic given the current evolutions in technology and the good practices observed in some geographic areas. | This level is considered as transformational and requires major additional efforts such as strong changes in the way society is organised, very quick market uptake of fundamental measures, the extended deployment of infrastructures, major technological advances and breakthroughs (but without relying on new fundamental research), etc. |
| **of policies** | The policy is unambitious and/or cannot be upscaled to achieve the needed ambition level. | The policy shows intermediate potential to reach the scenario target. | The policy lacks sufficient ambition to achieve the scenario targets, or it cannot be upscaled to its full potential. | The policy is highly ambitious and can be upscaled Europe-wide. The policy boosts transformational change in a rapid manner. |

Table 2: Level of ambition of levers and policies.

Using the described methodology, we take a stepwise approach to identify policy gaps and the policies necessary to bridge these gaps, lever by lever. To that end, we first assess current EU policy levels, then assess the level of ambition of good-practice policies if scaled up EU-wide, and finally, based on the good-practice analysis, existing literature and expert judgement, we propose a package of policies to achieve the required level of ambition.

## 4.3 Results: Enabling policy packages

The analysis of policies with respect to each lever identified the significant policy gaps that exist to date in the EU. A comprehensive policy package is needed to overcome this gap. The following section lays out such a package based on good practice and policy-gap analyses. We include all relevant policies from these analytical steps and elaborate them further to develop comprehensive, integral policy packages. For each proposed policy or set of policies we include a link to the good-practice policies discussed in Section 4.4, and/or literature sources that might be applicable in the elaboration of the policy.

### 4.3.1 Policies to avoid and reduce the need for motorised transport

| Passenger transport |
|---|
| **Urban planning should be centred on the Transit Oriented Development (TOD) concept** in metropolitan areas and in rural areas where applicable. Metropolitan areas should be composed of compact areas, centred on transit stations and green spaces; neighbourhoods should be a mix of residential, commercial and office use to avoid the need for travel. Urban development focuses on avoiding the need to travel and on public transport, walking and cycling, rather than focusing on the use of individual vehicles. Cities and municipalities should develop a Sustainable Urban Mobility Plan (SUMP) to reflect actions to achieve a long-term decarbonised transport system.<br><br>Based on the case studies “Develop sustainable metropolitan areas“ and “Avoid unsustainable infrastructure with a long lifespan“ , and expert judgement. |
| **Encourage shared mobility:**<br><br>**Incentivise trip sharing, using for example high-occupancy vehicle (HOV) lanes**, also called carpooling lanes.<br><br>Based on SLoCaT (2018), State of California (2018), Tal and Nicholas (2014), and expert judgement.<br><br>**Support a shift from passenger vehicle transportation to Mobility-as-a-Service (MaaS).** Provide financial or fiscal incentives for the use of car sharing services or the provision of one’s vehicle to official car sharing services (excluding ride hailing).<br><br>Based on the case study “Establish an intermodality regulatory framework“, SLoCaT (2018), Transport & Environment (2019b, 2019a), and expert judgement. |

| Freight transport |
|---|
| **Reduce transport in urban areas:**<br><br>**Elaborate (zero-emission) freight transport strategies** to supply urban areas with products as is done by the Copenhagen’s City Logistics Project that aims to reduce the number of freight vehicles in the city through the establishment of urban consolidation centres.<br><br>Based on the case study **“**Develop sustainable metropolitan areas**“** and Arbib and Seba (2017), Transport & Environment (2017a), European Environment Agency (EEA, 2019), Bestfact (2013) and expert judgement. |
| **Incentivise efficient logistics** so that freight demand does not increase by more than 15% in 2050:<br><br>**Develop appropriate revenue/cost sharing models to incentivise horizontal and vertical coordination and collaboration** between shippers and logistics service providers pursuing increases in load factors and asset utilisation: vehicles, hubs, warehouse; and reducing costly empty runs in both |

long-distance and urban freight contexts. It is also important to avoid excess capacity in terms of infrastructure, fleets, etc. associated with market needs.

**Set standards for the containerisation of goods for inland transport** compatible with already existing assets used in maritime transport, making use of smaller sub-containers and boxes more adequate to some freight flows and combinations of flows in order to ultimately increase load factors and thus reduce freight transport demand.

**Support and remove regulations that hinder innovation, cross-border transport operations and synchromodal transport** in logistics chains. To this end, set standards for data collection and the reporting of commercially and socially important information as well as data quality monitoring (e.g. emissions, load factors, congestion levels, etc.) coupled with strong regulations related to cyber-security, increasing trust in data sharing.

Based on the case study **“**Establish an intermodality regulatory framework“ and Transport & Environment (2017a), ACARE et. al. (2017), IEA (2017) and expert judgement.

## Box 4: Policies to reduce air travel and support alternatives

Due to the limited technical solutions that reduce emissions at commercial scale, general high-energy intensity levels compared with other modes of transport, and the resulting high $CO_2$ and non-$CO_2$ emissions (such as nitrogen oxides (NOx), vapour trails and cloud formation triggered by the altitude at which aircraft operate) (Transport & Environment, 2017b, 2020; BBC, 2019; EASA, EEA, EUROCONTROL, 2019), the modelling effort carried out here suggests European aviation demand needs to reduce by 50% from today's levels (pre-COVID-19 2020) by 2050 (see Section 2.2.3.1 Air transport). While this significantly reduces the need for zero emission synthetic aircraft fuel, the remaining 50% still needs to be covered by this to-date commercially unproven technology. To achieve such high levels of demand reduction, new and innovative policy solutions play an even stronger role. Unlike in many other areas discussed in this report, good-practice policy examples are limited in this area.

The global Covid-19 pandemic has brought with it behavioural changes that were inconceivable before, as companies' respond to restricted travel by introducing home office, virtual meetings, virtual webinars, or virtual conferences. While it is highly uncertain what will happen as countries start to reduce travel constraints, there are clear signs that the pandemic will have a lasting impact on future air travel (CAPA, 2020; Roland Berger, 2020; Whitley, 2020). Continued social and physical distancing practices might lead to the end of cheap discount flights for instance (Julia Kollewe, 2020), new opportunities for virtual communication, and a modal shift to trains might be triggered (Sam Morgan, 2020b; UBS, 2020).

It is not the aim to contribute to the vast – albeit speculative – body of literature on the impact of Covid-19. While we acknowledge the fact that Covid-19 will have an impact on air travel, we primarily aim to highlight policy options for policy makers to reduce air travel further. Having said this, an important element that is directly linked to the future of air travel are the economic recovery and large-scale bailout packages that governments put together for the aviation industry (Carbon Market Watch, 2020). While most countries do not add climate-relevant and binding conditions to their bailout packages, some have announced initial reflections on, for instance, providing alternative fuel mandates, a decrease in short-distance flights, or strengthened cooperation with railway services, as can be seen in the case of AirFrance, KLM and Austrian Airlines (Keohane and Khan, 2020; Morgan, 2020). While we encourage all governments to consider including binding climate conditions in their packages, we do not discuss them further here.

We propose policies in three areas that answer the following questions: 1) 'What type of regulation can reduce air travel?'; 2) 'How can alternatives to air travel be incentivised?'; and 3) 'How can inequality effects due to an effort to reduce air travel be addressed?'. Policies in all three areas need to be combined to achieve effective policy making.

### 1) Reduce air travel

Air travel can be reduced directly by restricting the number and type of flights, or indirectly by introducing instruments that increase the price of flying and therefore make flying less attractive.

**Regulatory changes to directly reduce air travel**

**Restrict flight slots in European airports** through a supply-side regulation. National carbon budgets in line with a Paris-compatible trajectory for the sector could be used to determine the number of slots at EU or Member State level. Based on these budgets, quotas per airport could be used to allocate the slots to airlines. While such an approach might be relatively straightforward to implement since slot allocation is a commonly used instrument in the airline industry, the allocation would need to be linked to the utilisation of slots and therefore to the emissions of the associated flights. In line with such supply restrictions, we suggest drastically decreasing evening and, more importantly, night flights, to disincentivise same-day return trips.

## Box 4 (continued): Policies to reduce air travel and to support alternatives.

**Ban domestic and intra-European flights** that meet the following criteria: a) The distance travelled is less than 1,500 km (i.e. short-haul flights) and b) an alternative is available with less than approximately 8 hours of travel time (Schulz, 2019). A ban needs to be combined with a strengthening of alternative infrastructures, which would also enable making the ban more strict over time, for instance banning all short-haul flights (under 1,500 km). To enable both conditions to be met, a plan to strengthen alternative infrastructures – railways in particular – to replace intra-EU travel routes over time should be put in place (see Section 4.3.2 - Support a shift to rail transport). In line with the ban, we recommend forbidding "ghost flights", supporting more flexible and efficient European air travel planning, and repealing the current law stipulating that carriers must make use of at least 80% of their allotted berths to keep airport slots, which is currently under a four-month moratorium (EASA, EEA, EUROCONTROL, 2019; Sam Morgan, 2020a).

**Regulatory changes to indirectly reduce air travel demand**

**Eliminate all types of tax exemptions** (e.g. from fuel duty, VAT or corporation tax). The aviation sector benefits from subsidies, for instance in the form of tax exemptions (CE Delft, 2019). To enable a level playing field between transport modes, it is important, at a minimum, to tax airline travel the same as the other modes.

**Introduce a higher air ticket** tax of at least EUR 30 per passenger (based on the UK's Band A – Standard rate), depending on the distance, ticket class, number of passengers and aircraft weight (CE Delft, 2019). The air ticket tax straight-forwardly aims to reduce demand for air transport.

**Introduce a carbon tax** with the possibility to increase the tax over time (Barbiroglio Emanuela, 2019; CE Delft, 2019). Sweden's nation-wide carbon tax, which can be regarded as an example of good practice, is currently 1180 Swedish Krona per $CO_2$ tonne, or slightly more than 110 euros. A carbon tax incentivises both less and cleaner air travel. The level of a carbon tax that incentivises these changes will likely need to be higher than in other sectors, since mitigation options are more expensive than in other sectors. Hence a separate (higher) carbon tax for aviation should be considered, and the tax needs to be accompanied by other measures that drive innovation and reduce mitigation costs. In addition to $CO_2$ emissions, this could include secondary emissions from air travel that contribute to the greenhouse effect such as nitrogen oxides (NOx), vapour trails and cloud formation, given that a carbon equivalent factor can be calculated based on the emissions' global warming potential (GWP). Such a measure would also incentivise more energy efficient aircraft and climate-optimised flight routing (CE Delft, 2017). A mandatory carbon tax could be an effective source of revenue, receive broad support from the population, and is most effective when applied to long-distance flights, given their high carbon emissions (Barbiroglio Emanuela, 2019; EIB, 2019; Sonnenschein and Smedby, 2019).

**Strengthen the EU Emissions Trading Scheme (ETS)** by including extra-European flights and thus reverting the EU ETS to its original full scope. And decrease the emissions cap more stringently over time, which in turn would lead to higher prices. To this end, the EU ETS cap should be adjusted to reflect the emission trajectory postulated in this report, and auctioning should be introduced as an allocation mechanism for all ETS credits, including for aviation where currently only 15% of credits are auctioned (European Commission, no date). Since the currently existing EU ETS also covers the energy supply and industry sectors, it is essential that the targets are stringent enough to incentivise change in the aviation sector. These other sectors tend to have cheaper emission reduction options and are currently responsible for a significant over-supply of certificates. Hence whether the EU ETS can become an effective instrument for reducing emissions in the aviation industry, especially in the short term, needs to be carefully reviewed. Similar to the carbon tax, additional policies to bring down mitigation costs need to complement such an instrument. Funds generated through the EU ETS could be used to incentivise a shift to rail transport and digitalised intermodal transport through infrastructure funding.

## Box 4 (continued): Policies to reduce air travel and to support alternatives

**Introduce behavioural policies** aimed at reducing air travel demand. This could include discontinuing airline loyalty schemes, stronger regulation and monitoring of air travel advertising and marketing information; introducing more stringent penalties for false or misleading advertising claims such as carbon (or climate) neutral flying; introducing mandatory carbon footprint reporting in marketing materials and at ticket point of sales.

### 2) Incentivise alternatives to air travel

**Incentivise virtual communication (virtual meetings, conferences, workshops and/or teleworking):**

**Public sector policies**: The public sector should be a role model by incentivising virtual communication in public offices and through public procurement and tender processes: establish a stringent travel policy for all of the public sector in Europe and require certification schemes for climate responsibility in public tenders (Arnfalk and Kogg, 2003; Arnfalk *et al.*, 2016; Pilerot *et al.*, 2016; Glover and Lewis, 2020).

**Regulatory and financial incentives:** for example by allowing virtual shareholder general meetings or tax exemptions on virtual communication equipment and guidance (OECD, 2016; Boris Kläsener, 2020; Gleiss Lutz, 2020; ISS Global Policy Board, 2020)

**Mandatory corporate travel policy and public disclosure of emissions:** Turn voluntary travel policies and climate reporting into mandatory disclosure, for example building on existing climate responsibility certification (e.g. EMAS type regulations), to incentivise alternatives to air travel such as video conferencing or using alternative transport modes. A mandatory corporate travel policy could include:

1. The tracking of emissions on a regular basis to facilitate an improved understanding of the drivers of air travel and their impact
2. Policy approaches to reduce air travel (and its associated climate impact) as far as possible through both rules and incentives. Such corporate policies could include the following:
    - Forbidding one-day return flights,
    - Requiring justification and internal approval for air travel,
    - Avoiding procuring business class seats,
    - Limiting annual flights per staff member,
    - Provision of an extra holiday to travel by train instead of flying (for non-work trips),
    - Encouraging train travel and the renting of electric vehicles over air travel.
3. Transparent communication by publicly disclosing the volume of business travel and its associated climate impact, the details of the approach taken to reducing emissions, including the reporting of progress, challenges and lessons learnt.

**Support a shift to rail travel**: To drastically reduce domestic and intra-European air travel, the continent needs efficient, well-connected and affordable railways (see Section 4.3.2 - Support a shift to rail transport). To reduce domestic or intra-EU flights connecting extra-EU long-distance flights, international air travel and rail connections should provide an integrated offering, including one booking system, a flexible and reliable train connection, the possibility to check-in (including luggage drop-off) at a given train station, such as the DB rail-and-fly ticket or AirFrance and KLM check-in option at several train stations, e.g. Brussels or Maastricht, when flying from Paris or Amsterdam (AccesRail, no date; KLM, no date).

## Box 4 (continued): Policies to reduce air travel and to support alternatives.

### 3) Address inequality effects

**A just transition**: In a transition to a fully decarbonised European transport sector, reducing air travel demand is crucial but will also result in reduced employment and economic activity in aviation supply chains. It is important to support the affected work force through income support, retraining, redeployment and secure pensions for older workers (Just Transition Centre, 2017). Revenues from air travel taxes can be used to redistribute government revenues (or savings when discontinuing air travel subsidies) to address structural economic issues.

### 4.3.2 Policies to shift to (more) environmentally friendly transport modes

**Passenger**

**Introduce modal shift targets at city/municipality, national and EU level.** While the modal shift targets will need to vary depending on the country/region/city context and especially population density, walking, cycling and public transport should be encouraged. Metropolitan areas should aim to cover at least 80% of public and non-motorised transport. Measuring and reporting of such targets should be mandatory and linked to Sustainable Urban Development Plans (SUMPs).

Based on the modal shift policies below.

**Improve walking and cycling infrastructure.**

**Develop national and city-level cycling plans with clear modal shift targets,** plans to develop safe and reliable cycling infrastructure, and allocate budget to its development (for urban but also non-urban areas and in particular in areas with many commuters). To create more room for cyclists, streets can become fully car-free or restricted to one-way for vehicles, and intersections should include cyclist-specific traffic lights with as little intersecting as possible with motorised vehicles.

Based on the case studies **"**Improving cycling infrastructure**"** and SLoCaT (2018) and expert judgement.

**Develop walking plans and allocate funds to measures** that facilitate a shift to more walking, and prioritise this mode of transport: e.g. green spaces, more pedestrian paths, less cars and intersections. To that end, dedicate car-free streets in city and district centres, around traffic hubs (e.g. schools, commercial areas) and/or install walking/cycling maps with distance/time information.

Based on the case studies **"**Improving walking infrastructure**",** and SLoCaT (2018) and expert judgement.

**Improve and invest in public transit infrastructure.** Develop public transport concepts for urban, suburban and, where applicable, rural areas to offer an alternative to private cars, taking into account just transition aspects (i.e. ticket fares). To this end, set-up or strengthen a public body to coordinate and manage all transport related activities, with transparent procurement processes for tenders and public-private partnerships, and an overarching development strategy encompassing short, medium and long-term solutions (i.e. buses vs. metro lines).

Based on the case study **"**Develop light-rail and bus transit through plans and public investment" and SLoCaT (2018)**,** World Economic Forum (2018)**,** and expert judgement.

**Support a shift to rail transport**

**Improve conventional train service (including night trains) and high-speed railway (HSR) infrastructure and services, develop comprehensive plans and regulations, and release public funding** to enable a self-sufficient, highly efficient and affordable railway system with proper interoperability of rail services:

1. **HSR:** Due to the high costs related to HSR infrastructure, investments should focus only where HSR has the greatest potential, for instance to replace popular flight routes with high travel demand. The investigation of such routes should be supported by transport modelling efforts.
2. **Conventional trains**: Investments in conventional lines should focus on upgrading selected sections where the potential for a modal shift is high, bearing in mind the need for inter-connectivity (e.g. with buses, biking, micro-mobility or cars).
3. **Night trains:** Night train routes can be an alternative to air travel, potentially at lower costs and for longer distances than high-speed connections by air.

**An improvement in the reliability of services is needed.** A seamless, integrated, coordinated and reliable European railway network can be achieved through:

- An integrated European (train) ticket booking system (potentially including air travel to enable a fair comparison) so that customers can purchase a ticket from e.g. Copenhagen to Madrid with one click and without booking separate trains or even without switching trains. Thalys seamless cross-border booking and travelling as well as the Dutch train travel planner "*Treinreiswinkel*" are examples.
- Support alliances and insurance schemes for reliable train connections in the event of delayed or cancelled trains, similar to air travel offerings. Such measures reduce "range anxiety" for medium-to-long-distance train travel.
- Easing intermodality for instance through affordable bicycle tickets, train and fly combined tickets, or the integration of public transport in the departure and arrival locations.
- Reliable data protection laws to strengthen the digitalisation, provision and sharing of information between transport service providers.

Based on the case study "Develop and support railway infrastructure and services (including high speed railways)“ and European Court of Auditors (2018), European Passengers' Federation (2019), Morgan (2020b), Pastori et al. (2018), Savelberg (2019), SLoCaT (2018), Wang et. al.(2020), and expert judgement.

**Introduce/adapt financial incentives**

**Support affordable (or even free) public transport services through strong financial incentives.** Policies can be in the form of fare-free public transit (e.g. to residents), partially free public transportation (e.g. on certain days), by subsidising public transportation fees directly or through tax relief for end-consumers or through employers, for instance by providing one-year tickets for EUR 365.

Based on the case study "Financial incentives (for public transportation)“, and SLoCaT (2018), World Economic Forum (2018), and expert judgement.

**Introduce or expand fiscal incentives for biking** especially for more expensive e-bikes, through tax relief or financial support programmes for end-consumers or through employers. At a minimum, provide support comparable to that for cars, where such exists. At the same time, phase out regulations supporting ICE company cars.

Based on the case study "Financial incentives (for public transportation)“, and Foletta and Field (2011), SLoCaT (2018), World Economic Forum (2018), and expert judgement.

**Disincentivise less climate friendly modes**

**Systematically assess the (in)compatibility of new infrastructure projects (e.g. airports and highways), with the long-term climate target** being full decarbonisation of the transport sector by 2040, in processes where this is possible. Countries should develop sector specific approaches that link individual infrastructure projects to the long-term targets, and enable the assessment of individual infrastructure with respect to the higher-level climate goal.

Based on the case study "Avoid unsustainable infrastructure with a long lifespan“ and Climate Action Tracker (2016), Germanwatch and NewClimate Institute (2018) and expert judgement.

**Develop or strengthen congestion zones and low to no emission zones** in urban areas to increase occupancy rates and decrease traffic, coupled with alternatives to the use of individual cars. National governments should provide a legal framework and combine the objectives of local zones with national transport strategies in a clear and consistent manner. While this policy is effective, it also poses just transition issues that should be carefully assessed and addressed following the principles of a set of basic rights for everyone; equal opportunities to change and adapt; and that inequalities should work in favour of the less advantaged.

Based on the case study "Avoid and reduce passenger and delivery service vehicles in cities“, and Badstuber (2018), van Amelsfort and Brundell-Freij (2018), Wang *et al.*,(2017), and expert judgement.

**No more subsidies for ICEs** to ensure accurate costing of transport and logistics costs, to increase the accountability and comparability of transport modes, and to allow the private sector to identify measures that reduce the need for transport and the impact of transport.

Based on ACARE et. al. (2017) Pastori *et al.* (2018), Rail Freight Forward (2018) and expert judgement.

**Increase taxes on fossil fuels to disincentivise the use of ICEs.** A common instrument currently implemented among Member States is the taxing of fuel, especially diesel and petrol. While still a popular instrument, for Germany the environmental agency for instance is proposing an increase in the present fuel tax of more than 100% [36] by 2030, an increase in such taxes has also been at the source of the EU-wide "yellow vests" movement. Hence, this can lead to significant inequalities since poorer populations in rural areas are most affected. This is also the reason why this policy is not included as a good practice policy. Given its remaining popularity among policy makers, however, is still mentioned here.

Based on Transport & Environment (no date) and expert judgement.

**Establish an intermodality regulatory framework** to ensure an integrated offering and provide a reliable, easy, affordable and comfortable alternative to individual motor vehicles. The policies should clearly prioritise low impact transport modes, for instance (shared) bicycles, buses and light-rail, or new mobility in urban areas, and car sharing and rail transport in rural areas. The policy framework should aim to increase occupancy rates of all vehicles: e.g. at least 2 persons for LDVs and at least 20 persons per bus by 2040. Negative side effects should be identified and avoided (see Box 5).

Based on the case study "Establish an intermodality regulatory framework" and European Commission (2011), SLoCaT (2018), and expert judgement.

**Freight transport**

**Develop sustainable infrastructure**

**Develop comprehensive plans and regulations, and allocate public funding to enable a self-sufficient, highly efficient and affordable railway system,** and develop freight routes in balance with passenger transport. Investments should only focus on high-speed railways where this has the greatest potential, and should focus on upgrading selected sections of conventional lines to complement the current EU railway "patchwork".

Based on the case study "Develop and support railway infrastructure and services (including high speed railways)" and ACARE et. al. (2017), IEA (2017), Pastori et al. (2018), Transport & Environment (2017a), (2018) and expert judgement.

**Systematically assess the compatibility of new infrastructure projects** (e.g. airports and highways), with the long-term climate target being full decarbonisation of the transport sector by 2040 in processes where this is possible. Countries should develop sector specific approaches that link individual infrastructure projects to the long-term targets, and enable the assessment of individual infrastructure with respect to the higher-level climate goal.

Based on the case study "Avoid unsustainable infrastructure with a long lifespan" and Climate Action Tracker (2016), Germanwatch and NewClimate Institute (2018) and expert judgement.

**Develop or strengthen congestion zones and low to no emission zones** in urban areas to increase load factors and decrease traffic. National governments should provide legal frameworks that enable this

[36] Source: https://www.sueddeutsche.de/wirtschaft/umweltbundesamt-klima-verkehr-sprit-preise-1.4709948

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| at the local level, and need to ensure that the objectives at the local level are aligned with and supported by national transport strategies in a clear and consistent manner.<br><br>Based on the case study "Avoid and reduce passenger and delivery service vehicles in cities", and Badstuber (2018), van Amelsfort and Brundell-Freij (2018), Wang *et al.*,(2017), and expert judgement. |
| **Establish a level playing field in regulating all transport modes,** particularly between road and rail transport, concerning operational requirements/regulations, (e-)customs procedures, energy taxes and infrastructure (safety) costs.<br><br>Based on Pastori et al. (2018), Transport & Environment (2017a), ACARE et. al. (2017), IEA (2017), Rail Freight Forward (2018), and expert judgement. |
| **Incentivise intermodal freight transport by amending Combined Transport Directive 92/106/EEC.** The existing directive needs to be reinforced since it currently only loosely addresses some key issues at EU level that aim to reduce the organisational and cost burdens of combined transport compared with road-only transport.<br><br>Based on Pastori et al. (2018), Transport & Environment (2017a), ACARE et. al. (2017), IEA (2017), Rail Freight Forward (2018), and expert judgement. |

### 4.3.3 Policies to improve vehicle efficiency and transport systems

| Passenger transport |
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| **Develop (ideally budget-neutral) schemes to support the shift to 100% zero-emission vehicle sales** by 2028, e.g. based on a bonus-malus system. Such a scheme should focus on introducing zero-emission vehicles until market maturity. A bonus-malus system is an alternative approach to purchase subsidies, and largely overlaps with the impact of emissions standards.<br><br>Based on the case study **"**Fuel economy financial incentives and taxes", and Kuramochi et. al. (2018), and expert judgement.<br><br>**Introduce a new and more ambitious EU Directive on emission standards** targeting 50 $gCO_2$/km by 2025 and 0 $gCO_2$/km by 2028. Ensure that these standards are implemented by car manufacturers by further improving testing methods and aligning the directive better with MS-level support for zero-emission vehicles. An option could be to explicitly link the emission standard with a zero-emissions vehicle/EV policy package at EU level. Extend the directive to cover all passenger vehicles, not just LDVs.<br><br>Based on the case study **"**Vehicle Emission standards/fuel economy standards for new vehicles", and Kuramochi et. al. (2018), and expert judgement. |
| **Ban fossil-fuel cars**<br><br>**Ban sales of new fossil fuel vehicles by a given year,** but no later than 2028 for LDV, and ban all types of ICEs for road by 2035.<br><br>Based on the case study "Ban on sale of vehicles with internal combustion engines (ICEs)", and Climate Transparency (2019), Kuramochi et. al. (2018), and expert judgement.<br><br>**Prohibit fossil fuelled cars that emit local pollutants from entering cities**. In the short term, especially until an ICE ban becomes effective, localised banning of ICEs can be done on the basis of local air pollution effects (e.g. health effects). This would mean that when local air pollutant levels rise above a certain threshold (these are region and country specific), ICEs would be banned from entering certain inner-city areas. This measure should be coupled with the promotion of alternative transport modes such as non-motorised transport infrastructure, subsidised public transport or park-and-ride facilities at city borders.<br><br>Based on Climate Transparency (2019), Kuramochi *et. al*. (2018), and expert judgement. |
| **Develop packages to support zero-emission vehicles**<br><br>**Develop a comprehensive and generous financial incentive package to support the uptake of electric (and/or fuel cell) mobility**[37] until zero-emission vehicles have reached cost-parity with ICE vehicles. The purchase subsidy should ideally represent at least the difference between the cost of an ICE and an EV, e.g. a EUR 10,500 purchase subsidy per vehicle as in Norway. This should be ideally done in a budget-neutral manner relying on emission related taxes (e.g. a bonus-malus system and/or fuel duties and emission taxes). Shared and smaller vehicles (to counteract the trend of growing SUV sales) should also be incentivised.<br><br>Based on the case studies "Zero-emission vehicles purchase subsidy and other financial incentives" and "Fuel economy financial incentives and taxes" and Kuramochi et. al. (2018), De Villafranca Casas et. al. (2018), Transport & Environment (2015) and expert judgement. |

[37] The authors acknowledge that in situations where transport cannot be shifted to more environmentally-friendly modes of transport, the shift to EVs entails new challenges such as battery waste. The development of more sustainable and recyclable electric batteries is needed to overcome these challenges.

**Develop comprehensive EV charging infrastructure packages** with short and medium-term targets depending on population and traffic density, e.g. around 6,000 stations per 1 million inhabitants as in the State of California, allocate public funds to the measure, and initiate cooperation with/regulation of the private sector.

Based on the case study "Improve EV charging infrastructure" and Kuramochi et. al. (2018), De Villafranca Casas et. al. (2018) and expert judgement.

**Implement behavioural incentives for the uptake of zero-emission vehicles** such as priority lanes and dedicated parking spots.

Based on the case study "Behavioural incentives for zero emission vehicles" and Kuramochi et. al. (Kuramochi *et al.*, 2018), and expert judgement.

**Ensure long lasting fleets (eco design)**

**Develop broad-based policy measures promoting a longer lifetime for products,** from the design of durable and high quality products, to promoting reparability and longevity or to proposing measures to tackle planned obsolescence; to encourage circular economy and collaborative economy actions, via "usage-oriented economic models"; for example, utilising products as services, and facilitating greater participation by small and medium-sized enterprises in the repair of products, ensuring reliable mobility and reducing the resource and energy needs of production processes.

Based on EC (2019), and expert judgement.

## Freight transport

**Adjust emissions standards and taxes**

**Introduce a new and more ambitious EU Directive on emission standards** targeting 50 $gCO_2$/km by 2025 and 0 $gCO_2$/km by 2030**.** Ensure that these standards are implemented by car manufacturers by further improving testing methods and aligning the directive better with MS-level support for zero-emission vehicles. An option could be to explicitly link the emission standard with a zero-emissions vehicle/EV policy package at EU level.

Based on the case study "Vehicle Emission standards/fuel economy standards for new vehicles", and Kuramochi et. al. (Kuramochi et al., 2018), Transport & environment (2017a), and expert judgement.

**Expand the emission standards to other transport modes with adjusted standards**: e.g. 0 $gCO_2$/km by 2027 for rail, 50 $gCO_2$/km for maritime (including inland waterways) by 2030, and 0 $gCO_2$/km by 2040.

Based on the case study "Vehicle Emission standards/fuel economy standards for new vehicles", and OECD/ITF(2018), Transport & Environment (2017a), and expert judgement.

**Introduce, expand and redesign road charges and tolls**. Gradually increase diesel fuel tax, ideally in larger groupings of countries (to avoid fuel tax tourism), and apply the revenues to zero-emission vehicle incentives.

Based on Transport & Environment (2017a), and expert judgement.

**Develop packages to support zero-emission vehicles**

**Develop fiscal and behavioural incentives.** While passenger vehicle purchase subsidies have a high impact, we suggest fiscal incentives for the uptake of electric vehicles for freight transport, in combination with the emission standards. These could include carbon-neutral freight distribution zones in the largest urban centres by a given year but no later than 2030, company tax exemptions, or a toll exemption for electric/zero-carbon HDVs.

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| Based on Transport & Environment (2017a) and expert judgement.<br><br>**Develop comprehensive EV charging infrastructure packages** with short and medium-term targets, allocated public funds and cooperation with/regulation of the private sector. Ensure their suitability for HDVs.<br><br>Based on the case study "Improve EV charging infrastructure" and Kuramochi et. al. (Kuramochi et al., 2018), De Villafranca Casas et. al. (2018) and expert judgement. |
| **Support alternative fuels for aviation and maritime transport**<br><br>**Introduce green port fees and/or similar schemes** such as green berth allocation policies, green procurement and carbon pricing schemes, and encourage ports to join the World Ports Climate Initiative (founded by fifty-five ports worldwide).<br><br>**Amend the EU Renewable Energy Directive to require fuel suppliers to supply** alternative synthetic fuels to the aviation and maritime transport sector, instead of boosting the supply of potentially unsustainable biofuels. Zero-emission liquid fuels are complementary to a fully decarbonised transport system, especially when technological alternatives are not as readily available as is the case for aviation.<br><br>**Actively support R&D and the uptake of alternative synthetic fuels for aviation and maritime transport,** particularly for long distance travel.<br><br>The three policy bundles are based on the case study "Support e-fuels for air and maritime transport", and Climate Transparency (Climate Transparency, 2019), OECD/ITF(2018), NewClimate Institute (2019), Rail Freight Forward (2018), Transport & Environment (2017a, 2018) and expert judgement. |
| **Ensure long lasting fleets (eco design)**<br><br>**Develop broad-based policy measures promoting a longer lifetime for products,** from the design of durable and high quality products, to promoting reparability and longevity or to proposing measures to tackle planned obsolescence; to encourage circular economy and collaborative economy actions, via "usage-oriented economic models"; for example, utilising products as services, and facilitating greater SME participation in the repair of products, ensuring reliable mobility, and reducing the resource and energy needs of production processes.<br><br>Based on EC (2019), and expert judgement. |

### Box 5: The EU's role in international shipping

Shipping within the European Economic Area contributes 3-4% of total EU $CO_2$ emissions and, globally, international shipping is responsible for 2-3% of global GHG emissions (Climate Action Tracker, 2020). Pathways to full decarbonisation for the sector have been identified, (ETC, 2018) and rely on a combination of demand management, energy efficiency and a shift to alternative synthetic fuels such as ammonia and hydrogen.

The International Maritime Organisation (IMO) is the international body responsible for governing emissions from international shipping, but action to date has been limited to and focused on energy efficiency only (Climate Action Tracker, 2020). Further planned improvements to energy efficiency standards will only achieve some of the required reductions for either meeting the IMO's own targets or for the full decarbonisation of the sector required by the 1.5°C temperature limit.

Due in part to slow movement by the IMO, the EU has taken independent action. In February 2020, the EU Parliament voted to include shipping within EU waters under the EU ETS from 2023, unless a similar approach is adopted by the IMO. The EU could push further by actively supporting the uptake of alternative synthetic fuels, requiring ports to develop the required infrastructure and continue to engage with the IMO to implement more stringent measures at global scale. These measures could include emissions standards, energy efficiency standards, and a global emissions levy (NewClimate Institute, 2019).

## 4.4 Intermediate step 1: Scaling up good-practice policies

We will structure the good practice policy analysis using the Avoid-Shift-Improve framework as laid out in Section 4.2.2 and will analyse 18 policy areas for which we select a good practice policy in the form of a case study. We will analyse scalability, in other words how a given case study can be upscaled across all EU Member States (plus Switzerland), along three dimensions: ***maturity –*** reflecting the degree of certainty a policy will do what it is intended to do; ***replicability -*** the extent to which the identified policy is able to be replicated; ***impact –*** the extent to which it is able to reduce emissions. For more information please refer to the analytical framework in Section 4.2.3. The analysis is based on an extensive literature review, not all aspects of which can be covered in this report. For more detailed information, please refer to the referenced literature.

### 4.4.1 Summary of the analysis

While many good-practice policies exist, very few are fully scalable to all EU Member States. Most analysed policies (14 out of 17) do not score well across all dimensions at the same time (maturity, replicability and impact). Overall, we analyse 17 policies, mostly Europe-based case studies, at EU, national and/or city level. While policies exist across all mitigation areas (avoid, shift and improve), it is difficult to find policies performing well on all three indicators. Of the 17 good-practice policies reviewed, three have a high scalability potential (green), namely London's ultra low emission zones (ULEZ), highly subsidised public transport in Paris, and Norway's electric vehicle (EV) support package. 14 policies have a medium scalability potential (yellow) since they do not score high on all three dimensions – maturity, replicability and emission mitigation – at the same time. Finally, we were unable to identify good-practice policies to support the uptake of alternative synthetic fuels (red).

We will analyse 17 individual policies or policy packages using the Avoid-Shift-Improve framework:

**"Avoid" policies**

- Measures to minimise transport needs
  1) Develop sustainable metropolitan areas
  2) Avoid unsustainable infrastructure with a long lifespan
- Encourage shared mobility
  3) Establish an intermodality regulatory framework

**"Shift" policies**

- Shift to walking and cycling
  4) Improve walking infrastructure
  5) Improve cycling infrastructure
- Shift to public transport
  6) Shift away from passenger and delivery service vehicles in cities
  7) Financial incentives (for public transport)
  8) Develop light-rail and bus transit through plans and public investment
- Shift to passenger and freight railways
  9) Develop and support railway infrastructure and services (including high speed railways)
  10) Taxing national and European flights at levels at least equal to that of high speed trains, and international flights even more

**"Improve" policies**

- Fuel economy improvement
  11) Fuel economy financial incentives and taxes
  12) Vehicle Emission standards/fuel economy standards for new vehicles
- Zero-emission (electric/hydrogen) mobility
  13) Zero-emission vehicles purchase subsidy and other financial incentives
  14) Ban on sale of vehicles with internal combustion engines (ICEs)
  15) Improve EV charging infrastructure
  16) Behavioural incentives for zero-emission vehicles
- Sustainable fuels in transport
  17) Support alternative fuels for aviation and maritime transport

### 4.4.2 "Avoid" policies

These measures aim to reduce the need for transport, and to increase occupancy and utilisation rates of vehicles such as favouring vehicles with more than one occupant (through-traffic privileges and financial incentives). These measures essentially lead to more people in an equivalent unit of space using pooling than private cars, which can reduce the total number of vehicle kilometres travelled (VKT) by passengers who might otherwise travel in their own vehicles (SLoCaT, 2018).

#### Measures to minimise transport needs

Better transport management reduces overall transport demand and the use of cars in urban areas, and does so to a lesser extent in non-urban areas. Avoid and reduce policies are important since they make it possible to achieve more stringent decarbonisation goals. In fact, the most stringent (global) emission mitigation scenarios show more profound changes on the demand side (Germanwatch & NewClimate Institute, 2018). Remote working incentives and high-speed internet may reduce the need for commuting and thus decrease emissions, but such measures could also lead to urban sprawl (Moeckel, 2017), potentially counteracting dense urban planning efforts. Such considerations are not directly related to the transport sector (Germanwatch & NewClimate Institute, 2018) and fall outside the scope of this research.

### Develop sustainable metropolitan areas

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| **Description:** More compact spatial development, in which neighbourhoods provide a full range of services, reduces the need for transport. For instance, Transit Oriented Development (TOD) refers to mixed, dense urban development centred on or located near a transit station designed as a community hub (within a city or in rural areas). A holistic approach to planning a transport system, such as sustainable urban mobility plans (SUMPs), increases the connectivity and efficiency of transportation, as an alternative to urban planning centred on the use of cars.<br><br>**Impact:** In an urbanising world, cities are living and consumption hubs, and play a key role in shaping societies. Reducing citizens' transport needs in the way a city map and its transport infrastructure is set-up reduces total (i.e. passenger and freight) vehicle travel. | EU, national and city level<br><br>Road and rail<br><br>Passenger/freight | Transport demand |

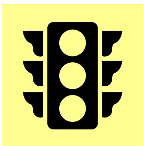
*Copenhagen's urban development plan*, the five-finger plan, focuses on metropolitan train lines (170 km) that spread like fingers from the "palm" of central Copenhagen, with green spaces in between, and neighbourhoods planned around train stations. The Greater Copenhagen area's planning requires an assessment of the development of the area as a whole, and must ensure that the main principles of the overall finger structure in the city is continued, i.e. with a focus on public transport services and cycling infrastructure (Danish Ministry of the Environment, 2015). The city's urban plan also encompasses strategies for freight transport (Baster *et al.*, 2014).

- Copenhagen started implementing the plan around 70 years ago in cooperation with neighbouring municipalities, so that the Copenhagen Metropolitan Area (3,000 $km^2$) is now green and cycling friendly, with only 26% of citizens travelling by car in 2017, demonstrating **high maturity** (Danish Ministry of the Environment, 2015; Deloitte Insight, 2018).
- Urban planning includes long and complicated processes, with strong differences in economic, social, political and ideological contexts. While these are strong barriers to the ability to replicate the scheme, similar transit-oriented urban plans have been implemented in multiple cities around the world, with New York even hiring a Danish urban planner to replicate the concept (Department of Transportation New York, 2014; Thomas *et al.*, 2018). This demonstrates **low to medium replicability.**
- Copenhagen's urban planning and inter-connection with other municipalities (city-to-city and city-to-suburban areas) has a very high impact in avoiding the need for transport and the choice of transport (for passenger and freight), and thus has a high emission mitigation potential (**high impact**).

### Avoid unsustainable infrastructure with a long lifespan

| | | |
|---|---|---|
| **Description:** Policies ensuring that long-term infrastructure projects are beneficial to decarbonising the transport sector through, for example, processes for obtaining permits. This implies no further airport or highway expansions and to some degree also no further construction of remote commercial centres.<br><br>**Impact:** By not incentivising unsustainable and high-emissions transport, the exponential upward trend of flying and the use of cars for long-distance travel is reconsidered, thus lowering transport demand or resulting in a modal shift (see shift to railway system). | EU and national level<br><br>All transport modes<br><br>Passenger and freight | Transport demand<br><br>Modal share |

***Marseille's airport expansion under scrutiny*.** Marseille, France's third largest city, has plans to expand its airport. Developers of the Marseille Provence Airport need to revisit expansion plans since France's environmental authority has pointed out that they are not in line with the country's climate targets, i.e. carbon neutrality by 2050 (Climate Home News, 2019).



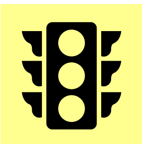
- The airport expansion is only on hold for now, will most likely not be halted in the light of a very recent decision (July 2019), and is the first of its kind in France. Thus the measure has very **low maturity.**
- Due to the fact that Europe has a well-established aviation infrastructure, aviation demand has increased exponentially in the last years, mainly due to leisure travel. Europe has viable alternatives to flying (train, car, bus or even videoconferencing and teleworking), thus this type of policy is **easily replicable.** Furthermore, a similar approach has been taken for the third runway at Heathrow, which the British court of appeal ruled violated the country's climate pledges under the Paris Agreement, although the judgement seems only to be applicable to public spending (Damian Carrington, 2020)
- Stopping the construction and expansion of airports is crucial to meeting climate targets. The Heathrow airport expansion requires the UK to overcompensate mitigation efforts in other areas of the economy to reach its climate goals (Monbiot, 2016). The avoidance of infrastructure projects that undermine climate efforts has a **high mitigation** impact.

## Encourage shared mobility

### Establish an intermodality regulatory framework

| | | |
|---|---|---|
| **Description:** Intermodal systems incorporate different modes of transport and facilitate the switch from one to another. As such, long-distance and short-distance transport services are well connected: e.g. central stations with a metro and shared bicycles for the "last mile". Facilitating policies to support intermodality could consist of monthly public transport passes and the easing of regulations, since intermodality requires cooperation among different transport operators (public and private companies), which could involve a metropolitan or regional transport authority as an effective central institution (compare (SLoCaT, 2018).<br><br>**Impact:** Intermodality leads to more effective, efficient and convenient trips from door to door, and thus incentivises a switch to public transport away from individual (ICE) cars. "A more efficient organisation of the entire mobility system based on digitalisation, data sharing and interoperable standards is of utmost importance to make mobility cleaner" (European Commission, 2018). | EU, national and city level<br><br>All transport modes<br><br>Passenger and freight | Utilisation rate<br><br>Occupancy rate<br><br>Modal share |

*The Finnish Act on Transport Services* specifically targets "interoperability of data and information systems" and "intelligent transport systems" to facilitate the use of public transport and shared services through "seamless, multimodal travel chains" (Finland Government, 2017; LVM, 2017).



- The Act only came into force in 2018 but has the support of various national agencies, transport companies and cities as well as regions, thus demonstrating **low to medium maturity** (Finnish Transport Agency, 2018).
- The Act is partly based on and incentivised by the EU's Intelligent Transport System Directive (Directive 2010/40/EU) and thus could be replicated across Member States. In addition, the (public) transport infrastructure in many Member States is very similar to or even better than in Finland, which gives the policy framework a **high replicability** potential**.**
- In the transport transition, creating a sound policy framework around intermodality is key to enabling flexibility, digitalisation and new business models, yet intermodality is based on the provision of public transport and shared services (which need to be developed in parallel) and thus has a **medium to high impact** (Ministry of Transport and Communications, 2018).

### 4.4.3 "Shift" policies

**Shift to walking and cycling**

The policies and measures are aimed at shifting from motorised transport (especially passenger cars) modes to more walking and cycling, which by nature are far more environmentally friendly.

**Improve walking infrastructure**

| | | |
|---|---|---|
| **Description:** Particularly cities and municipalities can improve pedestrian infrastructure for short distances through attractive pathways and safe streets. The availability of green and/or pedestrian paths, parks, benches, leisure facilities and sports grounds influence citizens' decision to walk.<br><br>**Impact:** A satisfactory local infrastructure influences citizens' choice to walk (e.g. coupled with public transport), facilitating an overall modal shift away from passenger cars and to more walking. | EU, national and city level<br><br>Road transport<br><br>Passenger | Modal shift |

*Austria's 2015 Master Plan for Walking* contains a strategy to promote walking and to meet pedestrian needs in federal, state, and local government policy making and planning. This strategy also allocates federal budget amounts (although no clear figures are given) to walking infrastructure, information campaigns as well as regulations promoting walking-friendly and safe road and urban planning (BMLFUW and bmvit, 2015). The year before, the city of Vienna developed a Strategy Paper for Pedestrian Traffic, which is complemented with a monitoring programme (City of Vienna, 2018).

- In 2017, more trips were taken in Vienna[38] on foot (28%) than by car (27%), and 64% of Vienna's monitoring survey respondents stated that pedestrians are treated preferentially over other road users, demonstrating the policy's **medium to high maturity** (City of Vienna, 2018).
- Developing an infrastructure conducive to walking contains elements that are easily replicable (such as preferred traffic signals) as well as elements that require investment in new infrastructure, which can take longer to implement. While this is relatively cheap compared to other infrastructure investments, it is limited in scope since it is mainly suitable for areas with a high population density. Overall this reflects **medium replicability.**
- Although a shift to more walking is a key element to decarbonising the transport sector, it alone is not sufficient, since walking is only applicable for short distances or leisure, thus we classify it as **medium impact.**

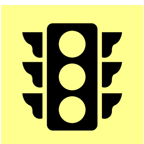
[38] The city of Vienna published its Monitoring Report in June 2018, whereas no monitoring report could be identified at national level. Thus Vienna's Monitoring Report, with useful statistics on the effectiveness of walking infrastructure, is used as a basis for discussion.

### Improve cycling infrastructure

| | | |
|---|---|---|
| **Description:** Cycling is typically space and cost-efficient and thus requires less infrastructure and capital investment than other modes of transport. Building or improving safe and efficient cycling lanes (low accident risks and low congestion rates) adapted to citizens' needs, providing bicycle parking or promoting bicycle rentals, are typical measures to improve cycling infrastructure. Recent developments around electric bicycles have increased the range of bicycles, thus creating the potential to tap into an even greater modal shift away from personal vehicles.<br><br>**Impact:** Providing safe and efficient cycling infrastructure incentivises people to shift away from passenger cars. To be most effective, this is best complemented with measures restricting the use of cars. Measures such as a bicycle lane that reduce the space for cars and replace it with space for bicycles combine both of these elements. Based on a life cycle assessment – thus taking into account all emissions e.g. those related to production and transport – cycling (not e-cycling) emits 8 grams of $CO_2$ per mile ($gCO_2$/mi), while passenger cars emit 414 $gCO_2$/mi, which highlights the potential emissions impact of the shift, a shift that also entails health and congestion benefits (SLoCaT, 2018; Hollingsworth, Copeland and Johnson, 2019). | EU, national and city level<br><br>Road transport<br><br>Passenger and (last-mile) freight transport | Modal shift |

*High-speed bicycle routes in the Netherlands*. In 2018, the Netherlands dedicated 100 million euros to building and/or modifying high-speed bicycle routes (additional 3 billion cycling kilometres) and bicycle parking facilities, a plan that will be jointly implemented with municipalities that plan to invest another 245 million euros. The plan should shift 200,000 commuters from private vehicles to cycling (Dutch Government, no date). At city level, Utrecht is entirely designed and built to give priority to cyclists and pedestrians: many streets were modified to favour bicycles over cars, the layout of streets and cycle ways gives more direct access to various parts of the city, potentially resulting in cycling being the fastest mode of travel, parking spaces and public bicycles are widely available (City of Utrecht, 2019)

**Just transition:** Cycling comes at a low cost and is thus accessible to all citizens. Furthermore, it brings with it a variety of benefits. For example, in Europe, where air pollution causes around 400,000 premature deaths per year, cycling results in 435 million euros in healthcare savings. In 2016, the bicycle industry had an estimated market value of EUR 13.2 billion, and this is expected to grow at an annual rate of 5.5% until 2022. In comparison, the European car market is expected to grow by only 1.7% until 2024. Cycling is also very space efficient, increasing the available public spaces in urban environments (UNFCCC, 2016; ECF, 2018)



- The Netherlands and many Dutch cities such as Utrecht, but also other European cities such as Munster (Germany) and Copenhagen (Denmark), have been prioritising cycling since the 70s, thus demonstrating **high maturity**.
- Improving cycling infrastructure is easily replicated but can be dependent on the geographic situation: The Netherlands is a densely populated and flat country, which makes such a modal shift easier. However, the large-scale introduction of electric bicycles might allow the replication of such infrastructure investments in less densely populated regions and/or regions with more rugged terrain. Overall this results in a **medium to high replicability**.
- Although according to kilometres travelled, cycling has an 8% modal share in the Netherlands, in urban areas it can be as high as 50%, surpassing the use of

cars. The potential for a modal shift to cycling is particularly strong for short to medium-distance trips up to seven kilometres and in urban areas, yet cycling policies could be further developed, demonstrating **medium to high impact** (Kennisinstutuut voor Mobiliteitsbeleid, 2018; Jonkeren, Wust and Haas, 2019).

### Shift to public transport

The policies and measures are aimed at shifting transport demand from passenger cars to public transport such as trains, buses and light rail. Public transport vehicles have much higher occupancy rates than LDVs, and thus more passengers can be transported in one vehicle. Particularly in urban areas, mass transit (e.g. metro, light rail transit (LRT), trams and bus rapid transit (BRT) offer an efficient and sustainable mobility solution for citizens across a city (C40 Knowledge, no date).

#### Shift away from passenger and delivery service vehicles in cities

| | | |
|---|---|---|
| **Description:** Generally rendering the use of passenger and commercial vehicles less attractive, or even prohibiting (certain types of) vehicles in specific areas. Low Emission Zones (LEZs) prohibit vehicles with a given level of emissions from entering a certain area, park & rides incentivise citizens to use public transport from the city limits. Vehicle quota systems and vehicle restrictions such as internal combustion engine bans, congestion charging, car-free streets, and car-sharing lanes are examples of approaches to reduce the use of cars and promote the shift to public transport. .<br><br>**Impact:** Such policies incentivise higher occupancy rates and at least a shift to low-carbon transport modes such as walking or cycling. | City level<br>Passenger and freight<br>Road | Modal shift<br>Transport demand<br>Tech uptake |

*London's congestion and ultra low emission zones*. Since 2003, London has been implementing a congestion zone with the charge rising from £5/day in 2003 to £11.50/day today for any vehicle entering the city during business hours (Transport for London, no date; Badstuber, 2018). In April 2019, London additionally launched an ultra low emission zone (ULEZ) that is smaller in size. It imposes a fee on top of the regular congestion zone, based on the vehicle and emission type (The Guardian, 2019).

**Just transition:** While the policy follows the polluter-pays principle, it also poses severe issues with respect to injustice: wealthier citizens can continue to pollute by paying the associated fees, while air pollution and the resulting environmental and health effects affect all citizens, including those that cannot (or do not want to) pay the fees. Consequently, it is important to consider just transition aspects when designing LEZs. Madrid (Spain), for example, grants an "access guarantee" through public transport, the Brussels-Capital Region partially offers free public transport and car sharing services to citizens who give up their cars, and Ghent (Belgium) incentivises the purchase of EVs that owners share through recognised car-sharing organisations (Transport & Environment, 2019b).

- The policy has **high maturity** since it has been in place since 2003, is well-established, and has proven to reduce the number of cars and pollution in London.
- Although the policy has had positive mitigation impacts, it does not result in a full decarbonisation of the transport system and would need to be more stringent over time, demonstrating **medium to high impact** (Badstuber, 2018; Transport & Environment, 2019b).

- The policy in itself is easily replicable, yet a city needs to provide proper public transportation and/or cycling and walking paths to make possible a modal shift with **high replicability**. In fact, over 250 EU cities have already introduced low emissions zones.

### Financial incentives (to promote public transport)

| | | |
|---|---|---|
| **Description:** Financial incentives ("pull" measures) encourage citizens to shift to public transportation. This can be done by providing fare-free public transit (e.g. to residents), partially free public transportation (e.g. on weekends or for certain age groups), subsidising public transportation fees directly or through tax relief for end-consumers or through employers.<br><br>**Impact:** Such policies can increase the attractiveness of public transport services so that more people shift to public transport. | National and potentially city level<br><br>Road and rail transport<br><br>Passenger | Modal share |

*Funding affordable public transport in the Paris Metropolitan Region*. Public transport and subsidies to support the use of public transport are frequently used strategies throughout Europe. In the main European cities, typically, more than 60% of the modal share is made up of walking, cycling and public transport. Each city approaches public transport differently in terms of infrastructure building, transport operations and fares. It is difficult to say which city supports public transport best, since such strategies are context specific and different metrics exist to measure them. For instance, 93% of trips taken within Paris were by walking, cycling and public transport. Slovenians spent the least on transport relative to household spending, and Tallinn, Dunkirk, and Luxembourg provide the highest financial subsidies in the form of fare-free public transit (EEA, 2013; Paris town hall, 2016; Cats, Susilo and Reimal, 2017; Eurostat, 2020).

For the purpose of this study, we choose the Paris metropolitan region as a good practice policy, due to its recent trends in achieving a high share of public transport coupled with walking and cycling, and its recent adjustment of public transport financing leading to modern (including shared bicycle infrastructure investments) affordable public transport, where ticket fares cover only 28% of total investment and operational costs[39] (2016 estimates) (Île-de-France Mobilités, 2020). Anchored in national law, the public transport network is mainly financed through 1) the transport tax (**"***versement transport***"**), collected as a tax through employers (companies with at least 9 employees), depending on the location of the company and 2) subsidies in the form of statutory contributions from the Paris metropolitan region and its municipalities (French Government, 2019; Conseil d'administration, 2020).

**Just transition**: Affordable (or even fare-free) transport makes it easier for people with low and average incomes to remain mobile (Estupinan *et al.*, 2007). In fact, transport is the EU's second largest household expenditure item after housing (Eurostat, 2020). This is important given that 7 out of 16 cities with the most expensive commutes are located in Europe (World Economic Forum, 2017).

[39] Although affordable compared with the "real" infrastructure and operating costs, there is room for the social tarification of public transport to improve access to public transport based on citizens' financial capacities (Greenpeace France, 2019).

- The Paris metropolitan region and national law have been encouraging public transport subsidies for decades, demonstrating the **high maturity** of such policies. In 2009 a law was introduced stating that the Île de France Transport Syndicate is in charge of the region's transport plan and thus manages transport services and the contracting of operators "to obtain the best use, economically and socially, of the corresponding transport system" (Heddebaut, 2017). The transport tax was anchored in national law as early as 1996 (French Government, 2020).
- Subsidising public transport occurs throughout the EU in various forms such as fiscal incentives and subsidised fares. Most European cities already rely on subsidies and grants to close the gap between operational revenues and expenses, reflecting **high replicability** (EEA, 2013; EMTA & RebelGroup, 2017)
- Paris has been able to shift away from the use of cars, reducing their share to only 13% since 2013. French national statistics show that in the Paris metropolitan region, close to half of working citizens use public transport, and close to 70% do so in Paris itself (Insee, 2017). Although inhabitants still rely on passenger cars, especially in the outskirts of the capital, Paris reversed the trend of relying on private passenger cars, demonstrating **high impact**[40].

[40] It is important to note that the modal shift is not solely impacted by public transport subsidies, but other policies such as traffic management (e.g. congestion zones) also influence the modal split.

| Develop light-rail and bus transit through plans and public investment | | |
|---|---|---|
| **Description:** For financial incentives supporting the shift to public transport to be effective, it is crucial to develop proper urban transport. Proper investments and urban planning to develop light trains, metro, bus and trams are necessary to offer high quality networks and a proper alternative to passenger cars. (SLoCaT, 2018)<br><br>**Impact:** Transporting more people than private cars in an equivalent unit of space, which can reduce the utilisation rate of passengers who might otherwise travel in their own vehicles. Policies supporting the increase in supply and the quality of public transport services can increase their attractiveness as a viable alternative to passenger cars and thus support a modal shift. This in turn increases the utilisation rates, resulting in an overall reduction of per capita emissions from mobility as well as due to congestion, urban space requirements and noise. Such a scheme could accelerate Transit-Oriented Development (TOD). | National and city level<br><br>Road and rail<br><br>Passenger | Occupancy rate<br><br>Modal share |

*Budapest's central public transport institution BKK*. While many good practice examples exist in European cities, transport plans in Budapest and Hungary have well-developed policies in support of public infrastructure. Since 2010, the Centre for Budapest Transport (BKK), a public body, has been coordinating and managing all transport-related activities for the city. In addition, Hungary's recent transport policies, aligned with European strategies, include just transition aspects and rely on external independent expertise through procurement processes.

**Just transition:** The electrification of public transport fleets based on renewable energy leads to greater emissions mitigation and more societal benefits when compared to cars. For one, the use of public transport is considerably more affordable than the purchase of EVs. In addition, although the manufacturing of cars leads to greater job creation, transit systems require a substantial workforce to operate and maintain fleets. Taking into account health benefits, the result is an overall gain in employment (UNFCCC, 2016).

- In its modal shift, Hungary has the highest share of public transport in Europe. The country's – particularly Budapest's – transport system is well-developed, with many metro, tram and bus lines in urban areas and a proper bus and railway system for suburban areas. Prices are comparatively cheap, with discounts for the disabled, senior citizens, children and students. Although there is room for improvement, Hungary's policies are mature, as is its public transport system (**high maturity**).
- Typically, but also in Hungary's case, the available transport network is based on historical developments, very dependent on the geographic context, and there are limited funds to change it rapidly. On the other hand, most European cities, particularly larger ones, have ring-shaped urban structures and already have public transport services, demonstrating **medium replicability**.
- The availability of public transportation is key to enabling a shift and thus to decarbonising the transport sector. Policies supporting the development of public transport infrastructure are highly relevant, and Hungary and its capital have worked towards that goal, demonstrating **high impact** (Oszter, 2017).

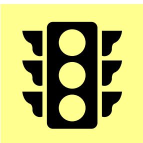
### Shift to passenger and freight railways

The policies and measures are aimed at shifting the mode of transport from individual vehicles and freight trucks to rail transport for medium to long distances. Shifting to rail transport has the potential to lead to higher occupation rates (passenger), load factors (freight) and utilisation rates (both). In general, rail freight generates a low level of externalities and much lower emissions, and uses less energy per tonne-km than road freight (SLoCaT, 2018).

#### Develop and support railway infrastructure and services

| | | |
|---|---|---|
| **Description:** Expanding, improving and connecting (high-speed) railway networks through the development of strategies and plans, the allocation of public spending, and regulatory processes.<br><br>**Impact:** While high-speed railways are essential for medium to long-distance travel and for a connected European continent, smaller railway connections and night trains are also essential for commuter and more affordable transport. An integrated railway system provides a viable alternative to air and road transport, thus shifting road (and air) passenger and freight transport to the tracks. | EU and national level<br><br>Railway transport<br><br>Passenger and freight | Modal shift<br><br>Occupancy rate<br><br>Load factor |

*Japan's railways* are organised along geographic lines yet avoid regional monopolies. After the country reformed the railway system in 1987 to partly privatise rail services, private companies and the public company JR Group run lines in the same area, interlaced with each other and in competition, offering choices to consumers and ensuring financially self-sufficiency. The fares of the public JR railways have an upper limit set by the transport ministry based on Japan's private railways. Overall, fares have increased less than the country's inflation rate. Public funding and commercial competition are coupled with high-speed train lines (Shinkansen, up to 320 km/h), punctual departures and a modern and user-friendly payment system (Marc, 2016; Rail Delivery Group, 2018; Financial Times, 2019).

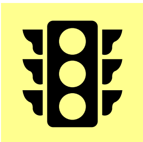


- Significant public investment in Japan's railways began as early as 1950. Multiple reforms and the continuous improvement of the country's railway infrastructure and services has led to high passenger numbers and a self-sufficient rail service industry with private and public investment, demonstrating **high maturity** (Marc, 2016; Rail Delivery Group, 2018)**.**
- Although Japan benefits from a dense population and is a high-income country, the core of Japan's model is replicable for countries with an existing railway system: nationalise or privatise railways line by line to find a balance in the market between public and private service providers coupled with regulation for benchmark competition (Financial Times, 2019). This demonstrates **low to medium replicability**.
- Japan's rail modal share has steadily increased, reaching almost 35% in 2014, the highest share worldwide. In contrast, freight transport by rail has significantly decreased (from 31% in 1965 to 5% in 2014) due to lack of investment and planning since the government was focusing on passenger transport. Furthermore, cheap overnight buses and low-cost airlines complete strongly with railway services, so that the once-popular night-train routes have disappeared (Marc, 2016; Rail Delivery Group, 2018). These contrary trends are having a **medium to high impact**.

**Taxing flights at levels at least equal to other modes of transport**

| | | |
|---|---|---|
| **Description:** Air travel is very GHG emission intensive, yet is nearly entirely tax exempt in the EU, thus undertaxed compared to other modes of transport (Reuters, 2019b). For instance, no EU Member State taxes jet fuels, although the European Energy Tax Directive 2003/96/EC permits doing so (CE Delft, 2019). The types of taxes that apply in this context are: ticket taxes, value added tax (VAT), fuel taxes, environmental taxes (noise and emission charges) and air freight taxes (CE Delft, 2019).<br><br>**Impact:** By, at a minimum, harmonising taxes across all transport modes in terms of euro per passenger-kilometre, citizens and corporations are able to make the most efficient choices in terms of technology and transport mode. (European Commission, 2018). A study estimates that a 1% tax increase would result in a 1% reduction in air travel (Reuters, 2019b). Due to this "right" pricing, passenger and freight transport are incentivised to shift from air to rail (Reuters, 2019b). | EU and national level<br><br>Rail and aviation<br><br>Passenger and freight | Transport demand<br><br>Modal shift |

*The UK's aviation tax.* According to a recently published study by CE Delft (2019), the UK has the highest aviation tax (EUR 40/passenger) across the EU for domestic and international flights[41]. Whereas some countries outperform the UK in specific taxes (such as Hong Kong's excise duty on jet fuel of EUR 0.70 per litre or Hungary's 27% VAT on flights, where the UK has none), the average per km/passenger of various taxes remains highest in the UK. This is due to the country's Air Passenger Duty that is a fixed departure tax depending on the distance, ticket class, number of passengers and aircraft weight; it ranges from EUR 14 to EUR 500 per passenger[42].



- UK's Air Passenger Duty has been in place since 2007, demonstrating **high maturity**.
- The UK is an island state, thus rather reliant on air travel, yet was able to enforce a rather ambitious air ticket policy, suggesting a high replicability potential. In fact, while several European countries do not tax air travel at all, globally most flights are taxed.
- In the UK, emissions from air travel are forecasted to grow further. The UK imposes no VAT or fuel taxes on the aviation industry, suggesting **low impact** for the measure (Aviation Environment Federation, no date). The level of taxes is simply too low.

[41] This study does not take into account charges set by airports (for services) or of a revolving nature (funding aviation activities). Taking such charges into account, the cost of flying is considerably higher depending on the country of departure.

[42] Caution needs to be added here since a one-to-one comparison of air travel taxes to rail taxes is difficult: while there is no VAT on rail tickets in most Member States, in the UK, high levels of funding are provided to the railway industry, and fuel taxes for rail transport are set to stagnate (Office of Rail and Road, 2018; RailFreight, 2019).

## Box 6: The role of Mobility-as-a-Service (MaaS), potential adverse effects and how to avoid them

**What is it**: New mobility services offer users access to shared transport modes on an ‘as-needed’ basis. Examples of new mobility services are shared mobility, bicycle and car sharing, ride sharing, ride sourcing/transportation network companies (TNCs), microtransit (such as electric scooters) and shared autonomous vehicles.

**Impact**: These mobility options can lead to more efficient usage of vehicles and infrastructure through better matching of supply and demand, and thus reduce the number of cars and the number of rides (higher occupancy and utilisation rates). Nevertheless, such mobility services can also have adverse effects, such as shorter vehicle lifetime or increased transport demand. Essentially the impacts are split in three categories:

1. reduced GHG emissions from a shift from private car use to (more fuel-efficient) shared vehicles;
2. increased GHG emissions when passengers shift from public transport to ride sharing; and
3. reduced GHG emissions from fewer vehicles (Jung and Koo, 2018).

### Avoid potential adverse effects of MaaS

**Ride hailing or autonomous driving** should be multi-modal. This needs to be included in a coordinated transport system to improve efficiency and complement existing shared mobility services (autonomous fleets complementing public and non-motorised transport). Emissions may not decrease in the case of monomodal use (autonomous fleets or ride hailing fleets substituted for public and non-motorised transport) (Agora Verkehrswende, 2017; SLoCaT, 2018). In fact, a 2017 study of 4,000 ride-hailing members in seven major United States cities concluded that services are increasing the vehicle kilometres travelled, and 49% to 61% of trips replaced trips that would not have occurred or would have occurred by public transport, bicycle or foot (Bliss, 2017).

Several studies have shown that **carsharing** often results in a decrease in vehicles on the road, a decrease in car ownership, and even in reduced transport demand to some extent (SLoCaT, 2018). While carsharing has proven to have positive impacts, it should not lead to a shift from public transport to the use of cars.

**E-scooters** should not replace walking and cycling, but are more environmentally-friendly than cars when used as a last-mile solution (e.g. coupled with public transport) (Hollingsworth, Copeland and Johnson, 2019).

**Bicycle sharing** has been successful in several cities worldwide (e.g. Paris’ Vélib’ or Mobike in China). Bicycle sharing emits far less emissions than motorised transport modes and can be complementary to public transport and thus enable a shift away from LDVs when well-coordinated (SLoCaT, 2018).

**Policies**: Policies in new mobility services should maximise the positive impacts of each solution and minimise potential negative effects. In general, policies can come in the form of research funding, regulations, tax incentives, infrastructure and urban planning. Shared service (potentially automated) vehicles must be zero-emission vehicles and must include high cyber security and minimum data sharing standards. Shared services should enjoy a tax advantage over ownership, and have clear and harmonised rules of operation, including for shared bicycles and scooters (see Transport & Environment, 2019a).

### 4.4.4 "Improve" policies

When transport demand cannot be avoided, reduced or shifted, the current transport supply needs to be improved in terms of vehicle energy efficiency, the uptake of improved technologies (most commonly electric vehicles) and/or a change in fuel.

**Fuel economy improvement**

These measures aim to the increase energy efficiency of cars by lowering their fuel consumption (litres per vehicle km). This can help reduce negative impacts by reducing oil use and $CO_2$ emissions as well as saving money, but is only a transitional solution since eventually the transport sector should be fully decarbonised (SLoCaT, 2018).

| Fuel economy financial incentives and taxes | | |
|---|---|---|
| **Description:** Fiscal incentives and/or tax schemes (fuel, energy intensity or emissions taxes) that encourage the purchase of low-carbon vehicles, ships, aircraft. Such measures can be implemented in various ways, such as subsidies or tax exemptions for the most efficient vehicles, or additional taxes on the least efficient ones in terms of fuel consumption or emission intensity. A first step in this policy area should be to abolish counterproductive subsidies, such as those for fossil fuels.<br><br>**Impact:** Financial incentives for low carbon vehicles encourage passenger and freight to shift to more efficient and climate-friendly alternatives such as low-emission vehicles since they internalise environmental externalities. Because the policy is technology-neutral, it is likely to face less push-back, yet changes to fossil fuel support – and tax reforms in general – are known to be difficult to implement. | EU and national level<br><br>Road, maritime and aviation<br><br>Passenger and freight | Vehicle efficiency<br><br>Low emission technology developmen t<br><br>Fuel mix |
| *Sweden's bonus-malus system* was adopted in 2017 and came into force in 2018. Zero-emission cars, vans and light buses receive up to SEK 60,000 (more than EUR 5,500), and vehicles that emit a maximum of 60 grams $CO_2$ per kilometre receive up to SEK 7,500 (around EUR 700). Vehicles that run on petrol or diesel will be taxed at a higher rate for the first three years, and even when meeting the Euro 6 emission requirement, petrol and diesel cars no longer receive a five-year tax exemption (Transport Agency, no date; SLoCaT, 2018). | | |

- Although the law is relatively new since it only came into force in 2018, Sweden had fuel economy and tax incentives in place before this. The 2018 Act revised the standards to be more ambitious, demonstrating **high maturity.**
- The bonus-malus system is rather simple and can be drafted as a budget neutral policy if “malus” tax income is redirected to “bonus” incentive spending, suggesting **high replicability.**
- The policy demonstrates low to **medium impact** in the context of the EU. In Sweden, it effectively promotes low-emission alternatives while discouraging fossil-fuel based cars. EV sales, for example, increased in the months after the implementation of the scheme, and the policy seems to be well designed: e.g. the bonus is only paid out six months after car registration so one cannot collect the bonus and immediately resell the car. However, the scheme overlaps with the European emissions standard which may lead to leakages in other countries to reach the overall fleet emission average of 95 $gCO_2e/km$[43]. That said, given the ambitions of the bonus-malus scheme, it might also enable car manufacturers to develop technologies beyond the current EU emission standard. Finally, in its current form, the policy does not ensure achieving 0 $gCO_2e/km$, given in particular that natural gas based vehicles do benefit from lowered taxes (Transport Agency, no date; ICCT, 2018b).

### Vehicle Emission standards/fuel economy standards for new vehicles

| | | |
|---|---|---|
| **Description:** Vehicle manufacturers need to comply with minimum emission/fuel economy performance standards for their average fleet of new vehicles by given years. The aim of such standards is to reduce the emission intensity of vehicles, eventually phasing out carbon-intensive vehicles and even achieving zero $gCO_2/km$. This triggers both an increase in efficiency of ICE vehicles (initially) as well as a shift to zero-carbon vehicles (later). Fuel economy and vehicle emissions standards work in the same way but target different indicators, whereby one can be translated into the other.<br><br>**Impact:** Carbon-intensive vehicle types are driven out of the market over time, while at the same time there is a push for higher efficiency in vehicles. This furthermore incentivises the development of climate friendlier technologies and fuels as the limits of efficiency reductions in ICE vehicles are reached. | EU and national level<br><br>Road, maritime and aviation<br><br>Passenger and freight | Vehicle efficiency<br><br>Low emission technology developme nt<br><br>Fuel mix |

*The EU’s and Norway’s LDV emission standards*. While the European Union has set a target of 95 $gCO_2/km$ for light-duty passenger vehicles (LDVs) starting in 2021, Norway has set an even more ambitious target of 85 $gCO_2/km$ for the same year with the aim of reaching 0 $gCO_2/km$ by 2025 (Ministry of Transport, 2017; SLoCaT, 2018). Because Norway exceeded the 85 $gCO_2/km$ target already in 2017, the country never anchored it as law.

[43] While Sweden is providing a market for low emission vehicles, car manufacturers might decide to sell high emitting vehicles elsewhere and still reach the average fleet emission target. The EU emission standard needs to be adapted accordingly.

- Emission standards are well established in the EU, and standards have been adapted over time, demonstrating the **high maturity of the policy.**
- This policy is already being implemented at EU level and exists in eight other countries, demonstrating **high replicability**.
- The average $CO_2$ emissions for passenger cars registered in Norway in 2016 was 93 $gCO_2e/km$; the target of 85 $gCO_2e/km$ was reached already in 2017. At EU level the picture is different, as shown by the latest EEA figures: the average emissions intensity was 121 $gCO_2e/km$ in 2018, hence 2 $g/gCO_2e/km$ higher than the previous year (ICCT, 2019a). Car manufacturers will have to decrease emission intensity on average by 7.6% per year to reach the 2021 values. In Norway a large part of the contributions came from other, overlapping, policies, especially the generous policy package around the uptake of EVs (Steinbacher, Goes and Jörling, 2018). In addition, there were a number of scandals around car manufacturers manipulating test stand results which further decreased the effectiveness of the policy (Financial Times, 2018). This shows that emission standards, if not designed right, can also lead to a lock-in of the status quo. Overall, they still have been one of the most effective policies at EU level and therefore are ranked here as having a **medium impact**.

*The EU's HDVs emission standard*. Regulation (EU) 2019/1242 that entered into force on 14 August 2019, and will come into effect in 2025, sets $CO_2$ emission reduction standards for new heavy-duty vehicles (HDVs). The targets are a 15% emission reduction below the EU average (1 July 2019 to 30 June 2020) by 2030, and a 30% reduction thereafter. The regulation is to be revised and potentially adapted(European Parliament and Council, 2019; ICCT, 2019b).

- The policy has **low maturity.** Since it came into force in August 2019, there is no experience with the measure to date.
- HDV standards have been implemented in 12 countries (including the EU). In their structure, however, they are similar to the LDV standards, which have been replicated repeatedly (see above) and thus demonstrate **medium to high replicability** (ICCT, 2018a).
- See LDV standards: the policy has a high potential if implemented correctly. Whether this will be the case in the EU remains to be seen. The overall scoring here is thus the same as for LDVs**, medium to high impact.**

## Zero-emission (electric/hydrogen) mobility

Internal combustion engines (ICEs) fuelled by petrol or diesel are primary emission sources in the transport sector. Since 2010, electric vehicles (EV) have risen as an alternative, clean power source for two and three-wheelers, public transport vehicles, LDVs and HDVs (SLoCaT, 2018). Other energy carriers such as hydrogen, however, are not fully off the table as they might find different areas of application. As it stands, EVs have seen a more successful uptake, but how a future low-carbon fuel mix will look is yet to be determined. Therefore, we consider policies aimed at zero-emission vehicles (currently EV and hydrogen technologies). It is important to note that both require the decarbonisation of the power sector if they are to result in effective emission reductions. Further issues that need to be addressed include sustainable production, and the recycling of vehicles and batteries.

### Zero-emission vehicles purchase subsidy and other financial incentives

| | | |
|---|---|---|
| **Description:** In addition to – or instead of – general fuel economy financial incentives, this policy directly targets a shift to electric mobility (and/or other zero-emission technologies). This can be in the form of purchase subsidies and/or tax exemptions (lowered VAT or income tax waivers) that are given to car owners to cover the additional costs of EVs until they have reached market maturity.<br><br>**Impact:** The government partly bears the risk that comes with new technologies, supports the penetration of EV in the market, and subsidises the additional cost born by the EV market introduction caused by their immaturity. This incentivises consumers/businesses to purchase electric vehicles over ICE vehicles and in turn leads to a faster transition to electric mobility. | EU and national level<br><br>Road transport<br><br>Passenger | Low emission technology development |

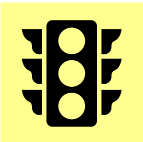
*Norway's generous EV support package*. The country provides generous financial incentives to support the uptake of electric and hydrogen mobility including purchase subsidies (up to EUR 10,000) or exemption from the 25% VAT (also on leased vehicles), as well as from import and purchase duties and fuel tax.

- The first financial incentives for EVs originated in the 1980s and developed since then, with purchase subsidies since early 2000 demonstrating **high maturity** (Ministry of Climate and Environment, 2018; Steinbacher, Goes and Jörling, 2018).
- It could be argued that based on the exponential growth of the EV market coupled with rapidly decreasing prices, any European country would be able to replicate such an ambitious financial incentive scheme, as demonstrated by renewable energy subsidies. Yet, it is important to note that this policy is highly linked to the level of wealth in the country/region in question. Some 20 countries have purchase subsidies in place, and successful implementation has occurred in regions such as Norway, Canada or California: all benefiting from exceptionally high GDPs (De Villafranca Casas *et al.*, 2018). Countries with a strong car manufacturing industry could face greater difficulties. Germany's reluctant car manufacturing industry shows this could also turn out to be an advantage in the transition to EVs, as is the case in China. This demonstrates **medium to high replicability.**
- The policy, if implemented right, shows **high impact** (especially in combination with other polices, see Box 6). In Norway, in the first half of 2019, EVs represented 48.4% of new car sales, leading even the current prime minister to suggest that a ban on fossil fuel cars is not needed due to the effectiveness of the financial incentives for EVs (Aftenposten, 2019; Reuters, 2019a).

### Ban on vehicles with internal combustion engines (ICEs)

| | | |
|---|---|---|
| **Description:** Under a ban on ICE sales, emitting vehicles may no longer be sold or put into circulation after a given date. Although the policy is typically discussed in the context of road transport, it could also be applied to rail, maritime and air transport.<br><br>**Impact:** Manufacturers turn away from ICE production and focus on alternative technologies since the ban provides a clear vision of where the sector is heading. Consumers reconsider buying a vehicle with ICEs and consider buying an EV or hydrogen car, or even prefer a shift to other transport modes such as public transport or cycling. | EU and national level<br><br>Road, rail, maritime and aviation<br><br>Passenger and freight | Low emission technology development<br><br>Fuel mix<br><br>Modal shift |

*Norway's upcoming ban on ICE* ***vehicle sales***. No country currently has a legally binding target for the ban of fossil fuel vehicles. Norway is planning to introduce a ban on the sale of vehicles with ICEs for 2025 (SLoCaT, 2018; Aftenposten, 2019).



- The ban was announced at a high-political level in 2016, but the commitment is still under debate and has not been anchored in law so far, demonstrating **low maturity**.
- A ban by a given date is difficult but is already being discussed by several countries and cities (8 countries on the European continent), and some European ministers have advocated an EU-wide ban on the sale of ICE vehicles (Ekblom, 2019), thus the measure has **medium replicability** (Coren, 2018).
- There is no experience with what impact a legally binding ban would have. In any case, even if binding in nature, this needs to be supported by other policies supporting a shift to alternative modes of transport and public transportation. Such a ban sends a strong economy-wide signal that a shift is needed (Aftenposten, 2019). This demonstrates **high impact.**

### Improve EV charging infrastructure

| | | |
|---|---|---|
| **Description:** To enable a shift to greater electro-mobility, charging infrastructure density needs to be improved through regulations and public funding.<br><br>**Impact:** Charging infrastructure helps overcome refuelling and convenience barriers, reduces range anxiety and thus leads to a quicker transition to electric mobility. | EU, national, regional and city level<br><br>Road transport<br><br>Passenger | Low emission technology development |

*California's EV infrastructure rollout.* To reach its goal of 5 million zero-emission vehicles (ZEVs) on the roads by 2030, California is aiming for 250,000 zero-emission vehicle charging stations (including 10,000 electric fast chargers and 200 hydrogen fuelling facilities) by 2025, which represents more than 6,000 stations per 1 million inhabitants. California is financing pilot programmes under the new Zero-Emission Vehicle Investment Initiative (2017-2025) to develop the state's charging infrastructure with public investments of around USD 2.5 billion (U.S. Department of Energy, no date; State of California, 2018, 2019).

- Currently, only 22,000 public charging outlets are available throughout California and many measures containing current pilot programmes are still in the proposal phase, demonstrating **low to medium maturity** (U.S. Department of Energy, no date).
- The level of replicability is hard to assess, since it requires the availability of public funds. The state's coordination role with transmission system operators (TSOs) and the easing of regulations around charging infrastructure (e.g. residential or commercial charging) can be more easily replicated, demonstrating **medium to high replicability**. In fact, France, Germany, Norway, Slovenia and others have EV charging infrastructure targets and funding in place.
- The charging infrastructure is the supporting infrastructure needed to achieve EV fleet targets. Linking the impact of EV uptake to charging infrastructure cannot be measured directly. This can be seen in Norway's case, where inhabitants prefer to charge at home and at the workplace rather than public charging stations. California supports residential, commercial and utility-scale infrastructure, suggesting **medium impact.**

| Behavioural incentives for zero-emission vehicles | | |
|---|---|---|
| **Description:** Behavioural incentives give owners of electric vehicles or other zero-emission vehicles priority access to certain services over other vehicle owners until EVs achieve market maturity. Common types of incentives include the high occupancy vehicle (HOV) or bus lane access, exemption from road tolls, ferry fees and municipal parking fees.<br><br>**Impact:** Behavioural incentives encourage the shift to low-emission vehicles since these vehicles are given priority over other types of vehicles. | EU, national, regional and city level<br><br>Road, rail maritime and aviation<br><br>Passenger | Low emission technology development |

*Norway's behavioural incentives for EVs*. Norway is the only country to have national policies in place to address behavioural incentives (De Villafranca Casas *et al.*, 2018). Some regions such as California also have similar incentives in place.

- Free parking and toll road fee exemptions were established as national BEV incentives from 1997 and 1999 by national laws, and in 2003, bus lanes were opened for BEV owners in Oslo and surrounding municipalities, demonstrating the **high maturity** of such policies (Steinbacher, Goes and Jörling, 2018).
- Behavioural incentives are almost budget neutral and can rather easily be replicated to other regions as well as to rail, aviation and maritime transport. Thus, behavioural incentives are **highly replicable.**
- Access to free public EV parking, exemptions from city driving restrictions or the privilege of driving in bus lanes, has rather low impact (De Villafranca Casas *et al.*, 2018). Yet, due to increasing toll roads and congestion zones around cities and main roads, exemptions and privileges have been shown to have high impact (Steinbacher, Goes and Jörling, 2018). Overall, behavioural incentives have a **low to medium impact.**

## Box 7: EV support as a package

EV support must be regarded as a policy package. While some policies will have an impact as standalone policies (e.g. financial support schemes) others will likely not (e.g. charging infrastructure). In either case, the most effective way to implement them is in combination with other policies. We will examine a good practice policy package along the Norwegian example (De Villafranca Casas et al., 2018).

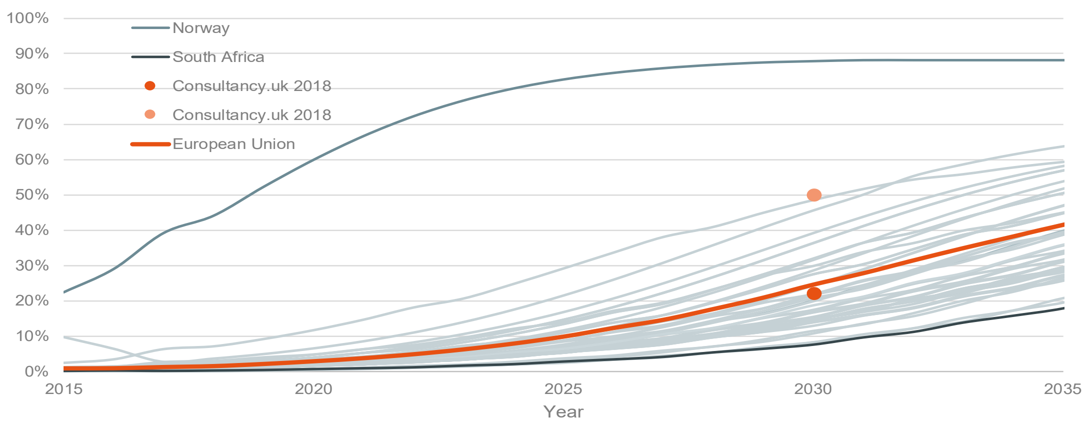
The Norwegian Government established new zero-emission vehicle targets in its National Transport Plan 2018–2029: by 2025, all new passenger cars, light vans and buses sold must be zero-emission vehicles, with some biogas allowed for buses; by 2030, all new heavy duty vehicles, 75% of new long distance coaches and 50% of new trucks must be zero-emission vehicles, and the distribution of freight in the largest urban centres must also be almost carbon neutral (Ministry of Transport, 2017). While these targets are not legally-binding, they give a clear vision and have proven powerful in combination with other policies:

| A good practice EV policy package | Norway's example |
|---|---|
| Charging infrastructure density represented as the number of publicly available chargers per million capita (no policy data) | After the Netherlands, Norway has the best EV charging infrastructure, with almost 2,000 chargers per million inhabitants |
| Purchase subsidy | After Canada, Norway has the highest purchase subsidy: just over EUR 10,000 per EV |
| Other financial incentives such as registration tax benefits, ownership tax benefits, company tax benefits, VAT benefits | Together with China, Norway provides the most lucrative financial incentives |
| Behavioural incentives include free parking benefits, toll benefits, access to bus lanes with EVs, and can also include exemptions from driving restrictions in cities | Norway is the only country with national policies for behavioural incentives |

Analysis undertaken in De Villafranca Casas et al., (2018) shows that the current policy package as implemented in Norway can lead to a share of EVs in new vehicles of around 90% by between 2025 and 2030. According to the analysis undertaken, by comparison the EU would only achieve a share of up to 20% in the same time period if current policies where to be continued (see graph below).

**Evaluation of policy package**

- Norway started the transition well before any other country, so that by the early 2000s the country already had a comprehensive policy package and around 10% of new car sales were EVs, demonstrating **high maturity** for the policy package.
- Another factor that needs to be taken into account when modelling EV uptake is GDP/capita, which has a high level of influence since electric mobility is presently more expensive than the incumbent technologies. While this is a clear barrier to replicability in the short-term, prices for EVs are coming down, with some analysts suggesting that EVs might achieve cost-parity with conventional vehicles soon. The continued uptake in economically stronger markets therefore will enable EV prices to fall further, which indirectly increases replicability, overall demonstrating **medium replicability** (Reuters, 2019a).
- As can be seen in the chart below, Norway's policy package for EVs has had a **high impact**, making the country the leader in EV uptake.




In Norway, the uptake of EVs is stagnating at almost 90%, potentially leaving room for other zero-emission vehicles such as hydrogen cars. The projections shown here are developed with an S-curve based model that estimates the impact of EV policy packages in individual countries. The grey lines represent the modelled uptake in other G20 countries. The results were compared to other studies on the EU (dots). Historical values extend to 2017. For more details on the approach, please see De Villafranca Casas et al., (2018)

## Sustainable fuels in transport

While EVs and hydrogen-based vehicles provide a ready solution for some parts of the transport sectors, others require the development of alternatives to current fuels. This is especially the case for the aviation and maritime sectors where, if biofuels are not to be used, alternative synthetic fuels generated by low and eventually no-carbon sources will need to play an important role.

### Support synthetic fuels for air and maritime transport[44]

| | | |
|---|---|---|
| **Description:** Policies actively promoting the use of zero emission synthetic fuels such as fuel policy targets and/or quotas, **fiscal and/or financial incentives, and obligation schemes or research and development funding.** Due to the food-to-fuel issues of biofuels and the lack of commercially viable synthetic fuels, policy measures are crucial to stimulating sustainable aviation and maritime fuel demand and supply (Transport & Environment, 2018)**.**<br><br>**Impact:** Synthetic fuels may offer an alternative fuel source for transport modes that cannot be electrified as easily as passenger vehicles, such as air travel or maritime transport. | EU and national level<br><br>Maritime and aviation<br><br>Passenger and freight | Fuel mix |

While some prototype projects partially or fully funded by public money are in place, there currently is no good practice policy on the use and promotion of e-fuels. Some private-public partnerships exist around the use of sustainable fuels, yet these rely on advanced biofuels (SkyNRG, no date; SLoCaT, 2018). Furthermore, as of January 2020, Norway has set a minimum requirement of 0.5 per cent of aviation fuel sold in the country to be advanced biofuels (Ministry of Climate and Environment, 2019; Karagiannopoulos, 2020). Such initiatives could be replicated for e-fuels.

**Currently no good practice policy.**

[44] In this analysis we consider synthetic fuels as zero emission fuels of non-biological origin (RFNBO), where additional zero emission electricity is used to extract hydrogen (power-to-liquid processes). Thus, it has a direct link to the power sector.

## 4.5 Intermediate step 2: Identifying and bridging policy gaps to achieve DT-2040

Good-practice policies provide a good starting point to help policy makers identify how more can be done on the basis of realistic and already proven policy actions. If applied in a structured manner by assuming the highest level of replication across the EU and all Member States, it can also help identify how far we can get scaling up that which already exists. This can be a relevant tool to help policy makers push for greater ambition. However, it does not ensure that the higher-level target of zero emissions by 2040, as set in this project, will be achieved. Proposed policies based on existing good-practice policies are highlighted in orange in the analysis below.

To identify whether existing and scaled-up good-practice policies are sufficient and where more action is needed, we compare the level of ambition of these policies with benchmarks that ensure that zero emissions by 2040 can be achieved. This is done in this section by comparing the level of ambition of current EU policies with the scaled impact of good-practice policies identified in Section 4.2. and the level of ambition needed under the DT-2040 scenarios. We analyse the level of ambition of policies for each of these 3 ambition levels and for all levers used in the scenario (see the conceptual framing Section 4.2).

The analysis below links policies at EU level, good-practice policies and the policies needed to achieve the level of ambition required in the scenarios, and only includes the name of the policy without further explanation. For a full description of good-practice policies, marked orange in this section, we refer you to Section 4.2.4. For a full description of the recommended policies, we refer you to the policy packages in Section 0. The same names are used in the three sections to allow the reader to easily find more detail on the policies.

Because the adjustments in policy design between good practice and the highest level of ambition (improving and complementing current good-practice policies) is not reflected in the policy title, and to avoid redundancies, the analysis below merges the qualitative description of scaled up good-practice policies and policies needed to achieve the highest level of ambition.

The analysis is undertaken on a qualitative level, using literature and informed expert judgements. Hence it serves to give an idea of the order of magnitude of the change needed at all three policy levels.

### Box 8: The role of research and development (R&D)

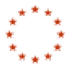
**What is it**: Policies supporting research, innovation and knowledge creation, typically in the form of funding. Scenarios and policies inform the science agenda concerning the areas, sectors and technologies for which the identification of decarbonisation solutions is most significant, most (cost) effective or where there is a lack of solutions.

**Impact**: Research, innovation and knowledge production are key to the process of defining sound policies. Research and development (R&D) activities may lead to the development of new solutions that can potentially fill need gaps. In fact, actively supporting the development of new technologies and solutions is essential to kick-starting solutions that go beyond the currently imaginable and to making radical innovations possible. The impact on direct emissions, however, is very small.

**R&D examples**: R&D funding for sustainable batteries, autonomous driving, behavioural science, long-distance travel alternatives, innovative mobility such as MaaS, alternative fuels (e-fuels and/or hydrogen fuel), scenario development, pilot projects (e.g. through public-private partnerships), using the internet of things and automation for efficient logistics and more.

Thus, caution should be used when using the analysis to develop ambition levels for concrete policy recommendations. Such an analysis needs to be complemented with a more detailed analysis in these cases. Where possible, we try to indicate the level of stringency for each of the policies proposed/analysed. In many cases, however, the number of dimensions is too great to be described here.

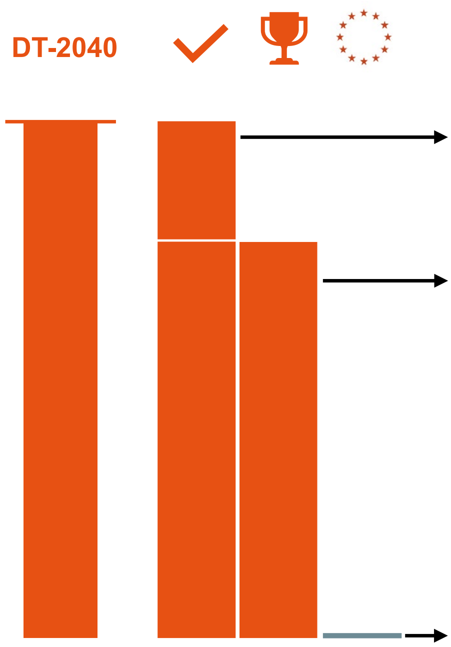
Figure 26: Nomenclature of symbols used in the linking analysis

| | |
|---|---|
| **DT-2040** | Ambition level of the DT-2040 scenario modelled in this study |
|  | Policies needed to reach the level of ambition of DT-2040 (based on scaling up good practice policies when available, which are marked in ornage) |
|  | Ambition level of good practice policies scaled up across the EU, based on maturity, replicability and (potential) impact |
|  | Ambition level of current EU policies |

### 4.5.1 Passenger transport

Policies at EU level to reduce passenger demand are basically non-existent or have achieved very little (such as the European structural investment fund). At MS level, and especially at city level, proven and effective examples of significant reductions in transport demand exist that could be replicated across Member States. Recent developments, such as those around transit-oriented development or the promotion of a virtual team at a large scale, could further reduce demand and eventually allow the levels defined by the DT-2040 scenario to be achieved. With some exceptions, the gap between the level of ambition needed in the scenarios to decarbonise passenger transport by 2040 and good-practice policies if scaled EU-wide, is typically filled by enhancing or ameliorating existing good-practice policies.

**Lever: Transport demand**
-15% for overall transport demand; -50% for aviation demand



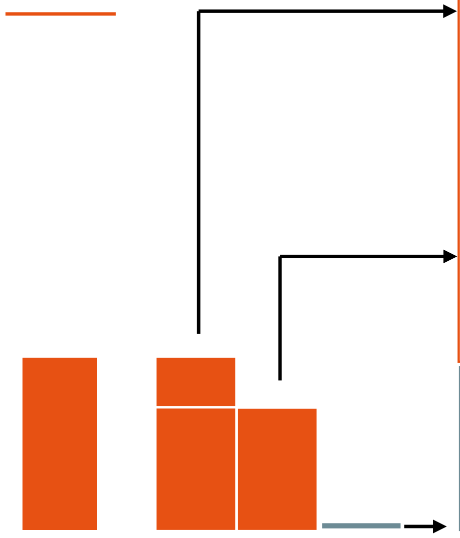

- Urban planning should be centred around the Transit Orientated Development (TOD) concept in metropolitan areas and in rural areas where applicable
- Promote virtual meetings and teleworking
- Ban short-to-medium distance flights.
- Introduce high air ticket taxes domestically and internationally
- Develop sustainable metropolitan areas
- Tax national and European flights at least equally to high speed trains as well as international flights

- European Structural investment fund
- EU – ETS (aviation)
- Support for Sustainable Urban Mobility Plans (SUMPs)

While there are no policies at EU level, existing good-practice policies if scaled up to European level do achieve a high level of ambition. We mainly refine these policies to achieve the scenario goal.

**Lever: Occupancy rate**
+25% compared to 2015 for cars (2 passengers per vehicle) and buses (22 passengers per vehicle)

**DT-2040**



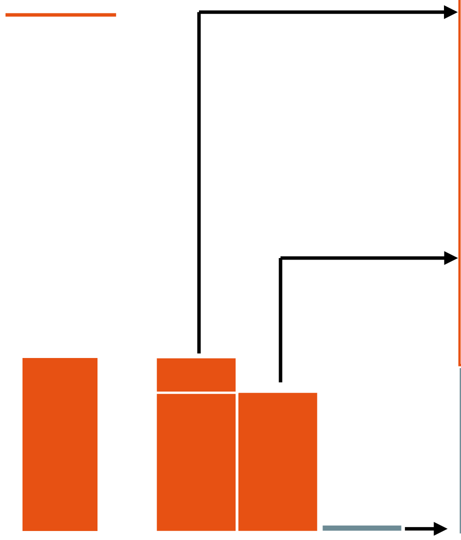
- Develop or strengthen congestion and low to no emission zones
- Incentivise sharing trips
- Support a shift from passenger vehicle transportation to Mobility as a Service (MaaS)
- Establish an inter-modality regulatory framework
- Shift away from passenger and delivery service vehicles in cities

- Directive 2010/40/EU (amended by Decision (EU) 2017/2380 and C(2018) 8264) on Cooperative Intelligent Transport Systems (C-ITS) and Interoperable payment / ticketing (MaaS)

To boost occupancy levels, we rely on policies pushing for carsharing, MaaS and intermodality of transport modes, partly based on good-practice policies but mainly on existing literature.

**Lever: Utilisation rate**
+20% compared to 2015 for cars and buses and +10% for two-wheelers

**DT-2040**

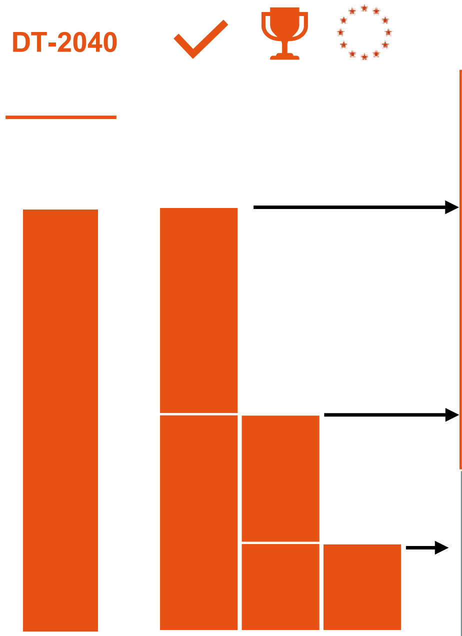


- Develop policies/ strategies to shift large shares of passenger vehicle transportation towards use of Mobility as a Service (MaaS)
- Establish an inter-modality regulatory framework

- Directive 2010/40/EU (amended by Decision (EU) 2017/2380 and C(2018) 8264) on Cooperative Intelligent Transport Systems (C-ITS) and Interoperable payment / ticketing (MaaS)

For occupancy rates, we rely on improving transport management through an intermodality framework and MaaS to increase a vehicle's utilisation rate.

**Lever: Modal share**
Urban areas: shift to walking, bike, public transport; Non-urban areas: shift to rail, bus and cycling



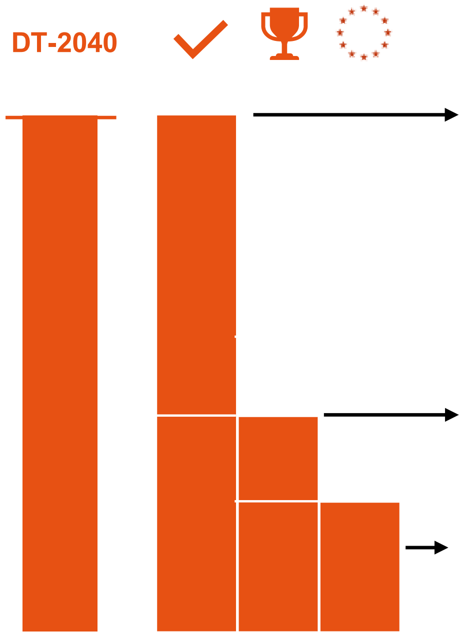

- Improve walking and cycling infrastructure
- Improve public transit infrastructure
- Support a shift to rail transport
- Introduce / adjust financial incentives
- Disincentivise less climate friendly modes

- Avoid unsustainable infrastructure with a long lifespan
- Shift away from passenger and delivery service vehicles in cities
- Improve walking and cycling infrastructure
- Develop light-rail and bus transit
- Financial incentives (public transport)
- Develop and support railway infrastructure and services
- Establish an inter-modality regulatory framework
- Taxing national and European flights (at least equally to high speed trains) and international flights even more

- Regulation no. 1370/2007 on public transport services by road and rail
- Trans-European Transport Network Policy (TEN-T)
- Fourth railway package of 2016
- European Structural investment fund

Essentially, the analysed policies shift transport demand away from individual passenger vehicles to alternative modes of transport. Although they are very sensitive to the local context, good-practice policies provide a good basis but their ambition levels need to be drastically increased.

**Lever: Vehicle efficiency**
A 40% to 50% increase in energy efficiency for all modes by 2050

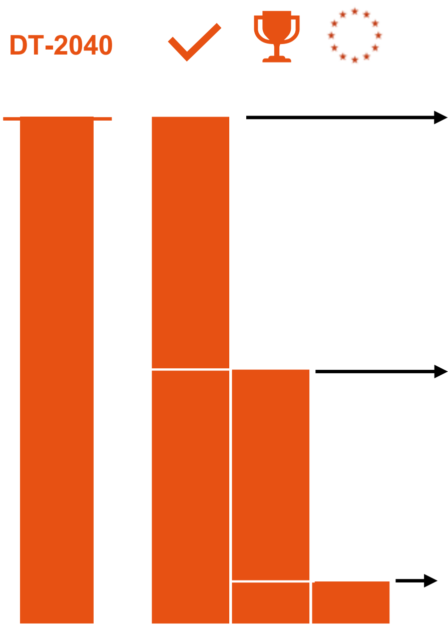



- Develop (ideally budget-neutral) schemes to support the shift to 100% zero-emission vehicles sales
- Introduce a new and more ambitious EU Directive on emission standards
- Fuel economy financial incentives and taxes

- Regulation (EU) 2019/631 - emission performance standards for new passenger LDVs

EU policies are in place to promote greater vehicle efficiency and, when properly enforced, have proven to be quite effective. Yet, their ambition is far too low to achieve the needed results, and further monitoring schemes are required to ensure proper enforcement. Based on good practice and the literature, we propose more stringent policies to achieve greater efficiency levels.

**Lever: Technology share**
LDV sales by 2028: 100% BEV; Bus sales by 2028: 75% BEV & 25% FC; By 2040: fully electrified new trains and 10% electric new planes




- Develop zero emission vehicles support packages, e.g.:
  - Implement behavioural incentives
  - Develop comprehensive and generous financial incentive package
  - Develop comprehensive EV charging infrastructure packages
- Ban fossil-fuel cars:
  - Clearly ban new sales of and registration of ICE vehicles
  - Ban ICE vehicles on a city-level

- Zero-emission vehicles purchase subsidy and other financial incentives
- Ban on vehicles with internal combustion engines (ICEs)
- Improve EV charging infrastructure
- Behavioural incentives for zero emission vehicles

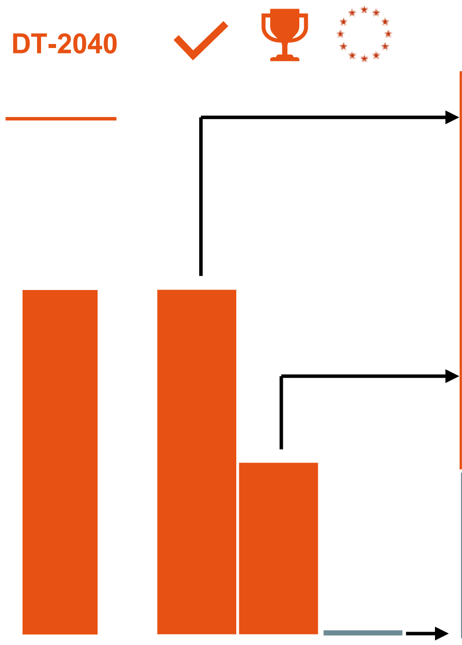
- Directive on the Promotion of Clean and Energy Efficient Road Transport Vehicles (Clean Vehicles Directive)

In order to achieve zero emissions by 2040, policies promoting a shift to zero-emission vehicles need to be much more stringent and ambitious than EU or good-practice policies. Here we gather policies from good-practice examples and available studies to push for mainly electric mobility.

### 4.5.2 Freight transport

In contrast to passenger transport policies, few freight transport policies for reducing emissions are in place today. This results in a wider gap between the scenario ambition levels and good-practice policies when scaled up to the EU, regardless of current EU policies.

**Lever: Transport Demand**
+15% by 2050 for all modes



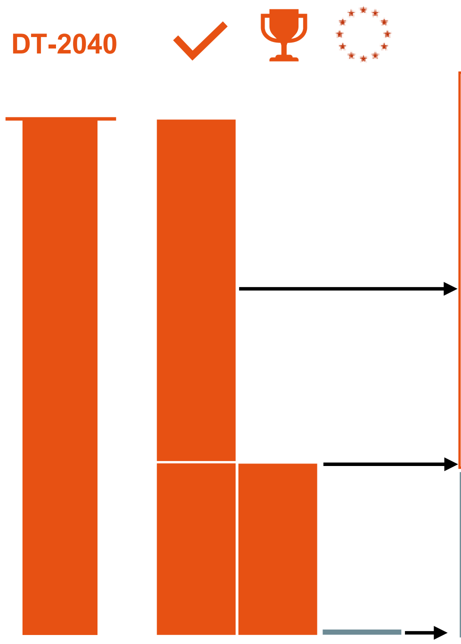

- Reduce transport in urban areas:
  - Elaborate freight transport strategies including logistics consolidation centres
  - Develop or strengthen congestion and low to no emission zones
- Accurate costing of transport and logistics costs
- Support efficient logistics such as cross-docking

- Shift away from delivery service ICE vehicles in cities
- Develop sustainable metropolitan areas (elaborate (zero-emission) freight transport strategies to supply urban areas)

- No policy

The good practice example shows that efficient logistics can reduce the overall need for freight transport, yet freight demand is also influenced by consumption, which is not covered here.

**Lever: Load factor**
+15% by 2050 for all modes



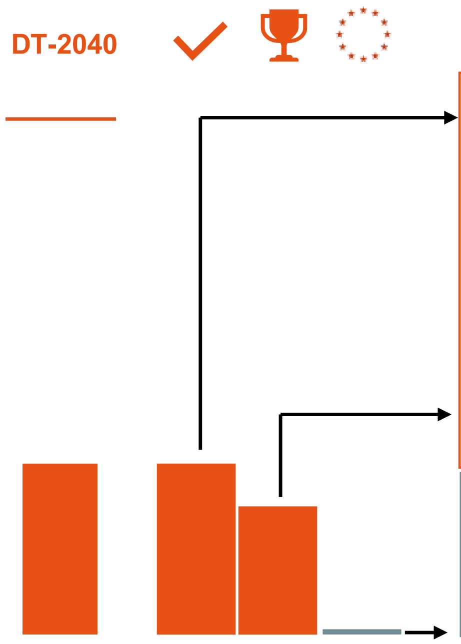

- Incentivise efficient logistics:
  - Develop appropriate revenue/cost sharing models to incentivise horizontal and vertical coordination and collaboration
  - Set standards for the containerization of goods for the inland transport

- Shift away delivery service vehicles in cities
- Developing sustainable metropolitan areas (elaborate (zero-emission) freight transport strategies to supply urban areas)

- No policy

We rely on the available literature to suggest policies for increasing freight transport load factors.

**Lever: Utilisation rate**
+3% by 2035 for all modes

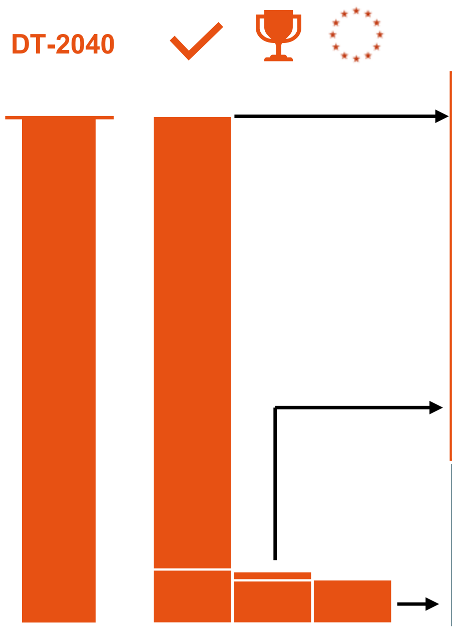



- Incentivise intermodal freight transport:
  - Develop appropriate revenue/cost sharing models to incentivise horizontal and vertical coordination and collaboration
  - Support and remove regulations that hinder innovation, cross border transport operations and synchromodal transport
  - Amend the Combined Transport Directive 92/106/EEC
- Establish an inter-modality regulatory framework

- Combined Transport Directive 92/106/EEC

We propose a regulatory framework that incentivises intermodality in order to increase utilisation rates.

**Lever: Modal share**
Medium to long distance: shift from HDV to rail and inland waterways (25% and 16% respectively by 2040);
Last mile solutions: shift from HDV to smaller HDV and cargo bikes

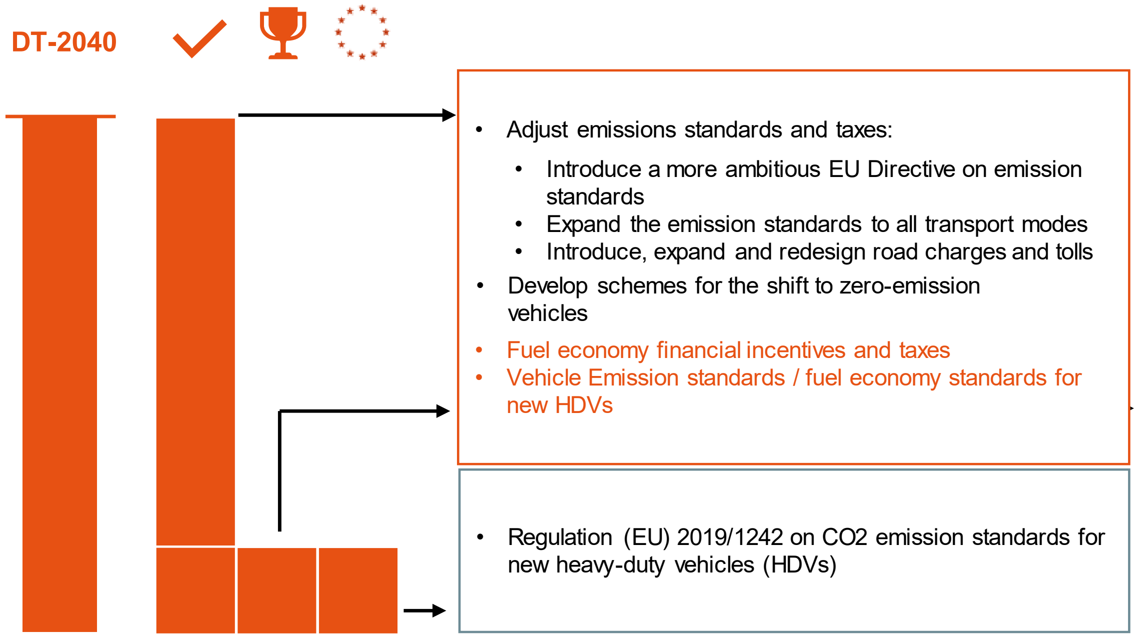



- Develop sustainable infrastructure:
  - Develop comprehensive plans, regulations and public funding
  - Systematically assess compatibility of new infrastructure projects
- Incentivise intermodal freight transport:
  - Amend the Combined Transport Directive 92/106/EEC
  - Establish a regulatory level playing field between road and rail transport
- Develop and support railway infrastructure and services (incl. high speed railways)
- Avoid unsustainable infrastructure with a long lifespan
- Establish an inter-modality regulatory framework

- Regulation (EC) No 1692/2006 EU Marco Polo Program
- Regulation no. 1370/2007 on public transport services by road and rail
- Fourth railway package of 2016
- Combined Transport Directive 92/106/EEC

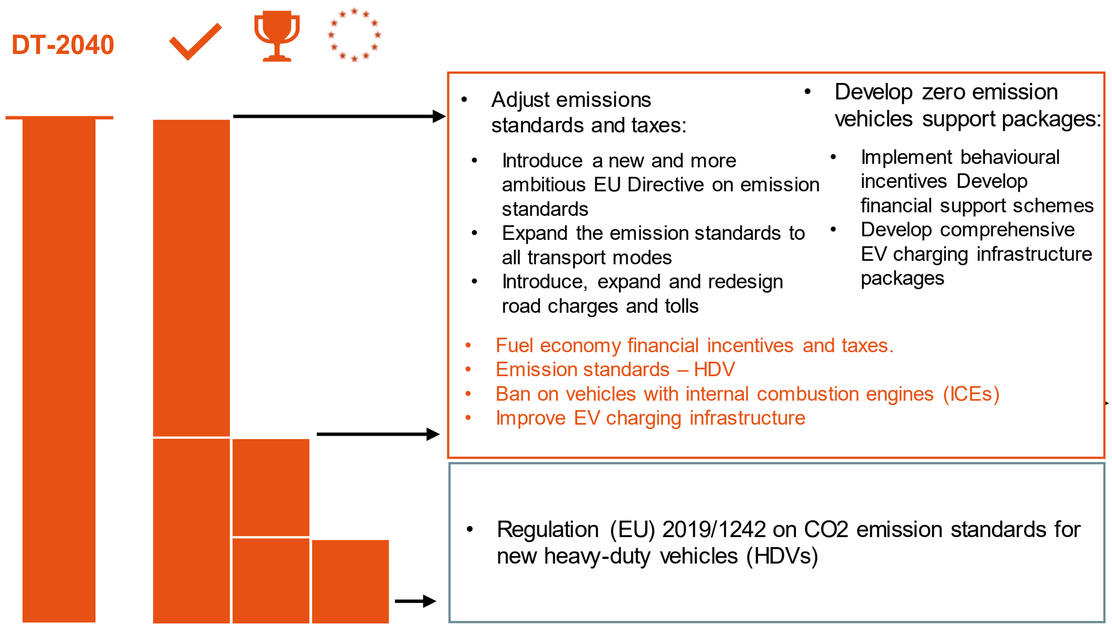
In contrast to passenger transport, there is little evidence of modal shift policies for freight transport. We are proposing a set of policies to shift transport to rail and to ensure sustainable infrastructure projects.

**Lever: Vehicle efficiency**
A 40% to 50% increase in energy efficiency for all modes by 2050



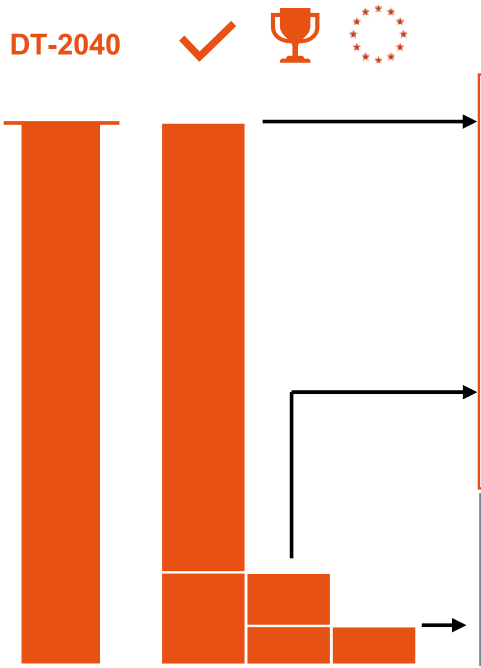

We would drastically ramp up the level of ambition of existing/upcoming policies to achieve the ambition level needed.

**Lever: Technology share**
By 2032: fully electrified new trucks and trains; By 2040: 25% electric new planes; By 2050: 50% electrified maritime ships and 75% electrified inland waterways ships




Based on existing passenger transport policies and the literature, we propose a set of policies to incentivise electric mobility for all transport modes, with a focus on road transport.

**Lever: Fuel mix**
0 % biofuel; 0% synthetic fuels for road transport; 100% synthetic fuels for maritime and aviation by 2040




- Support alternative fuels:
  - Introduce green port fees and/or similar schemes.
  - Amend the EU Renewable Energy Directive (e.g. by including binding target trajectory for e-fuels)
  - Actively support R&D and the uptake of synthetic fuels
- Support renewable synthetic fuels for air and maritime transport

- Regulation (EU) No 1291/2013 within the Horizon 2020 project, EUR 4 billion for Public-private partnership to develop cleaner aircraft

While road transport policies are more established and straight-forward, long-distance travel such as maritime and air transport lacks technical solutions to date. To ramp up synthetic fuels zero-emission electricity, extensive research and development is needed, and prototype projects (such as public-private partnerships) need to be expanded and supported generously. Current policies do not ensure a switch in fuels; good-practice policies only exist for supporting the uptake of sustainable bio-fuels. These could be replicated for the uptake of alternative synthetic fuels, but caution needs to be applied as the technologies differ in important regards.

# 5 Appendix - Details of the assumptions on levers

## 5.1 Passengers

| Lever | Description | Target value 45 | Comment (if different from EuCalc) |
|---|---|---|---|
| Transport demand | Number of kilometres travelled per person per year. | -15% for all modes<br>For aviation: -33% by 2040 or -50% by 2050 | Ambition for aviation increase vs EuCalc. |
| Occupancy | Number of persons in a vehicle (for cars and buses). Given the same transport demand, this influences the number of cars on the road. | +25% between 2020 and 2050 | |
| Modal share | Share of passenger demand for each passenger transport mode | Urban: 34% LDVs<br>Non-urban: 64% LDVs | |
| Technology share in new car sales | Percentage of sales for a given technology. A target exists for each transport mode (LDVs, two-wheelers, buses, etc.) Only LDVs are specified in this table. | 95% BEV<br>5% FCEV<br>These target values are reached by 2030 | Target year ambition set to 2030 (2040 initial parameter in EuCalc). Ambition value changed (70% BEV and 30% FCEV as initial parameters in EuCalc for LDVs). |
| Utilisation rate | Average number of vehicle kilometres travelled each year. With a higher utilisation rate, less vehicles are needed to travel the same number of vehicle-kilometres. | +20% between 2020 and 2050 | |

## 5.2 Freight

| Lever | Description | Target value | Comment (if different from EuCalc) |
|---|---|---|---|
| Transport demand | Total number of tonne-kilometres | +15% | |
| Load factor | Number of tonnes in a vehicle (only for HDVs) | +5% | |
| Modal share | Share of freight demand for each freight transport mode<br>This excludes international shipping (no related changes expected) | 42% to HDV<br>36% to rail<br>22% to IWW | Rail significantly increased (see Rail Freight Forward (2018)) |
| Technology share - share of new sales | Share of tech in new vehicle sales | - HDVs: No more FF in 2032[46], only FCEV (hydrogen) and BEV.<br>- Rail: idem<br>- Water-based transport: 5% of BEV, the rest is 95% of FCEV and ammonia | Target year ambition set to 2032 (2040 initial parameter in EuCalc). |
| Utilisation rate | Average number of vehicle kilometres travelled each year. With a higher | +3% | |

[45] Unless specified otherwise, the transition starts in 2020 and reaches its targets by 2050.
[46] Different ambition levels between FCEV and BEV depending on type of trucks.

| | | | |
|---|---|---|---|
| | utilisation rate, fewer vehicles are needed to travel the same number of vehicle-kilometres (only for HDVs) | | |

## 5.3 Transversal

| Subsector | Lever | Description | Target value | Comment (if different from EuCalc) |
|---|---|---|---|---|
| Transversal - Fuel mix | Biofuels (all) | Share of biofuels used for each vehicle type (cars, trucks, planes, ships) | 0% of biofuels | Ad-hoc assumptions linked with initial narratives |
| | Synthetic fuels | Share of synthetic fuels used for each vehicle type (cars, trucks, planes, ships) | 100% of synthetic fuels by 2040 (starting in 2030) excluding road transport | |
| Transversal - Energy efficiency | Energy efficiency - Cars & vans | Energy consumption of vehicle per vehicle-kilometre (or per passenger-kilometre for rail or airplane transport). | For HDVs and LDVs: ~40%-50%[47]<br>For ships: -30%<br>For planes: -22%<br>For bus: -30% | |
| | Energy efficiency - trucks & buses | | | |
| | Energy efficiency - trains | | | |
| | Energy efficiency - planes | | | |
| | Energy efficiency - ships | | | |
| Transversal - Ban | Ban on ICE vehicles | Ban all the road vehicles (LDVs, HDVs, 2-Wheelers, buses, etc.) – not only new sales. | Complete ban in 2040 | Ad-hoc assumption |

[47] Depends on the type of vehicle (e.g. LDVs vs HDVs & BEV vs thermals)

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