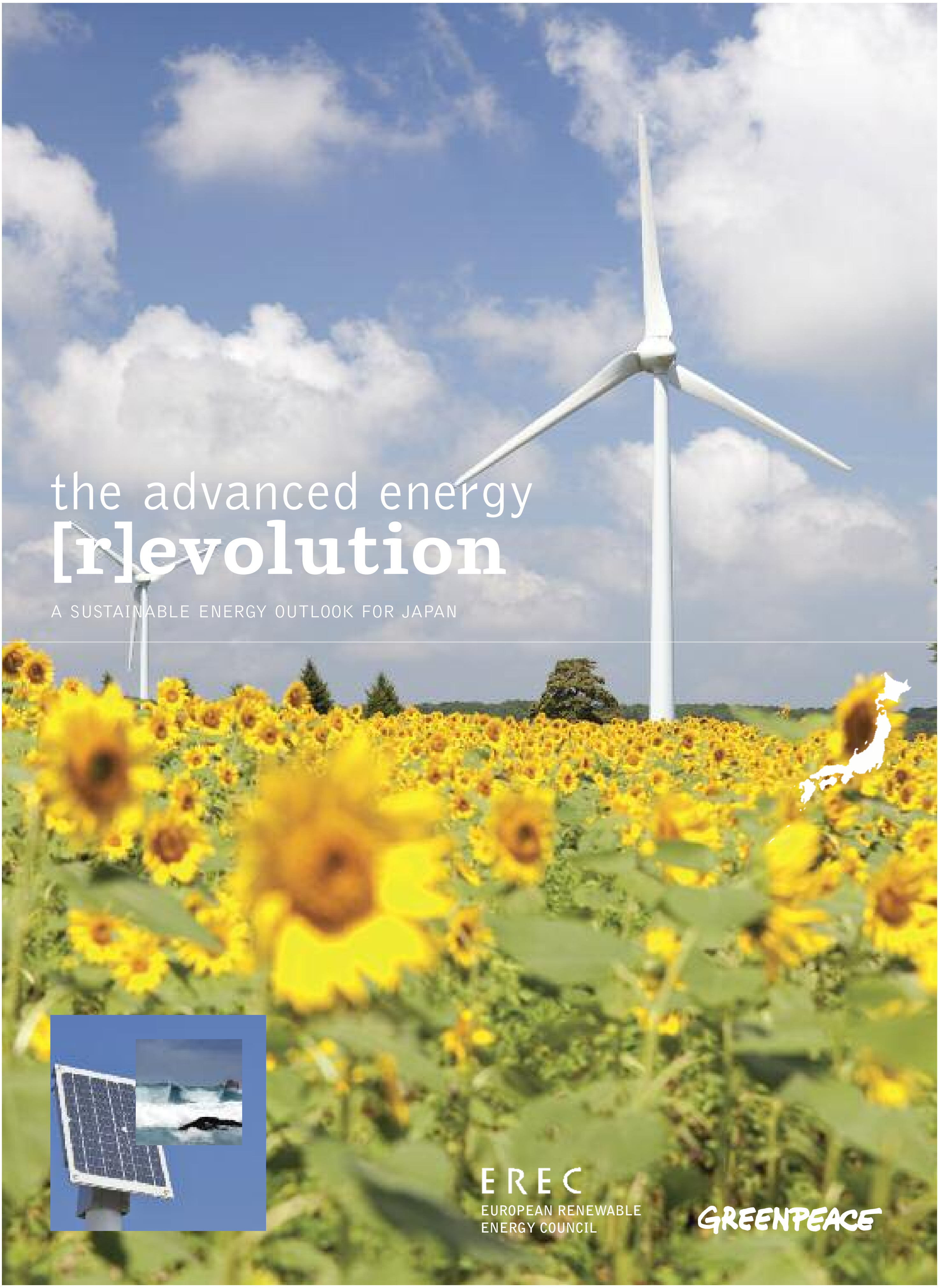
the advanced energy [r]evolution

A SUSTAINABLE ENERGY OUTLOOK FOR JAPAN



EREC
EUROPEAN RENEWABLE ENERGY COUNCIL

GREENPEACE

report 2nd edition 2011 japan energy scenario

"will we look into the eyes of our children and confess

that we had the **opportunity**,
but lacked the **courage?**
that we had the **technology**,
but lacked the **vision?"**

Greenpeace International, European Renewable Energy Council (EREC)

date September 2011

project manager & lead author
Sven Teske, Greenpeace International

EREC Arthouros Zervos

Greenpeace International
Sven Teske

Greenpeace Japan
Junichi Sato, Hisayo Takada

partners

image RICE FIELDS IN KAMIKATSU, TOKUSHIMA, JAPAN.

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research & co-authors
DLR, Institute of Technical Thermodynamics, Department of Systems Analysis and Technology Assessment, Stuttgart, Germany: Dr. Wolfram Krewitt (†), Dr. Thomas Pregger, Dr. Sonja Simon, Dr. Tobias Naegler, Institute for Sustainable Futures, University of Technology, Sydney: Jay Rutovitz, Nicky Ison (Chapter 7).

Regional Partner: ISEP, Institute for Sustainable Energy Policies, 4-54-11 Chuo, Nakano, Tokyo, Japan: Tetsunari Iida, Hironao Matsubara

editors Crispin Aubrey (underlying document) Caroline Chisholm

design & layout onehemisphere, Sweden, www.onehemisphere.se

contact sven.teske@greenpeace.org, erec@erec.org

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foreword

Over the past three years, the Energy [R]evolution has provided an invaluable contribution to the energy sector and has become a point of reference for many. It is a valuable source of information for the International Renewable Energy Agency (IRENA) which, with 152 affiliated states and 84 ratifications to date, has a clear political mandate to support the global transition to a sustainable energy system based largely on renewable energy.

IRENA's mandate also confirms the recognition by the international community that our planet is facing severe economic and environmental challenges, that we urgently need to create a clean, more secure energy industry, and that renewable energy is an essential – indeed an inexorable – part of the solution.

The energy system is characterized by capital stock with a long life span and by large infrastructure projects that take many years from conception to completion. Within such timeframes, many parameters can change. Climate change is probably currently the most compelling issue, but supply security and fossil fuel depletion,

ANDASOL 1 SOLAR POWER STATION SUPPLIES UP TO 200,000 PEOPLE WITH CLIMATE-FRIENDLY ELECTRICITY AND SAVES ABOUT 149,000 TONNES OF CARBON DIOXIDE PER YEAR COMPARED WITH A MODERN COAL POWER PLANT.

energy access and economic growth, and local air pollution all must be considered. Scenarios are a tool that help deal with uncertainty and assist in mapping out the complexity of issues that have to be considered in the decision making process. The energy [r]evolution studies on emerging economies as well as industrialized countries such as Japan highlight new and different challenges that such contexts pose. At the same time, it shows that countries can be put on a more sustainable development path that is practicable and affordable. This study will be an important building block for the IRENA strategy.

IRENA's work programme for 2011 incorporates action on three key fronts: First, the knowledge management and technology sub-programme designated to facilitate an increased role for renewable energy; Second, the policy advisory services and capacity building sub-program that will encourage an enabling environment for renewables. And third, under the innovation and technology sub-programme, IRENA will create a framework for technology support, work of cost reduction potentials and the wider use of standards. All of these will contribute to accelerating uptake of renewables.

IRENA cannot do this work alone, but only with the cooperation of a plethora of partners and expertise that organizations such as the European Renewable Energy Council and Greenpeace can bring. I hope we will work together with swift, decisive action to harness the full potential of IRENA to support the international community on the path to a sustainable energy future.

Adnan Amin,
DIRECTOR GENERAL
INTERNATIONAL RENEWABLE ENERGY AGENCY (IRENA)
SEPTEMBER 2011

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image NORTH HOYLE WIND FARM, UK'S FIRST WIND FARM IN THE IRISH SEA, WHICH WILL SUPPLY 50,000 HOMES WITH POWER.

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introduction

"JAPAN IS FORTUNATE ENOUGH TO HAVE HUGE RENEWABLE ENERGY RESOURCES AND, WITH THE POLITICAL WILL, COULD BECOME A RENEWABLE ENERGY LEADER."

image A WORKER ENTERS A TURBINE TOWER FOR MAINTENANCE AT DABANCHENG WIND FARM.

On 11 March 2011 an enormous earthquake and tsunami hit Japan. It is a day that will be remembered in history, not only for the unimaginable human tragedy, but for the resulting nuclear disaster, the scale of which, after Chernobyl, we were told could never happen again. The nuclear disaster at Japan's Fukushima Daiichi Nuclear Power Plant has had one positive outcome, however, as it will also be seen as a turning point in not only Japan's, but the world's energy policy.

The Fukushima crisis has triggered intensive discussions on the safety of nuclear power, and as a first result, Germany, Switzerland, and Italy have chosen to end their nuclear programmes and to phase out existing reactors. In Japan, public opinion now overwhelmingly favours renewable energy over nuclear, and while 74% of the installed nuclear capacity has been shut down for safety reasons since March until August (so the left over capacity is 12,600MW), a country-wide effort to reduce energy has proven that Japan can survive without them.

All nuclear reactors will be taken offline for safety checks by end of May 2012. This is a turning point for Japan, and a huge opportunity for it to move towards the sustainable energy future its people demand. With an abundance of renewable energy resources and top class technology, Japan can easily become a renewable energy leader, while simultaneously ending its reliance on risky and expensive nuclear technology. It is also well placed to become much more energy efficient, to reduce the costs of energy as well as emissions, and to do its part to address climate change, the biggest challenge of our age.

The solution is the Energy [R]evolution. Only a dynamic shift in how we generate and use energy will make it possible to achieve both the phase out of nuclear and minimize the risk of climate change. Harnessing the renewable resources would not only make a huge contribution to averting runaway climate change, but would also create a thriving green economy.

The Advanced Energy [R]evolution scenario for Japan is based on a detailed renewable energy resource assessment from Japan's Ministry of Environment published in April 2011, just weeks after the Fukushima accident. It has used the technical potentials for wind power (onshore and offshore), hydro power, geothermal energy and solar power provided in this study to illustrate a potential pathway. However only a fraction of the technical available renewable energy resources are needed to make the Advanced Energy [R]evolution scenario until 2050 a reality.

turning the nuclear crisis into an opportunity

By August 2011, 40 out of 54 nuclear reactors in Japan have been shut down, due to security and maintenance reasons – so only 26% of the installed nuclear capacity has be available for electricity generation.

The current situation indicates that no nuclear reactor will be able to pass the safety requirements and therefore ALL nuclear reactors may not be available in 2012, and that there is a further need for replacement capacity and electricity generation.

This report, The Advanced Energy [R]evolution—A sustainable Energy Outlook for Japan, has been created to show the paths we can follow for a clean energy future. The 'reference scenario' is based on International Energy Agencies (IEA) World Energy Outlook 2009. The Energy [R]evolution scenario is showing prediction of last Energy [R]evolution scenario (published in 2007) to highlight pre-3.11 Fukushima disaster happens. The Emergency Plan + Advanced Energy [R]evolution scenario is the one reflecting the situation after 3.11. Both Energy [R]evolution scenarios were calculated by the German Aerospace Center (DLR) with support from the Institute for Sustainable Energy Policies (ISEP).

If Japan takes the 'Energy [R]evolution' pathway it is possible to achieve a renewable energy future by:

- Phasing out nuclear power generation by 2012
- Generating 43% of electricity from renewable energy by 2020
- Reducing greenhouse gas emissions by 25% by 2020 (in comparison of 1990)

In the Advanced Energy [R]evolution scenario Japan can completely phase out nuclear power in 2012 and still reach its pledge of reducing Greenhouse gas emission by 25% below 1990 levels by 2020 with 24% reductions coming through domestic means, and the remaining sourced through flexible mechanisms internationally.

The global market for renewable energy is booming internationally. Between 2005 and 2010, installed capacity of wind power grew by 255% globally, while solar photovoltaic grew by over 1,000%. As renewable energy is scaled up, we can start phasing out nuclear and fossil fuel, and end the reliance on these risky and dirty forms power. Enhanced efficiency and renewable energy supply can not only meet Japan's energy demand, but also help minimize the effects of climate change and create green jobs and a sustainable clean future.

the forgotten solution: energy efficiency

The Japan Energy [R]evolution scenario takes advantage of the enormous potential for the country to become much more energy efficient. Energy efficiency offers some of the simplest, easiest and quickest measures for reducing energy demands, greenhouse gas emissions and cost to end-users. Japan has extensive experience in maximizing energy efficiency, but it proved just how much more can be done during its response to the Fukushima nuclear disaster. The Government forced businesses to reduce their electricity consumption by 15% in the summer compared with the previous year, the public was asked to conserve power wherever possible, and exciting other new ideas are already appearing on the scene. When the country overcomes its difficulties, there is no doubt that Japan will be a world leader in energy efficiency and it will be a huge asset for the economy.

on the front foot

The Advanced Energy [R]evolution scenario demonstrates that making the necessary transformation in how we use energy is achievable, it provides new opportunities, and creates green and sustainable jobs. We call on Japan's political leaders to turn the Energy [R]evolution scenario into a reality and to begin the inevitable transition from nuclear/fossil-fuels to renewable energy now, delivering a safe, nuclear-free environment, reduced threat from climate change and a sustainable, prosperous future.

Sven Teske
CLIMATE & ENERGY UNIT
GREENPEACE
INTERNATIONAL

Tetsunari Iida
EXECUTIVE DIRECTOR
INSTITUTE FOR SUSTAINABLE
ENERGY POLICIES

Junichi Sato
EXECUTIVE DIRECTOR
GREENPEACE JAPAN

Hisayo Takada
CLIMATE/ ENERGY CAMPAIGNER
GREENPEACE JAPAN

SEPTEMBER 2011

executive summary

"AT THE CORE OF THE ENERGY [R]EVOLUTION WILL BE A CHANGE IN THE WAY THAT ENERGY IS PRODUCED, DISTRIBUTED AND CONSUMED."

image THE PS10 CONCENTRATING SOLAR THERMAL POWER PLANT IN SEVILLA, SPAIN. THE 11 MEGAWATT SOLAR POWER TOWER PRODUCES ELECTRICITY WITH 624 LARGE MOVABLE MIRRORS CALLED HELIOSTATS. THE SOLAR RADIATION, MIRROR DESIGN PLANT IS CAPABLE OF PRODUCING 23 GWH OF ELECTRICITY WHICH IS ENOUGH TO SUPPLY POWER TO A POPULATION OF 10,000.

The threat of climate change, caused by rising global temperatures, is the most significant environmental challenge facing the world at the beginning of the 21st century. It has major implications for the world's social and economic stability, its natural resources and in particular, the way we produce our energy.

The Cancun Agreements, agreed at the UN climate change conference in December2010, have the stated aim of keeping the increase in global temperatures to below 2°C, and then considering a 1.5°C limit by 2015. However, the national emissions reduction pledges countries have made so far are likely to lead to a world with global emissions of between 49 and 53 billion tonnes (Gt) of carbon dioxide equivalents per year by 2020[1]. This is about 10% higher than today's levels. In the worst case, the Copenhagen Accord pledges could even permit emission allowances to exceed a business as usual projection. It is clear that much more ambition is needed – particularly from developed countries, who themselves acknowledged in the Cancun climate conference that their emission reduction pledges are not sufficient and that they must be increased, with a view of reducing their aggregate emissions by 25-40 % by 2020, from 1990 levels, as outlined by the IPCC Fourth Assessment Report.

In order to avoid the most catastrophic impacts of climate change, the global temperature increase must be kept as far below 2°C as possible. This is still possible, but time is running out. To stay within this limit, global greenhouse gas emissions will need to peak by 2015 and decline rapidly after that, reaching as close to zero as possible by the middle of the 21st century.

a safe level of warming?

Keeping the global temperature increase to 2°C is often referred to as a "safe level" of warming, but this does not reflect the reality of the latest science. A warming of 2°C above pre-industrial levels would already pose unacceptable risks to many of the world's key natural and human systems[2]. Even with a 1.5°C warming, increases in drought, heat waves and floods, along with other adverse impacts such as increased water stress for up to 1.7 billion people, wildfire frequency and flood risks, are projected in many regions. Neither does staying below 2°C rule out large scale disasters such as melting ice sheets. Partial de-glaciation of the Greenland ice sheet, and possibly the West Antarctic

references
1 UNEP: THE EMISSIONS GAP REPORT - ARE THE COPENHAGEN ACCORD PLEDGES SUFFICIENT TO LIMIT GLOBAL WARMING TO 2°C OR 1.5°C ? NOVEMBER 2010.
2 W. L. HARE. A SAFE LANDING FOR THE CLIMATE. STATE OF THE WORLD. WORLDWATCH INSTITUTE. 2009.

image WELDER WORKING AT VESTAS WIND TURBINE FACTORY, CAMPBELLTOWN, SCOTLAND.

ice sheet, could even occur from additional warming within a range of 0.8 - 3.8°C above current levels . If rising temperatures are to be kept within acceptable limits then we need to significantly and urgently reduce our greenhouse gas emissions. This makes both environmental and economic sense. The main greenhouse gas is carbon dioxide (CO_2) produced by using fossil fuels for energy and transport.[3]

climate change and security of supply

Spurred by recent rapidly fluctuating oil prices, the issue of security of supply – both in terms of access to supplies and financial stability – is now at the top of the energy policy agenda. One reason for these price fluctuations is the fact that supplies of all proven resources of fossil fuels – oil, gas and coal – are becoming scarcer and more expensive to produce. So-called 'non-conventional' resources such as shale oil have even in some cases become more prevalent, with devastating consequences for the local environment. What is certain is that the days of 'cheap oil and gas' are coming to an end. Uranium, the fuel for nuclear power, is also a finite resource. By contrast, the reserves of renewable energy that are technically accessible globally are large enough to provide about six times more power than the world currently consumes - forever.

Renewable energy technologies vary widely in their technical and economic maturity, but there are a range of sources which offer increasingly attractive options. These include wind, biomass, photovoltaics, solar thermal, geothermal, ocean and hydroelectric power. Their common feature is that they produce little or no greenhouse gases, and rely on virtually inexhaustible natural elements for their 'fuel'. Some of these technologies are already competitive. The wind power industry, for example, continued its explosive growth in the face of a global recession and a financial crisis and is a testament to the inherent attractiveness of renewable technology.

At the same time there is enormous potential for reducing our consumption of energy, and still continuing to provide the same level of energy services. This study details a series of energy efficiency measures which together can substantially reduce demand across industry, homes, business and services.

the energy [r]evolution

The climate change imperative demands nothing short of an Energy [R]evolution, a transformation that has already started as renewable energy markets continue to grow. In the first global edition of the Energy [R]evolution, published in January 2007, we projected a global installed renewable capacity of 156 GW by 2010. At the end of 2009, 158 GW has been installed. More needs to be done, however. At the core of this revolution will be a change in the way that energy is produced, distributed and consumed.

the five key principles behind this shift will be to:

- Implement renewable solutions, especially through decentralised energy systems
- Respect the natural limits of the environment
- Phase out dirty, unsustainable energy sources
- Create greater equity in the use of resources
- Decouple economic growth from the consumption of fossil fuels

Decentralised energy systems, where power and heat are produced close to the point of final use, will avoid the current waste of energy during conversion and distribution. Investments in 'climate infrastructure' such as smart interactive grids, as well as super grids to transport large quantities of offshore wind and concentrating solar power, are essential. Building up clusters of renewable micro grids, especially for people living in remote areas, will be a central tool in providing sustainable electricity to the almost two billion people around the world for whom access to electricity is presently denied.

japan: towards a renewable future

The Advanced Energy [R]evolution scenario for Japan is based on a detailed renewable energy resource assessment from Japan's Ministry of Environment published in April 2011, just weeks after the Fukushima accident. It has used the technical potentials for wind power (onshore and offshore), hydro power, geothermal energy and solar power provided in this study to illustrate a potential pathway. However only a fraction of the technical available renewable energy resources are needed to make the Advanced Energy [R]evolution scenario until 2050 a reality.

reference

3 JOEL B. SMITH, STEPHEN H. SCHNEIDER, MICHAEL OPPENHEIMER, GARY W. YOHE, WILLIAM HARE, MICHAEL D. MASTRANDREA, ANAND PATWARDHAN, IAN BURTON, JAN CORFEE-MORLOT, CHRIS H. D. MAGADZA, HANS-MARTIN FÜSSEL, A. BARRIE PITTOCK, ATIQ RAHMAN, AVELINO SUAREZ, AND JEAN-PASCAL VAN YPERSELE: ASSESSING DANGEROUS CLIMATE CHANGE THROUGH AN UPDATE OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC) 3REASONS FOR CONCERN". PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES. PUBLISHED ONLINE BEFORE PRINT FEBRUARY 26, 2009, DOI: 10.1073/PNAS.0812355106. THE ARTICLE IS FREELY AVAILABLE AT: HTTP://WWW.PNAS.ORG/CONTENT/EARLY/2009/02/25/0812355106.FULL.PDF A COPY OF THE GRAPH CAN BE FOUND ON APPENDIX 1.

"The long term scenario has been developed further towards a complete phasing out of fossil fuels in the second half of this century."

turning the nuclear crisis into an opportunity

By August 2011, 40 out of 54 nuclear reactors in Japan have been shut down, due to security and maintenance reasons – so only 26% of the installed nuclear capacity has been available for electricity generation. The current situation indicates that no nuclear reactor will be able to pass the safety requirements and therefore ALL nuclear reactors may not be available in 2012, and that there is a further need for replacement capacity and electricity generation.

emergency electricity plan for japan – nuclear phase-out in 2012

The Energy [R]evolution emergency plan which leads to a complete nuclear phase-out in 2012 follows a 3 step approach: Strict efficiency measures, increased renewable energy capacity - especially wind and solar – and a preliminary increase of the capacity factors of gas power plants between 2012 and 2020. The details of this plan are:

1. Energy Efficiency

Further dynamic efficiency programs need to be implemented immediately while most short term efficiency measures implemented between March and September 2011 need to remain in place.

- Decrease the annual total electricity demand by 1.7% per year on average between 2011 and 2020.
- Implement immediately a strict efficiency and load management concept to avoid shortages during peak demand hours as well as total annual demands for all sectors.

In that regard, the Advanced Energy [R]evolution scenario takes the ISEP efficiency concept into account:

Load reduction strategy to decrease load by up to 11 GW

- Households with demands less than 50kW, cutting all the ampere-capacities by 20% will decrease demand by 2.5GW
- Users with demands of 50kW-500kW each, introducing a special price for peak-demand period will decrease demand by approximately 2GW.
- Users with demands of 500kW-2000kW each, the introduction of price for peak-demand period and together with a gradual application of supply-demand contracts will decrease demand by approximately 1.5GW.
- Users with demands of more than 2000kW each, the application (led by the government in principle) of supply-demand contracts will decrease demand by approximately 5GW.

Implementation of the efficiency requirements: In order to implement efficiency measures, strict mandatory efficiency standards are required.

2. Power Generation

Faster uptake of renewables (especially solar photovoltaic and wind power due to their short construction times) and increased capacity factors for existing gas power plants are at the core of the emergency concept.

- Gas: increase average capacity factor of all gas power plants and use them as base load power plants over the coming years. By 2020, the average capacity factor will be back on "standard levels".
- Back-up power: Use gas power plants to counter flexible generation. Gas power plants will be used to cover dips in flexible generation, and no additional capacity will be needed as current gas power generation capacity is more than enough to cover the entire time period 2012 – 2020.
- Wind: increase average annual market from 220 MW in 2010 to 5000 MW/a between 2012 and 2015 and around 6000 MW/a between 2016 and 2020.
- Photovoltaic: increase average annual market from 990 MW in 2010 up to 5000 MW/a between 2012 and 2015 and around 6700 MW/a between 2016 and 2020.

Implementation of more renewable energy generation: In order to implement the needed additional renewable energy capacities, a feed-in law with a mandatory priority access to the grid is required in order to guarantee investment security. A "one-shop-stop" policy – all required construction permits will be organized from one government agency – enables project developers to ensure a faster planning and shorter construction time. Possible environmental impacts by the projects should be carefully assessed and appropriate measures should be taken accordingly.

Greenpeace recommends including a guaranteed access to the grid, as well as a streamlined licensing process into the feed-in law legislation, and ensuring a workable fixed price per kilowatt-hour over 20 years, in order to accelerate the renewable power market in Japan.

3. Infrastructure

In order to integrate flexible solar and wind power capacities into the existing grid while transporting more capacity from gas power plants to the load centres of Japan, grid enforcements may be required. Support programs for the expansion of "Smart-Grids" will lead to faster implementation of energy efficiency as well as the more efficient use of renewable electricity.

Implementation of grid enforcement: Equal to the suggested renewable power plant licensing process, clear policy frameworks are needed to enable grid operators to implement needed grid enforcement as fast as possible.


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image THOUSANDS OF FISH DIE AT THE DRY RIVER BED OF MANAQUIRI LAKE, 150 KILOMETERS FROM AMAZONAS STATE CAPITOL MANAUS, BRAZIL.

table 0.1: japan - overview energy [r]evolution immediate nuclear energy phase out

NUCLEAR PHASE-OUT 2012: REPLACEMENT STRATEGY

	UNIT	2012	2013	2014	2015	2016	2017	2018	2019	2020
NUCLEAR GENERATION REPLACEMENT	TWh/a	**135**	**135**	**135**	**135**	**121.0**	**106.9**	**92.66**	**78.3**	**63.8**
Increased power generation from gas power plants via higher capacity factors	TWh	98.0	90.8	83.7	76.3	64.1	53.1	42.3	31.7	17.3
Required capacity factor for gas power plants	h/a	7,565	7,335	7,115	6,900	6,780	6,675	6,570	6,465	6,290
Annual demand reduction 1.7% per year (instead of 1% per year)	TWh/a	30	30	30	30	30	30	30	30	30
Wind electricity to replace nuclear	TWh/a	5.8	11.7	17.7	23.5	21.8	18.8	15.3	11.4	12.0
PV electricity to replace nuclear	TWh/a	1.2	2.5	3.8	5.0	5.0	5.1	5.1	5.1	4.5
Total additional Wind + PV generation	TWh/a	7.0	14.2	21.5	28.6	26.8	23.9	20.4	16.5	16.4
NUCLEAR CAPACITY REPLACEMENT	GW	**19.3**	**19.3**	**19.3**	**19.3**	**17.2**	**15.1**	**13.1**	**11.0**	**8.9**
Annual wind market	GW	5.0	5.0	5.0	5.0	6.1	6.1	6.1	6.1	6.1
Total wind capacity	GW	8.3	13.3	18.3	23.3	29.4	35.6	41.7	47.9	56.0
Annual PV market	GW	5.0	5.0	5.0	5.0	6.7	6.7	6.7	6.8	6.8
Total PV capacity	GW	8.9	13.9	18.9	23.9	30.6	37.3	44.1	50.8	57.6
Total additional Wind + PV capacity	GW	10.0	10.0	10.0	10.0	12.9	12.9	12.9	12.9	12.9
Annual CO_2 emissions	million T CO_2/a	1,267	1,261	1,254	1,247	1,171	1,095	1,018	942	866
CO_2 emissions compared to 1990 levels	%	111%	110%	110%	109%	102%	96%	89%	82%	76%

the advanced energy [r]evolution scenario beyond 2020

The following summary shows the results of the Advanced Energy [R]evolution scenario after 2020, which will be achieved through the following measures:

1. Exploitation of existing large energy efficiency potentials will ensure that primary energy demand decreases - from the current 21,767 PJ/a (2007) to 11,114 PJ/a in 2050, compared to 21,362 PJ/a in the Reference scenario. This dramatic reduction is a crucial prerequisite for achieving a significant share of renewable energy sources in the overall energy supply system, compensating for the phasing out of nuclear energy and reducing the consumption of fossil fuels.

2. More electric drives are used in the transport sector and hydrogen produced by electrolysis from excess renewable electricity plays a much bigger role in the advanced than in the basic scenario. After 2020, the final energy share of electric vehicles on the road increases to 11% by 2020 and 2050 to 49%. More public transport systems also use electricity, as well as there being a greater shift in transporting freight from road to rail.

3. The increased use of combined heat and power generation (CHP) also improves the supply system's energy conversion efficiency, increasingly using natural gas and biomass. In the long term, the decreasing demand for heat and the large potential for producing heat directly from renewable energy sources limit the further expansion of CHP.

4. The electricity sector will be the pioneer of renewable energy utilisation. By 2020, 43% of electricity will be produced from renewable sources, increasing to 85% by 2050. A capacity of 277 GW will produce 813 TWh/a renewable electricity in 2050. A significant share of the fluctuating power generation from wind and solar photovoltaic will be used to supply electricity to vehicle batteries and produce hydrogen as a secondary fuel in transport and industry. By using load management strategies, excess electricity generation will be reduced and more balancing power made available.

5. In the heat supply sector, the contribution of renewables will increase to 22% by 2020 and 71% by 2050. Fossil fuels will be increasingly replaced by more efficient modern technologies, in particular biomass, solar collectors and geothermal.

6. In the transport sector the existing large efficiency potentials will be exploited by a modal shift from road to rail and by using much lighter and smaller vehicles. As biomass is mainly committed to stationary applications, the production of bio fuels is limited by the availability of sustainable raw materials. Electric vehicles, powered by renewable energy sources, will play an increasingly important role from 2020 onwards.

7. By 2050, 64% of primary energy demand will be covered by renewable energy sources.

To achieve an economically attractive growth of renewable energy sources, the balanced and timely mobilisation of all of the above-mentioned technologies is of great importance. Such mobilisation depends on technical potentials, actual costs, cost reduction potentials and technical maturity.

japan: future electricity generation

Renewable energy will initially cost more to implement than existing fossil fuels. The slightly higher electricity generation costs under the Advanced Energy [R]evolution scenario will be compensated for, however, by reduced demand for fuels in other sectors such as heating and transport. Assuming average costs of 3 $cents/kWh for implementing energy efficiency measures, the additional cost for electricity supply under the Advanced Energy [R]evolution scenario will amount to a maximum of $5 billion/a in 2015 compared to the Reference scenario and $100 million/a compared to the Basic Energy [R]evolution scenario. These additional costs, which represent society's investment in an environmentally benign, safe and economic energy supply, decrease after 2015. By 2050 the annual costs of electricity supply will be $152 billion/a below those in the Reference scenario.

japan: future fuel costs

It is assumed that average crude oil prices will increase from around $80 per barrel in 2009 to $130 per barrel in 2020, and continue to rise to $150 per barrel in 2050. Natural gas import prices are expected to increase by a factor of four between 2008 and 2050, while coal prices will nearly double, reaching $360 per tonne[4] in 2050. A CO_2 'price adder' is applied, which rises from $20 per ton of CO_2 in 2020 to $50 per ton in 2050.

japan: future investment in new power plants

The introduction of renewable technologies under the Energy [R]evolution scenario slightly increases the costs of electricity generation in Japan compared to the Reference scenario. This difference will be less than $1.1 cent/kWh up to 2020, however. Because of the lower CO_2 intensity of electricity generation, electricity generation costs will become economically favourable under the Energy [R]evolution scenarios and by 2050 costs will be more than 6 cents/kWh below those in the Reference scenario. Under the Reference scenario, by contrast, unchecked growth in demand, an increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's $77 billion per year to more than $252 billion in 2050. The Energy [R]evolution scenario not only complies with Japan´s CO_2 reduction targets but also helps to stabilise energy costs. Increasing energy efficiency and shifting energy supply to renewables lead to long term costs for electricity supply that are one third lower than in the Reference scenario.

Expansion of smart grids, demand side management and storage capacity through an increased share of electric vehicles will therefore be used to ensure better grid integration and power generation management.

The Advanced Energy [R]evolution scenario will lead to a higher proportion of variable power generation sources (PV, wind and ocean power), reaching 29% by 2030 and 45% by 2050.

In both Energy [R]evolution scenarios the specific generation costs are almost on the same level until 2030. By 2050, however the advanced version results in a reduction of 3.5 cents/kWh lower generation costs, mainly because of better economics of scale in renewable power equipment. Despite the increased electricity demand especially in the transport sector the overall total supply costs in 2040 are $11 billion lower in the advanced case than in the basic case. In 2050 total supply costs are $23 billion lower than in the Basic Energy [R]evolution scenario.

japan: future employment

Energy sector jobs are set to increase significantly by 2015 under both the Energy [R]evolution and the Advanced Energy [R]evolution scenarios, with a slight increase in the Reference scenario. In 2010, there are 81,500 electricity sector jobs. There is an increase in job numbers under both Energy [R]evolution scenarios and the Reference case for each technology up to 2030.

- In the Reference case, jobs stay constant to 2015, and then fall by 5% by 2020 (a loss of 4,800 jobs relative to 2010), and then decrease further to 57,000 jobs by 2030.
- In the [R]evolution scenario, jobs more than triple to 260,000 jobs in 2015 (179,000 additional jobs), then drop back to 147,000 jobs in 2020, reducing to 119,000 jobs in 2030, a 46% increase from 2010.
- In the Advanced scenario, jobs almost quadruple to 326,000 jobs in 2015 (244,000 additional jobs), then drop back to 198,000 jobs in 2020, and 144,000 jobs in 2030, a 76% increase from 2010.
- Solar PV shows particularly strong growth, reaching a peak of more than 170,000 jobs in 2015 in both the [R]evolution scenarios.

These calculations do not include the jobs associated with decommissioning nuclear power stations, which would be significant in all scenarios.

japan: development of CO_2 emissions

Whilst the Japan's emissions of CO_2 will increase by 6% under the Reference scenario, under the Energy [R]evolution scenario they will decrease from 1,301 million tonnes (t) in 2007 to 298 million t in 2050. Annual per capita emissions will fall from 10.2 t to 2.9 t. In the long run efficiency gains and the increased use of renewable electricity in vehicles will even reduce emissions in the transport sector. With a share of 35% of total CO_2 in 2050, the power sector will be the largest source of emissions.

In the Advanced Energy [R]evolution scenario Japan can completely phase out nuclear power in 2012 and still reach its pledge of reducing Greenhouse gas emission by 25% below 1990 levels by 2020 with 24% reductions coming through domestic means, and the remaining sourced through flexible mechanisms internationally.

references
4 IN THE ENTIRE DOCUMENT, WE REFER TO `METRIC TONS`.

image CONSTRUCTION OF THE OFFSHORE WINDFARM AT MIDDELGRUNDEN NEAR COPENHAGEN, DENMARK.

japan: policy changes

To make the Energy [R]evolution real and to avoid dangerous climate change, Greenpeace and EREC demand that the following policies and actions are implemented in the energy sector:

1. Phase out all subsidies for fossil fuels and nuclear energy.
2. Internalise the external (social and environmental) costs of energy production through 'cap and trade' emissions trading.
3. Mandate strict efficiency standards for all energy consuming appliances, buildings and vehicles.
4. Establish legally binding targets for renewable energy and combined heat and power generation.
5. Reform the electricity markets by guaranteeing priority access to the grid for renewable power generators and by separating the electricity utilities from the grid.
6. Provide defined and stable returns for investors, for example by effective feed-in tariff programmes.
7. Implement better labelling and disclosure mechanisms to provide more environmental product information.
8. Increase research and development budgets for renewable energy and energy efficiency.

figure 0.1: japan: development of primary energy consumption under the advanced energy [r]evolution scenario

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

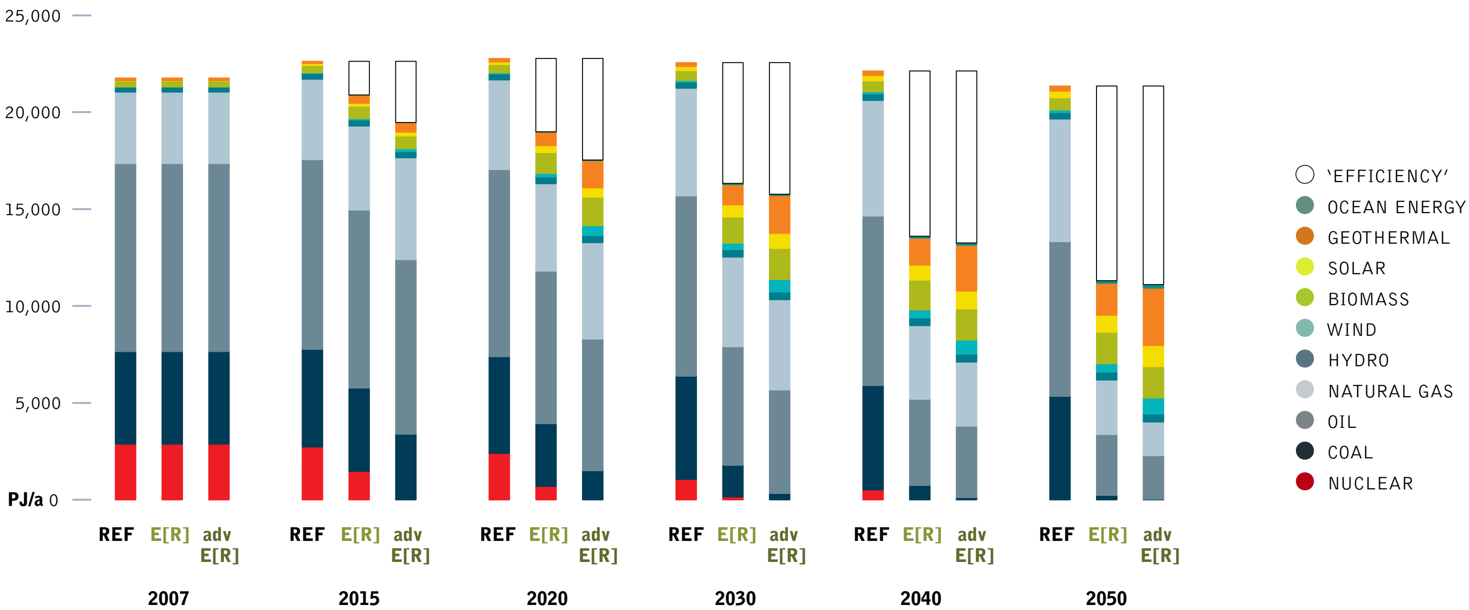

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image SOLAR PANEL. © BERND JUERGENS/DREAMSTIME

"japan should aim for a society that does not depend on nuclear energy."

NAOTO KAN
FORMER PRIME MINISTER OF JAPAN

image A STREET LAMP POWERED BY SOLAR POWER IN YOKOHAMA, JAPAN.

image WIND POWER GENERATION IN FRONT OF A THERMAL POWER STATION IN YOKOHAMA, JAPAN.

1.1 japan: energy demand by sector

The future development pathways for Japan's energy demand are shown in Figure 1.1 for the Reference and both Energy [R]evolution scenarios. Under the Reference scenario, total primary energy demand in Japan decreases by 2% from the current 21,767 PJ/a to 21,362 PJ/a in 2050. In the Energy [R]evolution scenario, by contrast, energy demand decreases by 48% and 49% in the advanced case, compared to current consumption and it is expected by 2050 to reach 11,310 PJ/a and 11,114 PJ/a in the advanced scenario. Under the Energy [R]evolution scenario, electricity demand in the industrial, residential and services sectors is expected to fall considerably below the current level (see Figure 6.2). The growing use of electric vehicles however, leads to an increased power demand reaching a level of 815 TWh/a 2050. Electricity demand in the Energy [R]evolution scenario is 498 TWh/a lower than in the Reference scenario.

The Advanced Energy [R]evolution scenario assumes an immediate nuclear phase-out in 2012 and strict implementation of a variety of efficiency measure, both to reduce (peak) load as well as annual electricity demand. Following the nuclear disaster at Fukushima Daiichi in March 2011, Japan's industry and businesses in Kanto and Tohoku regions were told to reduce their electricity usage by 15% from July to September. Other electricity consumers were also strongly encouraged to cut their power demands on voluntary basis.

After 2020 the Advanced Energy [R]evolution scenario introduces electric vehicles earlier while more journeys - for both freight and persons - will be shifted towards electric trains and public transport. Fossil fuels for industrial process heat generation are also phased out more quickly and replaced by electric geothermal heat pumps and hydrogen. This means that electricity demand in the Advanced Energy [R]evolution is higher and reaches 880 TWh/a in 2050, still 26% below the Reference case.

Efficiency gains in the heat supply sector are larger than in the electricity sector. Under both Energy [R]evolution scenarios, final demand for heat supply can even be reduced significantly (see Figure 1.3). Compared to the Reference scenario, consumption equivalent to 2,291 PJ/a is avoided through efficiency measures by 2050.

In the transport sector, it is assumed under the Energy [R]evolution scenario that energy demand will decrease by 50% to 1,761 PJ/a by 2050, compared to the Reference scenario. The advanced version factors in a faster decrease of the final energy demand for transport. This can be achieved through a mix of increased public transport, reduced annual person kilometres and wider use of more efficient engines and electric drives. While electricity demand increases, the overall final energy use falls to 1,391 PJ/a, 60% lower than in the Reference case.

figure 1.1: japan - projection of total final energy demand by sector under three scenarios

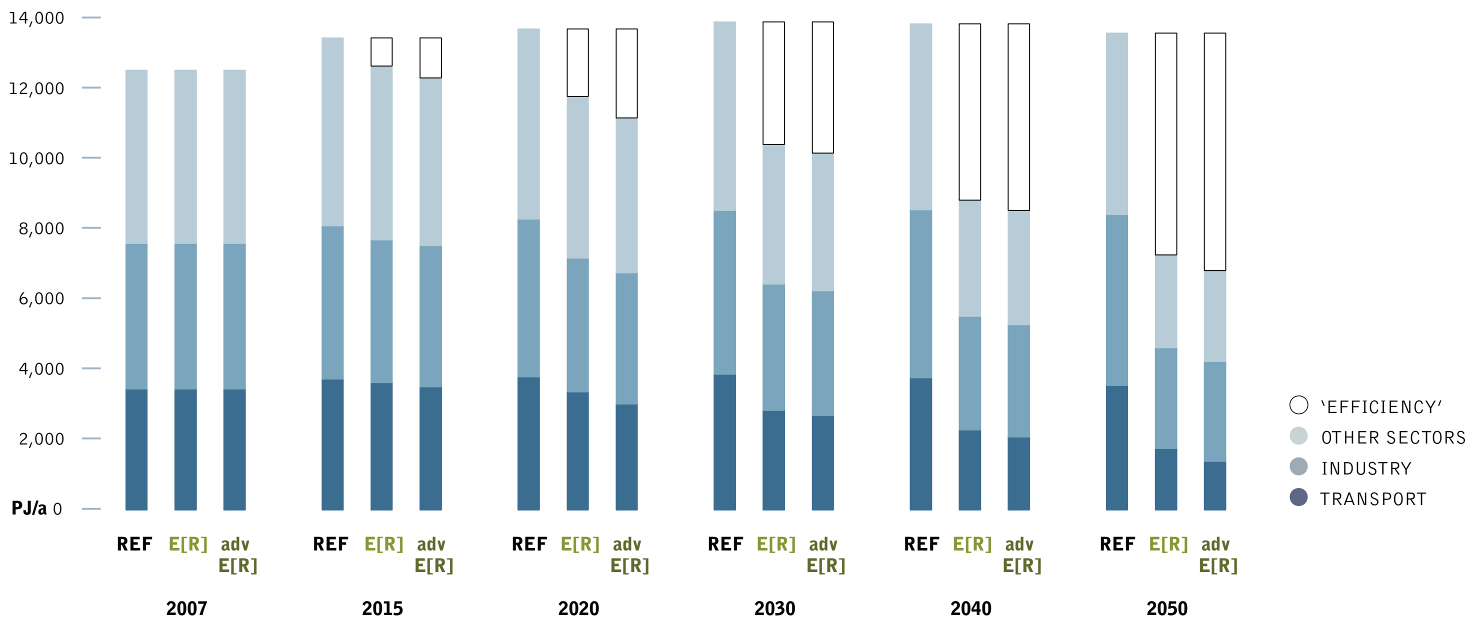


figure 1.2: japan - development of electricity demand by sector under both energy [r]evolution scenarios

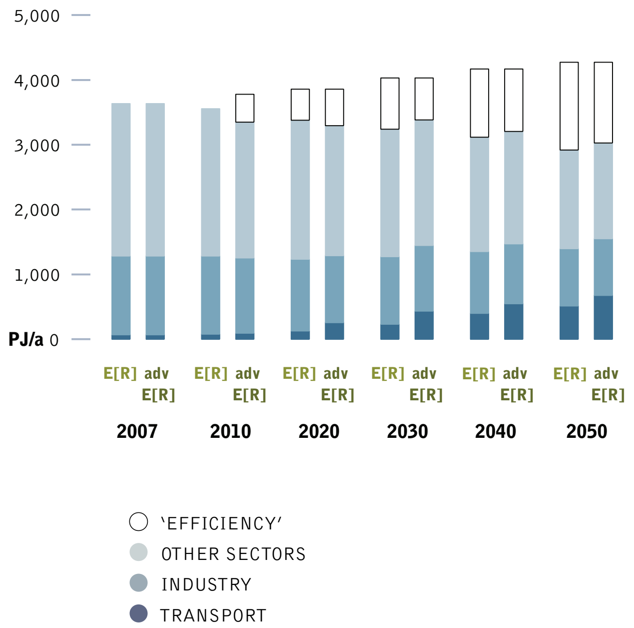
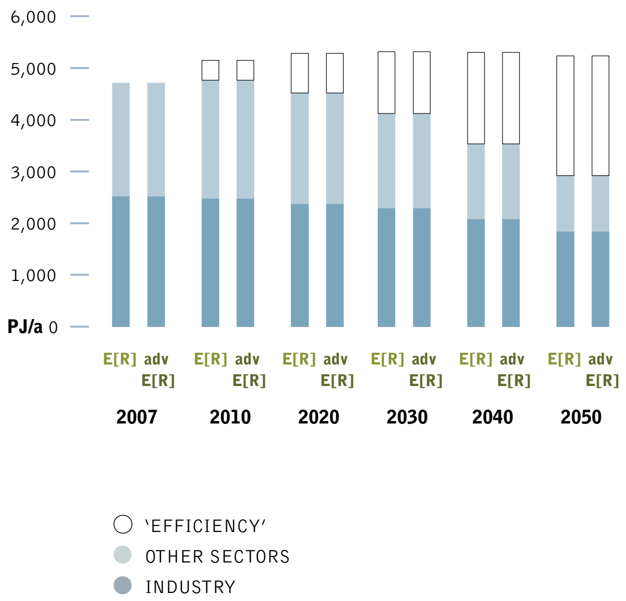


figure 1.3: japan - development of heat demand by sector under both energy [r]evolution scenarios



1.2 turning the nuclear crisis into an opportunity

By August 2011, 40 out of 54 nuclear reactors in Japan have been shut down, due to security and maintenance reasons – so only 26% of the installed nuclear capacity has been available for electricity generation.

The current situation indicates that no nuclear reactor will be able to pass the safety requirements and therefore ALL nuclear reactors may not be available in 2012, and that there is a further need for replacement capacity and electricity generation. Figure 1.4 shows the emergency plan for an immediate nuclear phase out compared to a "gradual phase out" of nuclear power by 2020.

1.3 emergency electricity plan for japan – nuclear phase-out in 2012

The Energy [R]evolution emergency plan which leads to a complete nuclear phase-out in 2012 follows a 3 step approach: Strict efficiency measures, increased renewable energy capacity - especially wind and solar – and a preliminary increase of the capacity factors of gas power plants between 2012 and 2020. The details of this plan are:

1.3.1 energy efficiency

Further dynamic efficiency programs need to be implemented immediately while most short term efficiency measures implemented between March and September 2011 need to remain in place.

- Decrease the annual total electricity demand by 1.7% per year on average between 2011 and 2020.
- Implement immediately a strict efficiency and load management concept to avoid shortages during peak demand hours as well as total annual demands for all sectors.

In that regard, the advanced energy [r]evolution scenario takes the ISEP efficiency concept into account:

Load reduction strategy to decrease load by up to 11 GW

- Households with demands less than 50kW, cutting all the ampere-capacities by 20% will decrease demand by 2.5GW.
- Users with demands of 50kW-500kW each, introducing a special price for peak-demand period will decrease demand by approximately 2GW.
- Users with demands of 500kW-2000kW each, the introduction of price for peak-demand period and together with a gradual application of supply-demand contracts will decrease demand by approximately 1.5GW.
- Users with demands of more than 2000kW each, the application (led by the government in principle) of supply-demand contracts will decrease demand by approximately 5GW.

Implementation of the efficiency requirements: In order to implement efficiency measures, strict mandatory efficiency standards are required.

image GREENPEACE RADIATION EXPERT RIANNE TEULE CHECKS CROPS FOR CONTAMINATION IN MINAMISOMA, 25KM NORTH OF THE STRICKEN FUKUSHIMA DAIICHI NUCLEAR PLANT.

image SOLAR INSTALLATION, JAPAN.

1.3.2 power generation

Faster uptake of renewables (especially solar photovoltaic and wind power due to their short construction times) and increased capacity factors for existing gas power plants are at the core of the emergency concept.

- Gas: increase average capacity factor of all gas power plants and use them as base load power plants over the coming years. By 2020, the average capacity factor will be back on "standard levels".
- Back-up power: Use gas power plants to counter flexible generation. Gas power plants will be used to cover dips in flexible generation, and no additional capacity will be needed as current gas power generation capacity is more than enough to cover the entire time period 2012 – 2020.
- Wind: increase average annual market from 220 MW in 2010 to 5,000 MW/a between 2012 and 2015 and around 6,000 MW/a between 2016 and 2020.
- Photovoltaic: increase average annual market from 990 MW in 2010 up to 5,000 MW/a between 2012 and 2015 and around 6,700 MW/a between 2016 and 2020.

Implementation of more renewable energy generation: In order to implement the needed additional renewable energy capacities a feed-in law with a mandatory priority access to the grid is required in order to guarantee investment security. A "one-shop-stop" policy – all required construction permits will be organize from one government agency – enable project developer to ensure a faster planning and shorter construction time. Possible environmental impacts by the projects should be carefully assessed and appropriate measures should be taken accordingly.

Greenpeace recommends including a guaranteed access to the grid, as well as streamlined licensing process into the feed-in law legislation, and ensuring a workable fixed price per kilowatt-hour over 20 years, in order to accelerate the renewable power market in Japan.

1.3.3 infrastructure

In order to integrate flexible solar and wind power capacities into the existing grid, while transporting more capacity from gas power plants to the load centres of Japan, grid enforcements may be required. Support programs for the expansion of "Smart-Grids" will lead to faster implementation of energy efficiency as well as the more efficient use of renewable electricity.

Implementation of grid enforcement: Equal to the suggested renewable power plant licensing process, clear policy frameworks are needed to enable grid operators to implement needed grid enforcement as fast as possible.

table 1.1: japan - overview energy [r]evolution immediate nuclear energy phase out

NUCLEAR PHASE-OUT 2012: REPLACEMENT STRATEGY

	UNIT	2012	2013	2014	2015	2016	2017	2018	2019	2020
NUCLEAR GENERATION REPLACEMENT	TWh/a	**135**	**135**	**135**	**135**	**121.0**	**106.9**	**92.66**	**78.3**	**63.8**
Increased power generation from gas power plants via higher capacity factors	TWh	98.0	90.8	83.7	76.3	64.1	53.1	42.3	31.7	17.3
Required capacity factor for gas power plants	h/a	7,565	7,335	7,115	6,900	6,780	6,675	6,570	6,465	6,290
Annual demand reduction 1.7% per year (instead of 1% per year)	TWh/a	30	30	30	30	30	30	30	30	30
Wind electricity to replace nuclear	TWh/a	5.8	11.7	17.7	23.5	21.8	18.8	15.3	11.4	12.0
PV electricity to replace nuclear	TWh/a	1.2	2.5	3.8	5.0	5.0	5.1	5.1	5.1	4.5
Total additional Wind + PV generation	TWh/a	7.0	14.2	21.5	28.6	26.8	23.9	20.4	16.5	16.4
NUCLEAR CAPACITY REPLACEMENT	GW	**19.3**	**19.3**	**19.3**	**19.3**	**17.2**	**15.1**	**13.1**	**11.0**	**8.9**
Annual wind market	GW	5.0	5.0	5.0	5.0	6.1	6.1	6.1	6.1	6.1
Total wind capacity	GW	8.3	13.3	18.3	23.3	29.4	35.6	41.7	47.9	56.0
Annual PV market	GW	5.0	5.0	5.0	5.0	6.7	6.7	6.7	6.8	6.8
Total PV capacity	GW	8.9	13.9	18.9	23.9	30.6	37.3	44.1	50.8	57.6
Total additional Wind + PV capacity	GW	10.0	10.0	10.0	10.0	12.9	12.9	12.9	12.9	12.9
Annual CO_2 emissions	million T CO_2/a	1,267	1,261	1,254	1,247	1,171	1,095	1,018	942	866
CO_2 emissions compared to 1990 levels	%	111%	110%	110%	109%	102%	96%	89%	82%	76%

This option leads to higher investments within the next 8 years due to larger annual market volumes between 2012 and 2020.

Figure 1.4 shows the emergency plan for an immediate nuclear phase out compared to a "gradual phase out" of nuclear power by 2030.

As opposed to figure 1.5 the power generation only represents the amount of wind, solar and gas electricity needed to replace nuclear electricity towards a complete phase-out.

figure 1.4: **japan - emergency plan: nuclear generation replacement strategy**

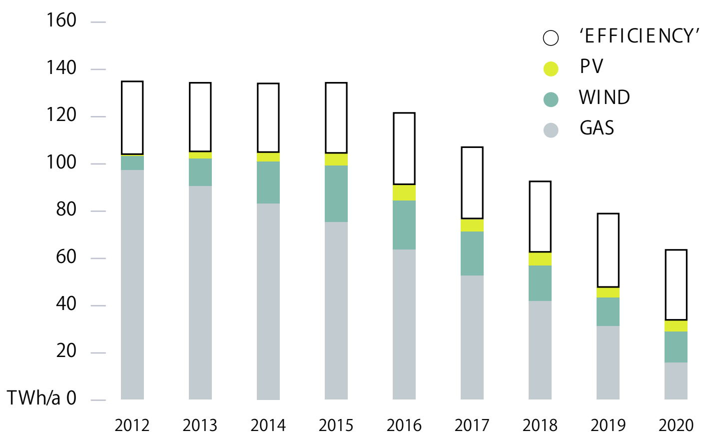


table 1.2: **summary: power generation and installed capacity development between 2012 and 2020:**

INSTALLED CAPACITY IN GW - EXCLUDING CHP	2007	2012	2013	2014	2015	2016	2017	2018	2019	2020
Coal	49.6	48.1	47.3	46.5	45.7	40.4	35.2	29.9	24.6	19.3
Gas	54.7	58.0	59.7	61.3	63.0	62.2	61.5	60.8	60.1	59.4
Oil	46.4	46.2	46.0	45.9	45.8	44.4	43.1	41.7	40.4	39.0
Diesel	3.2	2.9	2.8	2.6	2.5	2.4	2.3	2.2	2.1	2.0
Nuclear	48.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass	3.1	3.7	4.1	4.4	4.7	4.8	4.9	5.0	5.1	5.2
Hydro	19.0	20.0	20.5	21.0	21.5	22.1	22.7	23.3	23.9	24.5
Wind	1.5	8.3	13.3	18.3	23.3	29.4	35.6	41.7	47.9	56.0
Photovoltaics	1.7	8.9	13.9	18.9	23.9	30.6	37.3	44.1	50.8	57.0
Geothermal	0.6	1.4	1.9	2.3	2.8	3.6	4.4	5.3	6.1	6.9
Ocean Energy	0.0	0.1	0.2	0.2	0.3	0.7	1.2	1.7	2.1	2.6
ELECTRICITY GENERATION [TWH] - EXCLUDING CHP										
Coal	272	273	274	274	274	243	211	179	148	116
Gas	328	439	438	436	434	422	411	400	389	374
Oil	153	152	152	152	115	107	99	92	85	78
Diesel	3	3	3	3	3	2	2	2	2	2
Nuclear	264	0	0	0	0	0	0	0	0	0
Biomass	23	28	30	33	35	36	36	37	37	38
Hydro	74	79	82	85	88	91	93	96	98	101
Wind	3	15	24	34	44	59	76	94	114	140
Photovoltaics	2	10	15	20	26	34	41	49	56	64
Geothermal	3	8	11	14	17	23	29	35	42	49
Ocean Energy	0	0	1	1	1	3	4	6	7	9
Final electricity consumption Advanced E[R]	1,010	960	950	941	931	928	925	923	920	917

image MODERN BUILDING USING RENEWABLE ENERGY, JAPAN.

1.4 japan: electricity generation beyond 2020

A dynamically growing renewable energy market will compensate for the phasing out of nuclear energy and reduce the number of fossil fuel-fired power plants required for grid stabilisation. By 2050, in the Energy [R]evolution scenario, 66% of the electricity produced in Japan will come from renewable energy sources. 'New' renewables – mainly wind, geothermal energy and PV – will contribute 42% of electricity generation.

The installed capacity of renewable energy technologies will grow from the current 24 GW to 215 GW in 2050, increasing renewable capacity by a factor of 9.

The Advanced Energy [R]evolution scenario projects a faster market development with higher annual growth rates achieving a renewable electricity share of 57% by 2030 and 85% by 2050. The installed capacity of renewables will reach 218 GW in 2030 and 277 GW by 2050, 29% higher than in the basic version.

To achieve an economically attractive growth in renewable energy sources a balanced and timely mobilisation of all technologies is of great importance. Figure 1.5 shows the comparative of the different renewable technologies over time. Up to 2020 PV, wind and hydro will remain the main contributors of the growing market share. After 2020, the continuing growth of PV and wind will be complemented by electricity from geothermal. The Advanced Energy [R]evolution scenario will lead to a higher share of fluctuating power generation source (photovoltaic, wind and ocean) of 29% by 2030, therefore the expansion of smart grids, demand side management (DSM) and storage capacity from the increased share of electric vehicles will be used for a better grid integration and power generation management.

table 1.3: japan - projection of renewable electricity generation capacity under both energy [r]evolution scenarios

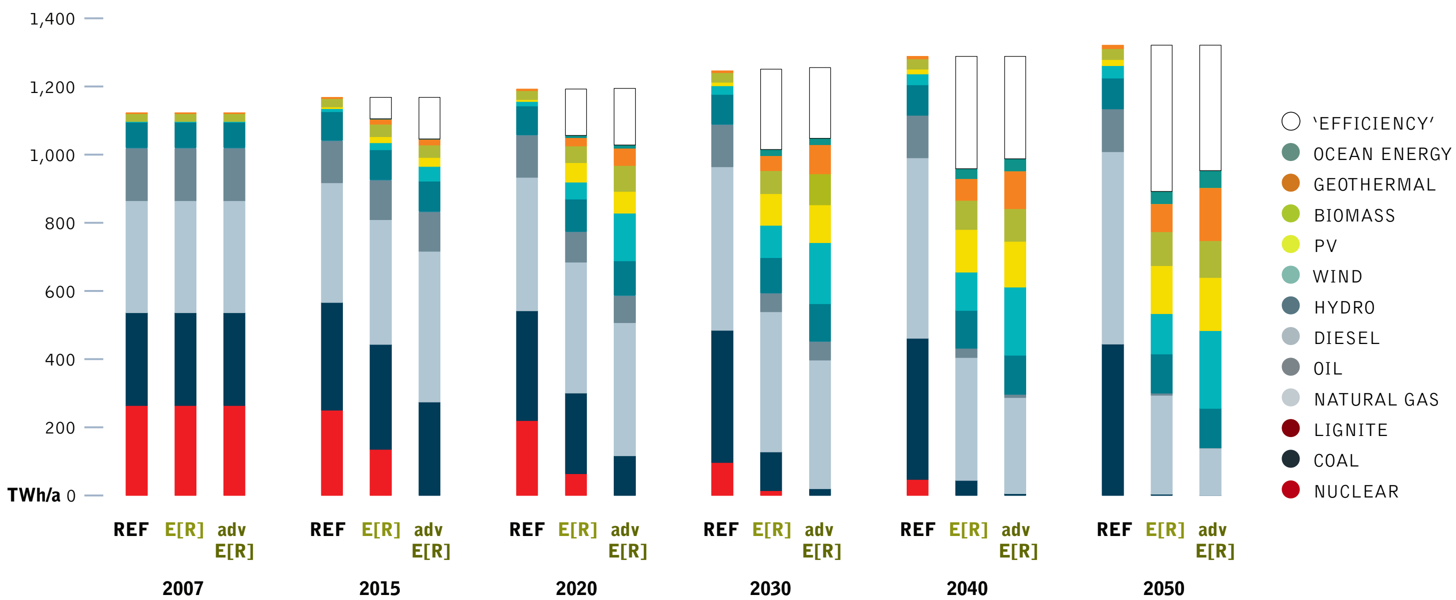
IN GW

		2007	2020	2030	2040	2050
Hydro	E[R]	19	23	25	26	27
	advanced E[R]	19	24	26	27	27
Biomass	E[R]	3	7	10	13	17
	advanced E[R]	3	13	14	15	18
Wind	E[R]	2	23	34	38	37
	advanced E[R]	2	51	64	68	71
Geothermal	E[R]	1	3	6	9	11
	advanced E[R]	1	7	12	16	22
PV	E[R]	0	51	80	104	113
	advanced E[R]	0	53	96	112	125
Ocean energy	E[R]	0	2	5	8	10
	advanced E[R]	0	3	5	10	14
Total	**E[R]**	**24**	**110**	**161**	**199**	**215**
	advanced E[R]	**24**	**152**	**218**	**248**	**277**

None of these numbers - even in the Advanced Energy [R]evolution scenario - utilise the maximum known technical potential of all the renewable resources. While the deployment rate compared to the technical potential (based on a 2009 study in commission of the Japanese Ministry of Environment) for geothermal power, for example, is relatively high at 87% in the advanced version, for wind less than 10% has been used.

figure 1.5: japan - development of electricity generation structure under three scenarios

(REFERENCE, ENERGY [R]EVOLUTION AND ADVANCED ENERGY [R]EVOLUTION) ["EFFICIENCY" = REDUCTION COMPARED TO THE REFERENCE SCENARIO]



1.5 japan: future costs of electricity generation

Figure 1.6 shows that the introduction of renewable technologies under the Energy [R]evolution scenario slightly increases the costs of electricity generation in Japan compared to the Reference scenario. This difference will be less than 1.1 cent/kWh up to 2020, however. Because of the lower CO_2 intensity of electricity generation, electricity generation costs will become economically favourable under the Energy [R]evolution scenarios and by 2050 costs will be more than 6 cents/kWh below those in the Reference scenario.

Under the Reference scenario, by contrast, unchecked growth in demand, an increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's $77 billion per year to more than $252 bn in 2050. Figure 1.6 shows that the Energy [R]evolution scenario not only complies with Japan's CO_2 reduction targets but also helps to stabilise energy costs. Increasing energy efficiency and shifting energy supply to renewables lead to long term costs for electricity supply that are one third lower than in the Reference scenario.

In both Energy [R]evolution scenarios, the specific generation costs are almost on the same level until 2030. By 2050 however, the advanced version results in a reduction of 9 cents/kWh lower generation costs, mainly because of better economics of scale in renewable power equipment. Despite the increased electricity demand especially in the transport sector the overall total supply costs in 2040 are $11 bn lower in the advanced case than in the basic case. In 2050 total supply costs are $23 bn lower than in the Basic Energy [R]evolution scenario.

1.6 japan: future investment

It would require around $1.0 trillion in investment for the Advanced Energy [R]evolution scenario to become reality - approximately $9.1 billion annual more than in the Reference scenario ($597 billion). Under the Reference version, the levels of investment in fossil and nuclear power plants add up to almost 85% while approx 15% would be invested in renewable energy and cogeneration until 2050. Under the advanced scenario, however, Japan would shift more than 70% of investment towards renewables and cogeneration. By 2050 the fossil fuel share of power sector investment would be focused mainly on combined heat and power and efficient gas-fired power plants. The average annual investment in the power sector under the Advanced Energy [R]evolution scenario between today and 2050 would be approximately $22.9 billion.

Because renewable energy has no fuel costs, however, the fuel cost savings in the Basic Energy [R]evolution scenario reach a total $1.7 trillion, or $40.6 billion per year. The Advanced Energy [R]evolution has even higher fuel cost savings of $2.2 trillion, or $51.9 billion per year.

Annual fuel cost savings under the Advanced Energy [R]evolution scenario are thus five times higher than the additional annual investment of $9.1 billion. Therefore fuel cost savings compensate for the entire investment in renewable and cogeneration capacity required to implement the advanced scenario. These renewable energy sources would then go on to produce electricity without any further fuel costs beyond 2050, while the costs for coal and gas will continue to be a burden on national economies. Part of this money could be used to cover stranded investments in fossil-fuelled power stations in developing countries.

figure 1.6: japan - development of total electricity supply costs & development of specific electricity generation costs under three scenarios

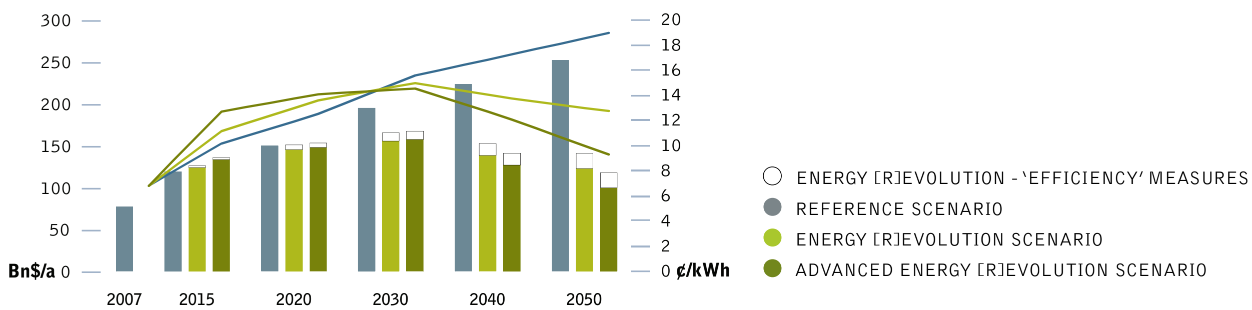


image SOLAR PANELS ARRANGED ON ROOFTOP, TOKYO, JAPAN.

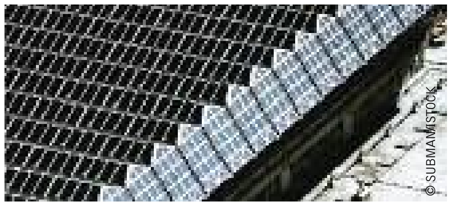
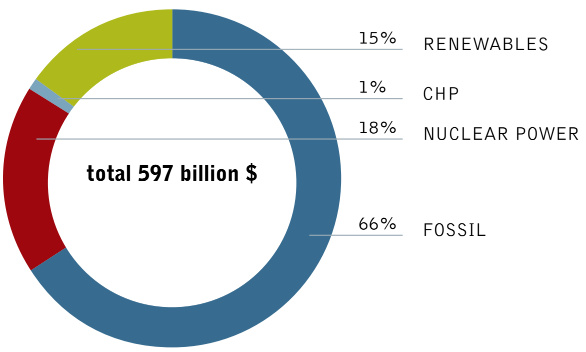


table 1.4: japan - fuel cost savings and investment costs under three scenarios

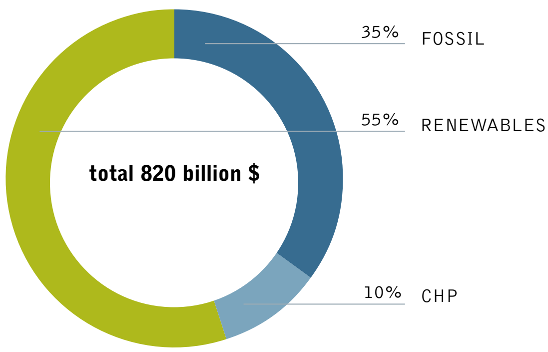
INVESTMENT COST	DOLLAR	2011-2020	2021-2030	2031-2040	2041-2050	2011-2050	2011-2050 AVERAGE PER YEAR
JAPAN (2011) DIFFERENCE E[R] VERSUS REF							
Conventional (fossil & nuclear)	billion $	-29	-15	-81	-91	-217	-5.0
Renewables	billion $	171	71	124	74	440	10.2
Total	billion $	**142**	**56**	**43**	**-18**	**223**	**5.2**
JAPAN (2011) DIFFERENCE ADV E[R] VERSUS REF							
Conventional (fossil & nuclear)	billion $	-30	-56	-82	-90	-257	-6.0
Renewables	billion $	280	84	175	109	648	15.1
Total	billion $	**251**	**28**	**94**	**19**	**391**	**9.1**
CUMULATED FUEL COST SAVINGS							
SAVINGS E[R] CUMULATED IN €							
Fuel oil	billion $/a	24	105	175	223	526	12
Gas	billion $/a	-7	59	200	422	674	16
Hard coal	billion $/a	14	99	186	244	543	0
Total	billion $/a	**31**	**263**	**561**	**889**	**1,744**	**41**
SAVINGS ADV E[R] CUMULATED IN €							
Fuel oil	billion $/a	29	113	194	245	581	13.5
Gas	billion $/a	-57	84	301	649	978	22.7
Hard coal	billion $/a	39	155	222	256	671	15.6
Total		**12**	**352**	**717**	**1,150**	**2,231**	**51.9**

figure 1.7: japan - investment shares - reference versus energy [r]evolution scenarios

reference scenario 2007 - 2050



energy [r]evolution scenario 2007 - 2050



advanced energy [r]evolution scenario 2007 - 2050

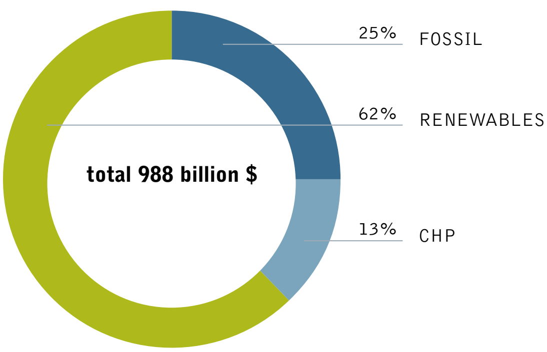
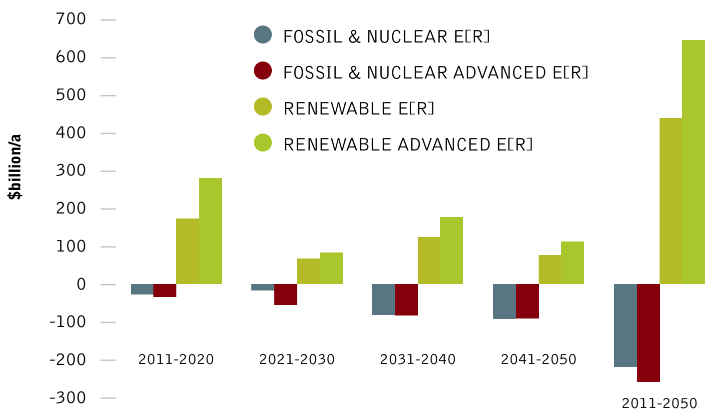


figure 1.8: japan - change in cumulative power plant investment in both energy [r]evolution scenarios



1.7 japan: heating and cooling supply

Renewables currently provide 3% of Japan's energy demand for heat supply, the main contribution coming from biomass. Dedicated support instruments are required to ensure a dynamic future development. In the Energy [R]evolution scenario, renewables provide 52% of Japan's total heating and cooling demand in 2050.

- Energy efficiency measures can decrease the current demand for heat supply by 38%, in spite of improving living standards.
- For direct heating, solar collectors, biomass/biogas as well as geothermal energy are increasingly substitute fossil fuel-fired systems.
- A shift from coal and oil to natural gas in the remaining conventional applications will lead to a further reduction of CO_2 emissions.

The Advanced Energy [R]evolution case introduces renewable heating and cooling systems around 5 years ahead of the Energy [R]evolution scenario. Solar collectors and geothermal heating systems achieve economies of scale via ambitious support programmes 5 to 10 years earlier and reach a share of 36% by 2030 and 71% by 2050.

1.8 japan: transport

In the transport sector, it is assumed under the Energy [R]evolution scenario that an energy demand reduction of 1,791 PJ/a can be achieved by 2050, saving 50% compared to the Reference scenario. This reduction can be achieved by the introduction of highly efficient vehicles, by shifting the transport of goods from road to rail and by changes in mobility-related behaviour patterns. Implementing attractive alternatives to individual cars, the car stock is growing slower than in the Reference scenario.

A shift towards smaller cars triggered by economic incentives together with a significant shift in propulsion technology towards electrified power trains and a reduction of vehicle kilometres travelled by 0.25% per year leads to significant final energy savings. In 2030, electricity will provide 8% of the transport sector's total energy demand in the Energy [R]evolution, while in the advanced case the share will be 16% in 2030 and 49% by 2050.

figure 1.9: japan - development of heat supply structure under three scenarios

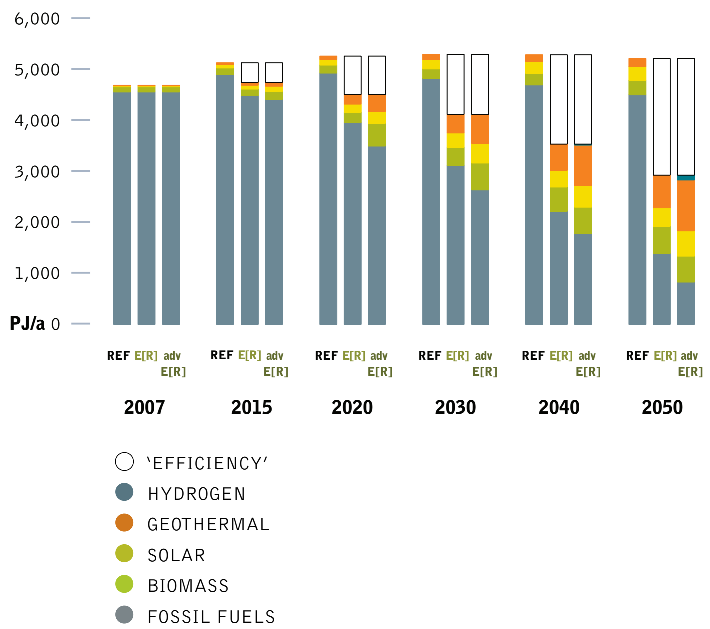


figure 1.10: japan - transport under three scenarios

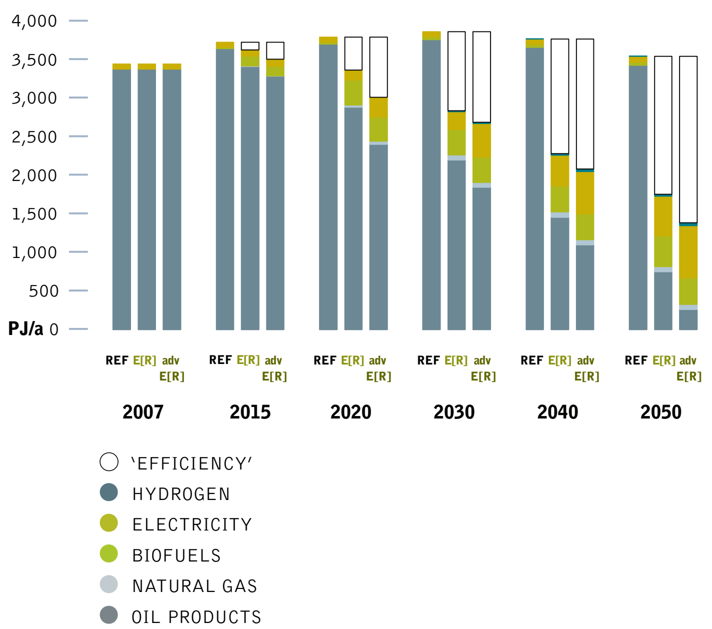


image WIND TURBINES CREATING CLEAN ENERGY IN FUKUSHIMA JAPAN.

1.9 japan: development of CO_2 emissions

Whilst Japan's emissions of CO_2 will decrease by 6% under the Reference scenario, under the Energy [R]evolution scenario they will decrease from 1,301 million tonnes (t) in 2007 to 298 million t in 2050. Annual per capita emissions will fall from 10.2 t to 2.9 t. In the long run efficiency gains and the increased use of renewable electricity in vehicles will even reduce emissions in the transport sector. With a share of 35% of total CO_2 in 2050, the power sector will remain the largest sources of emissions

In the Advanced Energy [R]evolution scenario Japan can completely phase out nuclear power in 2012 and still reach its pledge of reducing Greenhouse gas emission by 25% below 1990 levels by 2020 with 24% reductions coming through domestic means, and the remaining sourced through flexible mechanisms internationally.

1.10 japan: primary energy consumption

Taking into account the above assumptions, the resulting primary energy consumption under the Energy [R]evolution scenario is shown in Figure 1.12. Compared to the Reference scenario, overall energy demand will be reduced by 47% in 2050. Around 45% of the remaining demand will be covered by renewable energy sources.

The advanced version phases out coal and oil about 10 to 15 years faster than the basic scenario. This is made possible mainly by replacement of coal power plants with renewables after 20 rather than 40 years lifetime and a faster introduction of electric vehicles in the transport sector to replace oil combustion engines. This leads to an overall renewable primary energy share of 35% in 2030 and 64% in 2050. Nuclear energy is phased out in the Advanced Energy [R]evolution scenario in 2012.

figure 1.11: japan - development of CO_2 emissions by sector under both energy [r]evolution scenarios

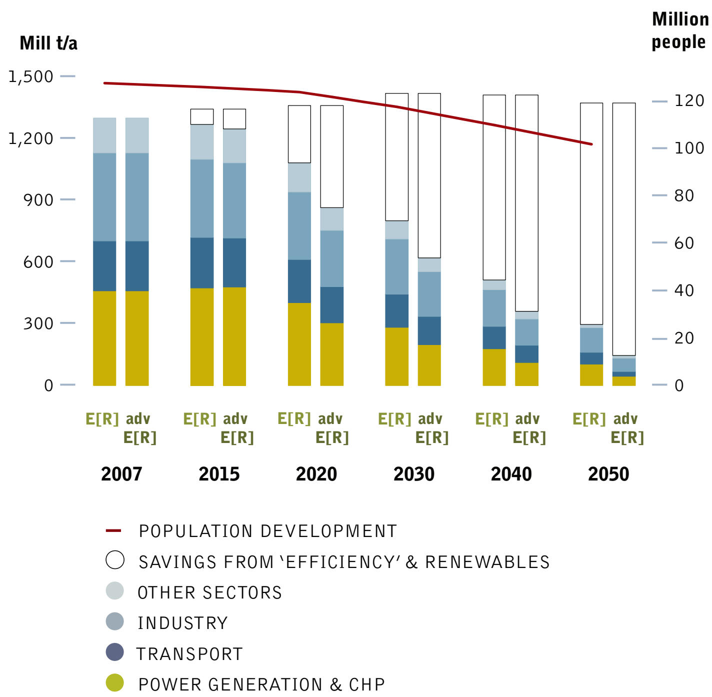
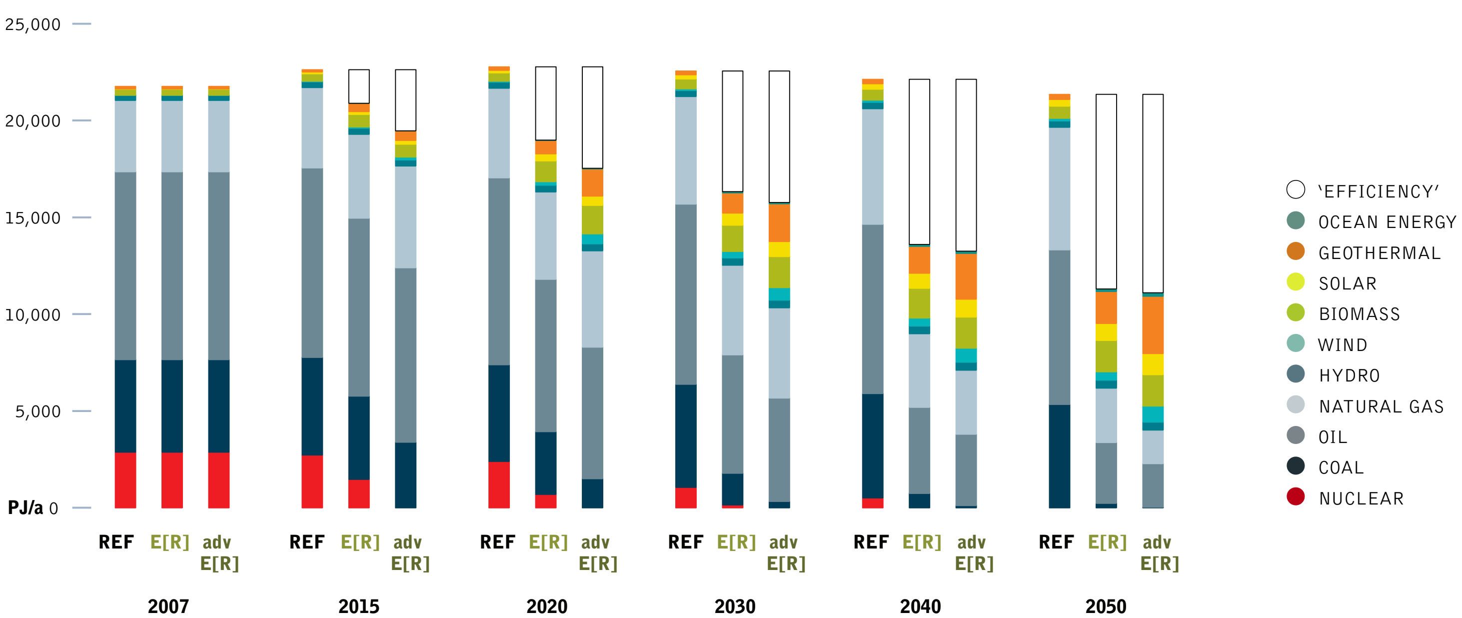


figure 1.12: japan - development of primary energy consumption under three scenarios



employment

2

“if we can get various Japanese technologies and cooperation from the public, we can achieve the 25% CO_2 cut target”

GOSHI HOSONO
ENVIRONMENT MINISTER OF JAPAN

image SOLAR POWER SYSTEM INSTALLED IN A COASTAL VILLAGE IN ACEH, INDONESIA.

image CONSTRUCTION OF WIND TURBINES.

2.1 japan: future employment

Energy sector jobs are set to increase significantly by 2015 under both the Energy [R]evolution and the Advanced Energy [R]evolution scenarios, with a slight increase in the Reference scenario. In 2010, there are 81,500 electricity sector jobs. Figure 2.1 shows the increase in job numbers under both Energy [R]evolution scenarios and the Reference case for each technology up to 2030, with details given in Table 2.1.

- In the Reference case, jobs stay constant to 2015, and then fall by 5% by 2020 (a loss of 4,800 jobs relative to 2010), and then decrease further to 57,000 jobs by 2030.
- In the [R]evolution scenario, jobs more than triple to 260,000 jobs in 2015 (179,000 additional jobs), then drop back to 147,000 jobs in 2020, reducing to 119,000 jobs in 2030, a 46% increase from 2010.
- In the Advanced scenario, jobs almost quadruple to 326,000 jobs in 2015 (244,000 additional jobs), then drop back to 198,000 jobs in 2020, and 144,000 jobs in 2030, a 76% increase from 2010.
- Solar PV shows particularly strong growth, reaching a peak of more than 170,000 jobs in 2015 in both the [R]evolution scenarios.

These calculations do not include the jobs associated with decommissioning nuclear power stations, which would be significant in all three scenarios.

The overall trend in the Reference scenario is dominated by the nuclear sector, which loses 20,000 jobs between 2010 and 2030. These are not compensated for by gains in other sectors.

The [R]evolution scenario increase of 179,000 jobs by 2015 includes massive growth across the renewable sector (198,000 new jobs), with solar PV accounting for 87% of the increase, followed by wind energy and bioenergy. By 2030, bioenergy is the largest sector. There are significant reductions in jobs in the coal and nuclear industries, although these are dwarfed by the job creation in the renewable sector. By 2030 there are 119,000 electricity sector jobs, 49% above 2010 levels.

The massive growth in jobs by 2015 in the Advanced renewable energy scenario is mainly concentrated in the PV industry, which accounts for 66% of the increase, taking PV jobs to 172,000 by 2015, Wind also has very significant growth, reaching 73,000 jobs by 2015, as does bioenergy, with 32, 000 jobs. These numbers in PV and wind are not maintained, and by 2020 fall to 96,000 and 27,000 respectively. Overall electricity sector numbers at 2015 are 318,000, nearly three times the 2010 level. From 2015 to 2030, overall job numbers drop and the renewable sector becomes more diverse. Bioenergy provides the greatest share of electricity sector jobs by 2030, followed by PV, wind, and hydro. Overall electricity sector employment in 2030 is 144,000, 76% more than 2010 levels.

figure 2.1: jobs by technology under three scenarios

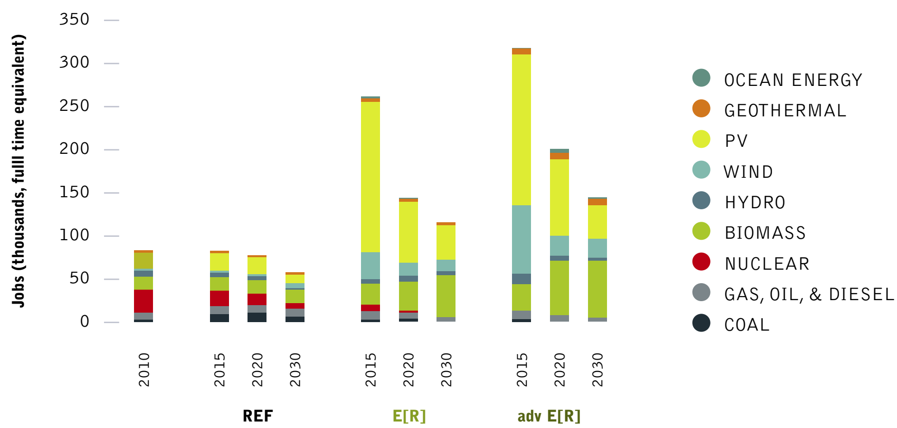


table 2.1: electricity sector jobs in the three scenarios

		REFERENCE			ENERGY [R]EVOLUTION			ADVANCED ENERGY [R]EVOLUTION		
Thousand Jobs	2010	2015	2020	2030	2015	2020	2030	2015	2020	2030
Coal	4.9	10.0	11.4	7.6	5.1	3.8	1.8	4.5	1.9	0.3
Gas, oil and diesel	9.7	10.3	10.8	10.6	9.1	8.3	7.3	9.6	8.8	7.9
Nuclear	24.8	17.4	12.2	4.4	6.3	2.9	0.6	0.0	0.0	0.0
Renewables	42.3	44.0	42.3	34.8	240	131	109	312	188	136
Total Jobs	**81.5**	**81.8**	**76.8**	**57.4**	**260**	**147**	**119**	**326**	**198**	**144**

2.2 methodology overview

Greenpeace engaged the Australian-based Institute for Sustainable Futures (ISF) to model the employment effects of the 2009 and 2010 global energy, published as "Working for the climate – Renewable Energy & The Green Job [R]evolution"[5]. The modelling methodology was updated and published in 2010[6].

The model calculates indicative numbers for jobs that would either be created or lost under the two Energy [R]evolution and the Reference scenarios, with the aim of showing the effect on employment if the world re-invents its energy mix to dramatically cut carbon emissions. The Reference ('business as usual') scenario and both the [R]evolution scenarios were constructed for Greenpeace and the European Renewable Energy Council by the German Aerospace Center (DLR).

To calculate how many jobs will either be lost or created under the three scenarios requires a series of assumptions or calculations. These are summarised below.

- Installed electrical capacity and generation by technology for each year, from the two Energy [R]evolution scenarios and the Reference scenario modelled by DLR. The Reference case has been modified to include actual data for nuclear[7], PV[8], and wind[9] capacity in 2010, and all scenarios have been set to have the same capacities in 2010.
- "Employment factors" for each technology, which give the number of jobs per unit of electrical capacity. These are key inputs to the analysis. Employment factors from OECD data are used when local factors are not available.
- Decline factors, or learning adjustment rates, which are used to reduce the employment factors by a specific percentage each year. Employment per unit of capacity reduces as technologies mature.
- The percentage of manufacturing for each technology which occurs within Japan, and whether there are any technology exports to the rest of the world.
- The percentage of coal and gas which originates within Japan.

Only direct employment is included, namely jobs in construction, manufacturing, operations and maintenance, and fuel supply associated with electricity generation. Employment numbers are indicative only, as a large number of assumptions are required to make calculations However, within the limits of data availability, the figures presented are indicative of employment levels under the three scenarios.

table 2.2: methodology to calculate employment

MANUFACTURING JOBS (FOR DOMESTIC USE)	=	MW INSTALLED PER YEAR	×	MANUFACTURING EMPLOYMENT FACTOR	×	% OF LOCAL MANUFACTURING
MANUFACTURING JOBS (FOR EXPORT, ADVANCED SCENARIO ONLY)	=	MW EXPORTED PER YEAR	×	MANUFACTURING EMPLOYMENT FACTOR	×	% OF LOCAL MANUFACTURING
CONSTRUCTION JOBS	=	MW INSTALLED PER YEAR	×	CONSTRUCTION EMPLOYMENT FACTOR		
OPERATION & MAINTENANCE JOBS	=	CUMULATIVE CAPACITY	×	O&M EMPLOYMENT FACTOR		
FUEL SUPPLY JOBS	=	ELECTRICITY GENERATION	×	FUEL EMPLOYMENT FACTOR		
JOBS IN REGION 2010	=	**JOBS (AS ABOVE)**				
JOBS IN REGION 2020	=	**JOBS (AS ABOVE)** × TECHNOLOGY DECLINE FACTOR$^{\text{(years after start)}}$				
JOBS IN REGION 2030	=	**JOBS (AS ABOVE)** × TECHNOLOGY DECLINE FACTOR$^{\text{(years after start)}}$				

5 GREENPEACE INTERNATIONAL AND EUROPEAN RENEWABLE ENERGY COUNCIL. 2009. WORKING FOR THE CLIMATE.
6 RUTOVITZ, J AND USHER, J. 2010. METHODOLOGY FOR CALCULATING ENERGY SECTOR JOBS. PREPARED FOR GREENPEACE INTERNATIONAL BY THE INSTITUTE OF SUSTAINABLE FUTURES, UNIVERSITY OF TECHNOLOGY, SYDNEY.
7 JAPAN ELECTRIC POWER INFORMATION CENTRE. 2011. OPERATIONAL AND FINANCIAL DATA.
8 EUROPEAN PHOTOVOLTAIC INDUSTRY ASSOCIATION (EPIA) 2011 GLOBAL MARKET OUTLOOK FOR PHOTOVOLTAICS UNTIL 2015.
9 GLOBAL WIND ENEGY ASSOCIATION. JAPAN TOTAL INSTALLED CAPACITY. WWW.GWEC.NET DOWNLOADED 30/6/2011.

image GEOTHERMIC WELL IN THE AZUFRES NATURAL PARK, MICHOACAN, MEXICO.

2.2.1 japan: employment factors

Electricity sector employment is calculated by using employment factors, which give the jobs created per unit of capacity (MW) or per unit of generation (GWh). In all cases except PV manufacturing and hydro, OECD employment factors from the global analysis have been used (see Rutovitz and Usher, 2010, for a full explanation).

General data on the nuclear industry and the PV industry was obtained, and the major electricity companies were contacted by phone and email in an attempt to obtain local data. The data obtained confirmed that the OECD employment factors were generally correct. A local factor for solar PV and hydro was derived. The comparison for local and OECD employment factors is given below, and the factor used in the analysis is identified. For details and the derivation of the global factors and the updated decline factors see Rutovitz and Usher, 2010.

2.2.2 japan: manufacturing and technology export

Japan is assumed to manufacture all components for domestic capacity expansion in all technologies, except during the period 2015 to 2020, when the expansion in solar PV and wind energy is so rapid that it is unlikely the manufacturing plant could expand sufficiently to keep up, and such expansion could become redundant as from 2020 onwards the annual installations fall back to the level of 2014.

It is assumed that during this peak growth period Japan imports solar PV and wind technology that is above the level of domestic demand in 2020. This results in imports corresponding to 40% of annual installation in both technologies from 2015 – 2019 in the Advanced scenario, and imports of 10% of wind installations and 50% of PV installations from 2015 – 2019 in the [R]evolution scenario.

Exports are not included for any technology other than solar PV. For solar PV it is assumed that the current annual production level is a minimum. Where this is less than annual installation, which only occurs in the Reference scenario after 2011, the remainder is assumed to be exported.

2.2.3 japan: coal and gas

There are no jobs in coal or gas production as Japan does imports nearly 100% of coal and gas, and this is expected to remain the case.

table 2.3: local employment factors compared to OECD factors (jobs/MW)

	OECD FACTOR	LOCAL FACTOR	USED IN ANALYSIS
Coal O&M	0.1	0.08 (weighted average thermal generation)[a] 0.06 – 0.13 (range for thermal generation)[a]	0.1[b]
Gas and oil O&M	0.05	0.08 for oil alone[a]	0.08[b]
Nuclear O&M	0.32	0.33 (weighted average)[a] 0.22 – 0.4 (range)[a] 0.22 (industry data 2005)[c]	0.32[b]
Hydro O&M	0.22	0.11 (weighted average)[a] 0.02 – 0.25 (range)[a]	0.11[a]
PV manufacturing	9.3	7.6 (industry data 2008)[d]	7.6[d]

notes
a DATA OBTAINED FROM ANNUAL REPORTS AND BY TELEPHONE WITH THE HUMAN RESOURCES DEPARTMENTS OF TOHUKU ELECTRIC POWER, CHUBU ELECTRIC POWER, HOKKAIDO ELECTRIC POWER COMPANY, HOKURIKU ELECTRIC POWER COMPANY AND OKINAWA ELECTRIC POWER COMPANY, JULY 2011.
b FACTOR FROM RUTOVITZ, J AND USHER, J. 2010. METHODOLOGY FOR CALCULATING ENERGY SECTOR JOBS. PREPARED FOR GREENPEACE INTERNATIONAL BY THE INSTITUTE OF SUSTAINABLE FUTURES, UNIVERSITY OF TECHNOLOGY, SYDNEY.
c DERIVED FROM 2005 TOTAL NUCLEAR EMPLOYMENT OF 10,570 GIVEN IN KENZO, M. AND AKIKO I. 2005. 47TH ATOMIC ENERGY INDUSTRY ACTUAL CONDITION INVESTIGATION REPORT. CONFERENCE PAPER, 2005 JAPAN ATOMIC POWER INDUSTRY CONFERENCE.
d EMPLOYMENT IN PV MANUFACTURING AND ANNUAL PRODUCTION FROM YAMAMOTO M. 2010 NATIONAL SURVEY REPORT OF PV POWER APPLICATIONS IN JAPAN 2009. INTERNATIONAL ENERGY AGENCY 2010.

3

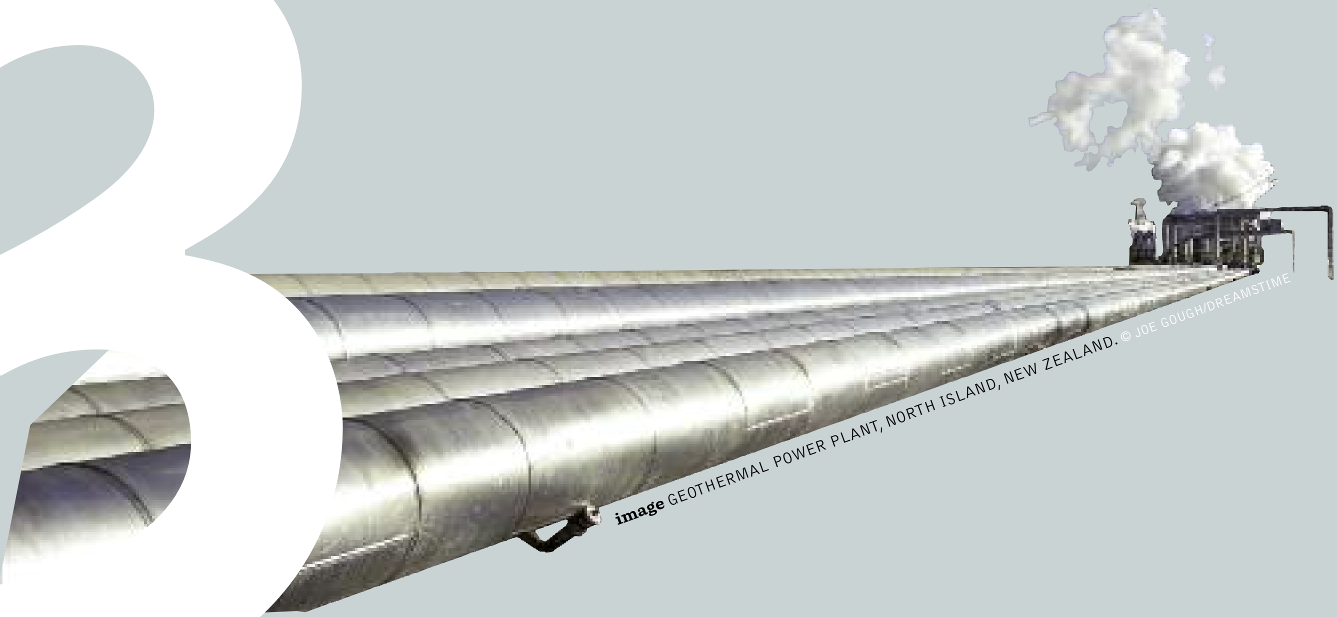


image GEOTHERMAL POWER PLANT, NORTH ISLAND, NEW ZEALAND. © JOE GOUGH/DREAMSTIME

"bridging the gap."

GREENPEACE INTERNATIONAL
CLIMATE CAMPAIGN

image A WORKER ASSEMBLES WIND TURBINE ROTORS AT GANSU JINFENG WIND POWER EQUIPMENT CO. LTD. IN JIUQUAN, GANSU PROVINCE, CHINA.

3.1 international energy policy

At present, renewable energy generators have to compete with old nuclear and fossil fuel power stations which produce electricity at marginal cost because consumers and taxpayers have already paid the interest and depreciation on the original investment. Political action is needed to overcome these distortions and create a level playing field for renewable energy technologies to compete.

At a time when governments around the world are in the process of liberalising their electricity markets, the increasing competitiveness of renewable energy should lead to higher demand. Without political support, however, renewable energy remains at a disadvantage, marginalised by distortions in the world's electricity markets created by decades of massive financial, political and structural support to conventional technologies. Developing renewables will therefore require strong political and economic efforts, especially through laws that guarantee stable tariffs over a period of up to 20 years. Renewable energy will also contribute to sustainable economic growth, high quality jobs, technology development, global competitiveness, as well as industrial and research leadership.

3.2 japan's energy policy brief

3.2.1 japan: overall policy on renewable energy

1. Establish Long-term, high numerical targets and political commitment.

- Set legally binding target (at least 20% by 2020) for the final energy use, as well as specific sectorial renewable targets for electricity, heating and transport.

2. Phasing out fossil fuel and nuclear to internalize external costs.

- Under a national consensus, establish a framework to share costs and/or burdens in a fair manner by reforming taxation in a way that promotes further introduction of renewable energy.
- Specifically, adopt an environmental tax (carbon tax) or energy consumption charge scheme.

3. Reduce the harmful obstacles of old customs, traditions and existing regulations in "energy markets".

- In attempt to introduce decentralized renewable energy, it is necessary to review a wide body of laws, which can create barriers through inconsistency and inflexibility; the nature parks law, the agriculture land law, building standard regulations, the waste and cleaning law, and others must be appraised with the necessary flexibility in mind.
- Review a scheme of existing/vested rights, especially water rights, geo- (hot-spring) thermal access, fishery rights and others, which have a potential for instigated rivalries, through restoring and integrating them so as to establish fair and transparent procedures.

4. Implement a reasonable and effective power saving plan.

Much of the type of "enduring power saving" which makes people feel pressure and inconveniences. We should switch to reasonable power saving that does not deteriorate convenience as much.

- To achieve this, it is important not only to expand mandatory emission reduction policy to all over Japan by applying the Green Building Program.
- Disclosure system (including energy expenditure and CO_2 emissions per unit floor) with respect to each business institution.
- Local governments should provide consultation services for the household energy saving.

5. Create a stable market with transparency.

In order to reduce the risks to financial interests of the renewable energy business over long periods of time, it is vital to take the following, necessary measures:

- Set long-term, stable monetary support for renewable energy businesses;
- Harmonize the verification of CO_2 emission reduction and the creation of a CO_2 market;
- Create a market which is demonstrably stable in the long term from an investor's point of view;
- Create a renewable energy market from which users may choose directly among various options;
- Create initial demand through active introduction of renewable energy by central and local government and other public offices;
- Place community development, new building construction, hotspring utilization under obligation to utilize renewable energy;
- Establish a "public-private fund for the development phase" in order to share the risks that renewable energy businesses face.

6. Public and community participation scheme.

Generating the benefits of renewable energy for the local community.

- In order to enable local residents to take an early role in the renewable energy development process, it is required to establish transparent land-use planning and environment assessment systems.
- In light of the fact that the introduction of renewable energy brings rewards to a local community, there is a need to establish a local financial scheme in which locals can own part of the renewable business by themselves.
- For increased participation by local governments, businesses and individuals in renewable energy, it is necessary to create an organization like a local energy office that is expected to form a partnership between community and renewable energy activities.

7. Review and reinforce existing policies.

The following measures have been implemented, but require further review and support:

- National support for research and development;
- Award ceremony for the best practice and system;
- Expansion and implementation of education, enlightenment and publicity activities.

3.2.2 japan: policies for a power system and electrical power markets

Regarding the renewable energy electricity sector, reviewing the rule of access to the power supply is a crucial element. To that end, the following measures are recommended:

1. Principle: Priority access to the power supply by the renewable energy business.

- At this moment, access to the power supply has been permitted solely at an electric power company's own discretion. This should be changed in order to give any renewable energy businesses, in principle, the "priority right" to use the network.
- Separate the electricity grid from utilities.

2. Cost: Social sharing of power supply costs for access of renewable energy, which needs strengthening system interconnection.

- Share the cost of access from renewable energy businesses to power supply network among all members of network users (renewable energy businesses need to pay for all costs as far as access point).

3. Cost: Social sharing of imbalance (ancillary) costs of renewable energy.

- Among the businesses, share costs of imbalanced (ancillary) situations which will be caused by any unstable features of renewable energy.

4. Technology: Take action to strengthen and utilize supply interconnection among the power utilities.

- By taking advantage of "power supply interconnection lines", which connects the power utilities to one another, operate the whole system flexibly enough to cover itself against any imbalance caused by access of renewable energy.
- Improve electric power transmission lines.
- Obligation of priority access.
- Complete strengthening of the Japan's FIT (Feed-In Tariff) scheme.

5. Technology: Increase the capacity for system interconnection coordination in order to make the demand side bear their own costs by themselves.

- By introducing an adjustment system through both engineering measures and market mechanisms against a load generated by the demand side, the coordinative capacity of the whole system's interconnection will be increased.
- Energy conservation/power saving technologies.

3.2.3 japan: policies for PV power generation

1. Introduce: an obligation for new building construction to install solar PV.

- Impose an obligation at the time of new building construction and/or rebuilding work to install renewable energy, including solar PV power at a certain rate.

3.2.4 japan: policies for micro-hydro power generation

1. Impose: an obligation in principle at the time of construction of a new waterway and of repair to utilize them with a steep surplus drop for power generation.

- At the any point of efficient utilization of renewable energy generated by new waterway construction and retrieval of water, use in principle a power generator with steep surplus water drop.

3.2.5 japan: policies for biomass power generation

1. Stabilize: the forestry business management and integrate forestry policy with environmental and energy policies.

- Based on establishing forestry as a sound business management, forestry policy should be integrated with environment and energy policies.

2. Establish: an efficient biomass supply chain.

- For biomass supplied from forest and agriculture to waste, there is a need to establish a scheme in order to realize efficient use of biomass energy.

3. Revise: the Waste and Clean Law to utilize biomass waste more flexibly.

- Review the definition and operation of biomass waste with practical function in mind in order to make it more efficient and effective.

image A NEWLY DEFORESTED AREA WHICH HAS BEEN CLEARED FOR AGRICULTURAL EXPANSION IN THE AMAZON, BRAZIL.

3.2.6 japan: policies for geothermal power generation

1. Enactment: of Geothermal Law.

• Enact a "Geothermal Law", which imposes an obligation in principle of utilization of geothermal energy at the point of underground development like hot-spa construction.

2. Implement: flexibly national policies so as to support commercialization of geothermal energy.

- Review the boundary of new energy.
- Introduce commercialization research at the time of the research for geothermal development and promotion.
- Second use of recycled waste hot water: utilization of hot spring warmth and direct heat.

3.2.7 japan: policies for renewable energy heat

1. Establish: heat and thermal policies of giving priority to renewable energy taking energy into account.

2. Unify: methods of building and energy saving.

- Utilize renewable energy, including solar heat and energy saving apparatus at a certain rate for renovation and new construction.
- Introduce the obligation for new housing construction to install solar heat.

3. Establish: CO_2 value incentives of green power certification policies for renewable energy fuel.

3.2.8 japan: policies for renewable energy fuel

1. create: and reach an agreement upon the international "Sustainable Bio-fuel Standard".

the energy [r]evolution

GLOBAL

KEY PRINCIPLES
FROM PRINCIPLES TO PRACTICE
A SUSTAINABLE DEVELOPMENT PATHWAY

NEW BUSINESS MODEL
THE NEW ELECTRICITY GRID

HYBRID SYSTEMS
SMART GRIDS

4

DECOUPLE GROWTH FROM FOSSIL FUEL USE. © G. POROPAT/DREAMSTIME

"half the solution to climate change is the smart use of power."

GREENPEACE INTERNATIONAL
CLIMATE CAMPAIGN

image GREENPEACE AND AN INDEPENDENT NASA-FUNDED SCIENTIST COMPLETED MEASUREMENTS OF MELT LAKES ON THE GREENLAND ICE SHEET THAT SHOW ITS VULNERABILITY TO WARMING TEMPERATURES.

The climate change imperative demands nothing short of an Energy [R]evolution. The expert consensus is that this fundamental shift must begin immediately and be well underway within the next ten years in order to avert the worst impacts. What is needed is a complete transformation of the way we produce, consume and distribute energy, while at the same time maintaining economic growth. Nothing short of such a revolution will enable us to limit global warming to less than a rise in temperature of 2° Celsius, above which the impacts become devastating.

Current electricity generation relies mainly on burning fossil fuels, with their associated CO_2 emissions, in very large power stations which waste much of their primary input energy. More energy is lost as the power is moved around the electricity grid network and converted from high transmission voltage down to a supply suitable for domestic or commercial consumers. The system is innately vulnerable to disruption: localised technical, weather-related or even deliberately caused faults can quickly cascade, resulting in widespread blackouts. Whichever technology is used to generate electricity within this old fashioned configuration, it will inevitably be subject to some, or all, of these problems. At the core of the Energy [R]evolution there therefore needs to be a change in the way that energy is both produced and distributed.

4.1 key principles

the energy [r]evolution can be achieved by adhering to five key principles:

1. **respect natural limits – phase out fossil fuels by the end of this century** We must learn to respect natural limits. There is only so much carbon that the atmosphere can absorb. Each year humans emit over 25 billion tonnes of carbon equivalent; we are literally filling up the sky. Geological resources of coal could provide several hundred years of fuel, but we cannot burn them and keep within safe limits. Oil and coal development must be ended.

   The global Energy [R]evolution scenario has a target to reduce energy related CO_2 emissions to a maximum of 10 Gigatonnes (Gt) by 2050 and phase out fossil fuels by 2085.

2. **equity and fairness** As long as there are natural limits there needs to be a fair distribution of benefits and costs within societies, between nations and between present and future generations. At one extreme, a third of the world's population has no access to electricity, whilst the most industrialised countries consume much more than their fair share.

   The effects of climate change on the poorest communities are exacerbated by massive global energy inequality. If we are to address climate change, one of the core principles must be equity and fairness, so that the benefits of energy services – such as light, heat, power and transport – are available for all: north and south, rich and poor. Only in this way can we create true energy security, as well as the conditions for genuine human wellbeing.

   The Advanced Energy [R]evolution scenario has a target to achieve energy equity as soon as technically possible. By 2050 the average per capita emission should be between 1 and 2 tonnes of CO_2.

3. **implement clean, renewable solutions and decentralise energy systems** There is no energy shortage. All we need to do is use existing technologies to harness energy effectively and efficiently. Renewable energy and energy efficiency measures are ready, viable and increasingly competitive. Wind, solar and other renewable energy technologies have experienced double digit market growth for the past decade.

   Just as climate change is real, so is the renewable energy sector. Sustainable decentralised energy systems produce less carbon emissions, are cheaper and involve less dependence on imported fuel. They create more jobs and empower local communities. Decentralised systems are more secure and more efficient. This is what the Energy [R]evolution must aim to create.

> "THE STONE AGE DID NOT END FOR LACK OF STONE, AND THE OIL AGE WILL END LONG BEFORE THE WORLD RUNS OUT OF OIL."
>
> ***Sheikh Zaki Yamani, former Saudi Arabian oil minister***

   To stop the earth's climate spinning out of control, most of the world's fossil fuel reserves – coal, oil and gas – must remain in the ground. Our goal is for humans to live within the natural limits of our small planet.

4. **decouple growth from fossil fuel use** Starting in the developed countries, economic growth must be fully decoupled from fossil fuel usage. It is a fallacy to suggest that economic growth must be predicated on their increased combustion.

   We need to use the energy we produce much more efficiently, and we need to make the transition to renewable energy and *away* from fossil fuels quickly in order to enable clean and sustainable growth.

5. **phase out dirty, unsustainable energy** We need to phase out coal and nuclear power. We cannot continue to build coal plants at a time when emissions pose a real and present danger to both ecosystems and people. And we cannot continue to fuel the myriad nuclear threats by pretending nuclear power can in any way help to combat climate change. There is no role for nuclear power in the Energy [R]evolution.

4.2 from principles to practice

In 2008, renewable energy sources accounted for 13% of the world's primary energy demand[10]. Biomass, which is mostly used for heating, was the main renewable energy source. The share of renewable energy in electricity generation was 19%. The contribution of renewables to primary energy demand for heat supply was around 24%. About 80% of primary energy supply today still comes from fossil fuels, and 6% from nuclear power[11].

The time is right to make substantial structural changes in the energy and power sector within the next decade. Many power plants in industrialised countries, such as the USA, Japan and the European Union, are nearing retirement; more than half of all operating power plants are over 20 years old. At the same time developing countries,

references
10 WORLD ENERGY OUTLOOK 2010, IEA 2010.
11 'ENERGY BALANCE OF NON-OECD COUNTRIES' AND 'ENERGY BALANCE OF OECD COUNTRIES', IEA, 2009.

such as China, India and Brazil, are looking to satisfy the growing energy demand created by their expanding economies.

Within the next ten years, the power sector will decide how this new demand will be met, either by fossil and nuclear fuels or by the efficient use of renewable energy. The Advanced Energy [R]evolution scenario is based on a new political framework in favour of renewable energy and cogeneration combined with energy efficiency.

To make this happen both renewable energy and cogeneration – on a large scale and through decentralised, smaller units – have to grow faster than overall global energy demand. Both approaches must replace old generating technologies and deliver the additional energy required in the developing world.

As it is not possible to switch directly from the current large scale fossil and nuclear fuel based energy system to a full renewable energy supply, a transition phase is required to build up the necessary infrastructure. Whilst remaining firmly committed to the promotion of renewable sources of energy, we appreciate that gas, used in appropriately scaled cogeneration plants, is valuable as a transition fuel, and able to drive cost-effective decentralisation of the energy infrastructure. With warmer summers, tri-generation, which incorporates heat-fired absorption chillers to deliver cooling capacity in addition to heat and power, will become a particularly valuable means of achieving emissions reductions.

4.3 a sustainable development pathway

The Energy [R]evolution envisages a development pathway which turns the present energy supply structure into a sustainable system. There are three main stages to this:

step 1: energy efficiency

The Energy [R]evolution is aimed at the ambitious exploitation of the potential for energy efficiency. It focuses on current best practice and technologies that will become available in the future, assuming continuous innovation. The energy savings are fairly equally distributed over the three sectors – industry, transport and domestic/business. Intelligent use, not abstinence, is the basic philosophy for future energy conservation.

The most important energy saving options are improved heat insulation and building design, super efficient electrical machines and drives, replacement of old style electrical heating systems by renewable heat production (such as solar collectors) and a reduction in energy consumption by vehicles used for goods and passenger traffic. Industrialised countries, which currently use energy in the most inefficient way, can reduce their consumption drastically without the loss of either housing comfort or information and entertainment electronics. The Advanced Energy [R]evolution scenario uses energy saved in OECD countries as a compensation for the increasing power requirements in developing countries. The ultimate goal is stabilisation of global energy consumption within the next two decades. At the same time the aim is to create 'energy equity' – shifting the current one-sided waste of energy in the industrialised countries towards a fairer worldwide distribution of efficiently used supply.

A dramatic reduction in primary energy demand compared to the Reference scenario – but with the same GDP and population development – is a crucial prerequisite for achieving a significant share of renewable energy sources in the overall energy supply system, compensating for the phasing out of nuclear energy and reducing the consumption of fossil fuels.

figure 4.1: energy loss, by centralised generation systems

image GREENPEACE OPENS A SOLAR ENERGY WORKSHOP IN BOMA, DEMOCRATIC REPUBLIC OF CONGO. A MOBILE PHONE GETS CHARGED BY A SOLAR ENERGY POWERED CHARGER.

step 2: the renewable Energy [R]evolution

decentralised energy and large scale renewables In order to achieve higher fuel efficiencies and reduce distribution losses, the Advanced Energy [R]evolution scenario makes extensive use of Decentralised Energy (DE).

DE is connected to a local distribution network system, supplying homes and offices, rather than the high voltage transmission system. The proximity of electricity generating plant to consumers allows any waste heat from combustion processes to be piped to nearby buildings, a system known as cogeneration or combined heat and power. This means that nearly all the input energy is put to use, not just a fraction as with traditional centralised fossil fuel plant.

DE also includes stand-alone systems entirely separate from the public networks, for example heat pumps, solar thermal panels or biomass heating. These can all be commercialised at a domestic level to provide sustainable low emission heating. Although DE technologies can be considered 'disruptive' because they do not fit the existing electricity market and system, with appropriate changes they have the potential for exponential growth, promising 'creative destruction' of the existing energy sector.

A huge proportion of global energy in 2050 will be produced by decentralised energy sources, although large scale renewable energy supply will still be needed in order to achieve a fast transition to a renewables dominated system. Large offshore wind farms and concentrating solar power (CSP) plants in the sunbelt regions of the world will therefore have an important role to play.

cogeneration The increased use of combined heat and power generation (CHP) will improve the supply system's energy conversion efficiency, whether using natural gas or biomass. In the longer term, a decreasing demand for heat and the large potential for producing heat directly from renewable energy sources will limit the need for further expansion of CHP.

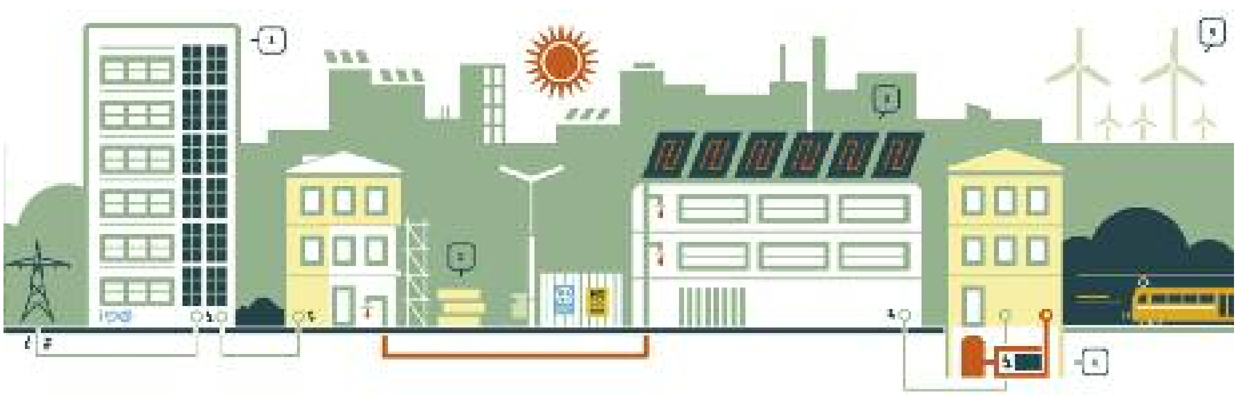
renewable electricity The electricity sector will be the pioneer of renewable energy utilisation. Many renewable electricity technologies have been experiencing steady growth over the past 20 to 30 years of up to 35% annually and are expected to consolidate at a high level between 2030 and 2050. By 2050, under the Advanced Energy [R]evolution scenario, the majority of electricity will be produced from renewable energy sources. The anticipated growth of electricity use in transport will further promote the effective use of renewable power generation technologies.

renewable heating In the heat supply sector, the contribution of renewables will increase significantly. Growth rates are expected to be similar to those of the renewable electricity sector. Fossil fuels will be increasingly replaced by more efficient modern technologies, in particular biomass, solar collectors and geothermal. By 2050, renewable energy technologies will satisfy the major part of heating and cooling demand.

figure 4.2: a decentralised energy future

EXISTING TECHNOLOGIES, APPLIED IN A DECENTRALISED WAY AND COMBINED WITH EFFICIENCY MEASURES AND ZERO EMISSION DEVELOPMENTS, CAN DELIVER LOW CARBON COMMUNITIES AS ILLUSTRATED HERE. POWER IS GENERATED USING EFFICIENT COGENERATION TECHNOLOGIES PRODUCING BOTH HEAT (AND SOMETIMES COOLING) PLUS ELECTRICITY, DISTRIBUTED VIA LOCAL NETWORKS. THIS SUPPLEMENTS THE ENERGY PRODUCED FROM BUILDING INTEGRATED GENERATION. ENERGY SOLUTIONS COME FROM LOCAL OPPORTUNITIES AT BOTH A SMALL AND COMMUNITY SCALE. THE TOWN SHOWN HERE MAKES USE OF – AMONG OTHERS – WIND, BIOMASS AND HYDRO RESOURCES. NATURAL GAS, WHERE NEEDED, CAN BE DEPLOYED IN A HIGHLY EFFICIENT MANNER.

city



1. **PHOTOVOLTAIC, SOLAR FAÇADES** WILL BE A DECORATIVE ELEMENT ON OFFICE AND APARTMENT BUILDINGS. PHOTOVOLTAIC SYSTEMS WILL BECOME MORE COMPETITIVE AND IMPROVED DESIGN WILL ENABLE ARCHITECTS TO USE THEM MORE WIDELY.
2. **RENOVATION CAN CUT ENERGY CONSUMPTION OF OLD BUILDINGS** BY AS MUCH AS 80% - WITH IMPROVED HEAT INSULATION, INSULATED WINDOWS AND MODERN VENTILATION SYSTEMS.
3. **SOLAR THERMAL COLLECTORS** PRODUCE HOT WATER FOR BOTH THEIR OWN AND NEIGHBOURING BUILDINGS.
4. **EFFICIENT THERMAL POWER (CHP) STATIONS** WILL COME IN A VARIETY OF SIZES - FITTING THE CELLAR OF A DETACHED HOUSE OR SUPPLYING WHOLE BUILDING COMPLEXES OR APARTMENT BLOCKS WITH POWER AND WARMTH WITHOUT LOSSES IN TRANSMISSION.
5. **CLEAN ELECTRICITY** FOR THE CITIES WILL ALSO COME FROM FARTHER AFIELD. OFFSHORE WIND PARKS AND SOLAR POWER STATIONS IN DESERTS HAVE ENORMOUS POTENTIAL.

references
12 SEE CHAPTER 6.

transport Before new technologies, including hybrid or electric cars and new fuels such as biofuels, can play a substantial role in the transport sector, the existing large efficiency potentials have to be exploited. In this study, biomass is primarily committed to stationary applications; the use of biofuels for transport is limited by the availability of sustainably grown biomass[12]. Electric vehicles will therefore play an even more important role in improving energy efficiency in transport and substituting for fossil fuels.

Overall, to achieve an economically attractive growth of renewable energy sources, the balanced and timely mobilisation of all technologies is essential. Such a mobilisation depends on the resource availability, cost reduction potential and technological maturity. And alongside technology driven solutions, lifestyle changes - like simply driving less and using more public transport – have a huge potential to reduce greenhouse gas emissions.

4.4 new business model

The Advanced Energy [R]evolution scenario will also result in a dramatic change in the business model of energy companies, utilities, fuel suppliers and the manufacturers of energy technologies. Decentralised energy generation and large solar or offshore wind arrays which operate in remote areas, without the need for any fuel, will have a profound impact on the way utilities operate in 2020 and beyond.

While today the entire power supply value chain is broken down into clearly defined players, a global renewable power supply will inevitably change this division of roles and responsibilities. Table 4.1 provides an overview of today's value chain and how it would change in a revolutionised energy mix.

While today a relatively small number of power plants, owned and operated by utilities or their subsidiaries, are needed to generate the required electricity, the Advanced Energy [R]evolution scenario projects a future share of around 60 to 70% of small but numerous decentralised power plants performing the same task. Ownership will therefore shift towards more private investors and away from centralised utilities. In turn, the value chain for power companies will shift towards project development, equipment manufacturing and operation and maintenance.

Simply selling electricity to customers will play a smaller role, as the power companies of the future will deliver a total power plant to the customer, not just electricity. They will therefore move towards becoming service suppliers for the customer. The majority of power plants will also not require any fuel supply, with the result that mining and other fuel production companies will lose their strategic importance.

The future pattern under the Advanced Energy [R]evolution scenario will see more and more renewable energy companies, such as wind turbine manufacturers, also becoming involved in project development, installation and operation and maintenance, whilst utilities will lose their status. Those traditional energy supply companies which do not move towards renewable project development will either lose market share or drop out of the market completely.

table 4.1: power plant value chain

TASK & MARKET PLAYER	(LARGE SCALE) GENERATION	PROJECT DEVELOPMENT	INSTALLATION	PLANT OWNER	OPERATION & MAINTENANCE	FUEL SUPPLY	DISTRIBUTION	SALES
STATUS QUO	Very few new power plants + central planning			large scale generation in the hand of few IPP´s & utilities		global mining operations	grid operation still in the hands of utilities	
MARKET PLAYER								
Utility								
Mining company								
Component manufacturer								
Engineering companies & project developers								
ENERGY [R]EVOLUTION POWER MARKET	many smaller power plants + decentralized planning			large number of players e.g. IPP´s, utilities, private consumer, building operators		no fuel needed (except biomass)	grid operation under state control	
MARKET PLAYER								
Utility								
Mining company								
Component manufacturer								
Engineering companies & project developers								

image THE TRUCK DROPS ANOTHER LOAD OF WOOD CHIPS AT THE BIOMASS POWER PLANT IN LELYSTAD, THE NETHERLANDS.

rural electrification[13] Energy is central to reducing poverty, providing major benefits in the areas of health, literacy and equity. More than a quarter of the world's population has no access to modern energy services. In sub-Saharan Africa, 80% of people have no electricity supply. For cooking and heating, they depend almost exclusively on burning biomass – wood, charcoal and dung.

Poor people spend up to a third of their income on energy, mostly to cook food. Women in particular devote a considerable amount of time to collecting, processing and using traditional fuel for cooking. In India, two to seven hours each day can be devoted to the collection of cooking fuel. This is time that could be spent on child care, education or income generation. The World Health Organisation estimates that 2.5 million women and young children in developing countries die prematurely each year from breathing the fumes from indoor biomass stoves.

The Millennium Development Goal of halving global poverty by 2015 will not be reached without adequate energy to increase production, income and education, create jobs and reduce the daily grind involved in having to just survive. Halving hunger will not come about without energy for more productive growing, harvesting, processing and marketing of food. Improving health and reducing death rates will not happen without energy for the refrigeration needed for clinics, hospitals and vaccination campaigns. The world's greatest child killer, acute respiratory infection, will not be tackled without dealing with smoke from cooking fires in the home. Children will not study at night without light in their homes. Clean water will not be pumped or treated without energy.

The UN Commission on Sustainable Development argues that "to implement the goal accepted by the international community of halving the proportion of people living on less than US $1 per day by 2015, access to affordable energy services is a prerequisite".

the role of sustainable, clean renewable energy To achieve the dramatic emissions cuts needed to avoid climate change – in the order of 80% in OECD countries by 2050 – will require a massive uptake of renewable energy. The targets for renewable energy must be greatly expanded in industrialised countries both to substitute for fossil fuel and nuclear generation and to create the necessary economies of scale necessary for global expansion. Within the Energy [R]evolution scenario we assume that modern renewable energy sources, such as solar collectors, solar cookers and modern forms of bio energy will replace inefficient, traditional biomass use.

step 3: optimised integration – renewables 24/7

A complete transformation of the energy system will be necessary to accommodate the significantly higher shares of renewable energy expected under the Advanced Energy [R]evolution scenario. The grid network of cables and sub-stations that brings electricity to our homes and factories was designed for large, centralised generators running at huge loads, usually providing what is known as 'baseload' power. Renewable energy has had to fit in to this system as an additional slice of the energy mix and adapt to the conditions under which the grid currently operates. If the Advanced Energy [R]evolution scenario is to be realised, this will have to change.

Some critics of renewable energy say it is never going to be able to provide enough power for our current energy use, let alone for the projected growth in demand. This is because it relies mostly on natural resources, such as the wind and sun, which are not available 24/7. Existing practice in a number of countries has already shown that this is wrong, and further adaptations to how the grid network operates will enable the large quantities of renewable generating capacity envisaged in this report to be successfully integrated.

We already have sun, wind, geothermal sources and running rivers available right now, whilst ocean energy, biomass and efficient gas turbines are all set to make a massive contribution in the future. Clever technologies can track and manage energy use patterns, provide flexible power that follows demand through the day, use better storage options and group customers together to form 'virtual batteries'. With all these solutions we can secure the renewable energy future needed to avert catastrophic climate change. Renewable energy 24/7 is technically and economically possible, it just needs the right policy and the commercial investment to get things moving and 'keep the lights on'[14].

4.5 the new electricity grid

The electricity 'grid' is the collective name for all the cables, transformers and infrastructure that transport electricity from power plants to the end users. In all networks, some energy is lost as it is travels, but moving electricity around within a localised distribution network is more efficient and results in less energy loss.

The existing electricity transmission (main grid lines) and distribution system (local network) was mainly designed and planned 40 to 60 years ago. All over the developed world, the grids were built with large power plants in the middle and high voltage alternating current (AC) transmission power lines connecting up to the areas where the power is used. A lower voltage distribution network then carries the current to the final consumers. This is known as a centralised grid system, with a relatively small number of large power stations mostly fuelled by coal or gas.

In the future we need to change the grid network so that it does not rely on large conventional power plants but instead on clean energy from a range of renewable sources. These will typically be smaller scale power generators distributed throughout the grid. A localised distribution network is more efficient and avoids energy losses during long distance transmission. There will also be some concentrated supply from large renewable power plants. Examples of these large generators of the future are the massive wind farms already being built in Europe's North Sea and the plan for large areas of concentrating solar mirrors to generate energy in Southern Europe or Northern Africa.

references
13 'SUSTAINABLE ENERGY FOR POVERTY REDUCTION: AN ACTION PLAN', IT POWER/GREENPEACE INTERNATIONAL, 2002.
14 THE ARGUMENTS AND TECHNICAL SOLUTIONS OUTLINED HERE ARE EXPLAINED IN MORE DETAIL IN THE EUROPEAN RENEWABLE ENERGY COUNCIL/GREENPEACE REPORT, "[R]ENEWABLES 24/7: INFRASTRUCTURE NEEDED TO SAVE THE CLIMATE", NOVEMBER 2009.

The challenge ahead is to integrate new generation sources and at the same time phase out most of the large scale conventional power plants, while still keeping the lights on. This will need novel types of grids and an innovative power system architecture involving both new technologies and new ways of managing the network to ensure a balance between fluctuations in energy demand and supply.

The key elements of this new power system architecture are micro grids, smart grids and an efficient large scale super grid. The three types of system will support and interconnect with each other..

A major role in the construction and operation of this new system architecture will be played by the IT sector. Because a smart grid has power supplied from a diverse range of sources and locations it relies on the gathering and analysis of a large quantity of data. This requires software, hardware and networks that are capable of delivering data quickly, and responding to the information that they contain. Providing energy users with real time data about their energy consumption patterns and the appliances in their buildings, for example, helps them to improve their energy efficiency, and will allow appliances to be used at a time when a local renewable supply is plentiful, for example when the wind is blowing.

There are numerous IT companies offering products and services to manage and monitor energy. These include IBM, Fujitsu, Google, Microsoft and Cisco. These and other giants of the telecommunications and technology sector have the power to make the grid smarter, and to move us faster towards a clean energy future. Greenpeace has initiated the 'Cool IT' campaign to put pressure on the IT sector to make such technologies a reality.

4.6 hybrid systems

The developed world has extensive electricity grids supplying power to nearly 100% of the population. In parts of the developing world, however, many rural areas get by with unreliable grids or polluting electricity, for example from stand-alone diesel generators. This is also very expensive for small communities.

The electrification of rural areas that currently have no access to any power system cannot go ahead as it has in the past. A standard approach in developed countries has been to extend the grid by installing high or medium voltage lines, new substations and a low voltage distribution grid. But when there is low potential electricity demand, and long distances between the existing grid and rural areas, this method is often not economically feasible.

Electrification based on renewable energy systems with a hybrid mix of sources is often the cheapest as well as the least polluting alternative. Hybrid systems connect renewable energy sources such as wind and solar power to a battery via a charge controller, which stores the generated electricity and acts as the main power supply. Back-up supply typically comes from a fossil fuel, for example in a wind-battery-diesel or PV-battery-diesel system. Such decentralised hybrid systems are more reliable, consumers can be involved in their operation through innovative technologies and they can make best use of local resources. They are also less dependent on large scale infrastructure and can be constructed and connected faster, especially in rural areas.

elements in the new power system architecture

A **hybrid system** based on more than one generating source, for example solar and wind power, is a method of providing a secure supply in remote rural areas or islands, especially where there is no grid-connected electricity. This is particularly appropriate in developing countries. In the future, several hybrid systems could be connected together to form a micro grid in which the supply is managed using smart grid techniques.

A **smart grid** is an electricity grid that connects decentralised renewable energy sources and cogeneration and distributes power highly efficiently. Advanced communication and control technologies such as smart electricity meters are used to deliver electricity more cost effectively, with lower greenhouse intensity and in response to consumer needs. Typically, small generators such as wind turbines, solar panels or fuels cells are combined with energy management to balance out the load of all the users on the system. Smart grids are a way to integrate massive amounts of renewable energy into the system and enable the decommissioning of older centralised power stations.

A **super grid** is a large scale electricity grid network linking together a number of countries, or connecting areas with a large supply of renewable electricity to an area with a large demand - ideally based on more efficient HVDC (High Voltage Direct Current) cables. An example of the former would be the interconnection of all the large renewable based power plants in the North Sea. An example of the latter would be a connection between Southern Europe and Africa so that renewable energy could be exported from an area with a large renewable resource to urban centres where there is high demand.

image THE WIND TURBINES ARE GOING TO BE USED FOR THE CONSTRUCTION OF AN OFFSHORE WINDFARM AT MIDDELGRUNDEN WHICH IS CLOSE TO COPENHAGEN, DENMARK.

Finance can often be an issue for relatively poor rural communities wanting to install such hybrid renewable systems. Greenpeace has therefore developed a model in which projects are bundled together in order to make the financial package large enough to be eligible for international investment support. In the Pacific region, for example, power generation projects from a number of islands, an entire island state such as the Maldives or even several island states could be bundled into one project package. This would make it large enough for funding as an international project by OECD countries. Funding could come from a mixture of a feed-in tariff and a fund which covers the extra costs, as proposed in the "Renewables 24/7" report - known as a Feed-in Tariff Support Mechanism. In terms of project planning, it is essential that the communities themselves are directly involved in the process.

4.7 smart grids

The task of integrating renewable energy technologies into existing power systems is similar in all power systems around the world, whether they are large centralised networks or island systems. The main aim of power system operation is to balance electricity consumption and generation.

Thorough forward planning is needed to ensure that the available production can match demand at all times. In addition to balancing supply and demand, the power system must also be able to:

- Fulfil defined power quality standards – voltage/frequency – which may require additional technical equipment, and
- Survive extreme situations such as sudden interruptions of supply, for example from a fault at a generation unit or a breakdown in the transmission system.

Integrating renewable energy by using a smart grid means moving away from the issue of baseload power and towards the question as to whether the supply is flexible or inflexible. In a smart grid a portfolio of flexible energy providers can follow the load during both day and night (for example, solar plus gas, geothermal, wind and demand management) without blackouts.

A number of European countries have already shown that it is possible to integrate large quantities of variable renewable power generation into the grid network and achieve a high percentage of the total supply. In Denmark, for example, the average supplied by wind power is about 20%, with peaks of more than 100% of demand. On those occasions surplus electricity is exported to neighbouring countries. In Spain, a much larger country with a higher demand, the average supplied by wind power is 14%, with peaks of more than 50%.

Until now renewable power technology development has put most effort into adjusting its technical performance to the needs of the existing network, mainly by complying with grid codes, which cover such issues as voltage frequency and reactive power. However, the time has come for the power systems themselves to better adjust to the needs of variable generation. This means that they must become flexible enough to follow the fluctuations of variable renewable power, for example by adjusting demand via demand-side management and/or deploying storage systems.

The future power system will no longer consist of a few centralised power plants but instead of tens of thousands of generation units such as solar panels, wind turbines and other renewable generation, partly distributed in the distribution network, partly concentrated in large power plants such as offshore wind parks.

The trade off is that power system planning will become more complex due to the larger number of generation assets and the significant share of variable power generation causing constantly changing power flows. Smart grid technology will be needed to support power system planning. This will operate by actively supporting day-ahead forecasts and system balancing, providing real-time information about the status of the network and the generation units, in combination with weather forecasts. It will also play a significant role in making sure systems can meet the peak demand at all times and make better use of distribution and transmission assets, thereby keeping the need for network extensions to the absolute minimum.

To develop a power system based almost entirely on renewable energy sources will require a new overall power system architecture, including smart grid technology. This concept will need substantial amounts of further work to fully emerge[15]. Figure 4.3shows a simplified graphic representation of the key elements in future renewable-based power systems using smart grid technology.

A range of options are available to enable the large-scale integration of variable renewable energy resources into the power supply system. These include demand side management, the concept of a Virtual Power Plant and a number of choices for the storage of power.

The level and timing of **demand for electricity** can be managed by providing consumers with financial incentives to reduce or shut off their supply at periods of peak consumption. This system is already used for some large industrial customers. A Norwegian power supplier even involves private household customers by sending them a text message with a signal to shut down. Each household can decide in advance whether or not they want to participate. In Germany, experiments are being conducted with time flexible tariffs so that washing machines operate at night and refrigerators turn off temporarily during periods of high demand.

This type of demand side management has been simplified by advances in communications technology. In Italy, for example, 30 million innovative electricity counters have been installed to allow remote meter reading and control of consumer and service information. Many household electrical products or systems, such as refrigerators, dishwashers, washing machines, storage heaters, water pumps and air conditioning, can be managed either by temporary shut-off or by rescheduling their time of operation, thus freeing up electricity load for other uses and dovetailing it with variations in renewable supply.

A **Virtual Power Plant** (VPP) interconnects a range of real power plants (for example solar, wind and hydro) as well as storage options distributed in the power system using information technology. A real life example of a VPP is the Combined Renewable Energy Power Plant developed by three German companies[16]. This system interconnects and controls 11 wind power plants, 20 solar power plants, four CHP plants based on biomass and a pumped storage unit, all geographically spread around Germany. The VPP combines the advantages of the various renewable energy sources by carefully monitoring (and anticipating through weather forecasts) when the wind turbines and solar modules will be generating electricity. Biogas and pumped storage units are then used to make up the difference, either delivering electricity as needed in order to balance short term fluctuations or temporarily storing it[17]. Together the combination ensures sufficient electricity supply to cover demand.

A number of mature and emerging technologies are viable options for storing electricity. Of these, pumped storage can be considered the most established technology. Pumped storage is a type of hydroelectric power station that can store energy. Water is pumped from a lower elevation reservoir to a higher elevation during times of low cost, off-peak electricity. During periods of high electrical demand, the stored water is released through turbines. Taking into account evaporation losses from the exposed water surface and conversion losses, roughly 70 to 85% of the electrical energy used to pump the water into the elevated reservoir can be regained when it is released. Pumped storage plants can also respond to changes in the power system load demand within seconds.

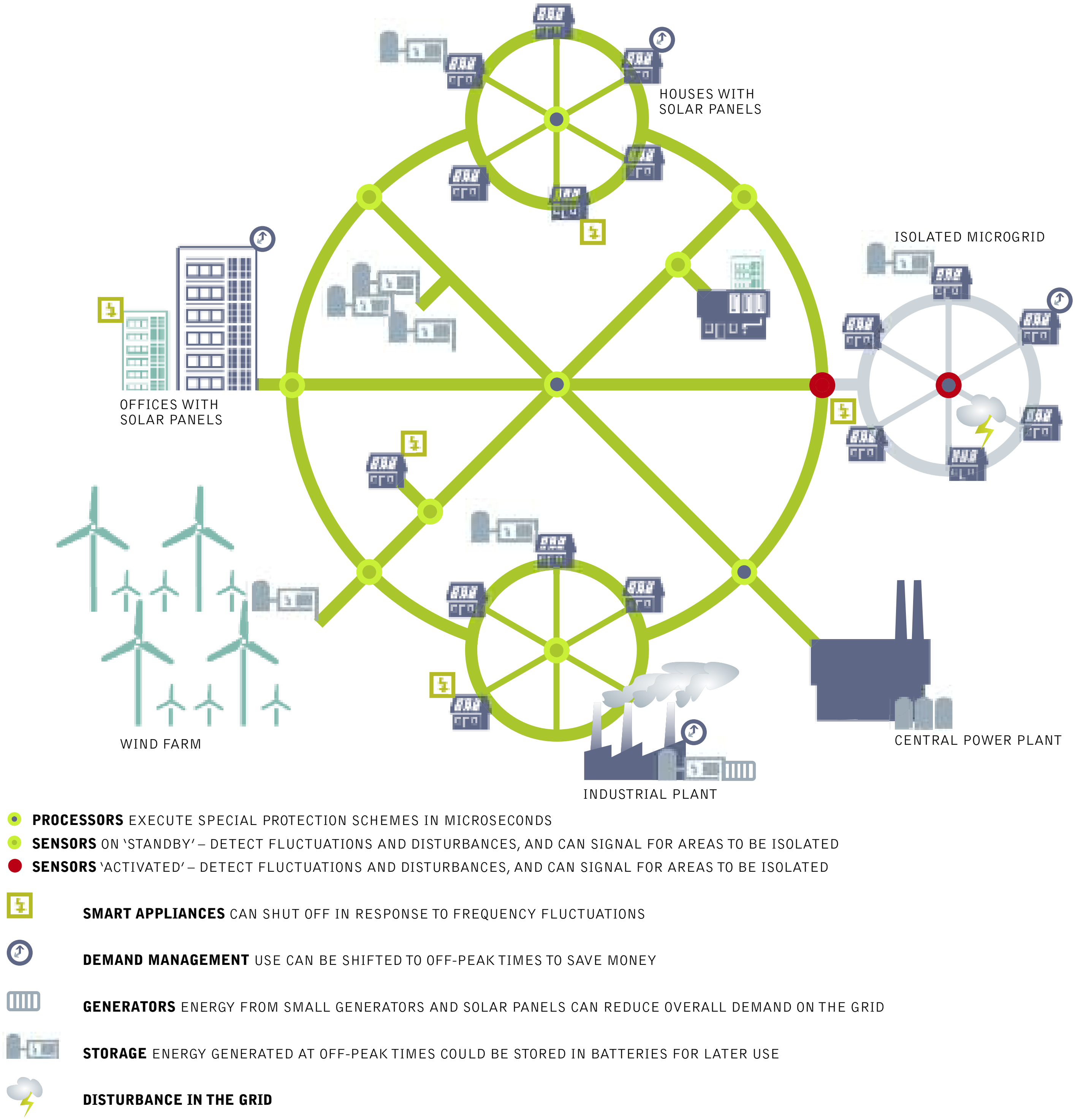
Another way of 'storing' electricity is to use it to directly meet the demand from electric vehicles. The number of electric cars and trucks is expected to increase dramatically under the Advanced Energy [R]evolution scenario. The Vehicle-to-Grid (V2G) concept, for example, is based on electric cars equipped with batteries that can be charged during times when there is surplus renewable generation and then discharged to supply peaking capacity or ancillary services to the power system while they are parked. During peak demand times cars are often parked close to main load centres, for instance outside factories, so there would be no network issues. Within the V2G concept a Virtual Power Plant would be built using ICT technology to aggregate the electric cars participating in the relevant electricity markets and to meter the charging/de-charging activities. In 2009 the EDISON demonstration project was launched to develop and test the infrastructure for integrating electric cars into the power system of the Danish island of Bornholm.

references
15 SEE ALSO ECOGRID PHASE 1 SUMMARY REPORT, AVAILABLE AT: HTTP://WWW.ENERGINET.DK/NR/RDONLYRES/8B1A4A06-CBA3-41DA-9402-B56C2C288FB0/0/ECOGRIDDK_PHASE1_SUMMARYREPORT.PDF
16 SEE ALSO HTTP://WWW.KOMBIKRAFTWERK.DE/INDEX.PHP?ID=27
17 SEE ALSO HTTP://WWW.SOLARSERVER.DE/SOLARMAGAZIN/ANLAGEJANUAR2008_E.HTML

image CHECKING THE SOLAR PANELS ON TOP OF THE GREENPEACE POSITIVE ENERGY TRUCK IN BRAZIL.

figure 4.3: the smart-grid vision for the energy [r]evolution

A VISION FOR THE FUTURE – A NETWORK OF INTEGRATED MICROGRIDS THAT CAN MONITOR AND HEAL ITSELF.



scenarios for a future energy supply

GLOBAL

PRICE PROJECTIONS FOR FOSSIL FUELS AND BIOMASS
COST OF CO_2 EMISSIONS

COST PROJECTIONS FOR EFFICIENT FOSSIL FUEL GENERATION

COST PROJECTIONS FOR RENEWABLE ENERGY TECHNOLOGIES

5

image WIND TURBINE IN SAMUT SAKHON, THAILAND. © GP/VINAI DITHAJOHN

"towards a sustainable global energy supply system."

GREENPEACE INTERNATIONAL
CLIMATE CAMPAIGN

image THE MARANCHON WIND TURBINE FARM IN GUADALAJARA, SPAIN IS THE LARGEST IN EUROPE WITH 104 GENERATORS, WHICH COLLECTIVELY PRODUCE 208 MEGAWATTS OF ELECTRICITY, ENOUGH POWER FOR 590,000 PEOPLE, ANUALLY.

5.1 price projections for fossil fuels and biomass

The recent dramatic fluctuations in global oil prices have resulted in slightly higher forward price projections for fossil fuels. Under the 2004 'high oil and gas price' scenario from the European Commission, for example, an oil price of just $34 per barrel was assumed in 2030. More recent projections of oil prices by 2030 in the IEA's WEO 2009 range from $2008 80/bbl in the lower prices sensitivity case up to $2008 150/bbl in the higher prices sensitivity case. The reference scenario in WEO 2009 predicts an oil price of $2008 115/bbl.

Since the first Energy [R]evolution study was published in 2007, however, the actual price of oil has moved over $100/bbl for the first time, and in July 2008 reached a record high of more than $140/bbl. Although oil prices fell back to $100/bbl in September 2008 and around $80/bbl in April 2010, the projections in the IEA reference scenario might still be considered too conservative. Taking into account the growing global demand for oil we have assumed a price development path for fossil fuels based on the IEA WEO 2009 higher prices sensitivity case extrapolated forward to 2050 (see Table 5.1).

As the supply of natural gas is limited by the availability of pipeline infrastructure, there is no world market price for gas. In most regions of the world the gas price is directly tied to the price of oil. Gas prices are therefore assumed to increase to $24-29/GJ by 2050.

For the Advanced Energy [R]evolution scenario, the local coal price projections are assumed, which are significantly lower than world market price projections.

5.2 cost of CO_2 emissions

Assuming that a CO_2 emissions trading system is established across all world regions in the longer term, the cost of CO_2 allowances needs to be included in the calculation of electricity generation costs. Projections of emissions costs are even more uncertain than energy prices, however, and available studies span a broad range of future estimates. As in the previous Energy [R]evolution study we assume CO_2 costs of $10/t$CO_2$ in 2010, rising to $50/t$CO_2$ by 2050. Additional CO_2 costs are applied in Kyoto Protocol Non-Annex B (developing) countries only after 2020.

table 5.1: development projections for fossil fuel prices in US$ 2008

	UNIT	2000	2005	2007	2008	2010	2015	2020	2025	2030	2040	2050
Crude oil imports												
IEA WEO 2009 "Reference"	barrel	34.30	50.00	75.00	97.19		86.67	100	107.5	115		
USA EIA 2008 "Reference"	barrel					86.64		69.96		82.53		
USA EIA 2008 "High Price"	barrel					92.56		119.75		138.96		
Energy [R]evolution 2010	barrel						110.56	130.00	140.00	150.00	150.00	150.00
Natural gas imports												
IEA WEO 2009 "Reference"												
United States	GJ	5.00	2.32	3.24	8.25		7.29	8.87	10.04	11.36		
Europe	GJ	3.70	4.49	6.29	10.32		10.46	12.10	13.09	14.02		
Japan LNG	GJ	6.10	4.52	6.33	12.64		11.91	13.75	14.83	15.87		
Energy [R]evolution 2010												
United States	GJ			3.24		8.70		10.70	12.40	14.38	18.10	23.73
Europe	GJ			6.29		10.89		16.56	17.99	19.29	22.00	26.03
Japan LNG	GJ			6.33		13.34		18.84	20.37	21.84	24.80	29.30
Hard coal imports												
Energy [R]evolution 2010	tonne	41.22	49.61	69.45		120.59	116.15	135.41	139.50	142.70	160.00	172.30
Biomass (solid)												
Energy [R]evolution 2010												
OECD Europe	GJ			7.4		7.7	8.2	9.2		10.0	10.3	10.5
OECD Pacific and North America	GJ			3.3		3.4	3.5	3.8		4.3	4.7	5.2
Other regions	GJ			2.7		2.8	3.2	3.5		4.0	4.6	4.9

source 2000-2030, IEA WEO 2009 HIGHER PRICES SENSITIVITY CASE FOR CRUDE OIL, GAS AND STEAM COAL; 2040-2050 AND OTHER FUELS, OWN ASSUMPTIONS.

table 5.2: assumptions on CO_2 emissions cost development

($/t$CO_2$)

COUNTRIES	2015	2020	2030	2040	2050
Kyoto Annex B countries	10	20	30	40	**50**
Non-Annex B countries		20	30	40	**50**

5.3 cost projections for efficient fossil fuel generation and carbon capture and storage (CCS)

While the fossil fuel power technologies in use today for coal, gas, lignite and oil are established and at an advanced stage of market development, further cost reduction potentials are assumed. The potential for cost reductions is limited, however, and will be achieved mainly through an increase in efficiency[18].

There is much speculation about the potential for CCS to mitigate the effect of fossil fuel consumption on climate change, even though the technology is still under development.

CCS is a means of trapping CO_2 from fossil fuels, either before or after they are burned, and 'storing' (effectively disposing of) it in the sea or beneath the surface of the earth. There are currently three different methods of capturing CO_2: 'pre-combustion', 'post-combustion' and 'oxyfuel combustion'. However, development is at a very early stage and CCS will not be implemented - in the best case - before 2020 and will probably not become commercially viable as a possible effective mitigation option until 2030.

Cost estimates for CCS vary considerably, depending on factors such as power station configuration, technology, fuel costs, size of project and location. One thing is certain, however: CCS is expensive. It requires significant funds to construct the power stations and the necessary infrastructure to transport and store carbon. The IPCC assesses costs at $15-75 per ton of captured CO_2[19], while a recent US Department of Energy report found installing carbon capture systems to most modern plants resulted in a near doubling of costs[20]. These costs are estimated to increase the price of electricity in a range from 21-91%[21].

Pipeline networks will also need to be constructed to move CO_2 to storage sites. This is likely to require a considerable outlay of capital[22]. Costs will vary depending on a number of factors, including pipeline length, diameter and manufacture from corrosion-resistant steel, as well as the volume of CO_2 to be transported. Pipelines built near population centres or on difficult terrain, such as marshy or rocky ground, are more expensive[23].

The Intergovernmental Panel on Climate Change estimates a cost range for pipelines of $1-8/ton of CO_2 transported. A United States Congressional Research Services report calculated capital costs for an 11 mile pipeline in the Midwestern region of the US at approximately $6 million. The same report estimates that a dedicated interstate pipeline network in North Carolina would cost upwards of $5 billion due to the limited geological sequestration potential in that part of the country[24]. Storage and subsequent monitoring and verification costs are estimated by the IPCC to range from $0.5-8/t$CO_2$ (for storage) and $0.1-0.3/t$CO_2$ (for monitoring). The overall cost of CCS could therefore serve as a major barrier to its deployment[25].

For the above reasons, CCS power plants are not included in our financial analysis.

Table 5.3 summarises our assumptions on the technical and economic parameters of future fossil-fuelled power plant technologies. In spite of growing raw material prices, we assume that further technical innovation will result in a moderate reduction of future investment costs as well as improved power plant efficiencies. These improvements are, however, outweighed by the expected increase in fossil fuel prices, resulting in a significant rise in electricity generation costs.

table 5.3: development of efficiency and investment costs for selected power plant technologies

		2007	2015	2020	2030	2040	2050
Coal-fired condensing power plant	Efficiency (%)	45	46	48	50	52	**53**
	Investment costs ($/kW)	1,320	1,230	1,190	1,160	1,130	**1,100**
	Electricity generation costs including CO_2 emission costs ($cents/kWh)	6.6	9.0	10.8	12.5	14.2	**15.7**
	CO_2 emissions [a)](g/kWh)	744	728	697	670	644	**632**
Lignite-fired condensing power plant	Efficiency (%)	41	43	44	44.5	45	**45**
	Investment costs ($/kW)	1,570	1,440	1,380	1,350	1,320	**1,290**
	Electricity generation costs including CO_2 emission costs ($cents/kWh)	5.9	6.5	7.5	8.4	9.3	**10.3**
	CO_2 emissions [a)](g/kWh)	975	929	908	898	888	**888**
Natural gas combined cycle	Efficiency (%)	57	59	61	62	63	**64**
	Investment costs ($/kW)	690	675	645	610	580	**550**
	Electricity generation costs including CO_2 emission costs ($cents/kWh)	7.5	10.5	12.7	15.3	17.4	**18.9**
	CO_2 emissions [a)](g/kWh)	354	342	330	325	320	**315**

source DLR, 2010 [a)] CO_2 EMISSIONS REFER TO POWER STATION OUTPUTS ONLY; LIFE-CYCLE EMISSIONS ARE NOT CONSIDERED.

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18 'GREENPEACE INTERNATIONAL BRIEFING: CARBON CAPTURE AND STORAGE', GOERNE, 2007.
19 ABANADES, J C ET AL., 2005, PG 10.
20 NATIONAL ENERGY TECHNOLOGY LABORATORIES, 2007.
21 RUBIN ET AL., 2005A, PG 40.
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23 HEDDLE, G ET AL., 2003, PG 17.
24 PARFOMAK, P & FOLGER, P, 2008, PG 5 AND 12.
25 RUBIN ET AL., 2005B, PG 4444.

image FIRE BOAT RESPONSE CREWS BATTLE THE BLAZING REMNANTS OF THE OFFSHORE OIL RIG DEEPWATER HORIZON APRIL 21, 2010. MULTIPLE COAST GUARD HELICOPTERS, PLANES AND CUTTERS RESPONDED TO RESCUE THE DEEPWATER HORIZON'S 126 PERSON CREW.

5.4 cost projections for renewable energy technologies

The range of renewable energy technologies available today display marked differences in terms of their technical maturity, costs and development potential. Whereas hydro power has been widely used for decades, other technologies, such as the gasification of biomass, have yet to find their way to market maturity. Some renewable sources by their very nature, including wind and solar power, provide a variable supply, requiring a revised coordination with the grid network. But although in many cases these are 'distributed' technologies - their output being generated and used locally to the consumer - the future will also see large-scale applications in the form of offshore wind parks, photovoltaic power plants or concentrating solar power stations.

By using the individual advantages of the different technologies, and linking them with each other, a wide spectrum of available options can be developed to market maturity and integrated step by step into the existing supply structures. This will eventually provide a complementary portfolio of environmentally friendly technologies for heat and power supply and the provision of transport fuels.

Many of the renewable technologies employed today are at a relatively early stage of market development. As a result, the costs of electricity, heat and fuel production are generally higher than those of competing conventional systems - a reminder that the external (environmental and social) costs of conventional power production are not included in market prices. It is expected, however, that compared with conventional technologies, large cost reductions can be achieved through technical advances, manufacturing improvements and large-scale production. Especially when developing long-term scenarios spanning periods of several decades, the dynamic trend of cost developments over time plays a crucial role in identifying economically sensible expansion strategies.

To identify long-term cost developments, learning curves have been applied which reflect the correlation between cumulative production volumes of a particular technology and a reduction in its costs. For many technologies, the learning factor (or progress ratio) falls in the range between 0.75 for less mature systems to 0.95 and higher for well-established technologies. A learning factor of 0.9 means that costs are expected to fall by 10% every time the cumulative output from the technology doubles. Empirical data shows, for example, that the learning factor for PV solar modules has been fairly constant at 0.8 over 30 years whilst that for wind energy varies from 0.75 in the UK to 0.94 in the more advanced German market.

Assumptions on future costs for renewable electricity technologies in the Advanced Energy [R]evolution scenario are derived from a review of learning curve studies, for example by Lena Neij and others[26], from the analysis of recent technology foresight and road mapping studies, including the European Commission funded NEEDS project (New Energy Externalities Developments for Sustainability)[27] or the IEA Energy Technology Perspectives 2008, projections by the European Renewable Energy Council published in April 2010 ("Re-Thinking 2050") and discussions with experts from a wide range of different sectors of the renewable energy industry.

5.4.1 photovoltaics (pv)

The worldwide PV market has been growing at over 40% per annum in recent years and the contribution it can make to electricity generation is starting to become significant. The importance of photovoltaics comes from its decentralised/centralised character, its flexibility for use in an urban environment and huge potential for cost reduction. Development work is focused on improving existing modules and system components by increasing their energy efficiency and reducing material usage. Technologies like PV thin film (using alternative semiconductor materials) or dye sensitive solar cells are developing quickly and present a huge potential for cost reduction. The mature technology crystalline silicon, with a proven lifetime of 30 years, is continually increasing its cell and module efficiency (by 0.5% annually), whereas the cell thickness is rapidly decreasing (from 230 to 180 microns over the last five years). Commercial module efficiency varies from 14 to 21%, depending on silicon quality and fabrication process.

The learning factor for PV modules has been fairly constant over the last 30 years, with a cost reduction of 20% each time the installed capacity doubles, indicating a high rate of technical learning. Assuming a globally installed capacity of 1,000 GW between 2030 and 2040 in the Basic Energy [R]evolution scenario, and with an electricity output of 1,400 TWh/a , we can expect that generation costs of around 5-10 $cents/kWh (depending on the region) will be achieved. During the following five to ten years, PV will become competitive with retail electricity prices in many parts of the world, and competitive with fossil fuel costs by 2030. The Advanced Energy [R]evolution version shows faster growth, with PV capacity reaching 1,000 GW by 2025 – five years ahead of the Basic Energy [R]evolution scenario.

table 5.4: photovoltaics (pv) cost assumptions

	2007	2015	2020	2030	2040	**2050**
Energy [R]evolution						
Global installed capacity (GW)	6	98	335	1,036	1,915	**2,968**
Investment costs ($/kWp)	3,746	2,610	1,776	1,027	785	**761**
Operation & maintenance costs ($/kW/a)	66	38	16	13	11	**10**
Advanced Energy [R]evolution						
Global installed capacity (GW)	6	108	439	1,330	2,959	**4,318**
Investment costs ($/kWp)	3,746	2,610	1,776	1,027	761	**738**
Operation & maintenance costs ($/kW/a)	66	38	16	13	11	**10**

26 NEIJ, L, 'COST DEVELOPMENT OF FUTURE TECHNOLOGIES FOR POWER GENERATION - A STUDY BASED ON EXPERIENCE CURVES AND COMPLEMENTARY BOTTOM-UP ASSESSMENTS', ENERGY POLICY 36 (2008), 2200-2211.
27 WWW.NEEDS-PROJECT.ORG

5.4.2 concentrating solar power (CSP)

Solar thermal 'concentrating' power stations (CSP) can only use direct sunlight and are therefore dependent on high irradiation locations. North Africa, for example, has a technical potential which far exceeds local demand. The various solar thermal technologies (parabolic trough, power towers and parabolic dish concentrators) offer good prospects for further development and cost reductions. Because of their more simple design, 'Fresnel' collectors are considered as an option for additional cost trimming. The efficiency of central receiver systems can be increased by producing compressed air at a temperature of up to 1,0000C, which is then used to run a combined gas and steam turbine.

Thermal storage systems are a key component for reducing CSP electricity generation costs. The Spanish Andasol 1 plant, for example, is equipped with molten salt storage with a capacity of 7.5 hours. A higher level of full load operation can be realised by using a thermal storage system and a large collector field. Although this leads to higher investment costs, it reduces the cost of electricity generation.

Depending on the level of irradiation and mode of operation, it is expected that long term future electricity generation costs of 6-10 $cents/kWh can be achieved. This presupposes rapid market introduction in the next few years.

5.4.3 wind power

Within a short period of time, the dynamic development of wind power has resulted in the establishment of a flourishing global market. While favourable policy incentives have made Europe the main driver for the global wind market, in 2009 more than three quarters of the annual capacity installed was outside Europe. This trend is likely to continue. The boom in demand for wind power technology has nonetheless led to supply constraints. As a consequence, the cost of new systems has increased. Because of the continuous expansion of production capacities, the industry is already resolving the bottlenecks in the supply chain. However, taking into account market development projections, learning curve analysis and industry expectations, we assume that investment costs for wind turbines will reduce by 30% for onshore and 50% for offshore installations up to 2050.

table 5.5: concentrating solar power (csp) cost assumptions

	2007	2015	2020	2030	2040	2050
Energy [R]evolution						
Global installed capacity (GW)	1	25	105	324	647	**1,002**
Investment costs ($/kW)*	7,250	5,576	5,044	4,263	4,200	**4,160**
Operation & maintenance costs ($/kW/a)	300	250	210	180	160	**155**
Advanced Energy [R]evolution						
Global installed capacity (GW)	1	28	225	605	1,173	**1,643**
Investment costs ($/kW)*	7,250	5,576	5,044	4,200	4,160	**4,121**
Operation & maintenance costs ($/kW/a)	300	250	210	180	160	**155**

* INCLUDING HIGH TEMPERATURE HEAT STORAGE.

table 5.6: wind power cost assumptions

	2007	2015	2020	2030	2040	2050
Energy [R]evolution						
Installed capacity (on+offshore)	95	407	878	1,733	2,409	**2,943**
Wind onshore						
Investment costs ($/kWp)	1,510	1,255	998	952	906	**894**
O&M costs ($/kW/a)	58	51	45	43	41	**41**
Wind offshore						
Investment costs ($/kWp)	2,900	2,200	1,540	1,460	1,330	**1,305**
O&M costs ($/kW/a)	166	153	114	97	88	**83**
Advanced Energy [R]evolution						
Installed capacity (on+offshore)	95	494	1,140	2,241	3,054	**3,754**
Wind onshore						
Investment costs ($/kWp)	1,510	1,255	998	906	894	**882**
O&M costs ($/kW/a)	58	51	45	43	41	**41**
Wind offshore						
Investment costs ($/kWp)	2,900	2,200	1,540	1,460	1,330	**1,305**
O&M costs ($/kW/a)	166	153	114	97	88	**83**

image AERIAL VIEW OF THE WORLD'S LARGEST OFFSHORE WINDPARK IN THE NORTH SEA HORNS REV IN ESBJERG, DENMARK.

5.4.4 biomass

The crucial factor for the economics of biomass utilisation is the cost of the feedstock, which today ranges from a negative cost for waste wood (based on credit for waste disposal costs avoided) through inexpensive residual materials to the more expensive energy crops. The resulting spectrum of energy generation costs is correspondingly broad. One of the most economic options is the use of waste wood in steam turbine combined heat and power (CHP) plants. Gasification of solid biomass, on the other hand, which opens up a wide range of applications, is still relatively expensive. In the long term it is expected that favourable electricity production costs will be achieved by using wood gas both in micro CHP units (engines and fuel cells) and in gas-and-steam power plants. Great potential for the utilisation of solid biomass also exists for heat generation in both small and large heating centres linked to local heating networks. Converting crops into ethanol and 'bio diesel' made from rapeseed methyl ester (RME) has become increasingly important in recent years, for example in Brazil, the USA and Europe. Processes for obtaining synthetic fuels from biogenic synthesis gases will also play a larger role.

A large potential for exploiting modern technologies exists in Latin and North America, Europe and the Transition Economies, either in stationary appliances or the transport sector. In the long term Europe and the Transition Economies will realise 20-50% of the potential for biomass from energy crops, whilst biomass use in all the other regions will have to rely on forest residues, industrial wood waste and straw. In Latin America, North America and Africa in particular, an increasing residue potential will be available.

In other regions, such as the Middle East and all Asian regions, increased use of biomass is restricted, either due to a generally low availability or already high traditional use. For the latter, using modern, more efficient technologies will improve the sustainability of current usage and have positive side effects, such as reducing indoor pollution and the heavy workloads currently associated with traditional biomass use.

5.4.5 geothermal

Geothermal energy has long been used worldwide for supplying heat, and since the beginning of the last century for electricity generation. Geothermally generated electricity was previously limited to sites with specific geological conditions, but further intensive research and development work has enabled the potential areas to be widened. In particular the creation of large underground heat exchange surfaces - Enhanced Geothermal Systems (EGS) - and the improvement of low temperature power conversion, for example with the Organic Rankine Cycle, open up the possibility of producing geothermal electricity anywhere. Advanced heat and power cogeneration plants will also improve the economics of geothermal electricity.

As a large part of the costs for a geothermal power plant come from deep underground drilling, further development of innovative drilling technology is expected. Assuming a global average market growth for geothermal power capacity of 9% per year up to 2020, adjusting to 4% beyond 2030, the result would be a cost reduction potential of 50% by 2050:

table 5.7: biomass cost assumptions

	2007	2015	2020	2030	2040	2050
Energy [R]evolution						
Biomass (electricity only)						
Global installed capacity (GW)	28	48	62	75	87	**107**
Investment costs ($/kW)	2,818	2,452	2,435	2,377	2,349	**2,326**
O&M costs ($/kW/a)	183	166	152	148	147	**146**
Biomass (CHP)						
Global installed capacity (GW)	18	67	150	261	413	**545**
Investment costs ($/kW)	5,250	4,255	3,722	3,250	2,996	**2,846**
O&M costs ($/kW/a)	404	348	271	236	218	**207**
Advanced Energy [R]evolution						
Biomass (electricity only)						
Global installed capacity (GW)	28	50	64	78	83	**81**
Investment costs ($/kW)	2,818	2,452	2,435	2,377	2,349	**2,326**
O&M costs ($/kW/a)	183	166	152	148	147	**146**
Biomass (CHP)						
Global installed capacity (GW)	18	65	150	265	418	**540**
Investment costs ($/kW)	5,250	4,255	3,722	3,250	2,996	**2,846**
O&M costs ($/kW/a)	404	348	271	236	218	**207**

table 5.8: geothermal cost assumptions

	2007	2015	2020	2030	2040	2050
Energy [R]evolution						
Geothermal (electricity only)						
Global installed capacity (GW)	10	19	36	71	114	**144**
Investment costs ($/kW)	12,446	10,875	9,184	7,250	6,042	**5,196**
O&M costs ($/kW/a)	645	557	428	375	351	**332**
Geothermal (CHP)						
Global installed capacity (GW)	1	3	13	37	83	**134**
Investment costs ($/kW)	12,688	11,117	9,425	7,492	6,283	**5,438**
O&M costs ($/kW/a)	647	483	351	294	256	**233**
Advanced Energy [R]evolution						
Geothermal (electricity only)						
Global installed capacity (GW)	10	21	57	191	337	**459**
Investment costs ($/kW)	12,446	10,875	9,184	5,196	4,469	**3,843**
O&M costs ($/kW/a)	645	557	428	375	351	**332**
Geothermal (CHP)						
Global installed capacity (GW)	0	3	13	47	132	**234**
Investment costs ($/kW)	12,688	11,117	9,425	7,492	6,283	**5,438**
O&M costs ($/kW/a)	647	483	351	294	256	**233**

- for conventional geothermal power, from 7 $cents/kWh to about 2 $cents/kWh;
- for EGS, despite the presently high figures (about 20 $cents/kWh), electricity production costs - depending on the payments for heat supply - are expected to come down to around 5 $cents/kWh in the long term.

Because of its non-fluctuating supply and a grid load operating almost 100% of the time, geothermal energy is considered to be a key element in a future supply structure based on renewable sources. Up to now we have only used a marginal part of the potential. Shallow geothermal drilling, for example, makes possible the delivery of heating and cooling at any time anywhere, and can be used for thermal energy storage.

5.4.6 ocean energy

Ocean energy, particularly offshore wave energy, is a significant resource, and has the potential to satisfy an important percentage of electricity supply worldwide. Globally, the potential of ocean energy has been estimated at around 90,000 TWh/year. The most significant advantages are the vast availability and high predictability of the resource and a technology with very low visual impact and no CO_2 emissions. Many different concepts and devices have been developed, including taking energy from the tides, waves, currents and both thermal and saline gradient resources. Many of these are in an advanced phase of R&D, large scale prototypes have been deployed in real sea conditions and some have reached pre-market deployment. There are a few grid connected, fully operational commercial wave and tidal generating plants.

The cost of energy from initial tidal and wave energy farms has been estimated to be in the range of 15-55 $cents/kWh, and for initial tidal stream farms in the range of 11-22 $cents/kWh. Generation costs of 10-25 $cents/kWh are expected by 2020. Key areas for development will include concept design, optimisation of the device configuration, reduction of capital costs by exploring the use of alternative structural materials, economies of scale and learning from operation. According to the latest research findings, the learning factor is estimated to be 10-15% for offshore wave and 5-10% for tidal stream. In the medium term, ocean energy has the potential to become one of the most competitive and cost effective forms of generation. In the next few years a dynamic market penetration is expected, following a similar curve to wind energy.

Because of the early development stage any future cost estimates for ocean energy systems are uncertain. Present cost estimates are based on analysis from the European NEEDS project[28].

5.4.7 hydro power

Hydro power is a mature technology with a significant part of its global resource already exploited. There is still, however, some potential left both for new schemes (especially small scale run-off river projects with little or no reservoir impoundment) and for repowering of existing sites. The significance of hydro power is also likely to be encouraged by the increasing need for flood control and the maintenance of water supply during dry periods. The future is in sustainable hydro power which makes an effort to integrate plants with river ecosystems while reconciling ecology with economically attractive power generation.

table 5.9: ocean energy cost assumptions

Energy [R]evolution	2007	2015	2020	2030	2040	**2050**
Global installed capacity (GW)	0	9	29	73	168	**303**
Investment costs ($/kW)	7,216	3,892	2,806	2,158	1,802	**1,605**
Operation & maintenance costs ($/kW/a)	360	207	117	89	75	**66**
Advanced Energy [R]evolution						
Global installed capacity (GW)	0	9	58	180	425	**748**
Investment costs ($/kW)	7,216	3,892	2,806	1,802	1,605	**1,429**
Operation & maintenance costs ($/kW/a)	360	207	117	89	75	**66**

table 5.10: hydro power cost assumptions

Energy [R]evolution	2007	2015	2020	2030	2040	**2050**
Global installed capacity (GW)	922	1,043	1,206	1,307	1,387	**1,438**
Investment costs ($/kW)	2,705	2,864	2,952	3,085	3,196	**3,294**
Operation & maintenance costs ($/kW/a)	110	115	123	128	133	**137**
Advanced Energy [R]evolution						
Global installed capacity (GW)	922	1,111	1,212	1,316	1,406	**1,451**
Investment costs ($/kW)	2,705	2,864	2,952	3,085	3,196	**3,294**
Operation & maintenance costs ($/kW/a)	110	115	123	128	133	**137**

28 WWW.NEEDS-PROJECT.ORG

image A COW IN FRONT OF A BIOREACTOR IN THE BIOENERGY VILLAGE OF JUEHNDE. IT IS THE FIRST COMMUNITY IN GERMANY THAT PRODUCES ALL OF ITS ENERGY NEEDED FOR HEATING AND ELECTRICITY, WITH CO_2 NEUTRAL BIOMASS.

5.4.8 summary of renewable energy cost development

Figure 5.1 summarises the cost trends for renewable energy technologies as derived from the respective learning curves. It should be emphasised that the expected cost reduction is basically not a function of time, but of cumulative capacity, so dynamic market development is required. Most of the technologies will be able to reduce their specific investment costs to between 30% and 70% of current levels by 2020, and to between 20% and 60% once they have achieved full maturity (after 2040).

Reduced investment costs for renewable energy technologies lead directly to reduced heat and electricity generation costs, as shown in Figure 5.2. Generation costs today are around 8 to 26 $cents/kWh for the most important technologies, with the exception of photovoltaics. In the long term, costs are expected to converge at around 5-12 $cents/kWh. These estimates depend on site-specific conditions such as the local wind regime or solar irradiation, the availability of biomass at reasonable prices or the credit granted for heat supply in the case of combined heat and power generation.

figure 5.1: future development of renewable energy investment costs (NORMALISED TO CURRENT COST LEVELS) FOR RENEWABLE ENERGY TECHNOLOGIES

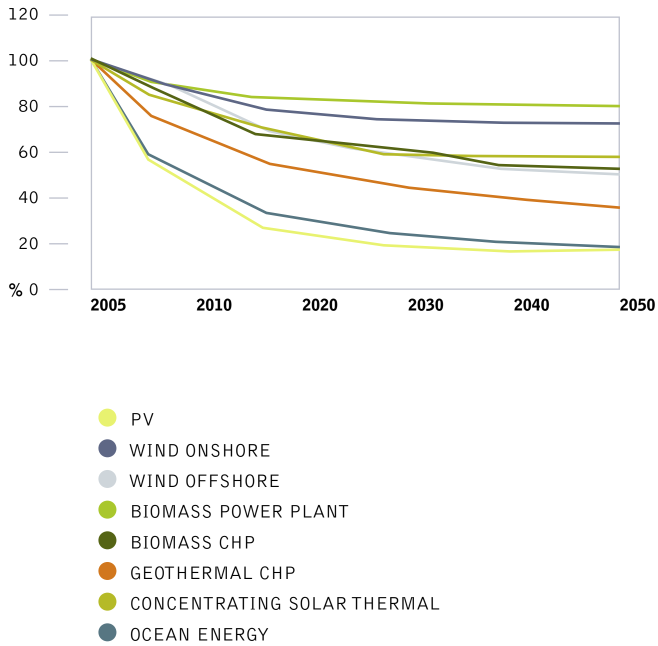
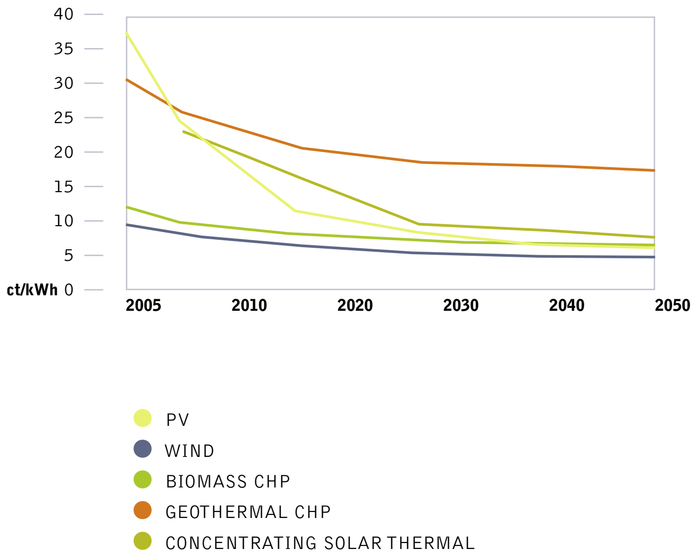


figure 5.2: expected development of electricity generation costs



map 5.1: CO_2 emissions reference scenario and the advanced energy [r]evolution scenario

WORLDWIDE SCENARIO

OECD NORTH AMERICA

		REF mio t	REF %	E[R] mio t	E[R] %
CO_2	2007	6,686H	165	6,686	165
	2050	6,822	169	215M	5
		t		**t**	
per person	2007	14.89H		14.89	
	2050	11.82H		0.37	

LATIN AMERICA

		REF mio t	REF %	E[R] mio t	E[R] %
CO_2	2007	1,010	167M	1,010	167
	2050	2,006	332M	119L	20
		t		**t**	
per person	2007	2.18		2.18	
	2050	3.34		0.20L	

EMISSIONS

CO_2

LEGEND

100-75 | 75-50 | 50-25 | 25-0 — % OF 1990 EMISSIONS IN THE 2050 ADVANCED ENERGY [R]EVOLUTION SCENARIO

REF — REFERENCE SCENARIO

E[R] — ADVANCED ENERGY [R]EVOLUTION SCENARIO

0 — 1000 KM

CO_2 — **EMISSIONS TOTAL** MILLION TONNES [mio t] | % OF 1990 EMISSIONS

EMISSIONS PER PERSON TONNES [t]

H HIGHEST | M MIDDLE | L LOWEST

OECD EUROPE

		REF		E[R]	
		mio t	%	mio t	%
CO_2	2007	4,017M	100	4,017	100
	2050	3,798	94	215	5
		t		t	
	2007	7.44		7.44	
	2050	6.61M		0.36	

MIDDLE EAST

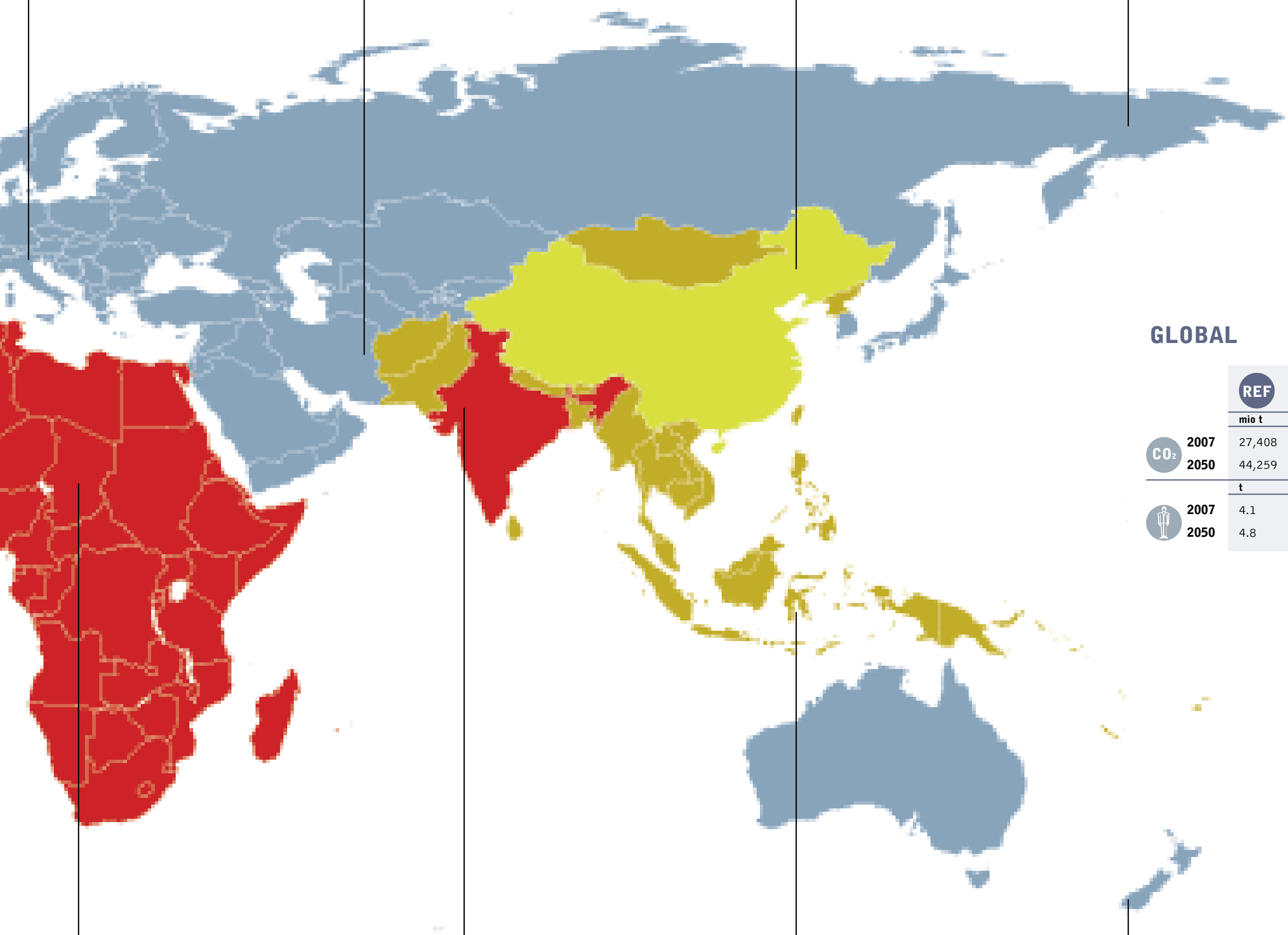
		REF		E[R]	
		mio t	%	mio t	%
CO_2	2007	1,374	234	1,374	234
	2050	3,208	546	122	21
		t		t	
	2007	6.79M		6.79	
	2050	9.08		0.35	

CHINA

		REF		E[R]	
		mio t	%	mio t	%
CO_2	2007	5,852	261	5,852	261
	2050	12,460H	555	925H	41
		t		t	
	2007	4.38		4.38	
	2050	8.74		0.65	

TRANSITION ECONOMIES

		REF		E[R]	
		mio t	%	mio t	%
CO_2	2007	2,650	66	2,650	66
	2050	3,564	88	258	6
		t		t	
	2007	7.79		7.79	
	2050	11.47		0.83H	



GLOBAL

		REF		E[R]	
		mio t	%	mio t	%
CO_2	2007	27,408	131	27,408	131
	2050	44,259	211	3,267	16
		t		t	
	2007	4.1		4.1	
	2050	4.8		0.4	

AFRICA

		REF		E[R]	
		mio t	%	mio t	%
CO_2	2007	881L	161	881	161
	2050	1,622L	297	423	77
		t		t	
	2007	0.91L		0.91	
	2050	0.81L		0.21	

INDIA

		REF		E[R]	
		mio t	%	mio t	%
CO_2	2007	1,307	222	1,307	222
	2050	5,110	868	449	85
		t		t	
	2007	1.12		1.12	
	2050	3.17		0.31	

DEVELOPING ASIA

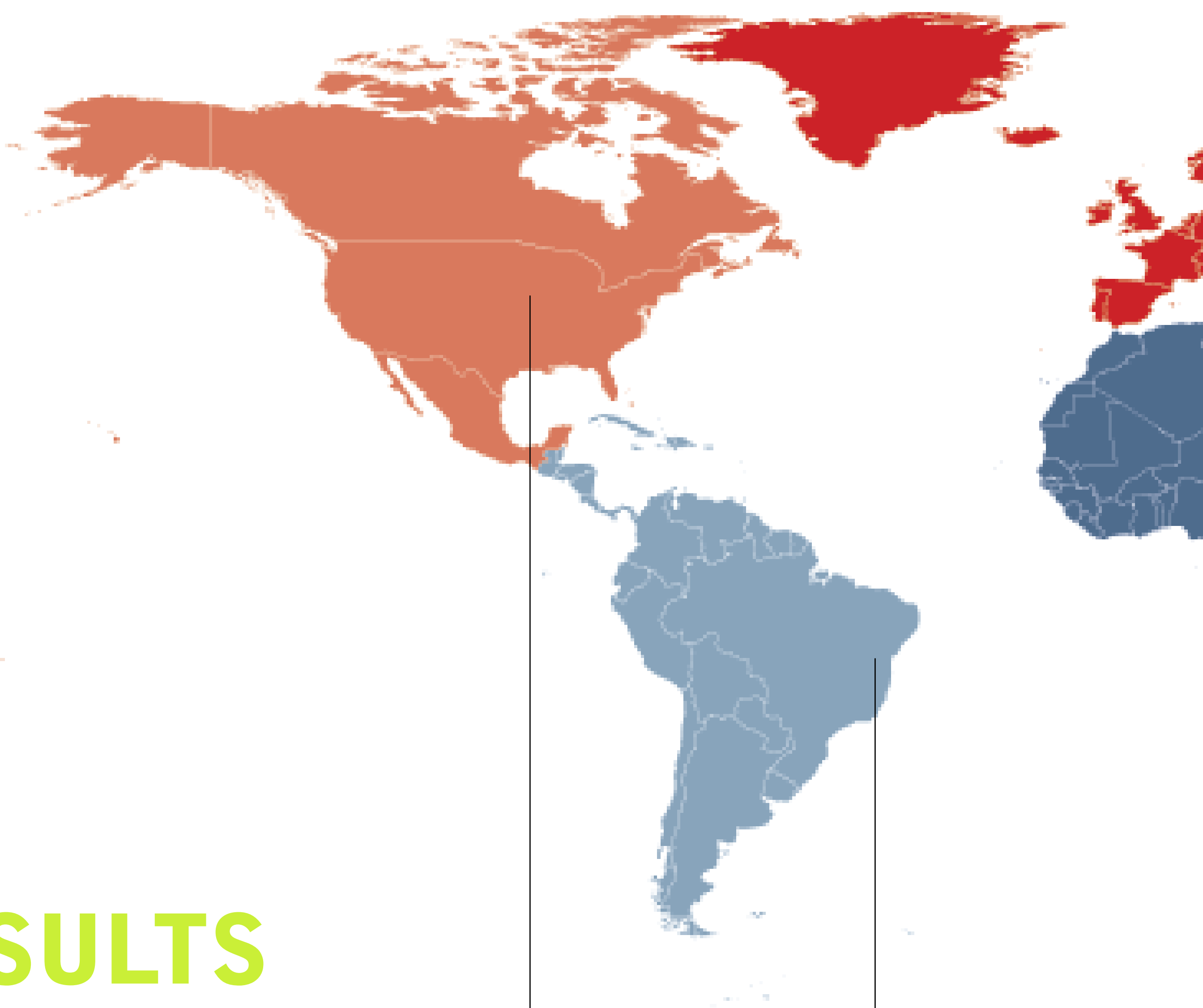
		REF		E[R]	
		mio t	%	mio t	%
CO_2	2007	1,488	216	1,488	216
	2050	3,846M	557	428	62
		t		t	
	2007	1.47		1.47	
	2050	2.54		0.28	

OECD PACIFIC

		REF		E[R]	
		mio t	%	mio t	%
CO_2	2007	2,144	136	2,144	136
	2050	1,822	116	74	5
		t		t	
	2007	10.70		10.70	
	2050	10.14		0.41M	

map 5.2: results reference scenario and the advanced energy [r]evolution scenario

WORLDWIDE SCENARIO



SCENARIO RESULTS

OECD NORTH AMERICA

		REF PE PJ	REF EL TWh	E[R] PE PJ	E[R] EL TWh
	2007	115,758H	5,221H	115,758H	5,221
	2050	129,374	7,917	70,227	7,925
		%		%	
Share of renewables	2007	7	15	7	15
	2050	15	25	85	98
		%		%	
Share of fossil fuels	2007	85	67M	85	67M
	2050	75	59M	9	2
		%		%	
Share of nuclear energy	2007	8	18	NUCLEAR POWER PHASED OUT BY 2040	
	2050	10	16		

LATIN AMERICA

		REF PE PJ	REF EL TWh	E[R] PE PJ	E[R] EL TWh
	2007	22,513L	998	22,513L	998
	2050	40,874	2,480	27,311	2,927
		%		%	
Share of renewables	2007	29	70H	29	70H
	2050	28	57H	88H	98
		%		%	
Share of fossil fuels	2007	70L	28L	70L	28L
	2050	69	40L	12L	2
		%		%	
Share of nuclear energy	2007	1	2	NUCLEAR POWER PHASED OUT BY 2030	
	2050	3	2		

LEGEND

> -50 | > -40 | > -30
> -20 | > -10 | > 0
> +10 | > +20 | > +30
> +40 | > +50

% CHANGE OF ENERGY CONSUMPTION IN THE ADVANCED ENERGY [R]EVOLUTION SCENARIO 2050 COMPARED TO CURRENT CONSUMPTION 2007

0 1000 KM

REF REFERENCE SCENARIO

E[R] ADVANCED ENERGY [R]EVOLUTION SCENARIO

SHARE OF RENEWABLES %

SHARE OF FOSSIL FUELS %

SHARE OF NUCLEAR ENERGY %

H HIGHEST | **M** MIDDLE | **L** LOWEST

PE PRIMARY ENERGY PRODUCTION/DEMAND IN PETA JOULE [PJ]

EL ELECTRICITY PRODUCTION/GENERATION IN TERAWATT HOURS [TWh]

OECD EUROPE

	REF PE PJ	REF EL TWh	E[R] PE PJ	E[R] EL TWh
2007	79,599	3,576	79,599	3,576
2050	82,634	5,351	46,754	4,233
	%		%	
2007	10	20	10	20
2050	21	42	85	97
	%		%	
2007	77	54	77	54
2050	71	46	16	2
	%		%	
2007	13	26H	NUCLEAR POWER PHASED OUT BY 2030	
2050	8	12		

MIDDLE EAST

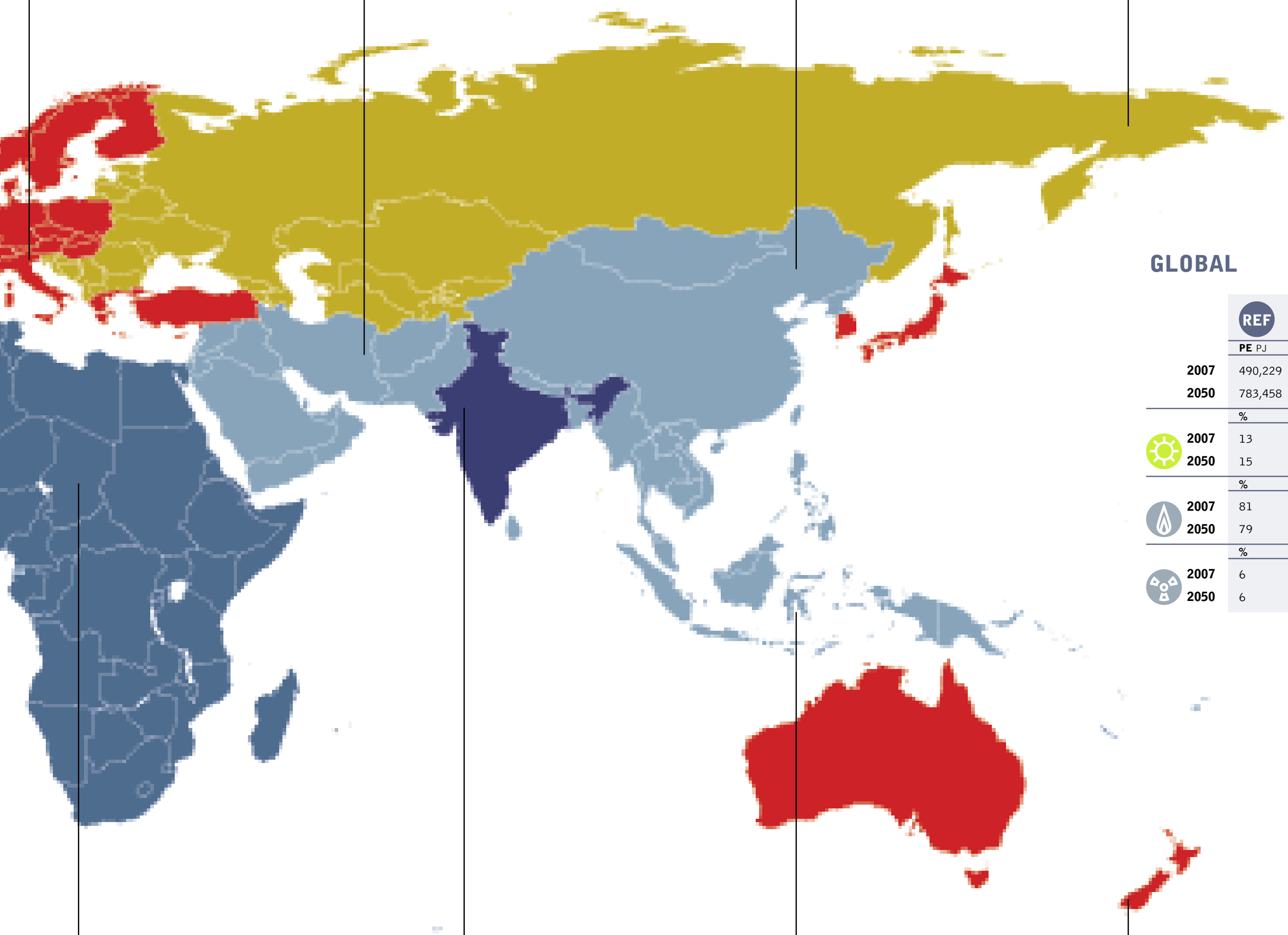
	REF PE PJ	REF EL TWh	E[R] PE PJ	E[R] EL TWh
2007	21,372	715	21,372	715
2050	51,281	2,404	27,475	2,786L
	%		%	
2007	1L	3	1L	3L
2050	2L	7	76	99H
	%		%	
2007	99H	97	99H	97H
2050	97H	92	23	1L
	%		%	
2007	0L	0	NO NUCLEAR ENERGY DEVELOPMENT	
2050	0L	0		

CHINA

	REF PE PJ	REF EL TWh	E[R] PE PJ	E[R] EL TWh
2007	83,922	3,319	83,922	3,319
2050	183,886H	12,188H	107,104H	10,190H
	%		%	
2007	12M	15	12M	15
2050	10	18	77L	90
	%		%	
2007	87	83	87	83
2050	85	75	23H	10H
	%		%	
2007	1	2	NUCLEAR POWER PHASED OUT BY 2045	
2050	5	7		

TRANSITION ECONOMIES

	REF PE PJ	REF EL TWh	E[R] PE PJ	E[R] EL TWh
2007	48,111M	1,685	48,111M	1,685
2050	64,449	3,110	34,710	2,438
	%		%	
2007	4	17M	4	17M
2050	7	22M	76	93
	%		%	
2007	89	65	89	65
2050	85	63	24	7
	%		%	
2007	7M	17	NUCLEAR POWER PHASED OUT BY 2045	
2050	8	15		



GLOBAL

	REF PE PJ	REF EL TWh	E[R] PE PJ	E[R] EL TWh
2007	490,229	19,773	490,229	19,773
2050	783,458	46,542	480,861	43,922
	%		%	
2007	13	18	13	18
2050	15	24	80	95
	%		%	
2007	81	68	81	68
2050	79	67	20	5
	%		%	
2007	6	14	NUCLEAR POWER PHASED OUT BY 2045	
2050	6	10		

AFRICA

	REF PE PJ	REF EL TWh	E[R] PE PJ	E[R] EL TWh
2007	26,355	615L	26,355	615L
2050	43,173	1,826L	35,805	2,490L
	%		%	
2007	48H	16	48H	16
2050	45H	36	79M	94
	%		%	
2007	51	82	51	82
2050	54L	62	20M	6
	%		%	
2007	0L	2	NUCLEAR POWER PHASED OUT BY 2025	
2050	0L	2		

INDIA

	REF PE PJ	REF EL TWh	E[R] PE PJ	E[R] EL TWh
2007	25,159	814	25,159	814
2050	77,7610M	4,918	52,120	5,062
	%		%	
2007	29	17	29	17
2050	13	12	78	93L
	%		%	
2007	70	81	70	81
2050	84	85	22	7
	%		%	
2007	1	2	NUCLEAR POWER PHASED OUT BY 2045	
2050	3	3		

DEVELOPING ASIA

	REF PE PJ	REF EL TWh	E[R] PE PJ	E[R] EL TWh
2007	31,903	978	31,903	978
2050	69,233	3,721	40,639	3,548
	%		%	
2007	27	16	27	16
2050	19	21	73L	94
	%		%	
2007	72	79	72	79
2050	79	77	27	6
	%		%	
2007	1	5M	NUCLEAR POWER PHASED OUT BY 2045	
2050	2	2		

OECD PACIFIC

	REF PE PJ	REF EL TWh	E[R] PE PJ	E[R] EL TWh
2007	37,588	1,851M	37,588	1,851M
2050	40,793	2,626	21,299L	2,322
	%		%	
2007	4	8	4	8
2050	10	16	84	98M
	%		%	
2007	84	70	84	70
2050	66	51	16	2M
	%		%	
2007	12H	22	NUCLEAR POWER PHASED OUT BY 2045	
2050	24H	33H		

the silent revolution – past and current market developments

GLOBAL SCENARIO

POWER PLANT MARKETS IN THE US, EUROPE AND CHINA
COUNTRY ANALYSIS: JAPAN

THE GLOBAL RENEWABLE ENERGY MARKET

EMPLOYMENT IN GLOBAL RENEWABLE ENERGY

6

“for the power industry the energy [r]evolution has already started but politicians haven´t noticed yet.”

SVEN TESKE
ENERGY EXPERT GREENPEACE INTERNATIONAL

image CONSTRUCTION OF THE OFFSHORE WINDFARM AT MIDDELGRUNDEN NEAR COPENHAGEN, DENMARK.

The bright future for renewable energy is already underway. This analysis of the global power plant market shows that since the late 1990s, wind and solar installations grew faster than any other power plant technology across the world - about 430,000 MW total installed capacity between 2000 and 2010. However it is too early to claim the end of the fossil fuel based power generation, as at the same time more than 475,000 MW new coal power plants, with embedded cumulative emissions of over 55 billion tonnes CO_2 over their technical lifetime.

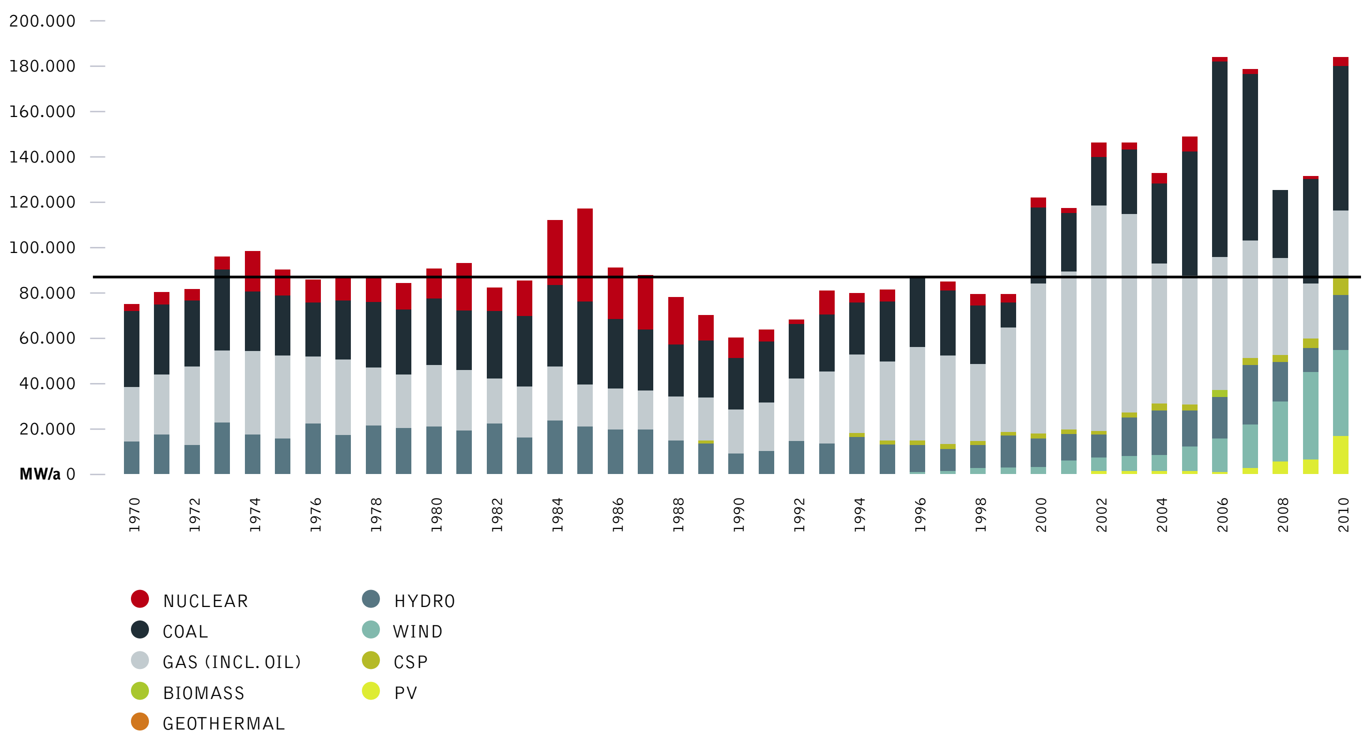
The global market volume of renewable energies in 2010 was on average, as much as the total global energy market volume each year between 1970 and 2000. The window of opportunity for renewables to both dominates new installations replacing old plants in OECD countries, as well as ongoing electrification in developing countries, closes within the next years. Good renewable energy policies and legally binding CO_2 reduction targets are urgently needed.

This briefing provides an overview of the global annual power plant market of the past 40 years and a vision of its potential growth over the next 40 years, powered by renewable energy. Between 1970 and 1990, OECD[29] countries that electrified their economies mainly with coal, gas and hydro power plants dominated the global power plant market. The power sector, at this time, was in the hands of state-owned utilities with regional or nationwide supply monopolies. The nuclear industry had a relatively short period of steady growth between 1970 and the mid 1980s - with a peak in 1985, one year before the Chernobyl accident - while the following years were in decline, with no sign of a 'nuclear renaissance', despite the rhetoric.

Between 1990 and 2000, the global power plant industry went through a series of changes. While OECD countries began to liberalise their electricity markets, electricity demand did not match previous growth, so fewer new power plants were built. Capital-intensive projects with long payback times, such as coal and nuclear power plants, were unable to get sufficient financial support. The decade of gas power plants started.

Economies of developing countries, especially in Asia, started growing during the 1990s, and a new wave of power plant projects began. Similarly to the US and Europe, most of the new markets in the 'tiger states' of Southeast Asia partly deregulated their power sectors. A large number of new power plants in this region were built from Independent Power Producer (IPP`s), who sell the electricity mainly to state-owned utilities. The dominating new built power plant technology in liberalised power markets are gas power plants. However, over the last decade, China focused on the development of new coal power plants. Excluding China, the global power plant market has seen a phase-out of coal since the late 1990s; the growth is in gas power plants and renewables particularly wind.

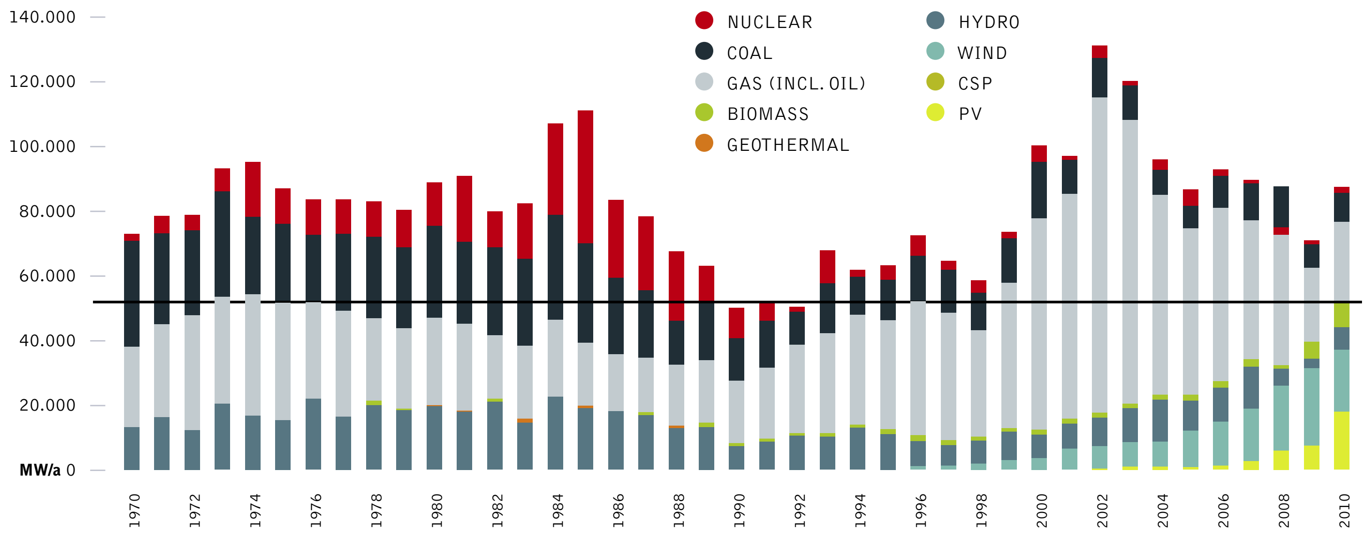
figure 6.1: global power plant market 1970-2010



source PLATTS, IEA, BREYER, TESKE.

29 ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT.

figure 6.2: global power plant market 1970-2010, excluding china



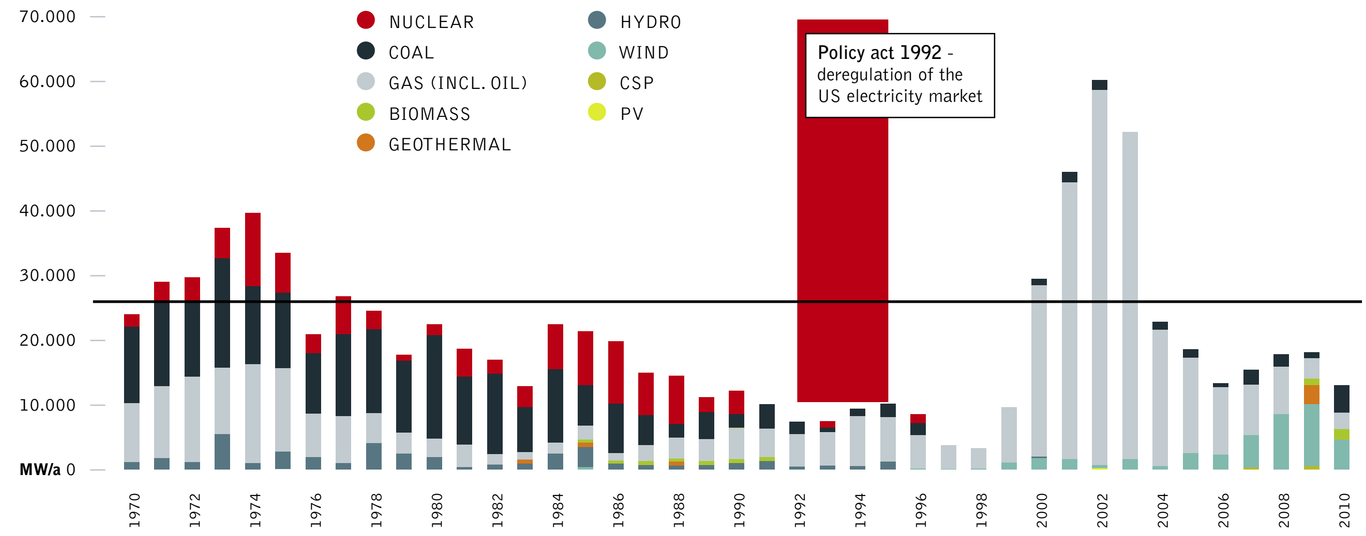
source PLATTS, IEA, BREYER, TESKE.

6.1 power plant markets in the us, europe and china

Electricity market liberalisation has a great influence on the chosen power plant technology. While the power sector in the US and Europe moved towards deregulated markets, which favour mainly gas power plants, China added a large amount of coal until 2009, with the first signs for a change in favour of renewables in 2009 and 2010.

USA: The liberalisation of the power sector in the US started with the Energy Policy Act 1992, and became a game changer for the entire power sector. While the US in 2010 is still far away from a fully liberalised electricity market, the effect on the chosen power plant technology has changed from coal and nuclear towards gas and wind. Since 2005, a growing number of wind power plants make up an increasing share of the new installed capacities as a result of mainly state based RE support programmes. Over the past year, solar photovoltaic plays a growing role with a project pipeline of 22.000 MW (Photon 4-2011, page 12).

figure 6.3: usa: annual power plant market 1970-2010



source PLATTS, IEA, BREYER, TESKE.

image GREENPEACE AND AN INDEPENDENT NASA-FUNDED SCIENTIST COMPLETED MEASUREMENTS OF MELT LAKES ON THE GREENLAND ICE SHEET THAT SHOW ITS VULNERABILITY TO WARMING TEMPERATURES.

Europe: About five years after the US began deregulating the power sector, the European Community started a similar process. Once again, the effect on the power plant market was the same. Investors backed fewer new power plants and extended the lifetime of the existing ones. New coal and nuclear power plants have seen a market share of well below 10% since than. The growing share of renewables, especially wind and solar photovoltaic, are due to a legally-binding target for renewables and the associated renewable energy feed-in laws which are in force in several member states of the EU 27 since the late 1990s. Overall, new installed power plant capacity jumped to a record high, due to the repowering needs of the aged power plant fleet in Europe.

figure 6.4: europe: annual power plant market 1970-2010

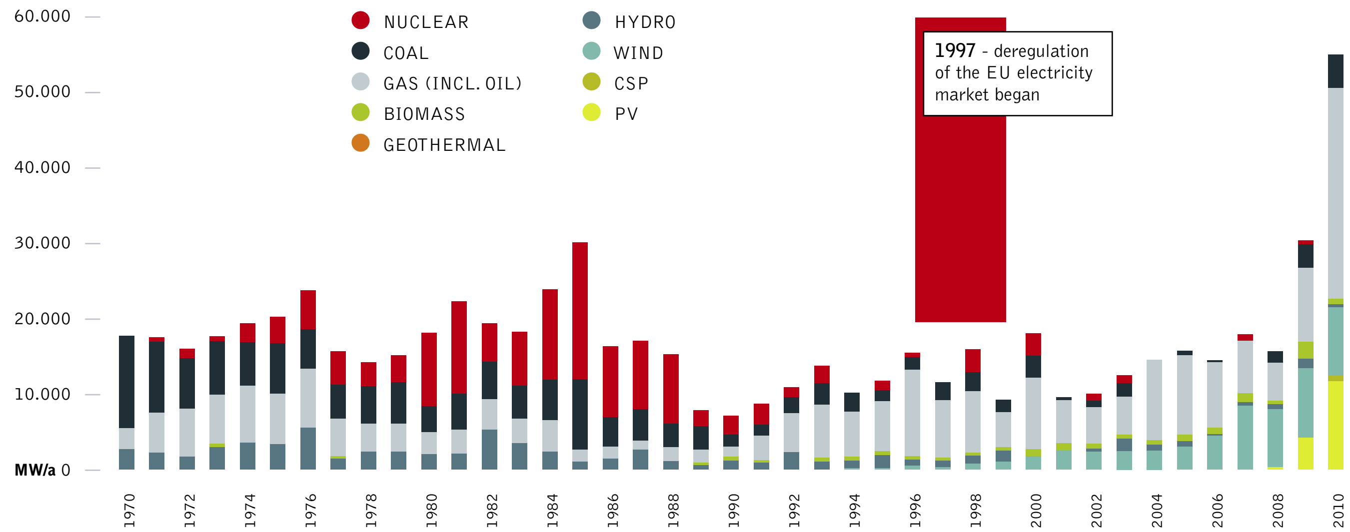
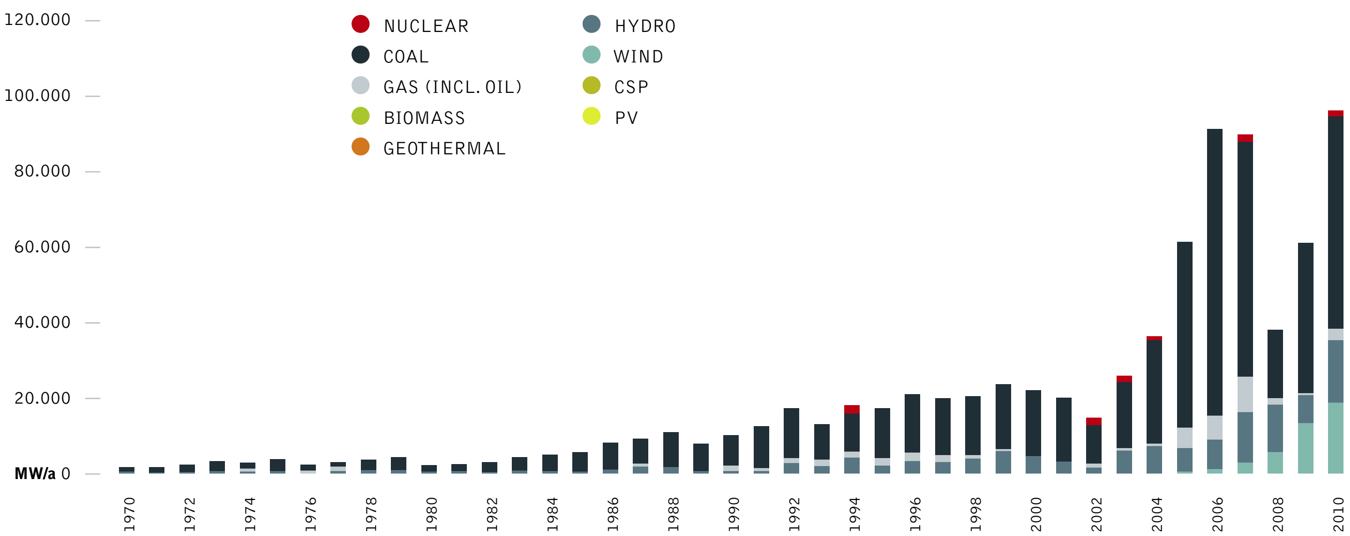


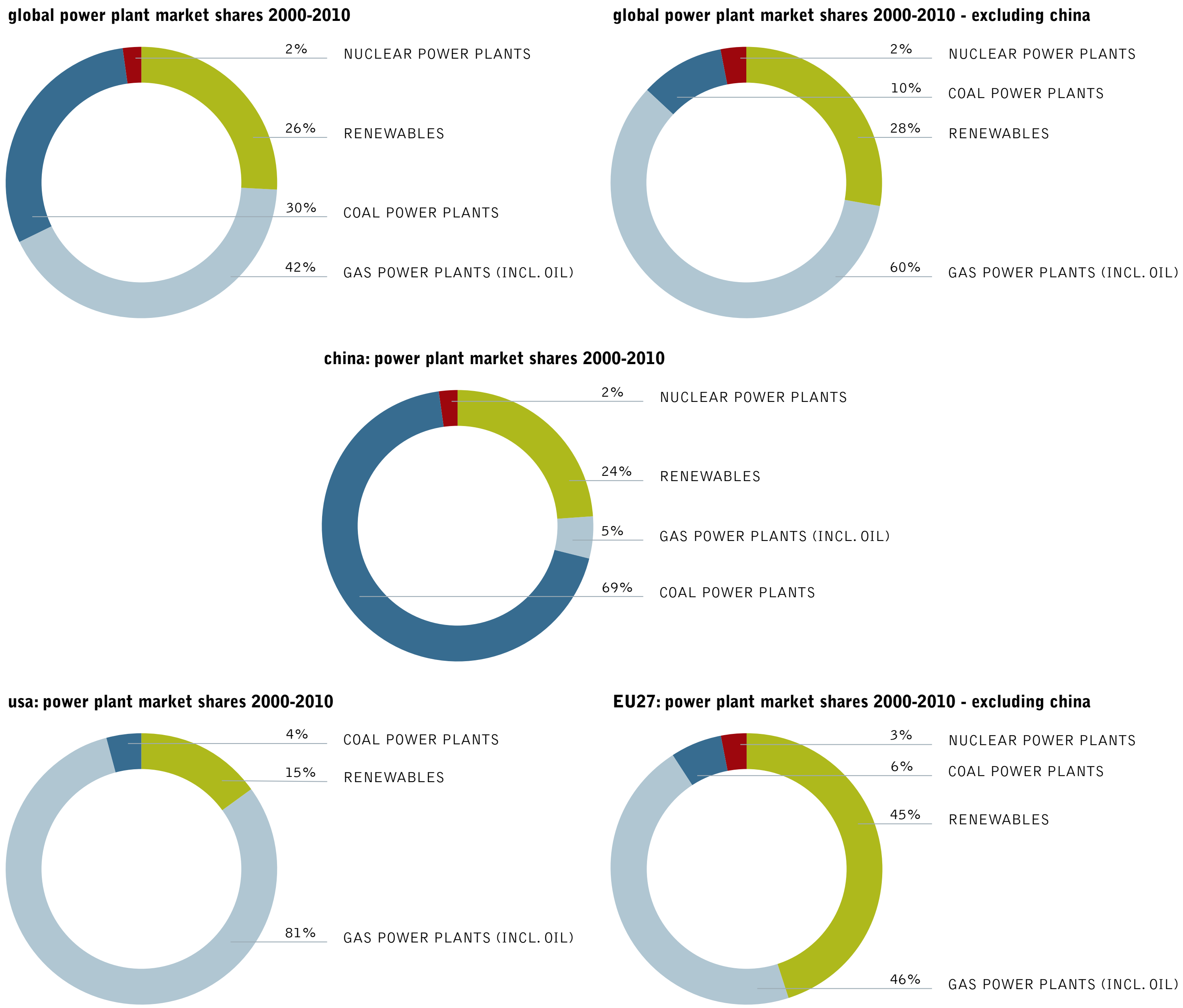
figure 6.5: china: annual power plant market 1970-2010



source PLATTS, IEA, BREYER, TESKE.

China: The steady economic growth in China since the late 1990s, and the growing power demand, led to an explosion of the coal power plant market, especially after 2002. In 2006 the market hit the peak year for new coal power plants: 88% of the newly installed coal power plants worldwide were built in China. At the same time, China is trying to take its dirtiest plants offline, within 2006~2010, total 76.825MW of small coal power plants were phased out under the "11th Five Year" programme. While coal still dominates the new added capacity, wind power is rapidly growing as well. Since 2003 the wind market doubled each year and was over 18.000 MW[30] by 2010, 49% of the global wind market. However, coal still dominates the power plant market with over 55 GW of new installed capacities in 2010 alone. The Chinese government aims to increase investments into renewable energy capacity, and during 2009, about US$25.1 billion (RMB162.7 billion) went to wind and hydro power plants which represents 44% of the overall investment in new power plants, for the first time larger than that of coal (RMB 149.2 billion), and in 2010 the figure was US$26 billion (RMB168 billion) – 4,8% more in the total investment mix compared with the previous year 2009.

figure 6.6: power plant market shares



source PLATTS, IEA, BREYER, TESKE, GWAC, EPIA.

30 WHILE THE OFFICIAL STATISTIC OF THE GLOBAL AND CHINESE WIND INDUSTRY ASSOCIATIONS (GWEC/CREIA) ADDS UP TO 18,900 MW FOR 2010, THE NATIONAL ENERGY BUREAU SPEAKS ABOUT 13,999 MW. DIFFERENCES BETWEEN SOURCES AS DUE TO THE TIME OF GRID CONNECTION, AS SOME TURBINES HAVE BEEN INSTALLED IN THE LAST MONTHS OF 2010, BUT HAVE BEEN CONNECTED TO THE GRID IN 2011.

image FIRST GEOTHERMAL POWER STATION IN GERMANY PRODUCING ELECTRICITY. WORKER IN THE FILTRATION ROOM.

The energy revolution towards renewables and gas, away from coal and nuclear, has started on a global level already. This picture is even clearer, when we look into the global market shares excluding China, the only country with a massive expansion of coal. About 28% of all new power plants have been renewables and 60% have been gas power plants (88% in total). Coal gained a market share of only 10% globally, excluding China. Between 2000 and 2010, China has added over 350.000 MW of new coal capacity: twice as much as the entire coal capacity of the EU. However China has recently kick-started its wind market, and solar photovoltaics is expected to follow in the years to come.

In the past decade, 50% of all new power plants are from gas-fired energy followed by coal-fired plants. Renewable energy technologies are accountable for 15%, mainly solar photovoltaic, while only 8% of the installations are nuclear power plants. Due to the severity of the accident at Fukushima Daiichi nuclear power plant in March 2011, the future development will be very unlikely to favour nuclear. However, the scale of growth in renewables is unclear and it is dependent on availability of political support.

6.2 japan: country analysis

Between 1970 and 1997, the majority of new power plants built were hydro, nuclear, and oil/gas-fired power plants. The year that saw the highest installation of nuclear capacity was 1985, one year before the Chernobyl accident. However, the accident did not stop nuclear power installation in Japan, and it kept fairly steady with new installments until 1997. After the mid-1990s installations of new coal power plants increased significantly until 2004.

Renewable energy started to grow in the market after 2000. Solar photovoltaic especially increased from 2009, when government funding to newly installed solar photovoltaic was re-started and a limited feed-in-tariff system was introduced. Although the feed-in law is restricted only for residual electricity from household solar photovoltaic, for the first time in 2010, solar became the most installed power plant in the market.

figure 6.8: japan: new build power plants - market shares 2000-2010

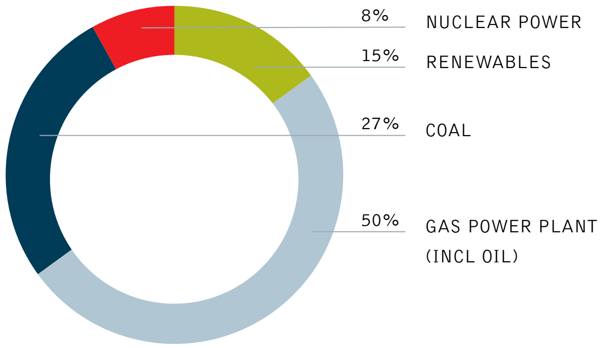
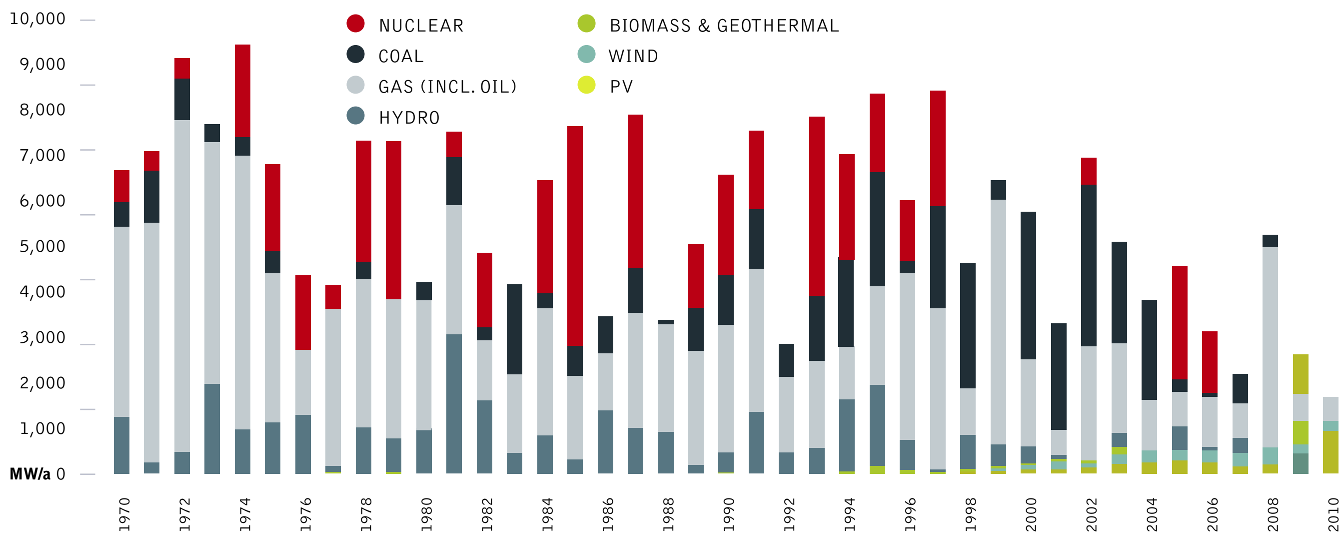


figure 6.7: japan: annual power plant market 1970-2010

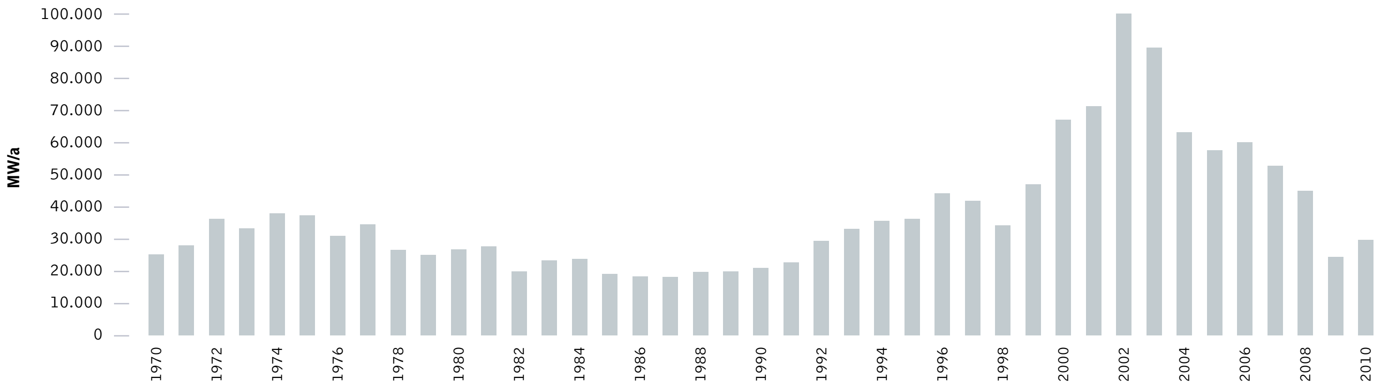


source PLATTS, IEA, BREYER, TESKE.

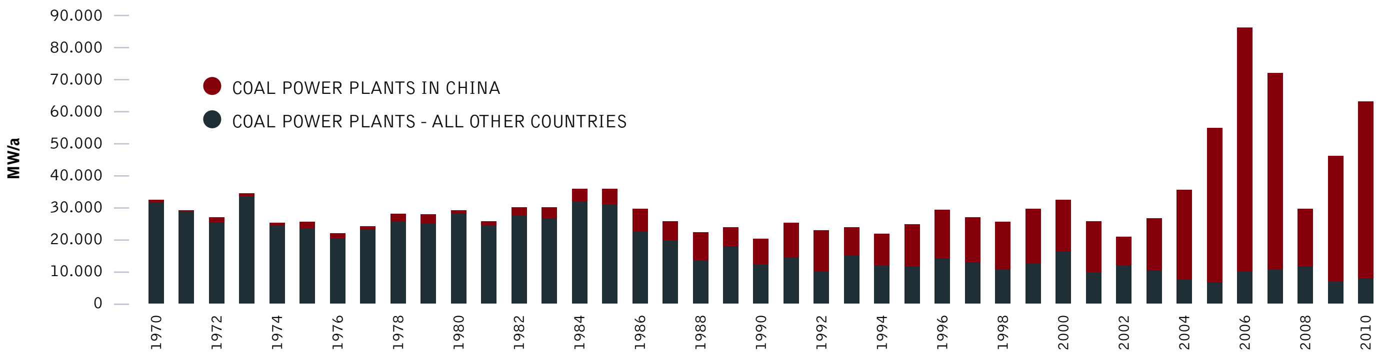
methodology THE ANALYSIS IS BASED ON DATABASES FROM UDI WEPP PLATTS, THE IEA, GLOBAL WIND ENERGY COUNCIL, EUROPEAN PHOTOVOLTAIC INDUSTRY ASSOCIATION, AND RESEARCH PAPER FROM DR. CHRISTIAN BREYER AND MARZELLA AMATA GÖRIG. PLEASE NOTE THAT THE DIFFERENT STATISTICAL DATABASE USE DIFFERENT FUEL CATEGORIES AND SOME POWER PLANTS RUN ON MORE THAN ONE FUEL. IN ORDER TO AVOID DOUBLE COUNTING, DIFFERENT FUEL GROUPS HAVE BEEN ESTABLISHED. NATIONAL DATA MIGHT DIFFER FROM THE INTERNATIONAL DATA BASIS.

figure 6.9: historic developments of the global power plant market by technology

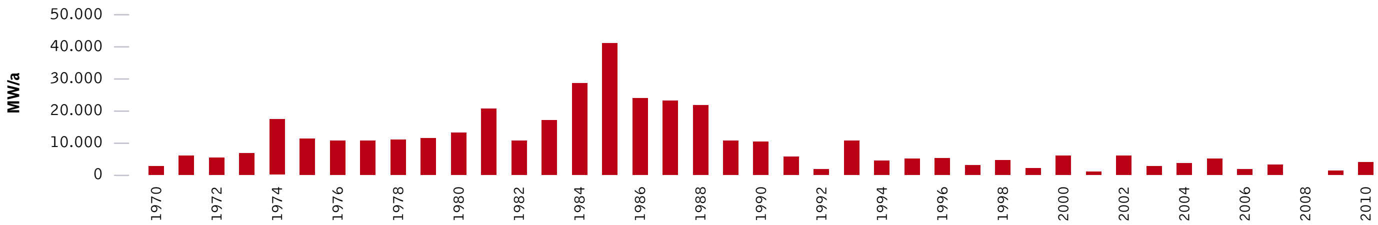
global annual gas power plant market (incl. oil) 1970-2010



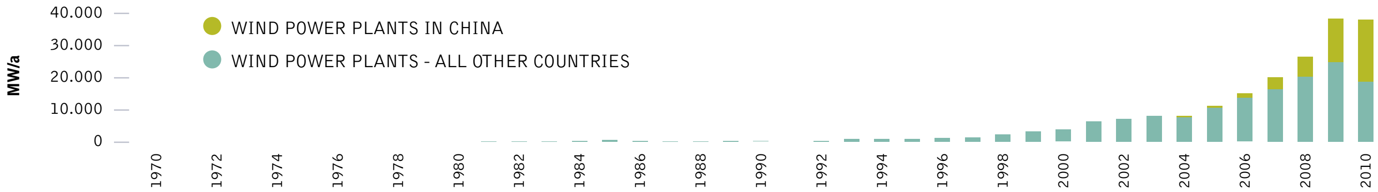
global annual coal power plant market 1970-2010



global annual nuclear power plant market 1970-2010



global annual wind power market 1970-2010



global annual solar photovoltaic market 1970-2010

image A WOMAN STUDIES SOLAR POWER SYSTEMS AT THE BAREFOOT COLLEGE. THE COLLEGE SPECIALISES IN SUSTAINABLE DEVELOPMENT AND PROVIDES A SPACE WHERE STUDENTS FROM ALL OVER THE WORLD CAN LEARN TO UTILISE RENEWABLE ENERGY. THE STUDENTS TAKE THEIR NEW SKILLS HOME AND GIVE THEIR VILLAGES CLEAN ENERGY.

6.3 the global renewable energy market

The renewable energy sector has been growing substantially over the last four years. In 2008, the increases in the installation level of both wind and solar power were particularly impressive. The total amount of renewable energy installed worldwide is reliably tracked by the Renewable Energy Policy Network for the 21st Century (REN21). Its latest global status report (2011) shows how the technologies have grown.

The global installed capacity of new renewable energy at the end of 2010 (excluding large hydro) was 310 GW, with wind power making up around two thirds (197 GW) and solar photovoltaic 12% (39 GW). The new capacity commissioned in 2010 alone amounted to roughly 65 GW (excluding large hydro power), with the highest growth in wind power and solar photovoltaic.

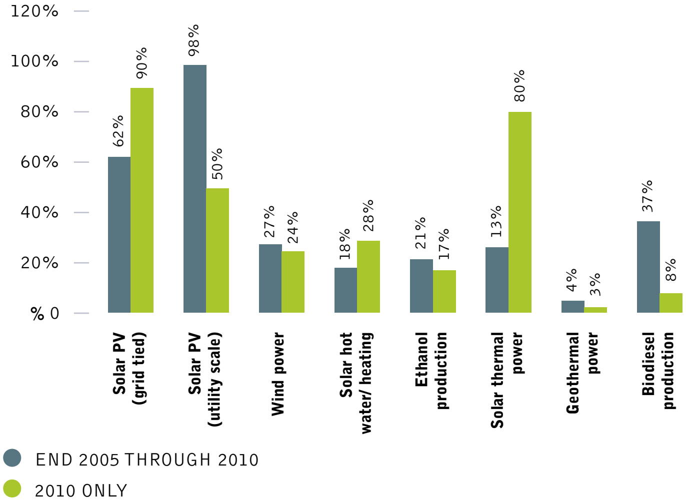
table 6.1: annual growth rates of global renewable energy

wind	29% increase in 2008	255% increase since 2005
solar photovoltaics (PV)	130% increase in 2010	1,063% increase since 2005

table 6.2: top five countries

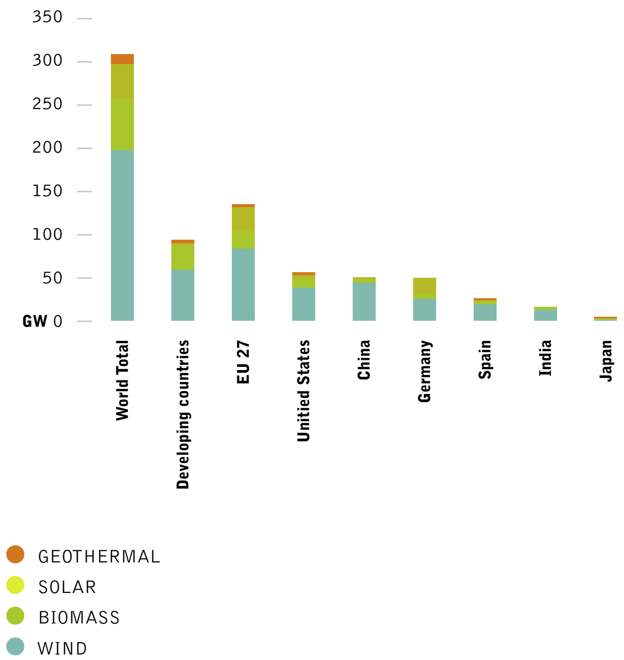
	#1	#2	#3	#4	#5
Annual amounts for 2010					
New capacity investment	China	Germany	Italy	United States	Czech Rep.
Wind power added	China	United States	Spain	India	Germany
Solar PV added (grid-connected)	Germany	Italy	Czech Rep.	Japan	United States
Solar hot water/heat added	China	Germany	Turkey	India	Australia
Ethanol production	United States	Brazil	China	Canada	France
Biodiesel production	Germany	Brazil	Argentina	France	United States
Existing capacity as of end-2010					
Renewables power capacity (not including hydro)	United States	China	Germany	Spain	India
Renewable power capacity (including hydro)	China	United States	Canada	Brazil	Germany
Wind power	China	United States	Germany	Spain	India
Biomass power	United States	Brazil	Germany	China	Sweden
Geothermal power	United States	Philippines	Indonesia	Mexico	Italy
Solar PV (grid-connected)	Germany	Spain	Japan	Italy	United States
Solar hot water/heat	China	Turkey	Germany	Japan	Greece

figure 6.10: average annual growth rates of renewable energy capacity and biofuel production, 2005-2010



The top five countries for new renewable energy in 2010 were China, Italy, Germany, the United States of America and Czech Republic. China doubled its wind power capacity for the seventh year in a row. The growth of grid-connected solar PV in Germany was six times the level in 2007 (2007: 1.2 GW – 2010: 7.4 GW)

figure 6.11: renewable power capacities, developing countries, eu and top six countries, 2010 (not including hydropower)



6.4 employment in global renewable energy

Based on those countries for which statistics are available, the current global employment in renewable energy is as high as 3.5 million people.

Although so far it has been mostly the advanced economies that have shown leadership in encouraging viable renewable energy, developing countries are beginning to play a growing role. China and Brazil, for example, account for a large share of the global total, with a strong commitment to both solar thermal and biomass development. Many of the jobs created are in installation, operation and maintenance, as well as in manufaction of wind and solar equipment. The outlook for the future is that more developing countries are expected to generate substantial numbers of jobs.

To make sure that the renewables sector can provide large scale green employment, strong energy policies are essential. Some countries have already shown that renewable energy can form an important part of national economic strategies. Germany, for instance, views its investment in wind and solar PV as making a crucial contribution to its export markets. The government's intention is to gain a major slice of the world market in the coming decades, with most German jobs in these industries depending on sales abroad of wind turbines and solar panels. Although only a few countries currently have the requisite scientific and manufacturing know-how to develop such a strategy, the markets for wind and solar equipment in particular are experiencing rapid growth.

table 6.3: employment in renewable electricity – selected countries and world estimates

INDUSTRY	ESTIMATED JOBS WORLDWIDE	SELECTED NATIONAL ESTIMATES
Biofuels	> 1,500,000	Brazil 730,000 for sugarcane and ethanol production
Wind power	~630,000	China 150,000; Germany 100,000; United States 85,000; Spain 40,000; Italy 28,000; Denmark 24,000; Brazil 14,000; India 10,000
Solar hot water	~300,000	China 250,000; Spain 7,000
Solar PV	~350,000	China 120,000; Germany 120,000; Japan 26,000; Spain 20,000; United States 17,000; Spain 14,000
Biomass power	---	Germany 120,000; United States 66,000; Spain 5,000
Hydropower	---	Europe 20,000; United States 8,000; Spain 7,000
Geothermal	---	Germany 13,000; United States 9,000
Biogas	---	Germany 20,000
Solar thermal power	~15,000	Spain 1,000; United States 1,000
Total estimated	**~3,500,000**	

notes/sources FIGURES ARE ROUNDED TO NEAREST 1.000 OR 10.000 AS ALL NUMBERS ARE ROUGH ESTIMATES AND NOT EXACT. GWEC/GREENPEACE 2010, GWEC 2010, WWEA 2009, EPIA 2010, BSW 2010, SOLAR PACES 2010, BMU 2010, CREIA 2010, MARTINOT AND LI 2007; NAVIGANT 2009; NIETO 2007; REN 21 2005 AND 2008; SUZION 2007; UNEP 2008; US GEOTHERMAL INDUSTRY ASSOCIATION 2009; US SOLAR ENERGY INDUSTRY ASSOCIATION 2009. DATA ADJUSTED BASED ON SUBMISSIONS FROM REPORT CONTRIBUTORS AND OTHER SOURCES, ALONG WITH ESTIMATES FOR BIOFUELS AND SOLAR HOT WATER BY ERIC MARTINOT. EARLIER ESTIMATES WERE MADE BY UNEP IN 2008 (1,7 MILLION GLOBAL TOTAL) AND BY SVEN TESKE AND GREENPEACE INTERNATIONAL IN 2009 (1,9 MILLION GLOBAL TOTAL) NOT INCLUDING BIOFUELS AND SOLAR HOT WATER. BRAZIL ETHANOL ESTIMATE FROM LABOR MARKET RESEARCH AND EXTENSTION GROUP (GEMT, ESALQ/USP). SOLAR HOT WATER EMPLOYMENT ESTIMATE USES THE FIGURE OF 150.000 FOR CHINA IN 2007 CITED IN MARTINOT AND LI 2007, ADJUSTED FOR GROWTH IN 2008-2009, AND ASSUMING EMPLOYMEN IN OTHER COUNTRIES IS IN PROPORTINO TO CHINA'S GLOBAL MARKET SHARE.

climate protection and energy policy

GLOBAL THE KYOTO PROTOCOL

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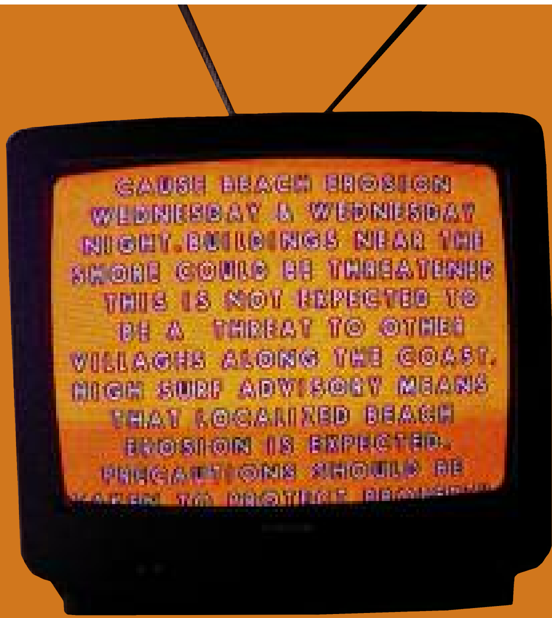

image THE LOCAL ALASKAN TELEVISION STATION BROADCASTS A WARNING FOR HIGH TIDES AND EROSION ALONG THE SEASIDE DURING A 2006 OCTOBER STORM WHICH IMPACTS ON THE VILLAGE OF SHISHMAREF. © GP/ROBERT KNOTH

"never before has humanity been forced to grapple with such an immense environmental crisis."

GREENPEACE INTERNATIONAL
CLIMATE CAMPAIGN

image WANG WAN YI, AGE 76, ADJUSTS THE SUNLIGHT POINT ON A SOLAR DEVICE USED TO BOIL HIS KETTLE. HE LIVES WITH HIS WIFE IN ONE ROOM CARVED OUT OF THE SANDSTONE, A TYPICAL DWELLING FOR LOCAL PEOPLE IN THE REGION. DROUGHT IS ONE OF THE MOST HARMFUL NATURAL HAZARDS IN NORTHWEST CHINA. CLIMATE CHANGE HAS A SIGNIFICANT IMPACT ON CHINA'S ENVIRONMENT AND ECONOMY.

The greenhouse effect is the process by which the atmosphere traps some of the sun's energy, warming the earth and moderating our climate. A human-driven increase in 'greenhouse gases' has enhanced this effect, artificially raising global temperatures and disrupting our climate. These greenhouse gases include carbon dioxide (produced by burning fossil fuels and through deforestation), methane (released from agriculture, animals and landfill sites), and nitrous oxide (resulting from agricultural production plus a variety of industrial chemicals).

Every day we damage our climate by using fossil fuels (oil, coal and gas) for energy and transport. The resulting impacts are likely to destroy the livelihoods of millions of people, especially in the developing world, as well as ecosystems and species, over the coming decades. We therefore need to significantly reduce our greenhouse gas emissions. This makes both environmental and economic sense.

According to the Intergovernmental Panel on Climate Change, the United Nations forum for established scientific opinion, the world's temperature is expected to increase over the next hundred years by up to 6.4° Celsius if no action is taken to reduce greenhouse gas emissions. This is much faster than anything experienced so far in human history. The goal of climate policy should be to keep the global mean temperature rise to less than 2°C above pre-industrial levels. If there is more than a 2°C rise, damage to ecosystems and disruption to the climate system increases dramatically. We have very little time within which we can change our energy system to meet these targets. This means that global emissions will have to peak and start to decline by the end of the next decade at the latest.

The reality of climate change can already be seen in disintegrating polar ice, thawing permafrost, rising sea levels and fatal heat waves. It is not only scientists that are witnessing these changes. From the Inuit in the far north to islanders near the equator, people are already struggling with impacts consistent with climate change. An average global warming of more than 2°C threatens millions of people with an increased risk of hunger, disease, flooding and water shortages. Never before has humanity been forced to grapple with such an immense environmental crisis. If we do not take urgent and immediate action to protect the climate, the damage could become irreversible. This can only happen through a rapid reduction in the emission of greenhouse gases into the atmosphere.

Below is a summary of some likely effects if we allow current trends to continue.

Likely effects of small to moderate warming:

1. Sea level rise due to melting glaciers and the thermal expansion of the oceans as global temperature increases. Massive releases of greenhouse gases from melting permafrost and dying forests.
2. A greater risk of more extreme weather events such as heat waves, droughts and floods. Already the global incidence of drought has doubled over the past 30 years.
3. Severe regional impacts such as an increase in river flooding in Europe as well as coastal flooding, erosion and wetland loss. Low-lying areas in developing countries such as Bangladesh and South China are likely to be severely affected by flooding.
4. Severe threats to natural systems, including glaciers, coral reefs, mangroves, alpine ecosystems, boreal forests, tropical forests, prairie wetlands and native grasslands.
5. Increased risk of species extinction and biodiversity loss.

The greatest impacts will be on poorer countries in sub-Saharan Africa, South Asia, Southeast Asia and Andean South America as well as small islands least able to protect themselves from increasing droughts, rising sea levels, the spread of disease and a decline in agricultural production.

longer term catastrophic effects Warming from rising emissions may trigger the irreversible meltdown of the Greenland ice sheet, adding up to seven metres of global sea level rise over several centuries. New evidence shows that the rate of ice discharge from parts of the Antarctic means it is also at risk of meltdown. Slowing, shifting or shutting down of the Atlantic Gulf Stream current would have dramatic effects in Europe, and disrupt the global ocean circulation system. Large releases of methane from melting permafrost and from the oceans would lead to rapid increases of the gas in the atmosphere and consequent warming.

"climate change has moved from being a predominantly physical phenomenon to being a social one" (hulme, 2009).

7.1 the kyoto protocol

Recognising these threats, the signatories to the 1992 UN Framework Convention on Climate Change (UNFCCC) agreed the Kyoto Protocol in 1997, which entered into force in early 2005. Only one major industrialised nation, the United States, has not ratified the Kyoto Protocol.

In the Kyoto Protocol, developed countries, took on individual legally binding emission caps to reduce or limit their greenhouse gas emissions by the target period of 2008-2012. Together developed countries agreed to reduce their emissions on average by 5.2% from their 1990 emissions. In the European Union, for instance, the commitment is to an overall reduction of 8%.

At present, the 195 members of the UNFCCC are continuously negotiating a package of new commitments that should put the world on a pathway to prevent dangerous climate change. As the Kyoto Protocol's first commitment period is coming to an end by the end of 2012, a new package needs to ensure a continuation of the Kyoto Protocol into a second commitment period as well as clear agreement about the provision of climate finance for poor countries, to support adaptation, clean technology uptake and reducing deforestation. It is clear that more ambition and commitment on emission reductions is required from all countries and that all the elements of climate cooperation need to be captured in a legally binding regime.

If the world really wants to prevent dangerous climate change, then we will need to ensure that industrialised countries reduce their emissions on average by at least 40% by 2020, compared to their 1990 level. They will further need to provide funding of at least $140 billion a year to developing countries to enable them to adapt to climate change, protect their forests and achieve their part of the energy revolution. Developing countries need to reduce their greenhouse gas emissions by 15 to 30% compared to their projected growth by 2020. It is clear that governments will need to make the energy revolution happen in order to be able to achieve such ambitious emission reduction targets.

"if we do not take urgent and immediate action to protect the climate the damage could become irreversible."

8

image SIGN ON A RUSTY DOOR AT CHERNOBYL ATOMIC STATION.
© DMYTRO/DREAMSTIME

"safety and security risks, radioactive waste, nuclear proliferation..."

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CLIMATE CAMPAIGN

Nuclear energy is a relatively minor industry with major problems. It covers just one sixteenth of the world's primary energy consumption, a share set to decline over the coming decades. The average age of operating commercial nuclear reactors is 25 years. The number of operating reactors as of May 2011 was 443, less than at the historical peak of 2002.

In terms of new power stations, the amount of nuclear capacity added annually between 2000 and 2009 was on average 2,500 MWe. This was six times less than wind power (14,500 MWe per annum between 2000 and 2009). In 2009, 37,466 MW of new wind power capacity was added globally to the grid, compared to only 1,068 MW of nuclear. This new wind capacity will generate as much electricity as 12 nuclear reactors; the last time the nuclear industry managed to add this amount of new capacity in a single year was in 1988.

Despite the rhetoric of a 'nuclear renaissance', the industry is struggling with a massive increase in costs and construction delays as well as safety and security problems linked to reactor operation, radioactive waste and nuclear proliferation. The Fukushima nuclear accident (see below) 25 years after the disastrous explosion in the Chernobyl nuclear power plant in former Soviet Union, proves nuclear energy is inherently unsafe and raises additional doubts about the nuclear industry's ability to deliver on their promises of safety and security.

As a consequence of the Fukushima accident, the German Parliament, with overwhelming support, passed a law on 30 June 2011 which puts an end to all 17 German nuclear plants by 2022. This includes the immediate shutdown of eight nuclear power stations and a gradual phase out of the remaining nine. On the same day, Germany also passed a set of laws which will further boost renewable energy and energy efficiency technologies to meet the nation's energy needs. Just two weeks before, 95% of Italian voters made the decision to reject nuclear energy in a referendum about nuclear power.

8.1 a solution to climate protection?

The nuclear industry's promise of nuclear energy to contribute to both climate protection and energy security needs to be checked against reality. In the most recent Energy Technology Perspectives report published by the International Energy Agency(IEA)[31], for example, its Blue Map scenario outlines a future energy mix which would halve global carbon emissions by the middle of this century. To reach this goal the IEA assumes a massive expansion of nuclear power between now and 2050, with installed capacity increasing four-fold and electricity generation reaching 9,857 TWh/year, compared to 2,608 TWh in 2007. In order to achieve this, the report says that on average 32 large reactors (1,000 MWe each) would have to be built every year from now until 2050. This is not only unrealistic, but also expensive, hazardous and too late to protect the climate. Even if realised, according to the IEA scenario, such a massive nuclear expansion would only cut carbon emissions by less than 5%.

unrealistic: Such a rapid nuclear growth is practically impossible given the technical limitations. This scale of development was achieved in the history of nuclear power for only two years at the peak of the state-driven boom of the mid-1980s. It is unlikely to be achieved again, not to mention maintained for 40 consecutive years. While 1984 and 1985 saw 31 GW of newly added nuclear capacity, the decade average was 17 GW each year. In the past ten years, less than three large reactors have been brought on line annually, and the current production capacity of the global nuclear industry cannot deliver more than an annual six units.

expensive: The IEA scenario assumes very optimistic investment costs of $2,100/kWe installed, in line with what the industry has been promising. The reality indicates three to four times that much. Recent estimates by US business analysts Moody's (May 2008) put the cost of nuclear investment as high as $7,500/kWe. Price quotes for projects under preparation in the US cover a range from $5,200 to 8,000/kWe[32]. The latest cost estimate for the first French EPR pressurised water reactor being built in Finland is $5,000/kWe, a figure likely to increase for later reactors as prices escalate. Building 1,400 large reactors of 1,000 MWe, even at the current cost of about $7,000/kWe, would require an investment of $9.8 trillion.

hazardous: Massive expansion of nuclear energy would necessarily lead to a large increase in related hazards. These include the risk of serious reactor accidents like in Fukushima, Japan, the growing stockpiles of deadly high level nuclear waste which will need to be safeguarded for thousands of years, and potential proliferation of both nuclear technologies and materials through diversion to military or terrorist use. The 1,400 large operating reactors in 2050 would generate an annual 35,000 tonnes of dangerous spent nuclear fuel (for light water reactors, the most common design for most new projects). This also means the production of 350,000 kilograms of plutonium each year, enough to build 35,000 crude nuclear weapons.

slow: Climate science says that we need to reach a peak of global greenhouse gas emissions in 2015 and reduce them by 20% by 2020. Even in developed countries with established nuclear infrastructure it takes at least a decade from the decision to build a reactor to the delivery of its first electricity, and often much longer. This means that even if the world's governments decided to implement strong nuclear expansion now, only a few reactors would start generating electricity before 2020. The contribution from nuclear power towards reducing emissions would come too late to help save the climate.

references

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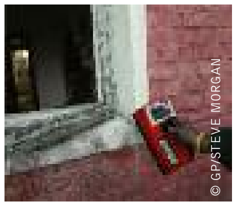
32 PLATTS, 2008; *ENERGY BIZ*, MAY/JUNE 2008

image MEASURING RADIATION LEVELS OF A HOUSE IN THE TOWN OF PRIPYAT THAT WAS LEFT ABANDONED AFTER THE CHERNOBYL NUCLEAR DISASTER, UKRAINE.



8.2 nuclear power blocks solutions

Even if the ambitious nuclear scenario is implemented, regardless of costs and hazards, the IEA concludes that the contribution of nuclear power to reductions in greenhouse gas emissions from the energy sector would only be 4.6% - less than 3% of the global overall reduction required.

There are other technologies that can deliver much larger emission reductions, and much faster. Their investment costs are lower and they do not create global security risks. Even the IEA finds that the combined potential of efficiency savings and renewable energy to cut emissions by 2050 is more than ten times larger than that of nuclear.

The world has limited time, finance and industrial capacity to change our energy sector and achieve a large reduction in greenhouse emissions. Choosing the pathway of spending $10 trillion on nuclear development would be a fatally wrong decision. Nuclear energy would not save the climate but it would necessarily take resources away from solutions described in this report and at the same time create serious global security hazards. Therefore new nuclear reactors are a clearly dangerous obstacle to the protection of the climate.

8.3 nuclear power in the energy [r]evolution scenario

For the reasons explained above, the Energy [R]evolution scenario envisages a nuclear phase-out. Existing reactors would be closed at the end of their average operational lifetime of 35 years. We assume that no new construction is started and only two thirds of the reactors currently under construction worldwide will be finally put into operation.

8.4 the dangers of nuclear power

Although the generation of electricity through nuclear power produces much less carbon dioxide than fossil fuels, there are multiple threats to people and the environment from its operations.

The main risks are:

- Safety Risks
- Nuclear Waste
- Nuclear Proliferation

This is the background to why nuclear power has been discounted as a future technology in the Advanced Energy [R]evolution scenario.

8.4.1 safety risks

Windscale (1957), Three Mile Island (1979), Chernobyl (1986), Tokaimura (1999) and Fukushima (2011) are only a few of the hundreds of nuclear accidents which have occurred to date. The Fukushima nuclear disaster in March 2011 has been a stark wake-up call causing governments all over the world to rethink their nuclear plans. Despite the nuclear industry's assurances that a nuclear accident on the scale of Chernobyl could never happen again, the earthquake and subsequent tsunami in Japan caused leaks and explosions in 4 reactors of the Fukushima nuclear power plant. Large areas around the nuclear power plant have been seriously contaminated by radioactive releases from the plant. An area of 30 km around the facility has been evacuated, and food and water restrictions apply at distances more than 100 km. The impacts on the lives of hundreds of thousands of people as well as the Japanese economy will be felt for decades to come.

Nuclear energy is inherently unsafe because:

- An accident like in Fukushima can happen in many of the existing nuclear reactors, as they all need continuous power to cool the reactors and spent nuclear fuel, even after the reactor has shut down. A simple power failure at a Swedish nuclear plant in 2006 highlighted this problem. Emergency power systems at the Forsmark plant failed for 20 minutes during a power cut and four of Sweden's ten nuclear power stations had to be shut down. If power had not been restored there could have been a major incident within hours.
- A nuclear chain reaction must be kept under control, and harmful radiation must, as far as possible, be contained within the reactor, with radioactive products isolated from humans and carefully managed. Nuclear reactions generate high temperatures, and fluids used for cooling are often kept under pressure. Together with the intense radioactivity, these high temperatures and pressures make operating a reactor a difficult and complex task.
- The risks from operating reactors are increasing and the likelihood of an accident is now higher than ever. Most of the world's reactors are more than 25 years old and therefore more prone to age related failures. Many utilities are attempting to extend their lifespan from the 30 years or so, they were originally designed for, to up to 60 years, posing new risks.
- De-regulation has meanwhile pushed nuclear utilities to decrease safety-related investments and limit staff whilst increasing reactor pressure and operational temperature and the burn-up of the fuel. This accelerates ageing and decreases safety margins.

8.4.2 nuclear waste

Despite 50 years of producing radioactive waste, there is no solution for the long term storage and safeguarding of these dangerous materials. Disposal sites of low level radioactive waste have already started leaking after decades, while the highly radioactive waste will need to be safely stored for hundreds of thousands of years. The nuclear industry claims it can 'dispose' of its nuclear waste by burying it deep underground, but this will not isolate the radioactive material from the environment forever. A deep dump only slows down the release of radioactivity into the environment. The industry tries to predict how fast a dump will leak so that it can claim that radiation doses to the public living nearby in the future will be "acceptably low". But scientific understanding is not sufficiently advanced to make such predictions with any certainty.

As part of its campaign to build new nuclear stations around the world, the industry claims that problems associated with burying nuclear waste are to do with public acceptability rather than technical issues. It points to nuclear dumping proposals in Finland, Sweden or the United States to underline its argument, but there is no scientific backing of its claims of safe disposal.

The most hazardous waste is the highly radioactive waste (or spent) fuel removed from nuclear reactors, which stays radioactive for hundreds of thousands of years. In some countries the situation is exacerbated by 'reprocessing' this spent fuel, which involves dissolving it in nitric acid to separate out weapons-usable plutonium. This process leaves behind a highly radioactive liquid waste. There are about 270,000 tonnes of spent nuclear waste fuel in storage, much of it at reactor sites. Spent fuel is accumulating at around 12,000 tonnes per year, with around a quarter of that going for reprocessing[33].

The least damaging currently available option for waste is to store it above ground, in dry storage at the site of origin. However, this option also presents major challenges and threats, as was seen in the Fukushima accident where the cooling of the spent nuclear fuel pools posed major problems. The only real solution is to stop producing the waste.

8.4.3 nuclear proliferation

Manufacturing a nuclear bomb requires fissile material - either uranium-235 or plutonium-239. Most nuclear reactors use uranium as a fuel and produce plutonium during their operation. It is impossible to adequately prevent the diversion of plutonium to nuclear weapons. A small-scale plutonium separation plant can be built in four to six months, so any country with an ordinary reactor can produce nuclear weapons relatively quickly.

The result is that nuclear power and nuclear weapons have grown up like Siamese twins. Since international controls on nuclear proliferation began, Israel, India, Pakistan and North Korea have all obtained nuclear weapons, demonstrating the link between civil and military nuclear power. Both the International Atomic Energy Agency (IAEA) and the Nuclear Non-proliferation Treaty (NPT) embody an inherent contradiction - seeking to promote the development of 'peaceful' nuclear power whilst at the same time trying to stop the spread of nuclear weapons.

Israel, India and Pakistan all used their civil nuclear operations to develop weapons capability, operating outside international safeguards. North Korea developed a nuclear weapon even as a signatory of the NPT. A major challenge to nuclear proliferation controls has been the spread of uranium enrichment technology to Iran, Libya and North Korea. The former Director General of the International Atomic Energy Agency, Mohamed ElBaradei, has said that "should a state with a fully developed fuel-cycle capability decide, for whatever reason, to break away from its non-proliferation commitments, most experts believe it could produce a nuclear weapon within a matter of months"[34].

The United Nations Intergovernmental Panel on Climate Change has also warned that the security threat of trying to tackle climate change with a global fast reactor programme (using plutonium fuel) "would be colossal"[35]. All of the reactor designs currently being promoted around the world could be fuelled by MOX (mixed oxide fuel), from which plutonium can be easily separated.

Restricting the production of fissile material to a few 'trusted' countries will not work. It will engender resentment and create a colossal security threat. A new UN agency is needed to tackle the twin threats of climate change and nuclear proliferation by phasing out nuclear power and promoting sustainable energy, in the process promoting world peace rather than threatening it.

"despite the rhetoric of a 'nuclear-renaissance', the industry is struggling with a massive increase in costs and construction delays as well as safety and security problems."

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34 MOHAMED ELBARADEI, 'TOWARDS A SAFER WORLD', ECONOMIST, 18 OCTOBER 2003.
35 IPCC WORKING GROUP II, 'IMPACTS, ADAPTATIONS AND MITIGATION OF CLIMATE CHANGE: SCIENTIFIC-TECHNICAL ANALYSES', 1995.

image NUCLEAR REACTOR IN LIANYUNGANG, CHINA.

figure 8.1: the nuclear fuel chain

U#92

1. uranium mining

Uranium, used in nuclear power plants, is extracted from mines in a handful of countries. Over 90% of supply comes from just seven countries: Canada, Kazakhstan, Australia, Namibia, Russia, Niger and Uzbekistan. Mine workers breathe in radioactive gas from which they are in danger of contracting lung cancer. Uranium mining produces huge quantities of mining debris, including radioactive particles that can contaminate surface water and food.

2. uranium enrichment

Natural uranium and concentrated 'yellow cake' contain just 0.7% of the fissionable uranium isotope 235. To be suitable for use in most nuclear reactors, its share must go up to 3 or 5% via enrichment. This process can be carried out in 16 facilities around the world. 80% of the total volume is rejected as 'tails', a waste product. Enrichment generates massive amounts of 'depleted uranium' that ends up as long-lived radioactive waste or is used in weapons or as tank shielding.

3. fuel rod – production

Enriched material is converted into uranium dioxide and compressed to pellets in fuel rod production facilities. These pellets fill 4 metre long tubes called fuel rods. There are 29 fuel rod production facilities globally. The worst accident in this type of facility happened in September 1999 in Tokaimura, Japan, when two workers died. Several hundred workers and villagers were also exposed to radiation.

4. power plant operation

Uranium nuclei are split in a nuclear reactor, releasing energy which heats up water. The compressed steam is converted in a turbine generator into electricity. This process creates a radioactive 'cocktail' which involves more than 100 products. One of these is the highly toxic and long-lasting plutonium. Radioactive material can enter the environment through accidents at nuclear power plants. The worst accidents to date happened at Chernobyl in 1986 and Fukushima in 2011. A typical nuclear reactor generates enough plutonium every year for the production of 40 nuclear weapons.

5. reprocessing

Reprocessing involves the chemical extraction of contaminated uranium and plutonium from used reactor fuel rods. There are now over 230,000 kilograms of plutonium stockpiled around the world from reprocessing – five kilograms is sufficient for one nuclear bomb. Reprocessing is not the same as recycling: the volume of waste increases many tens of times and millions of litres of radioactive waste are discharged into the sea and air each day. The process also demands the transport of radioactive material and nuclear waste by ship, rail, air and road around the world. An accident or terrorist attack could release vast quantities of nuclear material into the environment. There is no way to guarantee the safety of nuclear transport.

6. waste storage

There is not a single final storage facility for highly radioactive nuclear waste available anywhere in the world. Safe secure storage of high level waste over thousands of years remains unproven, leaving a deadly legacy for future generations. Despite this the nuclear industry continues to generate more and more waste each day.

energy resources & security of supply

GLOBAL | OIL | GAS | COAL | NUCLEAR | RENEWABLE ENERGY

9

AROUND 80% OF GLOBAL ENERGY DEMAND IS MET BY FINITE FOSSIL FUELS. © R. KASPRZAK/DREAMSTIME

"the issue of security of supply is now at the top of the energy policy agenda."

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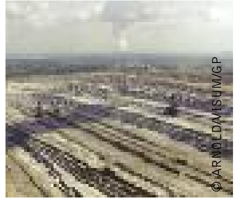
image BROWN COAL SURFACE MINING IN HAMBACH, GERMANY. GIANT COAL EXCAVATOR AND SPOIL PILE.



The issue of security of supply is now at the top of the energy policy agenda. Concern is focused both on price security and the security of physical supply. At present around 80% of global energy demand is met by fossil fuels. The unrelenting increase in energy demand is matched by the finite nature of these resources. At the same time, the global distribution of oil and gas resources does not match the distribution of demand. Some countries have to rely almost entirely on fossil fuel imports. The maps on the following pages provide an overview of the availability of different fuels and their regional distribution. Information in this chapter is based partly on the report 'Plugging the Gap'[36], as well as information from the International Energy Agency's World Energy Outlook 2008 and 2009 reports.

9.1 oil

Oil is the lifeblood of the modern global economy, as the effects of the supply disruptions of the 1970s made clear. It is the number one source of energy, providing 32% of the world's needs and the fuel employed almost exclusively for essential uses such as transportation. However, a passionate debate has developed over the ability of supply to meet increasing consumption, a debate obscured by poor information and stirred by recent soaring prices.

9.1.1 the reserves chaos

Public data about oil and gas reserves is strikingly inconsistent, and potentially unreliable for legal, commercial, historical and sometimes political reasons. The most widely available and quoted figures, those from the industry journals *Oil & Gas Journal and World Oil*, have limited value as they report the reserve figures provided by companies and governments without analysis or verification. Moreover, as there is no agreed definition of reserves or standard reporting practice, these figures usually stand for different physical and conceptual magnitudes. Confusing terminology - 'proved', 'probable', 'possible', 'recoverable', 'reasonable certainty' - only adds to the problem.

Historically, private oil companies have consistently underestimated their reserves to comply with conservative stock exchange rules and through natural commercial caution. Whenever a discovery was made, only a portion of the geologist's estimate of recoverable resources was reported; subsequent revisions would then increase the reserves from that same oil field over time. National oil companies, mostly represented by OPEC (Organisation of Petroleum Exporting Countries), have taken a very different approach. They are not subject to any sort of accountability and their reporting practices are even less clear. In the late 1980s, the OPEC countries blatantly overstated their reserves while competing for production quotas, which were allocated as a proportion of the reserves. Although some revision was needed after the companies were nationalised, between 1985 and 1990, OPEC countries increased their apparent joint reserves by 82%. Not only were these dubious revisions never corrected, but many of these countries have reported untouched reserves for years, even if no sizeable discoveries were made and production continued at the same pace. Additionally, the Former Soviet Union's oil and gas reserves have been overestimated by about 30% because the original assessments were later misinterpreted.

Whilst private companies are now becoming more realistic about the extent of their resources, the OPEC countries hold by far the majority of the reported reserves, and their information is as unsatisfactory as ever. Their conclusions should therefore be treated with considerable caution. To fairly estimate the world's oil resources a regional assessment of the mean backdated (i.e. 'technical') discoveries would need to be performed.

9.1.2 non-conventional oil reserves

A large share of the world's remaining oil resources is classified as 'non-conventional'. Potential fuel sources such as oil sands, extra heavy oil and oil shale are generally more costly to exploit and their recovery involves enormous environmental damage. The reserves of oil sands and extra heavy oil in existence worldwide are estimated to amount to around 6 trillion barrels, of which between 1 and 2 trillion barrels are believed to be recoverable if the oil price is high enough and the environmental standards low enough.

One of the worst examples of environmental degradation resulting from the exploitation of unconventional oil reserves is the oil sands that lie beneath the Canadian province of Alberta and form the world's second-largest proven oil reserves after Saudi Arabia. Producing crude oil from these 'tar sands' - a heavy mixture of bitumen, water, sand and clay found beneath more than 54,000 square miles[37] of prime forest in northern Alberta, an area the size of England and Wales - generates up to four times more carbon dioxide, the principal global warming gas, than conventional drilling. The booming oil sands industry will produce 100 million tonnes of CO_2 a year (equivalent to a fifth of the UK's entire annual emissions) by 2012, ensuring that Canada will miss its emission targets under the Kyoto treaty. The oil rush is also scarring a wilderness landscape: millions of tonnes of plant life and top soil are scooped away in vast opencast mines and millions of litres of water diverted from rivers. Up to five barrels of water are needed to produce a single barrel of crude and the process requires huge amounts of natural gas. It takes two tonnes of the raw sands to produce a single barrel of oil.

9.2 gas

Natural gas has been the fastest growing fossil energy source over the last two decades, boosted by its increasing share in the electricity generation mix. Gas is generally regarded as an abundant resource and public concerns about depletion are limited to oil, even though few in-depth studies address the subject. Gas resources are more concentrated, and a few massive fields make up most of the reserves. The largest gas field in the world holds 15% of the Ultimate Recoverable Resources (URR), compared to 6% for oil. Unfortunately, information about gas resources suffers from the same bad practices as oil data because gas mostly comes from the same geological formations, and the same stakeholders are involved.

36 'PLUGGING THE GAP - A SURVEY OF WORLD FUEL RESOURCES AND THEIR IMPACT ON THE DEVELOPMENT OF WIND ENERGY', GLOBAL WIND ENERGY COUNCIL/RENEWABLE ENERGY SYSTEMS, 2006.
37 *THE INDEPENDENT*, 10 DECEMBER 2007

Most reserves are initially understated and then gradually revised upwards, giving an optimistic impression of growth. By contrast, Russia's reserves, the largest in the world, are considered to have been overestimated by about 30%. Owing to geological similarities, gas follows the same depletion dynamic as oil, and thus the same discovery and production cycles. In fact, existing data for gas is of worse quality than for oil, with ambiguities arising over the amount produced, partly because flared and vented gas is not always accounted for. As opposed to published reserves, the technical reserves have been almost constant since 1980 because discoveries have roughly matched production.

9.2.1 shale gas[38]

Natural gas production, especially in the United States, has recently involved a growing contribution from non-conventional gas supplies such as shale gas. Conventional natural gas deposits have a well-defined geographical area, the reservoirs are porous and permeable, the gas is produced easily through a wellbore and does not generally require artificial stimulation. Non-conventional deposits, on the other hand, are often lower in resource concentration, more dispersed over large areas and require well stimulation or some other extraction or conversion technology. They are also usually more expensive to develop per unit of energy.

Research and investment in non-conventional gas resources has increased significantly in recent years due to the rising price of conventional natural gas. In some areas the technologies for economic production have already been developed, in others it is still at the research stage. Extracting shale gas, however, usually goes hand in hand with environmentally hazardous processes. Hydraulic fracturing, also called "fracking", is proposed as one of the processes to exploit shale gas reserves. This extraction method poses a threat to ground and surface water, bringing a significant risk of contamination. Also, fracking uses huge volumes of water.

table 9.1: overview of fossil fuel reserves and resources

RESERVES, RESOURCES AND ADDITIONAL OCCURRENCES OF FOSSIL ENERGY CARRIERS ACCORDING TO DIFFERENT AUTHORS. **C** CONVENTIONAL (PETROLEUM WITH A CERTAIN DENSITY, FREE NATURAL GAS, PETROLEUM GAS, **NC** NON-CONVENTIONAL) HEAVY FUEL OIL, VERY HEAVY OILS, TAR SANDS AND OIL SHALE, GAS IN COAL SEAMS, AQUIFER GAS, NATURAL GAS IN TIGHT FORMATIONS, GAS HYDRATES). THE PRESENCE OF ADDITIONAL OCCURRENCES IS ASSUMED BASED ON GEOLOGICAL CONDITIONS, BUT THEIR POTENTIAL FOR ECONOMIC RECOVERY IS CURRENTLY VERY UNCERTAIN. IN COMPARISON: IN 1998, THE GLOBAL PRIMARY ENERGY DEMAND WAS 402EJ (UNDP ET AL., 2000).

ENERGY CARRIER		WEO 2009, WEO 2008, WEO 2007 EJ	BROWN, 2002 EJ	IEA, 2002c EJ		IPCC, 2001a EJ		NAKICENOVIC ET AL., 2000 EJ		UNDP ET AL., 2000 EJ		BGR, 1998 EJ
Gas	reserves	182 tcm[a]	5,600	6,200	c	5,400	c	5,900	c	5,500	c	5,300
					nc	8,000	nc	8,000	nc	9,400	nc	100
	resources	405 tcm[a]	9,400	11,100	c	11,700	c	11,700	c	11,100	c	7,800
					nc	10,800	nc	10,800	nc	23,800	nc[d]	111,900
	additional occurrences	921 tcm[a]				796,000		799,700		930,000		
Oil	reserves	2,369 bb[b]	5,800	5,700	c	5,900	c	6,300	c	6,000	c	6,700
					nc	6,600	nc	8,100	nc	5,100	nc	5,900
	resources		10,200	13,400	c	7,500	c	6,100	c	6,100	c	3,300
					nc	15,500	nc	13,900	nc	15,200	nc	25,200
	additional occurrences					61,000		79,500		45,000		
Coal	reserves	847 bill tonnes[c]	23,600	22,500		42,000		25,400		20,700		16,300
	resources		26,000	165,000		100,000		117,000		179,000		179,000
	additional occurrences	921 tcm[c]				121,000		125,600				
Total resource (reserves + resources)			**180,600**	**223,900**		**212,200**		**213,200**		**281,900**		**361,500**
Total occurrence						**1,204,200**		**1,218,000**		**1,256,000**		

sources & notes A) WEO 2009, B) OIL WEO 2008, PAGE 205 TABLE 9.1
C) IEA WEO 2008, PAGE 127 & WEC 2007. D) INCLUDING GAS HYDRATES.
SEE TABLE FOR ALL OTHER SOURCES.

38 INTERSTATE NATURAL GAS ASSOCIATION OF AMERICA (INGAA), "AVAILABILITY, ECONOMICS AND PRODUCTION POTENTIAL OF NORTH AMERICAN UNCONVENTIONAL NATURAL GAS SUPPLIES", NOVEMBER 2008.

image PLATFORM OIL RIG DUNLIN IN THE NORTH SEA SHOWING OIL POLLUTION.

image ON A LINFEN STREET, TWO MEN LOAD UP A CART WITH COAL THAT WILL BE USED FOR COOKING. LINFEN, A CITY OF ABOUT 4.3 MILLION, IS ONE OF THE MOST POLLUTED CITIES IN THE WORLD. CHINA'S INCREASINGLY POLLUTED ENVIRONMENT IS LARGELY A RESULT OF THE COUNTRY'S RAPID DEVELOPMENT AND CONSEQUENTLY A LARGE INCREASE IN PRIMARY ENERGY CONSUMPTION, WHICH IS ALMOST ENTIRELY PRODUCED BY BURNING COAL.

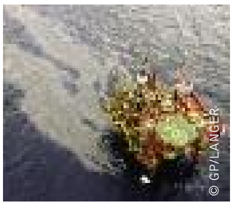


table 9.2: assumptions on fossil fuel use in the three scenarios

Oil	2007	2015	2020	2030	2040	2050
Reference [PJ]	155,920	161,847	170,164	192,431	209,056	224,983
Reference [million barrels]	25,477	26,446	27,805	31,443	34,159	36,762
E[R] [PJ]		153,267	143,599	123,756	101,186	81,833
E[R] [million barrels]		25,044	23,464	20,222	16,534	13,371
Adv E[R] [PJ]		152,857	142,747	115,002	81,608	51,770
Adv E[R] [million barrels]		24,977	23,325	18,791	13,335	8,459
Gas	2007	2015	2020	2030	2040	2050
Reference [PJ]	104,845	112,931	121,148	141,706	155,015	166,487
Reference [billion cubic metres = 10E9m³]	2,759	2,972	3,188	3,729	4,079	4,381
E[R] [PJ]		116,974	121,646	122,337	99,450	71,383
E[R] [billion cubic metres = 10E9m³]		3,078	3,201	3,219	2,617	1,878
Adv E[R] [PJ]		118,449	119,675	114,122	79,547	34,285
Adv E[R] [billion cubic metres = 10E9m³]		3,117	3,149	3,003	2,093	902
Coal	2007	2015	2020	2030	2040	2050
Reference [PJ]	135,890	162,859	162,859	204,231	217,356	225,245
Reference [million tonnes]	7,319	8,306	8,306	9,882	10,408	10,751
E[R] [PJ]		140,862	140,862	96,846	64,285	37,563
E[R] [million tonnes]		7,217	7,217	4,407	2,810	1,631
Adv E[R] [PJ]		135,005	135,005	69,871	28,652	7,501
Adv E[R] [million tonnes]		6,829	6,829	3,126	1,250	326

9.3 coal

Coal was the world's largest source of primary energy until it was overtaken by oil in the 1960s. Today, coal supplies almost one quarter of the world's energy. Despite being the most abundant of fossil fuels, coal's development is currently threatened by environmental concerns; hence its future will unfold in the context of both energy security and global warming.

Coal is abundant and more equally distributed throughout the world than oil and gas. Global recoverable reserves are the largest of all fossil fuels, and most countries have at least some coal. Moreover, existing and prospective big energy consumers like the US, China and India are self-sufficient in coal and will be for the foreseeable future. Coal has been exploited on a large scale for two centuries, so both the product and the available resources are well known; no substantial new deposits are expected to be discovered. Extrapolating the demand forecast forward, the world will consume 20% of its current reserves by 2030 and 40% by 2050. Hence, if current trends are maintained, coal would still last several hundred years.

9.4 nuclear

Uranium, the fuel used in nuclear power plants, is a finite resource whose economically available reserves are limited. Its distribution is almost as concentrated as oil and does not match global consumption. Five countries - Canada, Australia, Kazakhstan, Russia and Niger - control three quarters of the world's supply. As a significant user of uranium, however, Russia's reserves will be exhausted within ten years.

Secondary sources, such as old deposits, currently make up nearly half of worldwide uranium reserves. These will soon be used up, however. Mining capacities will have to be nearly doubled in the next few years to meet current needs.

A joint report by the OECD Nuclear Energy Agency and the International Atomic Energy Agency[39] estimates that all existing nuclear power plants will have used up their nuclear fuel, employing current technology, within less than 70 years. Given the range of scenarios for the worldwide development of nuclear power, it is likely that uranium supplies will be exhausted sometime between 2026 and 2070. This forecast includes the use of mixed oxide fuel (MOX), a mixture of uranium and plutonium.

39 'URANIUM 2003: RESOURCES, PRODUCTION AND DEMAND'

map 9.1: oil reference scenario and the advanced energy [r]evolution scenario

WORLDWIDE SCENARIO

OECD NORTH AMERICA

		REF		E[R]	
		TMB	%	TMB	%
Reserves total	2007	69.3	5.6%	69.3	5.6%
		MB	PJ	MB	PJ
Consumption per region	2007	7,429H	45,466H	7,429H	45,466H
	2050	6,594H	40,352H	1,225	7,494
		L		L	
Consumption per person	2007	2,707H		2,707H	
	2050	1,816H		337	

LATIN AMERICA

		REF		E[R]	
		TMB	%	TMB	%
Reserves total	2007	111.2	9.0%	111.2	9.0%
		MB	PJ	MB	PJ
Consumption per region	2007	1,691	10,349	1,691	10,349
	2050	2,597	15,895	292	1,788
		L		L	
Consumption per person	2007	598		598	
	2050	653		73	

NON RENEWABLE RESOURCE

OIL

LEGEND

>60 | 50-60 | 40-50 | 30-40 | 20-30 | 10-20 | 5-10 | 0-5 — % RESOURCES GLOBALLY

REF — REFERENCE SCENARIO

E[R] — ADVANCED ENERGY [R]EVOLUTION SCENARIO

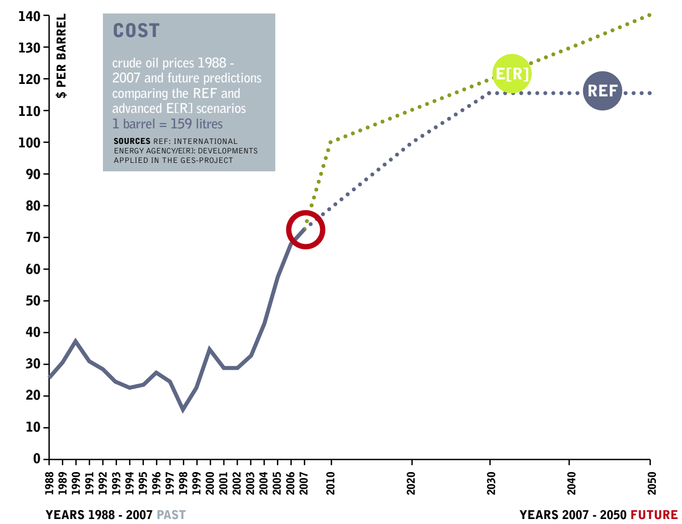
0 — 1000 KM

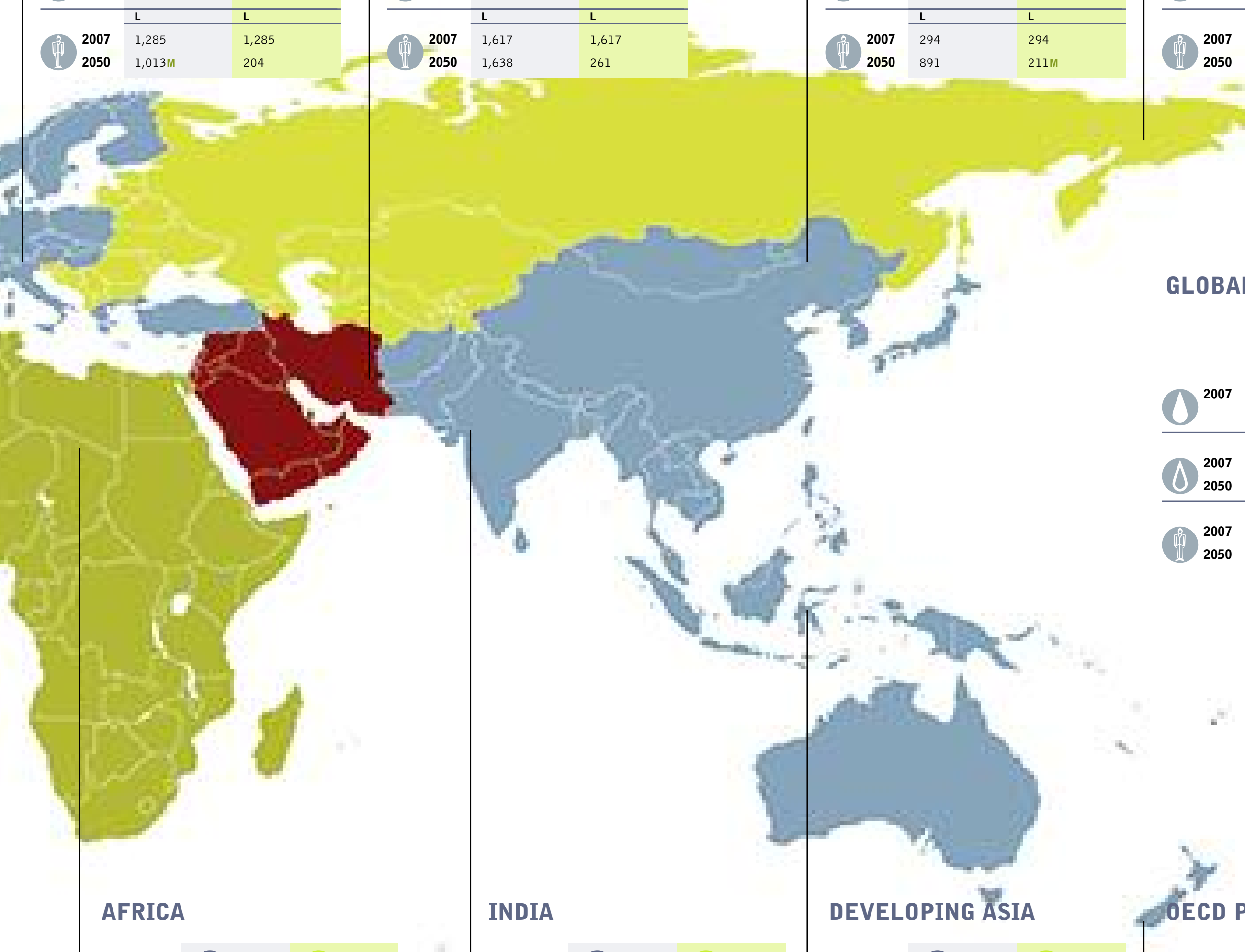
RESERVES TOTAL THOUSAND MILLION BARRELS [TMB] | SHARE IN % OF GLOBAL TOTAL [END OF 2007]

CONSUMPTION PER REGION MILLION BARRELS [MB] | PETA JOULE [PJ]

CONSUMPTION PER PERSON LITERS [L]

H HIGHEST | M MIDDLE | L LOWEST





OECD EUROPE

	REF TMB	REF %	E[R] TMB	E[R] %
2007	16.9	1.4%M	16.9	1.4%M
	MB	PJ	MB	PJ
2007	4,337	26,541	4,337	4,418
2050	3,590M	21,970M	722M	9,361M
	L		L	
2007	1,285		1,285	
2050	1,013M		204	

MIDDLE EAST

	REF TMB	REF %	E[R] TMB	E[R] %
2007	755.3H	61.0%H	755.3H	61.0%H
	MB	PJ	MB	PJ
2007	1,913	11,709	1,913	11,709
2050	3,574	21,871	569	3,482
	L		L	
2007	1,617		1,617	
2050	1,638		261	

CHINA

	REF TMB	REF %	E[R] TMB	E[R] %
2007	15.5	1.3%	15.5	1.3%
	MB	PJ	MB	PJ
2007	2,445	14,966	2,445	14,966
2050	7,946	48,629	1,881H	11,513H
	L		L	
2007	294		294	
2050	891		211M	

TRANSITION ECONOMIES

	REF TMB	REF %	E[R] TMB	E[R] %
2007	87.6	10.1%L	87.6	10.1%L
	MB	PJ	MB	PJ
2007	1,605	9,826	1,605	9,826
2050	1,953L	11,955L	441L	2,701L
	L		L	
2007	748M		748M	
2050	1,057		239	

GLOBAL

	REF TMB	REF %	E[R] TMB	E[R] %
2007	1,199	100%	1,199	100%
	MB	PJ	MB	PJ
2007	25,477	155,919	25,477	155,919
2050	36,762	224,981	8,459	51,770
	L		L	
2007	623		623	
2050	637		147	

AFRICA

	REF TMB	REF %	E[R] TMB	E[R] %
2007	117.5M	9.5%	117.5M	9.5%
	MB	PJ	MB	PJ
2007	924	5,654	924	5,654
2050	1,667	10,202	689	4,214
	L		L	
2007	159		159	
2050	133L		55L	

INDIA

	REF TMB	REF %	E[R] TMB	E[R] %
2007	5.5	0.5%	5.5	0.5%
	MB	PJ	MB	PJ
2007	1,011L	6,187L	1,011	6,187
2050	3,669	22,455	1,169	7,152
	L		L	
2007	142L		142L	
2050	352		112	

DEVELOPING ASIA

	REF TMB	REF %	E[R] TMB	E[R] %
2007	14.8	1.2%	14.8	1.2%
	MB	PJ	MB	PJ
2007	1,656	10,136	1,656	10,136
2050	3,448	21,099	1,014	6,204
	L		L	
2007	270		270	
2050	365		107	

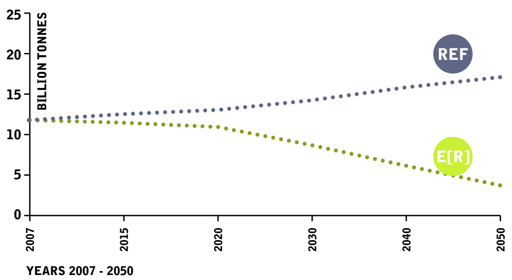
OECD PACIFIC

	REF TMB	REF %	E[R] TMB	E[R] %
2007	5.1L	0.4%	5.1L	0.4%
	MB	PJ	MB	PJ
2007	2,465M	15,089M	2,465	15,086
2050	1,724	10,552	458	2,805
	L		L	
2007	1,958		1,958	
2050	1,539		409H	

CO_2 EMISSIONS FROM OIL

comparison between the REF and advanced E[R] scenarios 2007 - 2050 billion tonnes

SOURCE GPI/EREC



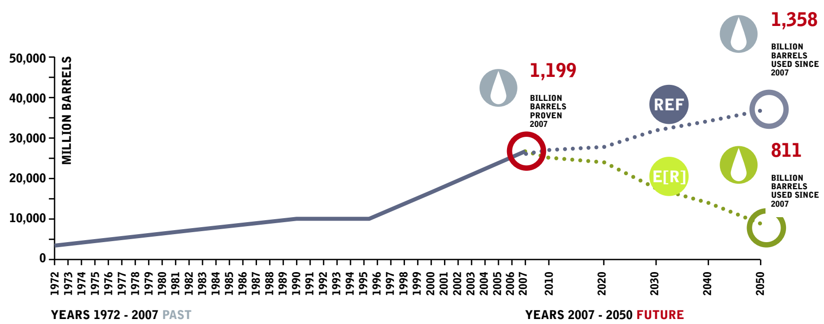
RESERVES AND CONSUMPTION

oil reserves versus global demand, production and consumption. global consumption comparison between the REF and advanced E[R] scenarios.

million barrels. 1 barrel = 159 litres

SOURCE BP 2008

REF global consumption
ADV E[R] global consumption



map 9.2: gas reference scenario and the advanced energy [r]evolution scenario

WORLDWIDE SCENARIO

OECD NORTH AMERICA

	REF		E[R]	
	tn m³	%	tn m³	%
2007	8.0	4.4%	8.0	4.4%
	bn m³	PJ	bn m³	PJ
2007	722H	27,435H	722H	27,435H
2050	767H	29,144H	71H	2,688H
	m³		m³	
2007	1,608		1,608	
2050	1,328		123	

LATIN AMERICA

	REF		E[R]	
	tn m³	%	tn m³	%
2007	7.7	4.3%	7.7	4.3%
	bn m³	PJ	bn m³	PJ
2007	117	4,465	117	4,465
2050	246M	9,358M	34	1,303
	m³		m³	
2007	254		254	
2050	410		57	

NON RENEWABLE RESOURCE

GAS

LEGEND

>50 | 40-50 | 30-40 | 20-30 | 10-20 | 5-10 | 0-5 % RESOURCES GLOBALLY

REF REFERENCE SCENARIO

E[R] ADVANCED ENERGY [R]EVOLUTION SCENARIO

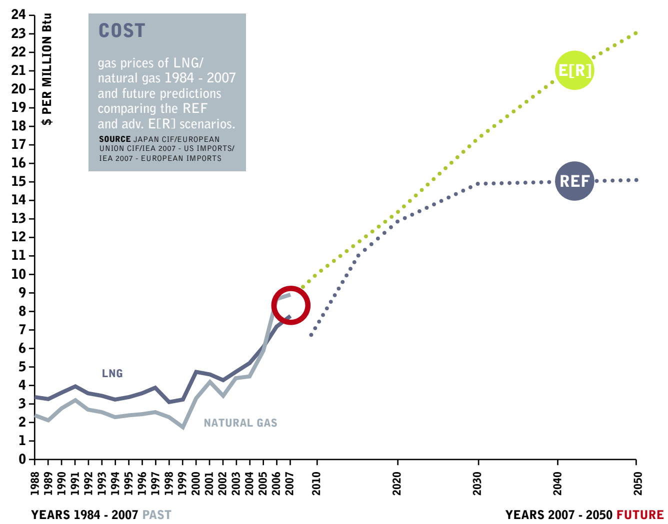
0 1000 KM

RESERVES TOTAL TRILLION CUBIC METRES [tn m³] | SHARE IN % OF GLOBAL TOTAL [END OF 2007]

CONSUMPTION PER REGION BILLION CUBIC METRES [bn m³] | PETA JOULE [PJ]

CONSUMPTION PER PERSON CUBIC METRES [m³]

H HIGHEST | **M** MIDDLE | **L** LOWEST



OECD EUROPE

		REF		E[R]	
		tn m^3	%	tn m^3	%
reserves	2007	9.8	5.4%	9.8	5.4%
		bn m^3	PJ	bn m^3	PJ
production	2007	504	19,170	504	19,170
	2050	644	24,469	69	2,613
		m^3		m^3	
per person	2007	934		934	
	2050	1,120M		120	

MIDDLE EAST

		REF		E[R]	
		tn m^3	%	tn m^3	%
reserves	2007	73.2H	40.4%H	73.2H	40.4%H
		bn m^3	PJ	bn m^3	PJ
production	2007	238M	9,056M	239	9,056
	2050	685	26,034	74	2,805
		m^3		m^3	
per person	2007	1,178		1,178	
	2050	1,939		209M	

CHINA

		REF		E[R]	
		tn m^3	%	tn m^3	%
reserves	2007	1.9	1.0%	1.9	1.0%
		bn m^3	PJ	bn m^3	PJ
production	2007	71	2,716	71	2,716
	2050	341	12,953	212	8,061
		m^3		m^3	
per person	2007	54		54	
	2050	239		149	

TRANSITION ECONOMIES

		REF		E[R]	
		tn m^3	%	tn m^3	%
reserves	2007	53.3	29.4%	53.3	29.4%
		bn m^3	PJ	bn m^3	PJ
production	2007	638	24,225	638	24,225
	2050	776	29,478	138	5,248
		m^3		m^3	
per person	2007	1,874H		1,874H	
	2050	2,496H		444H	

GLOBAL

		REF		E[R]	
		tn m^3	%	tn m^3	%
reserves	2007	181	100%	181	100%
		bn m^3	PJ	bn m^3	PJ
production	2007	2,759	104,846	2,759	104,846
	2050	4,381	166,489	902	34,285
		m^3		m^3	
per person	2007	424		424	
	2050	478		99	

AFRICA

		REF		E[R]	
		tn m^3	%	tn m^3	%
reserves	2007	14.6M	8.0%M	14.6M	8.0%M
		bn m^3	PJ	bn m^3	PJ
production	2007	91	3,472	91	3,472
	2050	167	6,338	65	2,456
		m^3		m^3	
per person	2007	95		95	
	2050	83		32L	

INDIA

		REF		E[R]	
		tn m^3	%	tn m^3	%
reserves	2007	1.1L	0.6%L	1.1L	0.6%L
		bn m^3	PJ	bn m^3	PJ
production	2007	37L	1,397L	37L	1,397L
	2050	164L	6,227L	107M	4,075M
		m^3		m^3	
per person	2007	32L		32L	
	2050	102L		66	

DEVELOPING ASIA

		REF		E[R]	
		tn m^3	%	tn m^3	%
reserves	2007	8.6	4.8%	8.6	4.8%
		bn m^3	PJ	bn m^3	PJ
production	2007	184	6,998	184	6,998
	2050	422	16,020	115	4,368
		m^3		m^3	
per person	2007	182		182	
	2050	278		76	

OECD PACIFIC

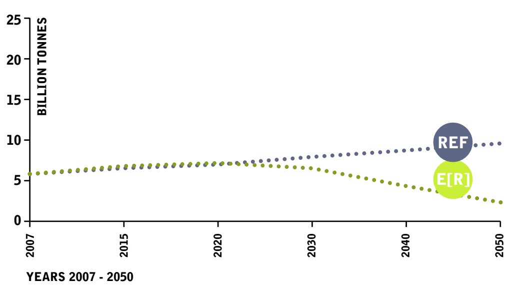
		REF		E[R]	
		tn m^3	%	tn m^3	%
reserves	2007	2.9	1.6%	2.9	1.6%
		bn m^3	PJ	bn m^3	PJ
production	2007	156	5,912	156	5,912
	2050	170	6,467	18L	667L
		m^3		m^3	
per person	2007	776M		776M	
	2050	946		98	

CO_2 EMISSIONS FROM GAS

comparison between the REF and adv. E[R] scenarios 2007 - 2050

billion tonnes

SOURCE GPI/EREC



RESERVES AND CONSUMPTION

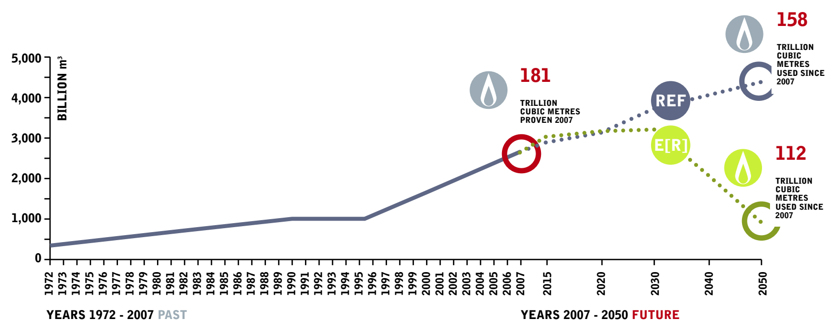
gas reserves versus global demand, production and consumption. global consumption comparison between the REF and advanced E[R] scenarios.

billion cubic metres

SOURCE 1970-2008 BP, 2007-2050 GPI/EREC

REF global consumption

ADV E[R] global consumption



GREENPEACE

DESIGN WWW.ONEHEMISPHERE.SE **CONCEPT** SVEN TESKE/GREENPEACE INTERNATIONAL.

map 9.3: coal reference scenario and the advanced energy [r]evolution scenario

WORLDWIDE SCENARIO

OECD NORTH AMERICA

		REF		E[R]	
		mn t	%	mn t	%
Reserves total	2007	250,510	29.6%	250,510	29.6%
		mn t	PJ	mn t	PJ
Consumption per region	2007	1,882	24,923	1,882	24,923
	2050	1,351	27,255	6	134
		t		t	
Consumption per person	2007	2.4		2.4	
	2050	2.0		0.0	

LATIN AMERICA

		REF		E[R]	
		mn t	%	mn t	%
Reserves total	2007	16,276	1.9%	16,276	1.9%
		mn t	PJ	mn t	PJ
Consumption per region	2007	45	891	45	891
	2050	165	3,122	11	247
		t		t	
Consumption per person	2007	0.1		0.1	
	2050	0.2		0.0	

NON RENEWABLE RESOURCE

COAL

LEGEND

>60 | 50-60 | 40-50 | 30-40 | 20-30 | 10-20 | 5-10 | 0-5 — % RESOURCES GLOBALLY

REF REFERENCE SCENARIO

E[R] ADVANCED ENERGY [R]EVOLUTION SCENARIO

0 — 1000 KM

RESERVES TOTAL MILLION TONNES [mn t] | SHARE IN % OF GLOBAL TOTAL [END OF 2007]

CONSUMPTION PER REGION MILLION TONNES [mn t] | PETA JOULE [PJ]

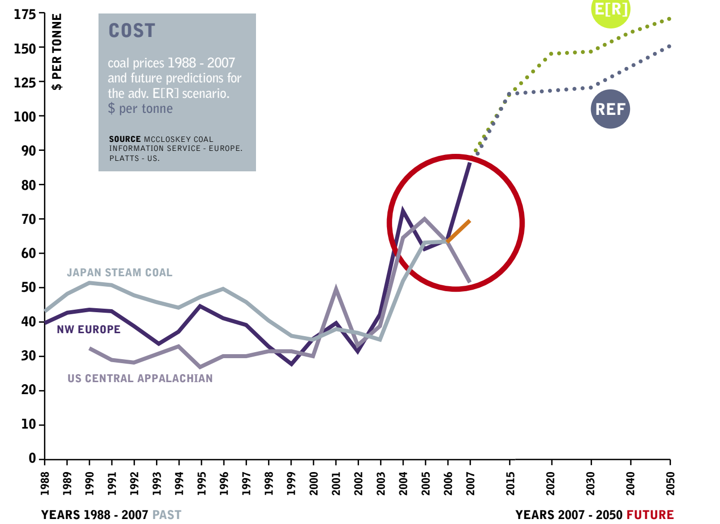
CONSUMPTION PER PERSON TONNES [t]

H HIGHEST | **M** MIDDLE | **L** LOWEST

COST

coal prices 1988 - 2007 and future predictions for the adv. E[R] scenario.
$ per tonne

SOURCE MCCLOSKEY COAL INFORMATION SERVICE - EUROPE. PLATTS - US.



OECD EUROPE

	Year	REF mn t	REF %	E[R] mn t	E[R] %
Reserves	2007	50,063	5.9%	50,063	5.9%
		mn t	**PJ**	**mn t**	**PJ**
Production	2007	897	14,371	897	14,371
	2050	710	11,899	10	231
		t		**t**	
Per capita	2007	1.2		1.2	
	2050	0.9		0.0	

MIDDLE EAST

	Year	REF mn t	REF %	E[R] mn t	E[R] %
Reserves	2007	1,386	0.2%L	1,386	0.2%L
		mn t	**PJ**	**mn t**	**PJ**
Production	2007	19L	437L	19	437
	2050	91L	2,092L	1L	13
		t		**t**	
Per capita	2007	0.0L		0.0	
	2050	0.2L		0.0	

CHINA

	Year	REF mn t	REF %	E[R] mn t	E[R] %
Reserves	2007	114,500	13.5%	114,500	13.5%
		mn t	**PJ**	**mn t**	**PJ**
Production	2007	2,403H	55,333H	2,403	55,333
	2050	4,148H	95,527H	218H	5,027H
		t		**t**	
Per capita	2007	1.8		1.8	
	2050	2.9H		0.2H	

TRANSITION ECONOMIES

	Year	REF mn t	REF %	E[R] mn t	E[R] %
Reserves	2007	222,183	26%	222,183	26%
		mn t	**PJ**	**mn t**	**PJ**
Production	2007	532	9,003	532	9,003
	2050	904	13,665	14	327
		t		**t**	
Per capita	2007	1.1		1.1	
	2050	1.9M		0.0	

GLOBAL

	Year	REF mn t	REF %	E[R] mn t	E[R] %
Reserves	2007	846,496	100%	846,496	100%
		mn t	**PJ**	**mn t**	**PJ**
Production	2007	7,319	135,890	7,319	135,890
	2050	10,751	225,244	326	7,501
		t		**t**	
Per capita	2007	0.9		0.9	
	2050	1.1		0.0	

AFRICA

	Year	REF mn t	REF %	E[R] mn t	E[R] %
Reserves	2007	49,605	5.9%	49,605	5.9%
		mn t	**PJ**	**mn t**	**PJ**
Production	2007	188	4,330	188	4,330
	2050	303	6,977	19	427
		t		**t**	
Per capita	2007	0.2		0.2	
	2050	0.2		0.0	

INDIA

	Year	REF mn t	REF %	E[R] mn t	E[R] %
Reserves	2007	56,498	6.7%M	56,498	6.7%M
		mn t	**PJ**	**mn t**	**PJ**
Production	2007	459	10,126	459	10,126
	2050	1,692	36,709	37	851
		t		**t**	
Per capita	2007	0.4		0.4	
	2050	1.0		0.0	

DEVELOPING ASIA

	Year	REF mn t	REF %	E[R] mn t	E[R] %
Reserves	2007	7,814	0.9%	7,814	0.9%
		mn t	**PJ**	**mn t**	**PJ**
Production	2007	330	5,824	330	5,824
	2050	868M	17,902	9	217
		t		**t**	
Per capita	2007	0.3		0.3	
	2050	0.5		0.0	

OECD PACIFIC

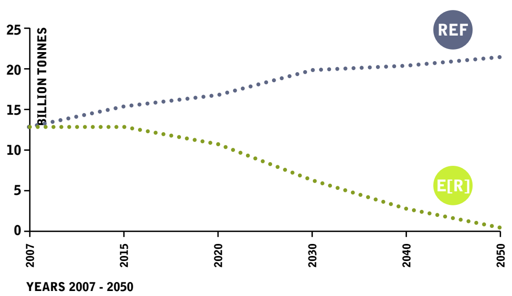
	Year	REF mn t	REF %	E[R] mn t	E[R] %
Reserves	2007	77,661	9%	77,661	9%
		mn t	**PJ**	**mn t**	**PJ**
Production	2007	565	10,652	565	10,652
	2050	518	10,097	1L	27
		t		**t**	
Per capita	2007	2.3		2.3	
	2050	2.4		0.0	

CO_2 EMISSIONS FROM COAL

comparison between the REF and adv. E[R] scenarios 2007 - 2050

billion tonnes

SOURCE GPI/EREC

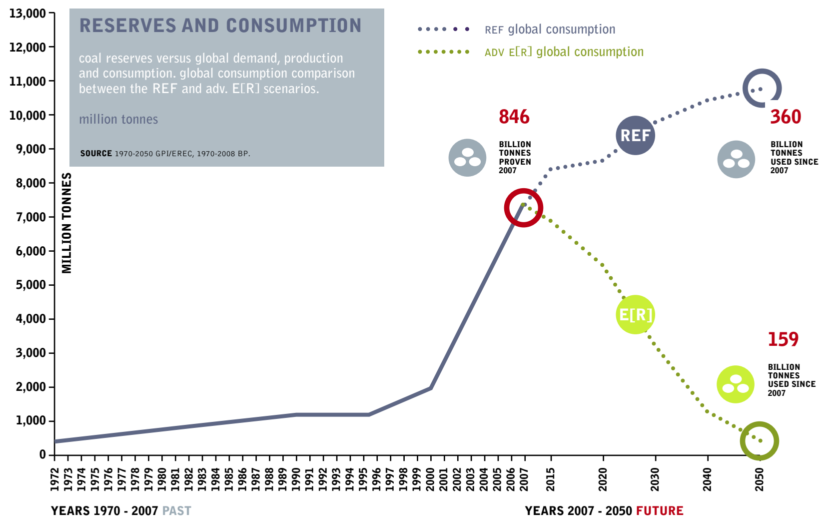


RESERVES AND CONSUMPTION

coal reserves versus global demand, production and consumption. global consumption comparison between the REF and adv. E[R] scenarios.

million tonnes

SOURCE 1970-2050 GPI/EREC, 1970-2008 BP.



map 9.4: nuclear reference scenario and the advanced energy [r]evolution scenario

WORLDWIDE SCENARIO

NON RENEWABLE RESOURCE

NUCLEAR

OECD NORTH AMERICA

		REF		E[R]	
		t	%	t	%
Reserves total	2007	680,109	**21.5%**	680,109	**21.5%**
		TWh		TWh	
Generation per region	2007	941H		NUCLEAR POWER PHASED OUT BY 2040	
	2050	1,259H			
		PJ		PJ	
Consumption per region	2007	10,260H		10,260H	
	2050	13,735H		0	
		kWh		kWh	
Consumption per person	2007	2,094H		2,094H	
	2050	2,181		0	

LATIN AMERICA

		REF		E[R]	
		t	%	t	%
Reserves total	2007	95,045	**3%**	95,045	**3%**
		TWh		TWh	
Generation per region	2007	20		PHASED OUT BY 2030	
	2050	60			
		PJ		PJ	
Consumption per region	2007	214		214	
	2050	655		0	
		kWh		kWh	
Consumption per person	2007	42		42	
	2050	100		0	

LEGEND

>30 | 20-30 | 10-20 | 5-10 | 0-5 % RESOURCES GLOBALLY

REF REFERENCE SCENARIO

E[R] ADVANCED ENERGY [R]EVOLUTION SCENARIO

0 1000 KM

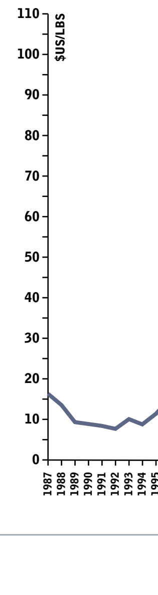
RESERVES TOTAL TONNES | SHARE IN % OF GLOBAL TOTAL [END OF 2007]

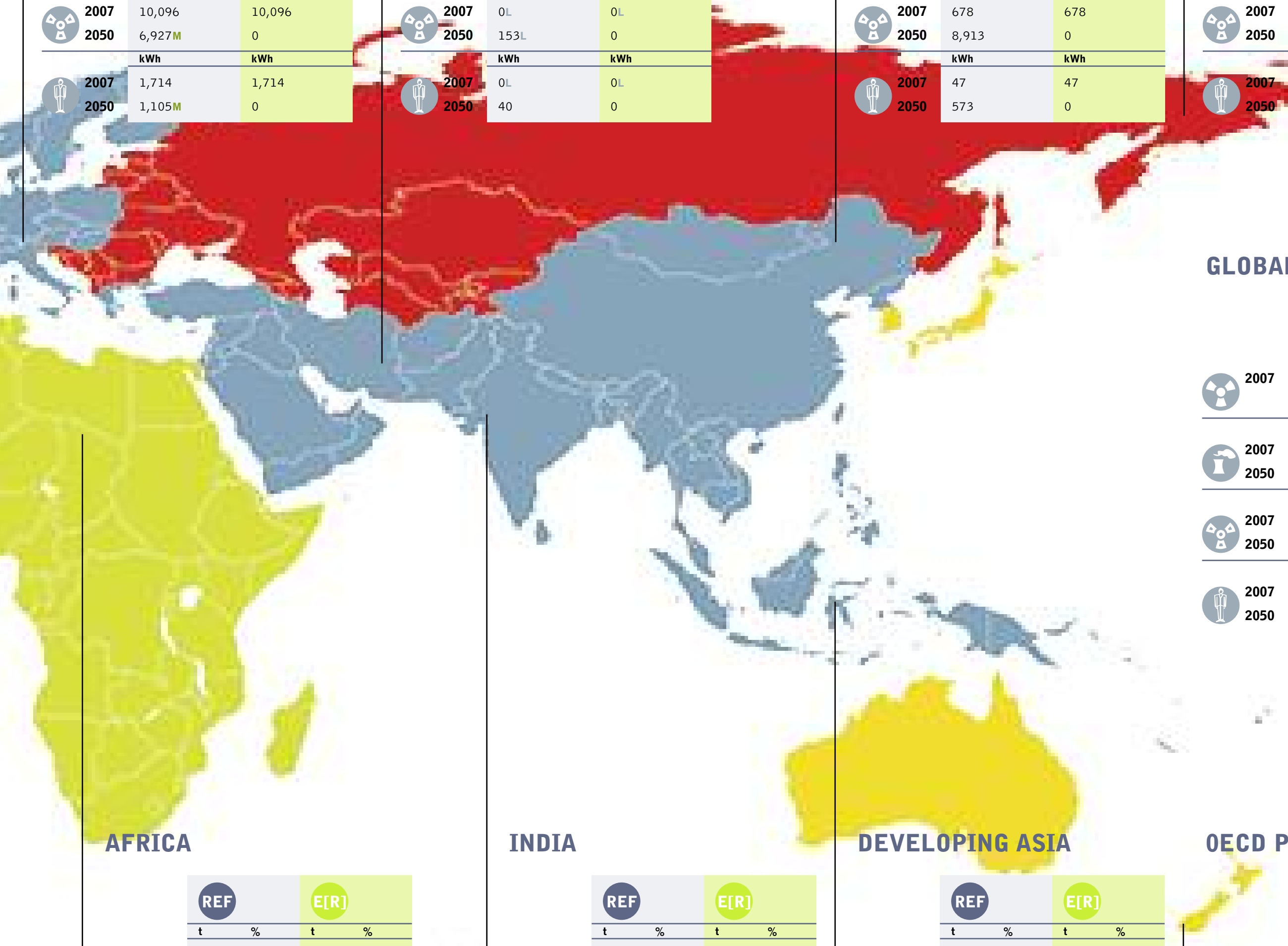
GENERATION PER REGION TERAWATT HOURS [TWh]

CONSUMPTION PER REGION PETA JOULE [PJ]

CONSUMPTION PER PERSON KILOWATT HOURS [kWh]

H HIGHEST | M MIDDLE | L LOWEST





OECD EUROPE

Year	REF t	REF %	E[R] t	E[R] %
2007	56,445	1.8%	56,445	1.8%
	TWh		**TWh**	
2007	925		PHASED OUT BY 2030	
2050	635M			
	PJ		**PJ**	
2007	10,096		10,096	
2050	6,927M		0	
	kWh		**kWh**	
2007	1,714		1,714	
2050	1,105M		0	

MIDDLE EAST

Year	REF t	REF %	E[R] t	E[R] %
2007	370L	0%L	370L	0%L
	TWh		**TWh**	
2007	0L		NO NUCLEAR ENERGY DEVELOPMENT	
2050	14L			
	PJ		**PJ**	
2007	0L		0L	
2050	153L		0	
	kWh		**kWh**	
2007	0L		0L	
2050	40		0	

CHINA

Year	REF t	REF %	E[R] t	E[R] %
2007	35,060	1.1%	35,060	1.1%
	TWh		**TWh**	
2007	62		NUCLEAR POWER PHASED OUT BY 2045	
2050	817			
	PJ		**PJ**	
2007	678		678	
2050	8,913		0	
	kWh		**kWh**	
2007	47		47	
2050	573		0	

TRANSITION ECONOMIES

Year	REF t	REF %	E[R] t	E[R] %
2007	1,043,687H	32.9%H	1,043,687H	32.9%H
	TWh		**TWh**	
2007	293M		NUCLEAR POWER PHASED OUT BY 2045	
2050	463			
	PJ		**PJ**	
2007	3,197M		3,197M	
2050	5,051		0	
	kWh		**kWh**	
2007	861M		861M	
2050	1,490		0	

GLOBAL

Year	REF t	REF %	E[R] t	E[R] %
2007	3,169,238	100%	3,169,238	100%
	TWh		**TWh**	
2007	2,719		NUCLEAR POWER PHASED OUT BY 2045	
2050	4,413			
	PJ		**PJ**	
2007	29,664		29,664	
2050	48,142		0	
	kWh		**kWh**	
2007	418		418	
2050	481		0	

AFRICA

Year	REF t	REF %	E[R] t	E[R] %
2007	470,312M	14.8%M	470,312M	14.8%M
	TWh		**TWh**	
2007	11		NUCLEAR POWER PHASED OUT BY 2025	
2050	45			
	PJ		**PJ**	
2007	123		123	
2050	491		0	
	kWh		**kWh**	
2007	12		12	
2050	23L		0	

INDIA

Year	REF t	REF %	E[R] t	E[R] %
2007	40,980	1.3%	40,980	1.3%
	TWh		**TWh**	
2007	17		NUCLEAR POWER PHASED OUT BY 2045	
2050	172			
	PJ		**PJ**	
2007	183		183	
2050	1,876		0	
	kWh		**kWh**	
2007	17		17	
2050	172		0	

DEVELOPING ASIA

Year	REF t	REF %	E[R] t	E[R] %
2007	5,630	0.2%	5,630	0.2%
	TWh		**TWh**	
2007	44		NUCLEAR POWER PHASED OUT BY 2045	
2050	80			
	PJ		**PJ**	
2007	476		476	
2050	873		0	
	kWh		**kWh**	
2007	43		43	
2050	53		0	

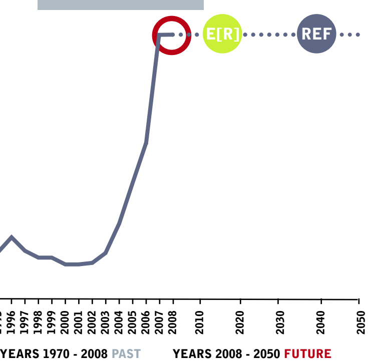
OECD PACIFIC

Year	REF t	REF %	E[R] t	E[R] %
2007	741,600	23.4%	741,600	23.4%
	TWh		**TWh**	
2007	407		NUCLEAR POWER PHASED OUT BY 2045	
2050	868			
	PJ		**PJ**	
2007	4,437		4,437	
2050	9,469		0	
	kWh		**kWh**	
2007	2,030		2,030	
2050	4,827H		0	

COST

yellow cake prices 1987 - 2008 and future predictions comparing the REF and adv. E[R] scenarios
tonnes

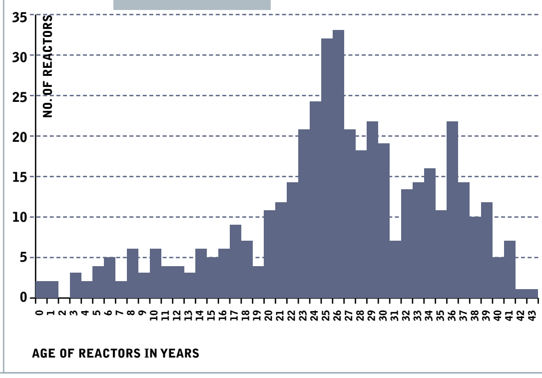
SOURCES REF: INTERNATIONAL ENERGY AGENCY/E[R]: DEVELOPMENTS APPLIED IN THE GES-PROJECT



REACTORS

age and number of reactors worldwide

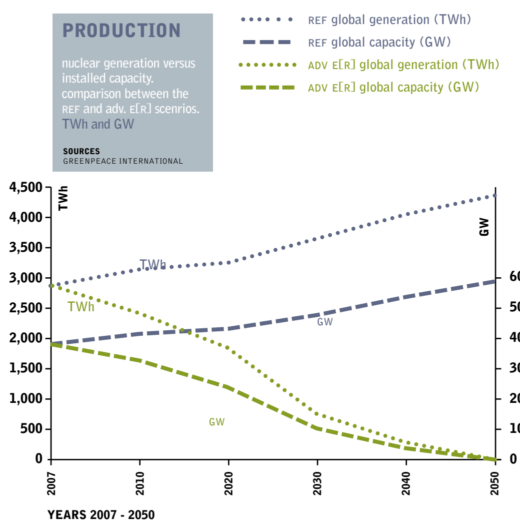
SOURCES IAEA



PRODUCTION

nuclear generation versus installed capacity. comparison between the REF and adv. E[R] scenrios. TWh and GW

SOURCES GREENPEACE INTERNATIONAL



9.5 renewable energy

Nature offers a variety of freely available options for producing energy. Their exploitation is mainly a question of how to convert sunlight, wind, biomass or water into electricity, heat or power as efficiently, sustainably and cost-effectively as possible.

On average, the energy in the sunshine that reaches the earth is about one kilowatt per square metre worldwide. According to the Research Association for Solar Power, power is gushing from renewable energy sources at a rate of 2,850 times more energy than is needed in the world. In one day, the sunlight which reaches the earth produces enough energy to satisfy the world's current power requirements for eight years. Even though only a percentage of that potential is technically accessible, this is still enough to provide just under six times more power than the world currently requires.

Before looking at the role renewable energies can play in the range of scenarios in this report, however, it is worth understanding the upper limits of their potential. To start with, the overall technical potential of renewable energy – the amount that can be produced taking into account the primary resources, the socio-geographical constraints and the technical losses in the conversion process – is huge and several times higher than current total energy demand. Assessments of the global technical potential vary significantly from 2,477 Exajoules per annum (EJ/a) (Nitsch 2004) up to 15,857 EJ/a (UBA 2009). Based on the global primary energy demand in 2007 (IEA 2009) of 503 EJ/a, the total technical potential of renewable energy sources at the upper limit would exceed demand by a factor of 32. However, barriers to the growth of renewable energy technologies may come from economical, political and infrastructural constraints. That is why the technical potential will never be realised in total.

Assessing long term technical potentials is subject to various uncertainties. The distribution of the theoretical resources, such as the global wind speed or the productivity of energy crops, is not always well analysed. The geographical availability is subject to variations such as land use change, future planning decisions on where certain technologies are allowed, and accessibility of resources, for example underground geothermal energy. Technical performance may take longer to achieve than expected. There are also uncertainties in terms of the consistency of the data provided in studies, and underlying assumptions are often not explained in detail.

The meta study by the DLR (German Aerospace Agency), Wuppertal Institute and Ecofys, commissioned by the German Federal Environment Agency, provides a comprehensive overview of the technical renewable energy potential by technologies and world region[41]. This survey analysed ten major studies of global and regional potentials by organisations such as the United Nations Development Programme and a range of academic institutions. Each of the major renewable energy sources was assessed, with special attention paid to the effect of environmental constraints on their overall potential. The study provides data for the years 2020, 2030 and 2050 (see Table 8.3).

The complexity of calculating renewable energy potentials is particularly great because these technologies are comparatively young and their exploitation involves changes to the way in which energy is both generated and distributed. Whilst a calculation of the theoretical and geographical potentials has only a few dynamic parameters, the technical potential is dependent on a number of uncertainties.

definition of types of energy resource potential[40]

theoretical potential The theoretical potential identifies the physical upper limit of the energy available from a certain source. For solar energy, for example, this would be the total solar radiation falling on a particular surface.

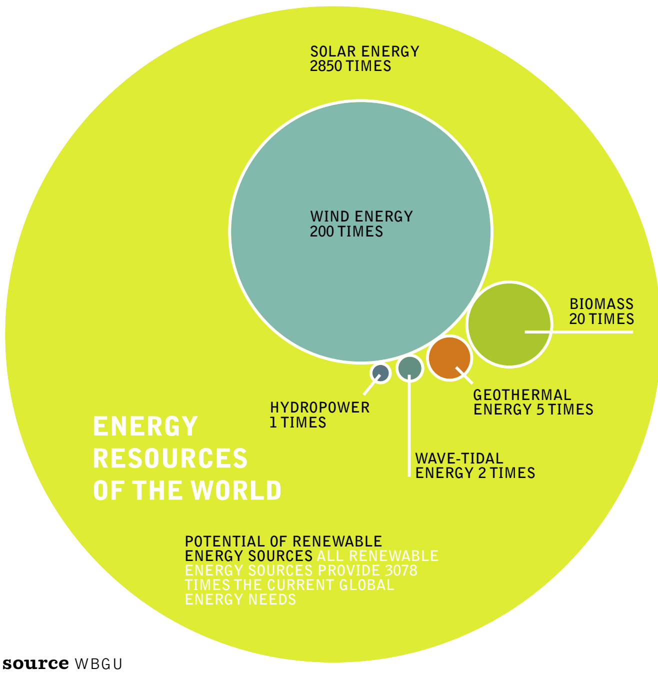
conversion potential This is derived from the annual efficiency of the respective conversion technology. It is therefore not a strictly defined value, since the efficiency of a particular technology depends on technological progress.

technical potential This takes into account additional restrictions regarding the area that is realistically available for energy generation. Technological, structural and ecological restrictions, as well as legislative requirements, are accounted for.

economic potential The proportion of the technical potential that can be utilised economically. For biomass, for example, those quantities are included that can be exploited economically in competition with other products and land uses.

sustainable potential This limits the potential of an energy source based on evaluation of ecological and socio-economic factors.

figure 9.1: energy resources of the world



source WBGU

40 WBGU (GERMAN ADVISORY COUNCIL ON GLOBAL CHANGE).
41 DLR, WUPPERTAL INSTITUTE, ECOFYS, 'ROLE AND POTENTIAL OF RENEWABLE ENERGY AND ENERGY EFFICIENCY FOR GLOBAL ENERGY SUPPLY', COMMISSIONED BY GERMAN FEDERAL ENVIRONMENT AGENCY, FKZ 3707 41 108, MARCH 2009;

image SOLON AG PHOTOVOLTAICS FACILITY IN ARNSTEIN OPERATING 1,500 HORIZONTAL AND VERTICAL SOLAR "MOVERS". LARGEST TRACKING SOLAR FACILITY IN THE WORLD. EACH "MOVER" CAN BE BOUGHT AS A PRIVATE INVESTMENT FROM THE S.A.G. SOLARSTROM AG, BAYERN, GERMANY.

image WIND ENERGY PARK NEAR DAHME. WIND TURBINE IN THE SNOW OPERATED BY VESTAS.

table 9.3: technical potential by renewable energy technology for 2020, 2030 and 2050

	TECHNICAL POTENTIAL ELECTRICITY EJ/YEAR ELECTRIC POWER							TECHNICAL POTENTIAL HEAT EJ/A		TECHNICAL POTENTIAL PRIMARY ENERGY EJ/A		
	SOLAR CSP	SOLAR PV	HYDRO POWER	WIND ON-SHORE	WIND OFF-SHORE	OCEAN ENERGY	GEO-THERMAL ELECTRIC	GEO-THERMAL DIRECT USES	SOLAR WATER HEATING	BIOMASS RESIDUES	BIOMASS ENERGY CROPS	TOTAL
World 2020	1,125.9	5,156.1	47.5	368.6	25.6	66.2	4.5	498.5	113.1	58.6	43.4	7,505
World 2030	1,351.0	6,187.3	48.5	361.7	35.9	165.6	13.4	1,486.6	117.3	68.3	61.1	9,897
World 2050	1,688.8	8,043.5	50.0	378.9	57.4	331.2	44.8	4,955.2	123.4	87.6	96.5	15,857
World energy demand 2007: 502.9 EJ/a[a]												
Technical potential in 2050 versus world primary energy demand 2007.	3.4	16.0	0.1	0.8	0.1	0.7	0.1	9.9	0.2	0.2	0.2	32

source DLR, WUPPERTAL INSTITUTE, ECOFYS; ROLE AND POTENTIAL OF RENEWABLE ENERGY AND ENERGY EFFICIENCY FOR GLOBAL ENERGY SUPPLY; COMMISSIONED BY THE GERMAN FEDERAL ENVIRONMENT AGENCY FKZ 3707 41 108, MARCH 2009; POTENTIAL VERSUS ENERGY DEMAND: S. TESKE
a IEA 2009

A technology breakthrough, for example, could have a dramatic impact, changing the technical potential assessment within a very short time frame. Considering the huge dynamic of technology development, many existing studies are based on out of date information. The estimates in the DLR study could therefore be updated using more recent data, for example significantly increased average wind turbine capacity and output, which would increase the technical potentials still further.

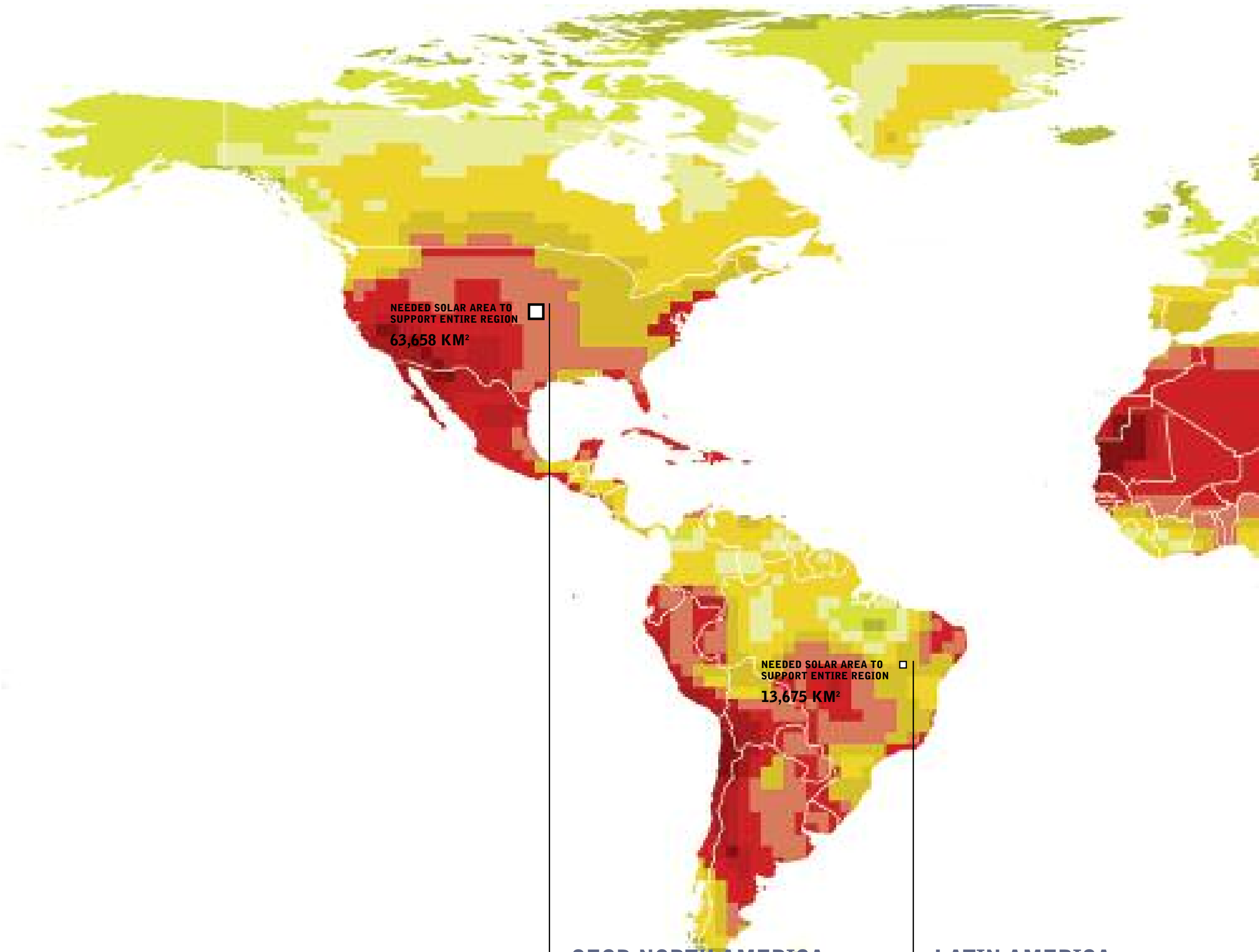
Given the large unexploited resources which exist, even without having reached the full development limits of the various technologies, it can be concluded that the technical potential is not a limiting factor to expansion of renewable energy generation.

It will not be necessary to exploit the entire technical potential, however, nor would this be unproblematic. Implementation of renewable energies has to respect sustainability criteria in order to achieve a sound future energy supply. Public acceptance is crucial, especially bearing in mind that the decentralised character of many renewable energy technologies will move their operations closer to consumers. Without public acceptance, market expansion will be difficult or even impossible. The use of biomass, for example, has become controversial in recent years as it is seen as competing with other land uses, food production or nature conservation. Sustainability criteria will have a huge influence on whether bio-energy in particular can play a central role in future energy supply.

As important as the technical potential of worldwide renewable energy sources is their market potential. This term is often used in different ways. The general understanding is that market potential means the total amount of renewable energy that can be implemented in the market taking into account the demand for energy, competing technologies, any subsidies available as well as the current and future costs of renewable energy sources. The market potential may therefore in theory be larger than the economic potential. To be realistic, however, market potential analyses have to take into account the behaviour of private economic agents under specific prevailing conditions, which are of course partly shaped by public authorities. The energy policy framework in a particular country or region will have a profound impact on the expansion of renewable energies.

map 9.5: solar reference scenario and the advanced energy [r]evolution scenario

WORLDWIDE SCENARIO



OECD NORTH AMERICA

		REF %	REF PJ	E[R] %	E[R] PJ
Production per region	2007	0.06M	64H		
	2050	1.04M	1,343	25M	17,683
			kWh		kWh
Production per person	2007		40		
	2050		646		8,508

LATIN AMERICA

		REF %	REF PJ	E[R] %	E[R] PJ
Production per region	2007	0.03	6		
	2050	0.52	214	14L	3,799L
			kWh		kWh
Production per person	2007		4		
	2050		99		1,758

RENEWABLE RESOURCE

SOLAR

LEGEND

2600-2800 | 2400-2600 | 2200-2400 | 2000-2200 | 1800-2000 | 1600-1800 | 1400-1600 | 1200-1400 | 1000-1200 | 800-1000 | 600-800 | 400-600 | 200-400 | 0-200

RADIATION IN kW/h PER SQUARE METER
SOURCE DLR

REF **REFERENCE SCENARIO**

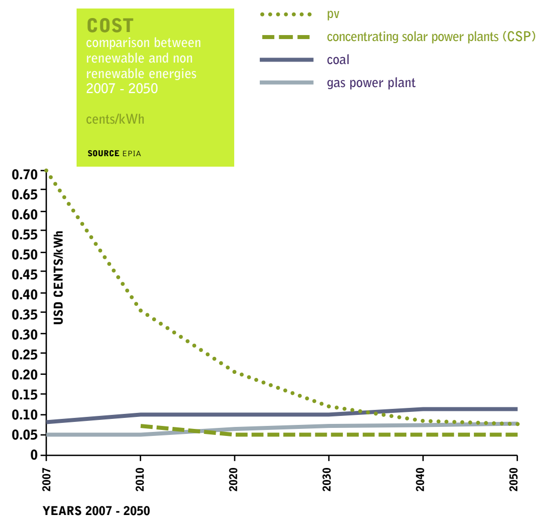
E[R] **ADVANCED ENERGY [R]EVOLUTION SCENARIO**

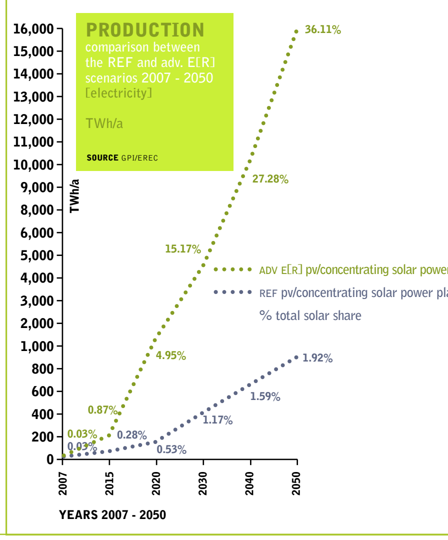
0 1000 KM

PRODUCTION PER REGION % OF GLOBAL SHARE | PETA JOULE [PJ]

PRODUCTION PER PERSON KILOWATT HOUR [kWh]

H HIGHEST | M MIDDLE | L LOWEST





OECD EUROPE

	REF %	REF PJ	E[R] %	E[R] PJ
2007	0.09M	70		
2050	1.42H	1,173	23	10,680
		kWh		kWh
2007		36M		
2050		567		5,160M

MIDDLE EAST

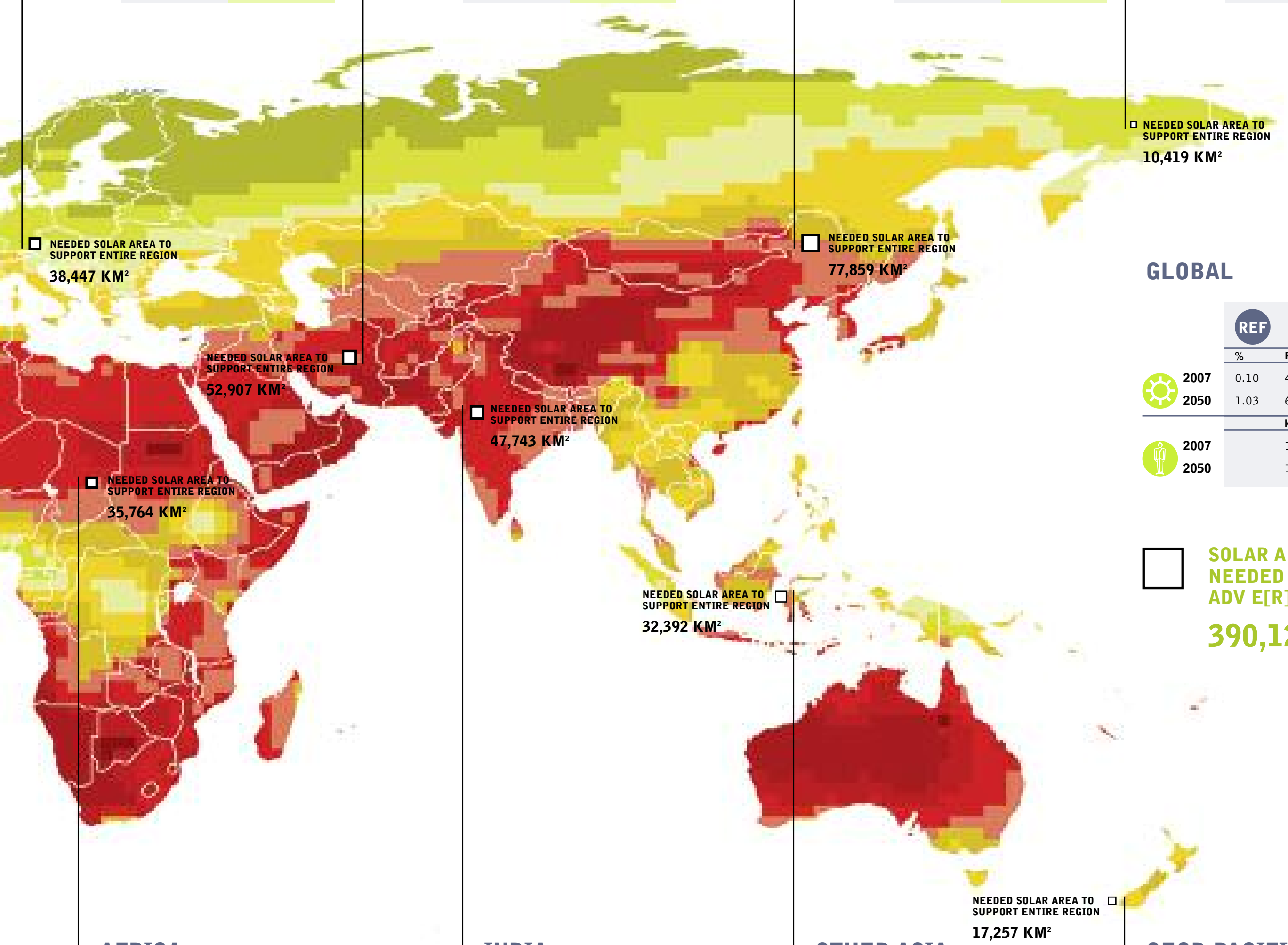
	REF %	REF PJ	E[R] %	E[R] PJ
2007	0.17H	36		
2050	0.62	319	53H	14,696
		kWh		kWh
2007		50H		
2050		251		11,552H

CHINA

	REF %	REF PJ	E[R] %	E[R] PJ
2007	0.22L	182L		
2050	0.95	1,754H	20	21,628H
		kWh		kWh
2007		38		
2050		342M		4,213

TRANSITION ECONOMIES

	REF %	REF PJ	E[R] %	E[R] PJ
2007	0.01L	2		
2050	0.10L	63L	8,34	2,894
		kWh		kWh
2007		2		
2050		56		2,586



GLOBAL

	REF %	REF PJ	E[R] %	E[R] PJ
2007	0.10	402		
2050	1.03	6,322	23.26	108,367
		kWh		kWh
2007		17		
2050		192		2,468

SOLAR AREA NEEDED TO SUPPORT ADV E[R] 2050 SCENARIO

390,122 KM²

AFRICA

	REF %	REF PJ	E[R] %	E[R] PJ
2007	0.00	1		
2050	0.94	405	28	9,934
		kWh		kWh
2007		0.2		
2050		56L		1,380

INDIA

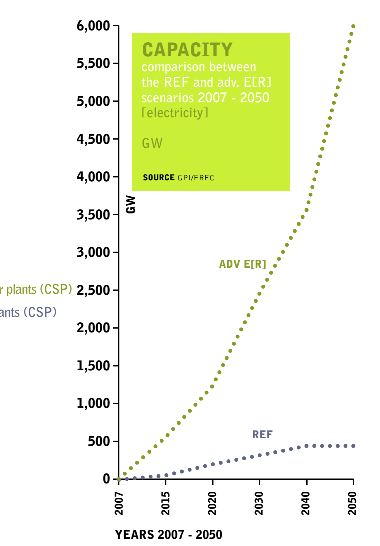
	REF %	REF PJ	E[R] %	E[R] PJ
2007	0.02L	6L		
2050	0.23	182	24	13,262M
		kWh		kWh
2007		1		
2050		31		2,282

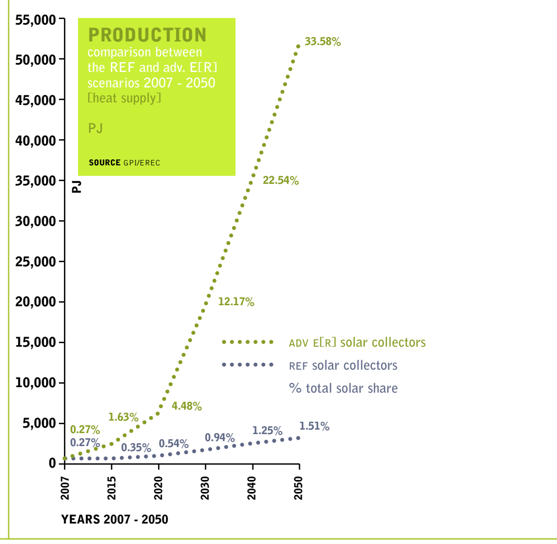
OTHER ASIA

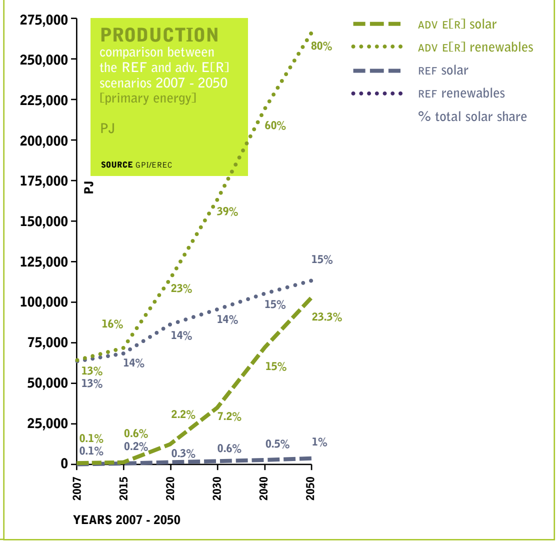
	REF %	REF PJ	E[R] %	E[R] PJ
2007	0.01L	4L		
2050	0.58	405	22	8,998
		kWh		kWh
2007		1L		
2050		74		1,649L

OECD PACIFIC

	REF %	REF PJ	E[R] %	E[R] PJ
2007	0.08	30M		
2050	1.14	466M	23	4,794
		kWh		kWh
2007		42		
2050		719H		7,405

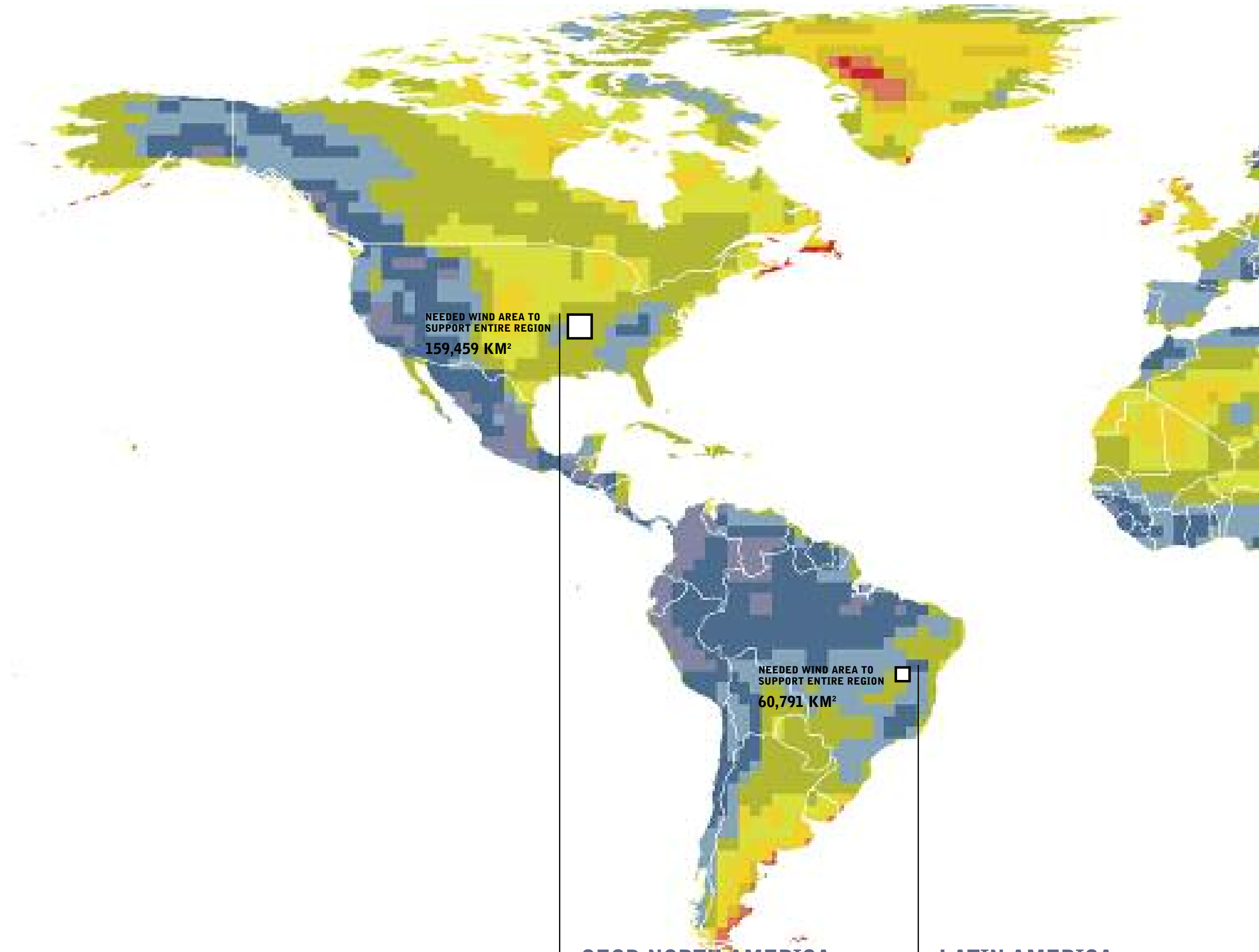






map 9.6: wind reference scenario and the advanced energy [r]evolution scenario

WORLDWIDE SCENARIO



RENEWABLE RESOURCE

WIND

OECD NORTH AMERICA

	REF %	REF PJ	E[R] %	E[R] PJ
2007	0.12M	136		
2050	1.71	2,210	11.11	7,805H
		kWh		kWh
2007		84		
2050		1,064		3,755

LATIN AMERICA

	REF %	REF PJ	E[R] %	E[R] PJ
2007	0.02	3		
2050	0.65	266	10.54	2,878
		kWh		kWh
2007		2		
2050		123		1,332

LEGEND

>11 | 10-11 | 9-10 | 8-9 | 7-8 | 6-7 | 5-6 | 4-5 | 3-4 | 1-2 | 0-1

AVERAGE WIND SPEED IN METRES PER SECOND
SOURCE DLR

REF REFERENCE SCENARIO

E[R] ADVANCED ENERGY [R]EVOLUTION SCENARIO

0 1000 KM

PRODUCTION PER REGION % OF GLOBAL SHARE | PETA JOULE [PJ]

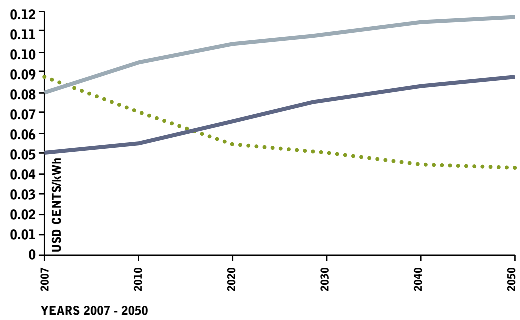
PRODUCTION PER PERSON KILOWATT HOUR [kWh]

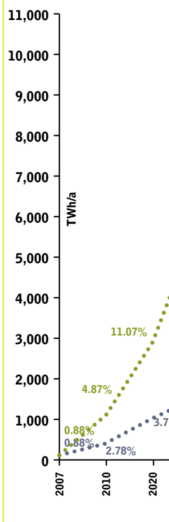
H HIGHEST | **M** MIDDLE | **L** LOWEST

COST
comparison between renewable and non renewable energies 2007 - 2050

$cents/kWh

SOURCE GWEC





OECD EUROPE

	REF %	REF PJ	E[R] %	E[R] PJ
2007	0.49H	379H		
2050	4.14H	3,420H	10.41	4,867
		kWh		kWh
2007		195H		
2050		1,652H		2,352M

MIDDLE EAST

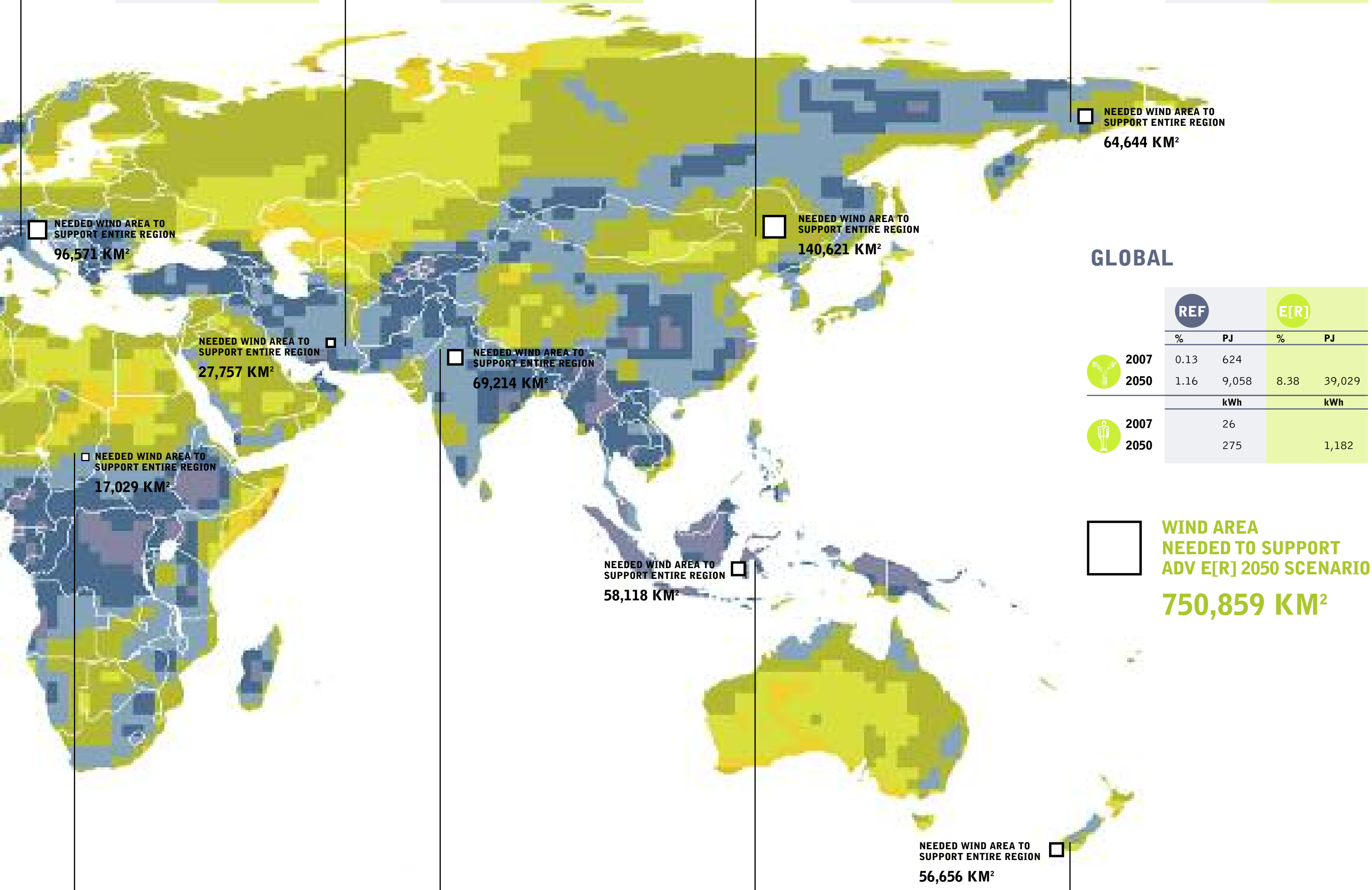
	REF %	REF PJ	E[R] %	E[R] PJ
2007	0.00L	1L		
2050	0.26L	133L	4.78	1,314
		kWh		kWh
2007		1		
2050		105		1,033

CHINA

	REF %	REF PJ	E[R] %	E[R] PJ
2007	0.04	32		
2050	0.66	1,220M	6.85M	7,340
		kWh		kWh
2007		7		
2050		238		1,430

TRANSITION ECONOMIES

	REF %	REF PJ	E[R] %	E[R] PJ
2007	0.00	1		
2050	0.56	360	9.83	3,413
		kWh		kWh
2007		1		
2050		322M		3,050



GLOBAL

	REF %	REF PJ	E[R] %	E[R] PJ
2007	0.13	624		
2050	1.16	9,058	8.38	39,029
		kWh		kWh
2007		26		
2050		275		1,182

WIND AREA NEEDED TO SUPPORT ADV E[R] 2050 SCENARIO

750,859 KM²

AFRICA

	REF %	REF PJ	E[R] %	E[R] PJ
2007	0.02	4		
2050	0.47	202	3.00L	1,073L
		kWh		kWh
2007		1		
2050		28L		149L

INDIA

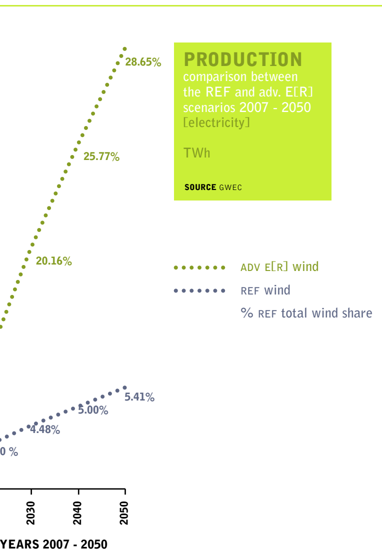
	REF %	REF PJ	E[R] %	E[R] PJ
2007	0.17	42M		
2050	0.48	374	6.38	3,488
		kWh		kWh
2007		10		
2050		64		600

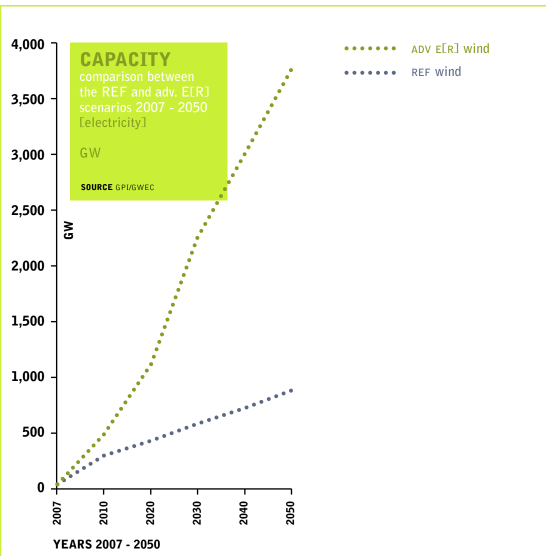
ASIA

	REF %	REF PJ	E[R] %	E[R] PJ
2007	0.01	2L		
2050	0.69	475	8.75	3,557
		kWh		kWh
2007		0L		
2050		87		652

OECD PACIFIC

	REF %	REF PJ	E[R] %	E[R] PJ
2007	0.06	24		
2050	0.97M	396	15.47H	3,294M
		kWh		kWh
2007		33M		
2050		611		5,089H





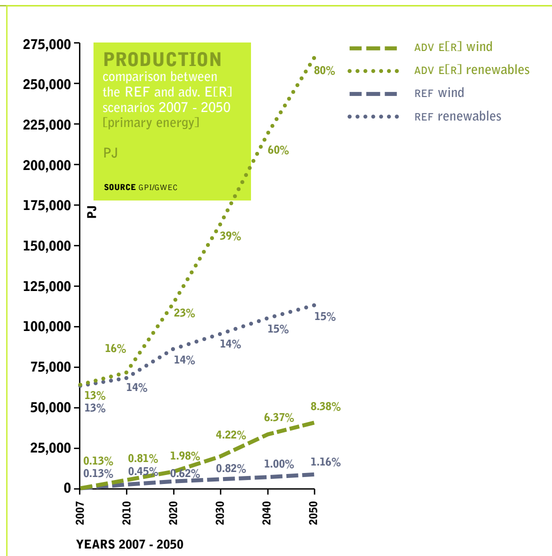
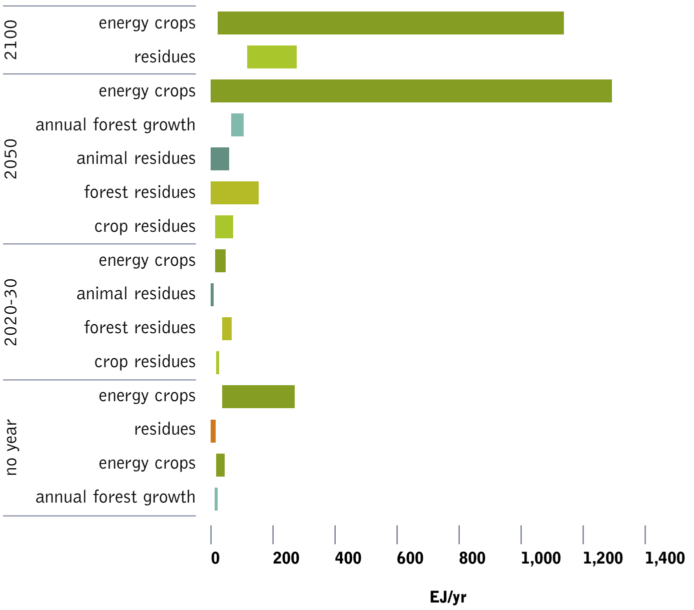


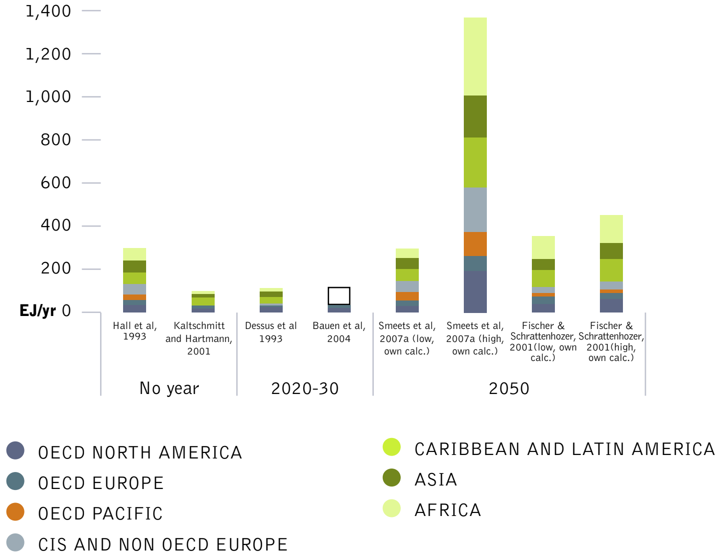
figure 9.2: ranges of potential for different biomass types



source GERMAN BIOMASS RESEARCH CENTRE (DBFZ)

figure 9.3: bio energy potential analysis from different authors

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)



source GERMAN BIOMASS RESEARCH CENTRE (DBFZ)

9.5.1 the global potential for sustainable biomass

As part of background research for the Advanced Energy [R]evolution Scenario, Greenpeace commissioned the German Biomass Research Centre, the former Institute for Energy and Environment, to investigate the worldwide potential for energy crops up to 2050. In addition, information has been compiled from scientific studies of the global potential and from data derived from state of the art remote sensing techniques, such as satellite images. A summary of the report's findings is given below; references can be found in the full report [42].

9.5.2 assessment of biomass potential studies

Various studies have looked historically at the potential for bio energy and come up with widely differing results. Comparison between them is difficult because they use different definitions of the various biomass resource fractions. This problem is particularly significant in relation to forest derived biomass. Most research has focused almost exclusively on energy crops, as their development is considered to be more significant for satisfying the demand for bio energy. The result is that the potential for using forest residues (wood left over after harvesting) is often underestimated.

Data from 18 studies has been examined, with a concentration on those which report the potential for biomass residues. Among these there were ten comprehensive assessments with more or less detailed documentation of the methodology. The majority focus on the long-term potential for 2050 and 2100. Little information is available for 2020 and 2030. Most of the studies were published within the last ten years. Figure 9.2 shows the variations in potential by biomass type from the different studies.

Looking at the contribution of different types of material to the total biomass potential, the majority of studies agree that the most promising resource is energy crops from dedicated plantations. Only six give a regional breakdown, however, and only a few quantify all types of residues separately. Quantifying the potential of minor fractions, such as animal residues and organic wastes, is difficult as the data is relatively poor.

9.5.3 potential of energy crops

Apart from the utilisation of biomass from residues, the cultivation of energy crops in agricultural production systems is of greatest significance. The technical potential for growing energy crops has been calculated on the assumption that demand for food takes priority. As a first step the demand for arable and grassland for food production has been calculated for each of 133 countries in different scenarios. These scenarios are:

- Business as usual (BAU) scenario: Present agricultural activity continues for the foreseeable future
- Basic scenario: No forest clearing; reduced use of fallow areas for agriculture
- Sub-scenario 1: Basic scenario plus expanded ecological protection areas and reduced crop yields
- Sub-scenario 2: Basic scenario plus food consumption reduced in industrialised countries
- Sub-scenario 3: Combination of sub-scenarios 1 and 2

42 SEIDENBERGER T., THRÄN D., OFFERMANN R., SEYFERT U., BUCHHORN M. AND ZEDDIES J. (2008). GLOBAL BIOMASS POTENTIALS. INVESTIGATION AND ASSESSMENT OF DATA. REMOTE SENSING IN BIOMASS POTENTIAL RESEARCH. COUNTRY-SPECIFIC ENERGY CROP POTENTIAL. GERMAN BIOMASS RESEARCH CENTRE (DBFZ). FOR GREENPEACE INTERNATIONAL. 137 P.

image THE BIOENERGY VILLAGE OF JUEHNDE WHICH WAS THE FIRST COMMUNITY IN GERMANY TO PRODUCE ALL ITS ENERGY NEEDED FOR HEATING AND ELECTRICITY, WITH CO_2 NEUTRAL BIOMASS.

In a next step the surpluses of agricultural areas were classified either as arable land or grassland. On grassland, hay and grass silage are produced, on arable land fodder silage and Short Rotation Coppice (SRC) (such as fast-growing willow or poplar) are cultivated. Silage of green fodder and grass are assumed to be used for biogas production, wood from SRC and hay from grasslands for the production of heat, electricity and synthetic fuels. Country specific yield variations were taken into consideration.

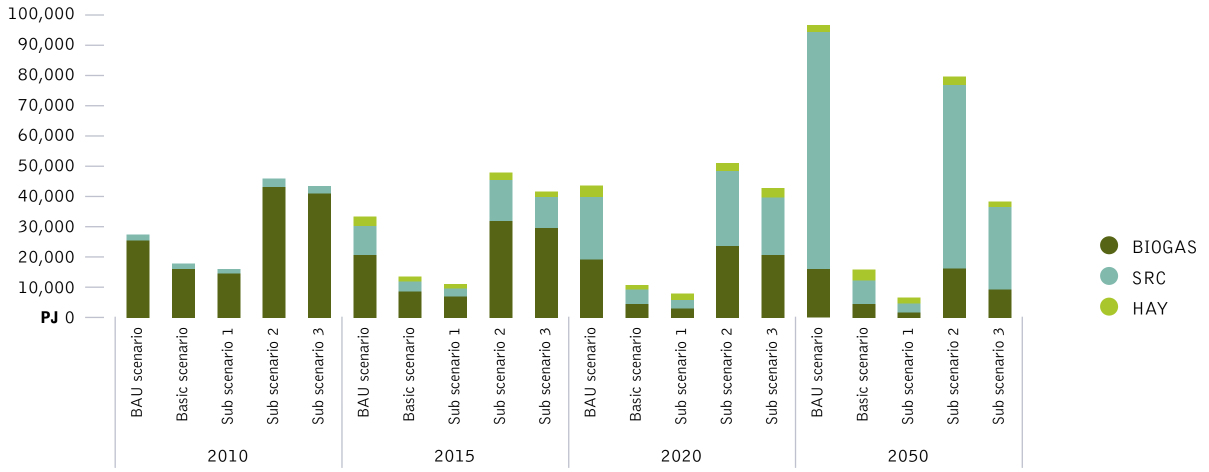
The result is that the global biomass potential from energy crops in 2050 falls within a range from 6 EJ in Sub-scenario 1 up to 97 EJ in the BAU scenario.

The best example of a country that would see a very different future under these scenarios in 2050 is Brazil. Under the BAU scenario large agricultural areas would be released by deforestation, whereas in the Basic and Sub 1 scenarios this would be forbidden, and no agricultural areas would be available for energy crops. By contrast a high potential would be available under Sub-scenario 2 as a consequence of reduced meat consumption. Because of their high populations and relatively small agricultural areas, no surplus land is available for energy crop production in Central America, Asia and Africa. The EU, North America and Australia, however, have relatively stable potentials.

The results of this exercise show that the availability of biomass resources is not only driven by the effect on global food supply but the conservation of natural forests and other biospheres. So the assessment of future biomass potential is only the starting point of a discussion about the integration of bioenergy into a renewable energy system.

The total global biomass potential (energy crops and residues) therefore ranges in 2020 from 66 EJ (Sub-scenario 1) up to 110 EJ (Sub-scenario 2), and in 2050 from 94 EJ (Sub-scenario 1) to 184 EJ (BAU scenario). These numbers are conservative and include a level of uncertainty, especially for 2050. The reasons for this uncertainty are the potential effects of climate change, possible changes in the worldwide political and economic situation, a higher yield as a result of changed agricultural techniques and/or faster development in plant breeding.

figure 9.4: world wide energy crop potentials in different scenarios



The Energy [R]evolution takes a precautionary approach to the future use of biofuels. This reflects growing concerns about the greenhouse gas balance of many biofuel sources, and also the risks posed by expanded biofuels crop production to biodiversity (forests, wetlands and grasslands) and food security. In particular, research commissioned by Greenpeace in the development of the Energy [R]evolution suggests that there will be acute pressure on land for food production and habitat protection in 2050. As a result, the Energy [R]evolution does not include any biofuels from energy crops at 2050, restricting feedstocks to a limited quantity of forest and agricultural residues. It should be stressed, however, that this conservative approach is based on an assessment of today's technologies and their associated risks. The development of advanced forms of biofuels which do not involve significant land-take, are demonstrably sustainable in terms of their impacts on the wider environment, and have clear greenhouse gas benefits, should be an objective of public policy, and would provide additional flexibility in the renewable energy mix.

Concerns have also been raised about how countries account for the emissions associated with biofuels production and combustion. The lifecycle emissions of different biofuels can vary enormously. Rules developed under the Kyoto Protocol mean that under many circumstances, countries are not held responsible for all the emissions associated with land-use change or management. At the same time, under the Kyoto Protocol and associated instruments such as the European Emissions Trading scheme, biofuels is 'zero-rated' for emissions as an energy source. To ensure that biofuels are produced and used in ways which maximize its greenhouse gas saving potential, these accounting problems will need to be resolved in future.

9.6 japan: renewable energy resources

The Advanced Energy [R]evolution scenario for Japan is based on a detailed renewable energy resource assessment of the Japan´s Ministery of Environment published in April 2011, just weeks after the Fukushima accident. The Energy [R]evolution scenario took the technical potentials for wind power (onshore and offshore), hydro power, geothermal energy and solar power provided in this study as part of the input parameters and stayed within the resource potential ranges.

9.6.1 study of potential for the introduction of renewable energy

As a 2009 project, the Ministry of Environment appointed Ex Corporation Environmental & Urban Planning, Research and Consulting, Itochu Techno-Solutions Corporation, Pacific Consultants Co., Ltd., and Asia Air Survey Co., Ltd. to carry out an study entitled "Study of Potential for the introduction of Renewable Energy" (hereinafter referred to as the "Potential Study"). The details of this study are discussed here.

In this Potential Study, energy resources which can be estimated theoretically but do not take into account various limiting factors (such as land application or application technology) are defined as "potential"; whereas, feasible energy resources where various limiting factors concerning energy collection (extraction) and application are taken into consideration and which are estimated after creating a scenario (assumption) for limiting factors are defined as "introduction potential". Although the so-called targeted value are set within the introduction potential, the introduction potential should be reviewed accordingly since limiting factors such as economical efficiency may change.

table 9.4: introduction potential (in 10,000 kW) by renewable generation technology and electricity supply region

		WIND POWER GENERATION			MEDIUM AND SMALL SCALE HYDRO POWER GENERATION*	GEOTHERMAL POWER GENERATION**			GENERATING CAPACITY OF ELECTRIC COMPANIES (FY2008)
		ONSHORE	OFFSHORE (FIXED TYPE)	OFFSHORE FLOATING (TYPE)		OVER 150°C	120 TO 150°C	53 TO 120°C	
Potential		**140,000**	**770,000**		**1,800**	**2,400**	**110**	**850**	**20,218**
Introduction potential (by electricity supply region)	Summary by value by scenario	7,000 to 30,000	510 to 31,000	5,600 to 130,000	80 to 1,500	110 to 220	0.8 to 21	0 to 740	
	Hokkaido	3,000 to 15,000	470 to 12,000	3,800 to 28,000	2 to 130	39 to 71	0.6 to 7	0 to 246	650
	Tohoku	2,100 to 7,400	7 to 4,400	1,000 to 18,000	14 to 410	38 to 67	0 to 5	0 to 194	1,680
	Tokyo	100 to 450	32 to 2,800	640 to 5,200	15 to 220	10 to 18	0 to 1	0 to 112	6,398
	Hokuriku	44 to 520	0 to 420	0 to 5,900	19 to 190	0 to 0.3	0.1 to 3	0 to 26	796
	Chubu	250 to 870	0 to 1,900	110 to 1,900	2 to 270	1.2 to 5.5	0 to 1	0 to 88	3,263
	Kansai	330 to 1,300	0 to 160	0 to 2,400	4 to 38	0 to 0.2	0	0 to 8	3,386
	Chugoku	190 to 1,000	0 to 460	0 to 15,000	3 to 64	0	0	0 to 15	1,183
	Shikoku	110 to 530	0 to 390	0 to 3,800	3 to 73	0	0	0 to 4	666
	Kyushu	630 to 2,200	2 to 5,400	48 to 40,000	3 to 100	25 to 49	0.1 to 3	0 to 52	2,002
	Okinawa	280 to 550	1 to 2,800	1 to 6,300	0 to 0.2	0	0	0	192

* LESS THAN 30,000 KW OF FACILITY CAPACITY: WATER SUPPLY, SEWERAGE AND WATER FOR INDUSTRIAL USE (APPROXIMATELY 180,000 KW OF POTENTIAL) ARE NOT INCLUDED.
** THE POTENTIAL OF HOT SPRING POWER GENERATION IS INCLUDED.
source STUDY OF POTENTIAL FOR THE INTRODUCTION OF RENWABLE ENERGY", MINISTRY OF ENVIRONMENT OF JAPAN, APRIL 2011.

image A MAINTENANCE WORKER MARKS A BLADE OF A WINDMILL AT GUAZHOU WIND FARM NEAR YUMEN IN GANSU PROVINCE, CHINA.

table 9.5: introduction potential of pv power generation on non-residential buildings classification

FACILITY CATEGORY	INTRODUCTION POTENTIAL (10,000 KW)
Public / Government buildings	30 to 150
Schools	740 to 1,100
Cultural facilities (such as community centers)	100 to 390
Medical and welfare institutions	10 to 110
Michi-no-eki (Roadside stations)	10 to 260
Water supply and sewer systems	60 to 80
Subtotal	950 to 2,100
Industry	1,500 to 3,400
Power stations, etc.	1 to 5
Subtotal	1,500 to 3,400
Total	2,400 to 5,600

table 9.6: potential for pv cell installation at low and unused lots

CATEGORY	INTRODUCTION POTENTIAL (10,000 KW)
Abandoned cultivated land (*)	6,700
Industrial estates (sold in lots) (*2)	160 to 370
Final disposal sites	310
Others (*3)	390 to 2,000
Total	7,600 to 9,400

sources
* NEW ENERGY AND INDUSTRIAL TECHNOLOGY DEVELOPMENT ORGANIZATION (NEDO), PHOTOVOLTAIC (PV) ROADMAP TOWARD 2030 (PV2030+), JUNE 2009, P115 (HTTP://WWW.NEDO.GO.JP/LIBRARY/PV2030/PV2030+.PDF)
** JAPANESE WIND POWER ASSOCIATION, LONG-TERM WIND POWER GENERATION INTRODUCTION GOAL AND ROADMAP, V1.1, JANUARY 2010, P13 (HTTP://LOG.JWPA.JP/CONTENT/0000288882.HTML)
*** YUKIO ETO AND HIROFUMI MURAOKA ET AL., CONTRIBUTION OF GEOTHERMAL ENERGY TO 2050 NATURAL ENERGY VISION, JOURNAL OF THE GEOTHERMAL RESEARCH SOCIETY OF JAPAN (GRSJ), 30 (3), 2008

climate and energy policy

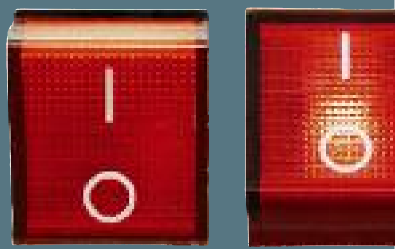
GLOBAL

CLIMATE POLICY
ENERGY POLICY AND MARKET REGULATION

TARGETS AND INCENTIVES FOR RENEWABLES

ENERGY EFFICIENCY AND INNOVATION

10



STANDBY POWER IS WASTED POWER. GLOBALLY, WE HAVE 50 DIRTY POWER PLANTS RUNNING JUST FOR OUR WASTED STANDBY POWER. OR: IF WE WOULD REDUCE OUR STANDBY TO JUST 1 WATT, WE CAN AVOID THE BUILDING OF 50 NEW DIRTY POWER PLANTS.
© M. DIETRICH/DREAMSTIME

> “The poor, the vulnerable and the hungry are exposed to the harsh edge of climate change every day of their lives.”

ARCHBISHOP EMERITUS DESMOND TUTU
THE GUARDIAN, 2007

image MINOTI SINGH AND HER SON AWAIT FOR CLEAN WATER SUPPLY BY THE RIVERBANK IN DAYAPUR VILLAGE IN SATJELLIA ISLAND, INDIA: "WE DO NOT HAVE CLEAN WATER AT THE MOMENT AND ONLY ONE TIME WE WERE LUCKY TO BE GIVEN SOME RELIEF. WE ARE NOW WAITING FOR THE GOVERNMENT TO SUPPLY US WITH WATER TANKS".

If the Energy [R]evolution is to happen, then governments around the world need to play a major part. Their contribution will include regulating the energy market, both on the supply and demand side, educating everyone from consumers to industrialists, and stimulating the market for renewable energy and energy efficiency by a range of economic mechanisms. They can also build on the successful policies already adopted by other countries.

To start with they need to agree on further binding emission reduction commitments in the second phase of the Kyoto Protocol. Only by setting stringent greenhouse gas emission reduction targets will the cost of carbon become sufficiently high to properly reflect its impact on society. This will in turn stimulate investments in renewable energy. Through massive funding for mitigation and technology cooperation, industrialised countries will also stimulate the development of renewable energy and energy efficiency in developing countries.

Alongside these measures specific support for the introduction of feed-in tariffs in the developing world - the extra costs of which could be funded by industrialised countries - could create similar incentives to those in countries like Germany and Spain, where the growth of renewable energy has boomed. Energy efficiency measures should be more strongly supported through the Kyoto process and its financial mechanisms.

Carbon markets can also play a distinctive role in making the Energy [R]evolution happen, although the functioning of the carbon market needs a thorough revision in order to ensure that the price of carbon is sufficiently high to reflect its real cost. Only then can we create a level playing field for renewable energy and be able to calculate the economic benefits of energy efficiency.

Industrialised countries should ensure that all financial flows to energy projects in developing countries are targeted towards renewable energy and energy efficiency. All financial assistance, whether through grants, loans or trade guarantees, directed towards supporting fossil fuel and nuclear power production, should be phased out in the next two to five years. International financial institutions, export credit agencies and development agencies should provide the required finance and infrastructure to create systems and networks to deliver the seed capital, institutional support and capacity to facilitate the implementation of the Energy [R]evolution in developing countries.

While all energy policies need to be adapted to the local situation, we are proposing the following policies to encourage the Energy [R]evolution that all countries should adopt:

10.1 climate policy

Policies to limit the effects of climate change and move towards a renewable energy future must be based on penalising energy sources that contribute to global pollution.

Action: Phase out subsidies for fossil fuel and nuclear power production and inefficient energy use

The United Nations Environment Programme (UNEP) estimates (August 2008) the annual bill for worldwide energy subsidies at about $300 billion, or 0.7% of global GDP[43]. Approximately 80% of this is spent on funding fossil fuels and more than 10% to support nuclear energy. The lion's share is used to artificially lower the real price of fossil fuels. Subsidies (including loan guarantees) make energy efficiency less attractive, keep renewable energy out of the market place and prop up non-competitive and inefficient technologies.

Eliminating direct and indirect subsidies to fossil fuels and nuclear power would help move us towards a level playing field across the energy sector. Scrapping these payments would, according to UNEP, reduce greenhouse gas emissions by as much as 6% a year, while contributing 0.1% to global GDP. Many of these seemingly well intentioned subsidies rarely make economic sense anyway, and hardly ever address poverty, thereby challenging the widely held view that such subsidies assist the poor.

Instead, governments should use subsidies to stimulate investment in energy-saving measures and the deployment of renewable energy by reducing their investment costs. Such support could include grants, favourable loans and fiscal incentives such as reduced taxes on energy efficient equipment, accelerated depreciation, tax credits and tax deductions.

The G20 countries, meeting in Philadelphia in September 2009, called for world leaders to eliminate fossil fuel subsidies, but hardly any progress has been made since then towards implementing the resolution.

Action: Introduce the "polluter pays" principle

A substantial indirect form of subsidy comes from the fact that the energy market does not incorporate the external, societal costs of the use of fossil fuels and nuclear power. Pricing structures in the energy markets should reflect the full costs to society of producing energy.

This requires that governments apply a 'polluter pays' system that charges the emitters accordingly, or applies suitable compensation to non-emitters. Adoption of 'polluter pays' taxation to electricity sources, or equivalent compensation to renewable energy sources, and exclusion of renewables from environment-related energy taxation, is essential to achieve fairer competition in the world's electricity markets.

references
43 "REFORMING ENERGY SUBSIDIES: OPPORTUNITIES TO CONTRIBUTE TO THE CLIMATE CHANGE AGENDA", UNEP, 2008.

The real cost of conventional energy production includes expenses absorbed by society, such as health impacts and local and regional environmental degradation - from mercury pollution to acid rain – as well as the global negative impacts of climate change. Hidden costs include the waiving of nuclear accident insurance that is too expensive to be covered by the nuclear power plant operators. The Price Anderson Act, for instance, limits the liability of US nuclear power plants in the case of an accident to an amount of up to $98 million per plant, and only $15 million per year per plant, with the rest being drawn from an industry fund of up to $10 billion. After that the taxpayer becomes responsible[44].

Although environmental damage should, in theory, be rectified by forcing polluters to pay, the environmental impacts of electricity generation can be difficult to quantify. How do you put a price on lost homes on Pacific Islands as a result of melting icecaps or on deteriorating health and human lives?

An ambitious project, funded by the European Commission - ExternE – has tried to quantify the full environmental costs of electricity generation. It estimates that the cost of producing electricity from coal or oil would double and that from gas would increase by 30% if external costs, in the form of damage to the environment and health, were taken into account. If those environmental costs were levied on electricity generation according to its impact, many renewable energy sources would not need any support. If, at the same time, direct and indirect subsidies to fossil fuels and nuclear power were removed, the need to support renewable electricity generation would seriously diminish or cease to exist.

One way to achieve this is by a carbon tax that ensures a fixed price is paid for each unit of carbon that is released into the atmosphere. Such taxes have, or are being, implemented in countries such as Sweden and the state of British Columbia. Another approach is through cap and trade, as operating in the European Union and planned in New Zealand and several US states. This concept gives pollution reduction a value in the marketplace.

In theory, cap and trade prompts technological and process innovations that reduce pollution down to the required levels. A stringent cap and trade system can harness market forces to achieve cost-effective greenhouse gas emission reductions. But this will only happen if governments implement true 'polluter pays' schemes that charge emitters accordingly.

Government programmes that allocate a maximum amount of emissions to industrial plants have proved to be effective in promoting energy efficiency in certain industrial sectors. To be successful, however, these allowances need to be strictly limited and their allocation auctioned.

10.2 energy policy and market regulation

Essential reforms are necessary in the electricity sector if new renewable energy technologies are to be implemented more widely.

Action: Reform the electricity market to allow better integration of renewable energy technologies

Complex licensing procedures and bureaucratic hurdles constitute one of the most difficult obstacles faced by renewable energy in many countries. A clear timetable for approving renewable energy projects should be set for all administrations at all levels, and they should receive priority treatment. Governments should propose more detailed procedural guidelines to strengthen the existing legislation and at the same time streamline the licensing procedures.

Other general barriers include the lack of long term and integrated resource planning at national, regional and local level; the lack of predictability and stability in the markets; the complete grid ownership by Eskom and the absence of (access to) grids for large scale renewable energy sources, such as offshore wind power or concentrating solar power plants. The International Energy Agency has identified Denmark, Spain and Germany as examples of best practice in a reformed electricity market that supports the integration of renewable energy.

In order to remove these market barriers, governments should:

- streamline planning procedures and permit systems and integrate least cost network planning;
- ensure access to the grid at fair and transparent prices;
- ensure priority access and transmission security for electricity generated from renewable energy resources, including fina;
- unbundle all utilities into separate generation, distribution and selling companies;
- ensure that the costs of grid infrastructure development and reinforcement are borne by the grid management authority rather than individual renewable energy projects;
- ensure the disclosure of fuel mix and environmental impact to end users;
- establish progressive electricity and final energy tariffs so that the price of a kWh costs more for those who consume more;
- set up demand-side management programmes designed to limit energy demand, reduce peak loads and maximise the capacity factor of the generation system. Demand-side management should also be adapted to facilitate the maximum possible share of renewable energies in the power mix;
- introduce pricing structures in the energy markets to reflect the full costs to society of producing energy.

references
44 HTTP://EN.WIKIPEDIA.ORG/WIKI/PRICE-ANDERSON_NUCLEAR_INDUSTRIES_INDEMNITY_ACT

image A WOMAN IN FRONT OF HER FLOODED HOUSE IN SATJELLIA ISLAND. DUE TO THE REMOTENESS OF THE SUNDARBANS ISLANDS, SOLAR PANELS ARE USED BY MANY VILLAGERS. AS A HIGH TIDE INVADES THE ISLAND, PEOPLE REMAIN ISOLATED SURROUNDED BY THE FLOODS.

10.3 targets and incentives for renewables

At a time when governments around the world are in the process of liberalising their electricity markets, the increasing competitiveness of renewable energy should lead to higher demand. Without political support, however, renewable energy remains at a disadvantage, marginalised by distortions in the world's electricity markets created by decades of massive financial, political and structural support to conventional technologies. Developing renewables will therefore require strong political and economic efforts, especially through laws which guarantee stable tariffs over a period of up to 20 years.

At present new renewable energy generators have to compete with old nuclear and fossil fuelled power stations which produce electricity at marginal costs because consumers and taxpayers have already paid the interest and depreciation on the original investments. Political action is needed to overcome these distortions and create a level playing field.

Support mechanisms for different sectors and technologies can vary according to regional characteristics, priorities or starting points, but some general principles should apply. These are:

- **Long term stability:** Policy makers need to make sure that investors can rely on the long-term stability of any support scheme. It is absolutely crucial to avoid stop-and-go markets by changing the system or the level of support frequently.
- **Encouraging local and regional benefits and public acceptance:** A support scheme should encourage local/regional development, employment and income generation. It should also encourage public acceptance of renewables, including increased stakeholder involvement.

Incentives can be provided for renewable energy through both targets and price support mechanisms.

Action: Establish legally binding targets for renewable energy and combined heat and power generation

An increasing number of countries have established targets for renewable energy, either as a general target or broken down by sector for power, transport and heating. These are either expressed in terms of installed capacity or as a percentage of energy consumption. China and the European Union have a target for 20% renewable energy by 2020, for example, and New Zealand has a 90% by 2025 target.

Although these targets are not always legally binding, they have served as an important catalyst for increasing the share of renewable energy throughout the world. The electricity sector clearly needs a long term horizon, as investments are often only paid back after 20 to 40 years. Renewable energy targets therefore need to have short, medium and long term stages and must be legally binding in order to be effective. In order for the proportion of renewable energy to increase significantly, targets must also be set in accordance with the potential for each technology (wind, solar, biomass etc) and taking into account existing and planned infrastructure. Every government should carry out a detailed analysis of the potential and feasibility of renewable energies in its own country, and define, based on that analysis, the deadline for reaching, either individually or in cooperation with other countries, a 100% renewable energy supply.

Action: Provide a stable return for investors through price support mechanisms

Price support mechanisms for renewable energy are a practical means of correcting market failures in the electricity sector. Their aim is to support market penetration of those renewable energy technologies, such as wind and solar thermal, that currently suffer from unfair competition due to direct and indirect support to fossil fuel use and nuclear energy, and to provide incentives for technology improvements and cost reductions so that technologies such as PV, wave and tidal can compete with conventional sources in the future.

Overall, there are two types of incentives to promote the deployment of renewable energy. These are Fixed Price Systems where the government dictates the electricity price (or premium) paid to the producer and lets the market determine the quantity, and Renewable Quota Systems (in the USA referred to as Renewable Portfolio Standards) where the government dictates the quantity of renewable electricity and leaves it to the market to determine the price. Both systems create a protected market against a background of subsidised, depreciated conventional generators whose external environmental costs are not accounted for. Their aim is to provide incentives for technology improvements and cost reductions, leading to cheaper renewables that can compete with conventional sources in the future.

The main difference between quota based and price based systems is that the former aims to introduce competition between electricity producers. However, competition between technology manufacturers, which is the most crucial factor in bringing down electricity production costs, is present regardless of whether government dictates prices or quantities. Prices paid to wind power producers are currently higher in many European quota based systems (UK, Belgium, Italy) than in fixed price or premium systems (Germany, Spain, Denmark).

The European Commission has concluded that fixed price systems are to be preferred above quota systems. If implemented well, fixed price systems are a reliable, bankable support scheme for renewable energy projects, providing long term stability and leading to lower costs. In order for such systems to achieve the best possible results, however, priority access to the grid must be ensured.

10.3.1 fixed price systems

Fixed price systems include investment subsidies, fixed feed-in tariffs, fixed premium systems and tax credits.

- **Investment subsidies** are capital payments usually made on the basis of the rated power (in kW) of the generator. It is generally acknowledged, however, that systems which base the amount of support on generator size rather than electricity output can lead to less efficient technology development. There is therefore a global trend away from these payments, although they can be effective when combined with other incentives.
- **Fixed feed-in tariffs (FITs)** widely adopted in Europe, have proved extremely successful in expanding wind energy in Germany, Spain and Denmark. Operators are paid a fixed price

for every kWh of electricity they feed into the grid. In Germany the price paid varies according to the relative maturity of the particular technology and reduces each year to reflect falling costs. The additional cost of the system is borne by taxpayers or electricity consumers.

The main benefit of a FIT is that it is administratively simple and encourages better planning. Although the FIT is not associated with a formal Power Purchase Agreement, distribution companies are usually obliged to purchase all the production from renewable installations. Germany has reduced the political risk of the system being changed by guaranteeing payments for 20 years. The main problem associated with a fixed price system is that it does not lend itself easily to adjustment – whether up or down - to reflect changes in the production costs of renewable technologies.

- **Fixed premium systems** sometimes called an "environmental bonus" mechanism, operate by adding a fixed premium to the basic wholesale electricity price. From an investor perspective, the total price received per kWh is less predictable than under a feed-in tariff because it depends on a constantly changing electricity price. From a market perspective, however, it is argued that a fixed premium is easier to integrate into the overall electricity market because those involved will be reacting to market price signals. Spain is the most prominent country to have adopted a fixed premium system.
- **Tax credits** as operated in the US and Canada, offer a credit against tax payments for every kWh produced. In the United States the market has been driven by a federal Production Tax Credit (PTC) of approximately 1.8 $cents per kWh. It is adjusted annually for inflation.

10.3.2 renewable quote systems

Two types of renewable quota systems have been employed - tendering systems and green certificate systems.

- **Tendering systems** involve competitive bidding for contracts to construct and operate a particular project, or a fixed quantity of renewable capacity in a country or state. Although other factors are usually taken into account, the lowest priced bid invariably wins. This system has been used to promote wind power in Ireland, France, the UK, Denmark and China.

  The downside is that investors can bid an uneconomically low price in order to win the contract, and then not build the project. Under the UK's NFFO (Non-Fossil Fuel Obligation) tender system, for example, many contracts remained unused. It was eventually abandoned. If properly designed, however, with long contracts, a clear link to planning consent and a possible minimum price, tendering for large scale projects could be effective, as it has been for offshore oil and gas extraction in Europe's North Sea.

- **Tradable green certificate (TGC) systems** operate by offering "green certificates" for every kWh generated by a renewable producer. The value of these certificates, which can be traded on a market, is then added to the value of the basic electricity. A green certificate system usually operates in combination with a rising quota of renewable electricity generation. Power companies are bound by law to purchase an increasing proportion of renewables input. Countries which have adopted this system include the UK and Italy in Europe and many individual states in the US, where it is known as a Renewable Portfolio Standard.

  Compared with a fixed tender price, the TGC model is more risky for the investor, because the price fluctuates on a daily basis, unless effective markets for long-term certificate (and electricity) contracts are developed. Such markets do not currently exist. The system is also more complex than other payment mechanisms.

10.4 energy efficiency and innovation

Action: Set stringent efficiency and emissions standards for appliances, buildings, power plants and vehicles

Policies and measures to promote energy efficiency exist in many countries. Energy and information labels, mandatory minimum energy performance standards and voluntary efficiency agreements are the most popular measures. Effective government policies usually contain two elements - those that push the market through standards and those that pull through incentives - and have proved to be an effective, low cost way to coordinate a transition to more energy efficiency.

The Japanese front-runner programme, for example, is a regulatory scheme with mandatory targets which gives incentives to manufacturers and importers of energy-consuming equipment to continuously improve the efficiency of their products. It operates by allowing today's best models on the market to set the level for future standards.

In the residential sector in industrialised countries, standby power consumption ranges from 20 to 60 watts per household, equivalent to 4 to 10% of total residential energy consumption. Yet the technology is available to reduce standby power to 1 watt. A global standard, as proposed by the IEA, could mandate this reduction. Japan, South Korea and the state of California have not waited for this international approach and have already adopted standby standards.

Governments should mandate the phase-out of incandescent and inefficient light bulbs and replace them with the most efficient lighting. Countries like Cuba, Venezuela and Australia have already banned incandescent light bulbs.

Governments should also set emissions standards for cars and power plants, such as those proposed in Europe for passenger cars of 120g CO_2/km and 350 g/kWh for power plants. Similar emissions standards, as already implemented in China, Japan and the states of Washington and California, will support innovation and ensure that inefficient vehicles and power plants are outlawed.

image A YOUNG INDIGENOUS NENET BOY PRACTICES WITH HIS ROPE. THE BOYS ARE GIVEN A ROPE FROM PRETTY MUCH THE MOMENT THEY ARE BORN. BY THE AGE OF SIX THEY ARE OUT HELPING LASSOING THE REINDEER. THE INDIGENOUS NENETS PEOPLE MOVE EVERY 3 OR 4 DAYS SO THAT THEIR REINDEER DO NOT OVER GRAZE THE GROUND AND THEY DO NOT OVER FISH THE LAKES. THE YAMAL PENINSULA IS UNDER HEAVY THREAT FROM GLOBAL WARMING AS TEMPERATURES INCREASE AND RUSSIAS ANCIENT PERMAFROST MELTS.

Action: Support innovation in energy efficiency, low carbon transport systems and renewable energy production

Innovation will play an important role in making the Energy [R]evolution happen, and is needed to realise the ambition of ever-improving efficiency and emissions standards. Programmes supporting renewable energy and energy efficiency development and diffusion are a traditional focus of energy and environmental policies because energy innovations face barriers all along the energy supply chain (from R&D to demonstration projects to widespread deployment). Direct government support through a variety of fiscal instruments, such as tax incentives, is vital to hasten deployment of radically new technologies due to a lack of industry investment. This suggests that there is a role for the public sector in increasing investment directly and in correcting market and regulatory obstacles that inhibit investment in new technology.

Governments need to invest in research and development for more efficient appliances and building techniques, in new forms of insulation, in new types of renewable energy production (such as tidal and wave power) as well as in a low carbon transport future, through the development of better batteries for plug-in electric cars or fuels for aviation from renewable sources. Governments need to engage in innovation themselves, both through publicly funded research and by supporting private research and development.

There are numerous ways to support innovation. The most important policies are those that reduce the cost of research and development, such as tax incentives, staff subsidies or project grants. Financial support for research and development on 'dead end' energy solutions such as nuclear fusion should be diverted to supporting renewable energy, energy efficiency and decentralised energy solutions.

Specific proposals for efficiency and innovation measures include:

10.4.1 appliances and lighting

Two types of renewable quota systems have been employed - tendering systems and green certificate systems.

- **Efficiency standards** Governments should set ambitious, stringent and mandatory efficiency standards for all energy consuming appliances that constantly respond to technical innovation and enforce the phase-out of the most inefficient appliances. These standards should allow the banning of inefficient products from the market, with penalties for non-compliance.
- **Consumer awareness** Governments should inform consumers and/or set up systems that compel retailers and manufacturers to do so, about the energy efficiency of the products they use and buy, including awareness-raising and educational programmes. Consumers often make their choices based on non-financial factors but lack the necessary information.
- **Energy labelling** Labels provide the means to inform consumers of the product's relative or absolute performance and energy operating costs. Governments should support the development of endorsement and comparison labels for electrical appliances.

10.4.2 buildings

- **Residential and commercial building codes** Governments should set mandatory building codes that require the use of a set share of renewable energy for heating and cooling and compliance with a limited annual energy consumption level. These codes should be regularly upgraded in order to make use of fresh products on the market and non-compliance should be penalised.
- **Financial incentives** Given that investment costs are often a barrier to implementing energy efficiency measures, in particular for retrofitting renewable energy options, governments should offer financial incentives including tax reductions schemes, investment subsidies and preferential loans.
- **Energy intermediaries and audit programmes** Governments should develop strategies and programmes to promote the education of architects, engineers and other professionals in the building sector as well as end-users about energy efficiency opportunities in new and existing buildings. As part of this strategy governments should invest in 'energy intermediaries' and energy audit programmes in order to assist professionals and consumers in identifying opportunities for improving the efficiency of their buildings.

10.4.3 transport

- **Emissions standards** Governments should regulate the efficiency of private cars and other transport vehicles in order to push manufacturers to reduce emissions through downsizing, design and technology improvement. Improvements in efficiency will reduce CO_2 emissions irrespective of the fuel used.

  After this further reductions could be achieved by using low-emission fuels. Emissions standards should provide for an average reduction of 5g CO_2/km/year in industrialised countries. These standards need to be mandatory. To dissuade car makers from overpowering high end cars a maximum CO_2 emissions limit for individual car models should be introduced.
- **Electric vehicles** Governments should develop incentives to promote the further development of electric cars and other efficient and sustainable low carbon transport technologies. Linking electric cars to a renewable energy grid is the best possible option to reduce emissions from the transport sector.
- **Transport demand management** Governments should invest in developing, improving and promoting low emission transport options, such as public and non-motorised transport, freight transport management programmes, teleworking and more efficient land use planning in order to limit journeys.

glossary & appendix

GLOBAL

GLOSSARY OF COMMONLY USED TERMS AND ABBREVIATIONS

DEFINITIONS OF SECTORS

METHODOLOGY TO CALCULATE EMPLOYMENT

11

"because we use such inefficient lighting, 80 coal fired power plants are running day and night to produce the energy that is wasted."

GREENPEACE INTERNATIONAL
CLIMATE CAMPAIGN

image COAL FIRED POWER PLANT.

image A PRAWN SEED FARM ON MAINLAND INDIA'S SUNDARBANS COAST LIES FLOODED AFTER CYCLONE AILA. INUNDATING AND DESTROYING NEARBY ROADS AND HOUSES WITH SALT WATER.

11.1 glossary of commonly used terms and abbreviations

CHP Combined Heat and Power
CO_2 Carbon dioxide, the main greenhouse gas
GDP Gross Domestic Product (means of assessing a country's wealth)
PPP Purchasing Power Parity (adjustment to GDP assessment to reflect comparable standard of living)
IEA International Energy Agency

J Joule, a measure of energy:
kJ = 1,000 Joules,
MJ = 1 million Joules,
GJ = 1 billion Joules,
PJ = 10^{15} Joules,
EJ = 10^{18} Joules

W Watt, measure of electrical capacity:
kW = 1,000 watts,
MW = 1 million watts,
GW = 1 billion watts

kWh Kilowatt-hour, measure of electrical output: TWh = 10^{12} watt-hours
t/Gt Tonnes, measure of weight: Gt = 1 billion tonnes

table 11.1: **conversion factors - fossil fuels**

FUEL				
Coal	23.03	MJ/t	1 cubic	0.0283 m^3
Lignite	8.45	MJ/t	1 barrel	159 liter
Oil	6.12	GJ/barrel	1 US gallon	3.785 liter
Gas	38000.00	kJ/m^3	1 UK gallon	4.546 liter

table 11.2: **conversion factors - different energy units**

FROM / TO: MULTIPLY BY	TJ	Gcal	Mtoe	Mbtu	GWh
TJ	1	238.8	2.388×10^{-5}	947.8	0.2778
Gcal	4.1868×10^{-3}	1	$10^{(-7)}$	3.968	1.163×10^{-3}
Mtoe	4.1868×10^{4}	10^{7}	1	3968×10^{7}	11630
Mbtu	1.0551×10^{-3}	0.252	2.52×10^{-8}	1	2.931×10^{-4}
GWh	3.6	860	8.6×10^{-5}	3412	1

11.2 definition of sectors

The definition of different sectors below is the same as the sectoral breakdown in the IEA World Energy Outlook series.

All definitions below are from the IEA Key World Energy Statistics

Industry sector: Consumption in the industry sector includes the following subsectors (energy used for transport by industry is not included -> see under "Transport")

- Iron and steel industry
- Chemical industry
- Non-metallic mineral products e.g. glass, ceramic, cement etc.
- Transport equipment
- Machinery
- Mining
- Food and tobacco
- Paper, pulp and print
- Wood and wood products (other than pulp and paper)
- Construction
- Textile and Leather

Transport sector: The Transport sector includes all fuels from transport such as road, railway, domestic aviation and domestic navigation. Fuel used for ocean, costal and inland fishing is included in "Other Sectors".

Other sectors: 'Other sectors' covers agriculture, forestry, fishing, residential, commercial and public services.

Non-energy use: Covers use of other petroleum products such as paraffin waxes, lubricants, bitumen etc.

japan: reference scenario

table 11.1: japan: electricity generation

TWh/a	2007	2015	2020	2030	2040	2050
Power plants	**1,123**	**1,162**	**1,182**	**1,231**	**1,270**	**1,298**
Coal	272	316	323	388	414	444
Lignite	0	0	0	0	0	0
Gas	328	345	380	465	512	543
Oil	153	123	123	124	124	124
Diesel	3	3	2	2	1	1
Nuclear	264	251	219	97	47	0
Biomass	23	25	26	28	29	31
Hydro	74	84	85	87	89	91
Wind	3	9	13	26	32	36
PV	0	4	6	10	14	18
Geothermal	3	4	5	6	8	10
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Combined heat & power production	**0**	**6**	**11**	**15**	**19**	**23**
Coal	0	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	6	11	15	18	22
Oil	0	0	0	0	0	0
Biomass	0	0	0	0	1	1
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	6	11	15	19	23
Total generation	**1,123**	**1,168**	**1,193**	**1,246**	**1,289**	**1,321**
Fossil	757	792	839	993	1,069	1,134
Coal	272	316	323	388	414	444
Lignite	0	0	0	0	0	0
Gas	328	351	391	480	530	565
Oil	153	123	123	124	124	124
Diesel	3	3	2	2	1	1
Nuclear	264	251	219	97	47	0
Hydrogen	0	0	0	0	0	0
Renewables	**103**	**126**	**135**	**157**	**173**	**187**
Hydro	74	84	85	87	89	91
Wind	3	9	13	26	32	36
PV	0	4	6	10	14	18
Biomass	23	25	26	28	30	32
Geothermal	3	4	5	6	8	10
Solar thermal	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Distribution losses	51	53	54	57	58	60
Own consumption electricity	62	65	66	69	71	73
Electricity for hydrogen production	0	0	0	0	0	0
Final energy consumption (electricity)	**1,010**	**1,050**	**1,073**	**1,121**	**1,159**	**1,188**
Fluctuating RES (PV, Wind, Ocean)	3	13	19	36	46	54
Share of fluctuating RES	0.2%	1.1%	1.6%	2.9%	3.6%	4.1%
RES share	**9.1%**	**10.8%**	**11.3%**	**12.6%**	**13.4%**	**14.2%**

table 11.2: japan: heat supply

PJ/a	2007	2015	2020	2030	2040	2050
District heating plants	**25**	**29**	**30**	**27**	**25**	**23**
Fossil fuels	19	21	22	19	19	17
Biomass	7	8	8	7	7	6
Solar collectors	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Heat from CHP	**0**	**18**	**33**	**46**	**59**	**66**
Fossil fuels	0	18	32	45	56	63
Biomass	0	0	1	2	2	4
Geothermal	0	0	0	0	0	0
Fuel cell (hydrogen)	0	0	0	0	0	0
Direct heating[1]	**4,678**	**5,098**	**5,217**	**5,240**	**5,218**	**5,138**
Fossil fuels	4,555	4,874	4,890	4,777	4,638	4,437
Biomass	92	123	147	178	220	272
Solar collectors	23	71	116	179	229	274
Geothermal[2]	9	31	63	105	131	155
Total heat supply[1]	**4,703**	**5,145**	**5,280**	**5,313**	**5,302**	**5,228**
Fossil fuels	4,573	4,913	4,945	4,842	4,713	4,517
Biomass	99	131	156	186	229	281
Solar collectors	23	71	116	179	229	274
Geothermal[2]	9	31	63	105	131	155
Fuel cell ((hydrogen)	0	0	0	0	0	0
RES share (including RES electricity)	**2.8%**	**4.5%**	**6.4%**	**8.9%**	**11.1%**	**13.6%**

1) including cooling. 2) including heat pumps

table 11.3: japan: co₂ emissions

MILL t/a	2007	2015	2020	2030	2040	2050
Condensation power plants	**460**	**480**	**498**	**580**	**607**	**615**
Coal	220	254	259	310	330	330
Lignite	0	0	0	0	0	0
Gas	143	147	160	191	198	207
Oil	96	77	77	77	78	78
Diesel	2	1	1	1	1	0
Combined heat & power production	**0**	**3**	**5**	**7**	**8**	**9**
Coal	0	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	3	5	7	8	9
Oil	0	0	0	0	0	0
CO_2 emissions power generation (incl. CHP public)	**460**	**482**	**503**	**587**	**615**	**624**
Coal	220	254	259	310	330	330
Lignite	0	0	0	0	0	0
Gas	143	150	166	199	207	215
Oil & diesel	98	78	78	78	78	78
CO_2 emissions by sector	**1,301**	**1,344**	**1,360**	**1,420**	**1,413**	**1,373**
% of 1990 emissions	114%	118%	119%	124%	124%	120%
Industry	210	213	211	204	196	189
Other sectors	170	189	187	171	156	138
Transport	244	263	267	271	264	247
Power generation (incl. CHP public)	460	480	498	580	607	615
Other conversion	217	200	198	194	191	184
Population (Mill.)	127.4	125.8	123.7	117.4	109.8	101.7
CO_2 emissions per capita (t/capita)	**10.2**	**10.7**	**11.0**	**12.1**	**12.9**	**13.5**

table 11.4: japan: installed capacity

GW	2007	2015	2020	2030	2040	2050
Power plants	**226**	**225**	**229**	**242**	**251**	**255**
Coal	50	49	52	61	64	65
Lignite	0	0	0	0	0	0
Gas	55	61	67	82	90	95
Oil	46	41	41	41	41	41
Diesel	3.2	2.5	2.0	1.5	1.0	0.8
Nuclear	48	40	31	14	7	0
Biomass	3.1	3.4	3.5	3.8	4.1	4.4
Hydro	19	20	21	21	21	21
Wind	1.5	4.7	5.9	9.3	10.9	11.3
PV	0.01	3.9	5.4	8.6	11.6	14.4
Geothermal	0.6	0.6	0.7	0.8	1.1	1.3
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Combined heat & power production	**0**	**0.9**	**1.7**	**2.6**	**3.8**	**4.5**
Coal	0	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	0.9	1.7	2.6	3.6	4.4
Oil	0	0	0	0	0	0
Biomass	0	0	0	0.1	0.1	0.2
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	0.9	1.7	2.6	3.8	4.5
Total generation	**226**	**226**	**230**	**245**	**255**	**260**
Fossil	154	154	164	188	200	207
Coal	50	49	52	61	64	65
Lignite	0	0	0	0	0	0
Gas	55	62	69	84	94	100
Oil	46	41	41	41	41	41
Diesel	3.2	2.5	2.0	1.5	1.0	0.8
Nuclear	48	40	31	14	7	0
Hydrogen	0	0	0	0	0	0
Renewables	**24**	**33**	**36**	**43**	**49**	**53**
Hydro	19	20	21	21	21	21
Wind	1.5	4.7	5.9	9.3	10.9	11.3
PV	0.01	3.9	5.4	8.6	11.6	14.4
Biomass	3.1	3.4	3.5	3.9	4.2	4.6
Geothermal	0.6	0.6	0.7	0.8	1.1	1.3
Solar thermal	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Fluctuating RES (PV, Wind, Ocean)	1.5	8.6	11.3	18	22	26
Share of fluctuating RES	0.7%	3.8%	4.9%	7.3%	8.8%	9.9%
RES share	**10.7%**	**14.6%**	**15.7%**	**17.7%**	**19.1%**	**20.3%**

table 11.5: japan: primary energy demand

PJ/a	2007	2015	2020	2030	2040	2050
Total	**21,767**	**22,633**	**22,776**	**22,566**	**22,136**	**21,362**
Fossil	**18,162**	**18,966**	**19,287**	**20,185**	**20,111**	**19,662**
Hard coal	4,782	5,038	4,994	5,321	5,389	5,342
Lignite	0	0	0	0	0	0
Natural gas	3,680	4,149	4,633	5,555	5,971	6,340
Crude oil	9,699	9,780	9,659	9,309	8,752	7,981
Nuclear	**2,879**	**2,733**	**2,393**	**1,056**	**509**	**0**
Renewables	**726**	**933**	**1,097**	**1,326**	**1,516**	**1,699**
Hydro	266	302	306	313	320	328
Wind	9	32	47	94	115	130
Solar	23	86	138	215	279	339
Biomass	310	390	437	499	563	636
Geothermal	118	123	169	205	238	267
Ocean Energy	0	0	0	0	0	0
RES share	**3.3%**	**4.1%**	**4.8%**	**5.9%**	**6.8%**	**8.0%**

table 11.6: japan: final energy demand

PJ/a	2007	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**14,311**	**15,232**	**15,483**	**15,681**	**15,633**	**15,367**
Total (energy use)	**12,541**	**13,462**	**13,713**	**13,911**	**13,863**	**13,597**
Transport	**3,450**	**3,734**	**3,800**	**3,870**	**3,776**	**3,552**
Oil products	3,382	3,648	3,706	3,766	3,666	3,431
Natural gas	0	0	0	0	0	0
Biofuels	0	18	26	35	39	43
Electricity	68	68	68	69	71	77
RES electricity	6	7	8	9	10	11
Hydrogen	0	0	0	0	0	0
RES share Transport	**0.2%**	**0.7%**	**0.9%**	**1.1%**	**1.3%**	**1.5%**
Industry	**4,154**	**4,369**	**4,496**	**4,669**	**4,788**	**4,870**
Electricity	1,219	1,312	1,373	1,461	1,529	1,579
RES electricity	111	141	155	184	205	224
District heat	1	19	34	47	59	67
RES district heat	0	3	5	6	6	7
Coal	788	672	574	357	213	165
Oil products	1,239	1,266	1,201	1,181	1,105	951
Gas	793	942	1,106	1,342	1,520	1,665
Solar	0	13	27	56	86	116
Biomass and waste	114	130	148	169	204	239
Geothermal	0	16	32	56	72	87
Hydrogen	0	0	0	0	0	0
RES share Industry	**5.4%**	**6.9%**	**8.2%**	**10.1%**	**12.0%**	**13.8%**
Other Sectors	**4,937**	**5,359**	**5,418**	**5,371**	**5,300**	**5,176**
Electricity	2,350	2,402	2,421	2,505	2,572	2,621
RES electricity	215	259	274	316	345	371
District heat	24	28	29	26	24	23
RES district heat	6	7	8	7	6	6
Coal	25	25	24	22	20	18
Oil products	1,450	1,572	1,515	1,238	971	693
Gas	1,055	1,237	1,277	1,363	1,452	1,514
Solar	23	58	89	123	143	158
Biomass and waste	1	22	32	45	57	80
Geothermal	9	15	31	49	60	68
RES share Other Sectors	**5.1%**	**6.7%**	**8.0%**	**10.1%**	**11.5%**	**13.2%**
Total RES	**486**	**690**	**834**	**1,054**	**1,234**	**1,411**
RES share	**3.9%**	**5.1%**	**6.1%**	**7.6%**	**8.9%**	**10.4%**
Non energy use	**1,770**	**1,770**	**1,770**	**1,770**	**1,770**	**1,770**
Oil	1,737	1,737	1,737	1,737	1,737	1,737
Gas	16	16	16	16	16	16
Coal	16	16	16	16	16	16

japan: energy [r]evolution scenario

table 11.7: japan: electricity generation

TWh/a	2007	2015	2020	2030	2040	2050
Power plants	**1,123**	**1,095**	**1,026**	**947**	**852**	**754**
Coal	272	308	237	114	44	3
Lignite	0	0	0	0	0	0
Gas	328	358	363	370	308	238
Oil	153	115	88	54	26	6
Diesel	3	3	2	2	1	1
Nuclear	264	135	64	14	0	0
Biomass	23	35	39	42	41	33
Hydro	74	88	95	104	111	115
Wind	3	20	50	95	113	118
PV	0	18	57	93	125	141
Geothermal	3	15	23	41	54	63
Solar thermal power plants	0	0	0	0	0	1
Ocean energy	0	1	7	18	29	35
Combined heat & power production	**0**	**10**	**31**	**68**	**107**	**138**
Coal	0	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	8	21	41	53	52
Oil	0	0	0	0	0	0
Biomass	0	2	10	25	44	66
Geothermal	0	0	1	3	10	19
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	2	11	23	44	65
Autoproducers	0	8	20	45	63	73
Total generation	**1,123**	**1,105**	**1,057**	**1,015**	**959**	**892**
Fossil	757	791	711	580	432	300
Coal	272	308	237	114	44	3
Lignite	0	0	0	0	0	0
Gas	328	366	384	411	361	290
Oil	153	115	88	54	26	6
Diesel	3	3	2	2	1	1
Nuclear	264	135	64	14	0	0
Hydrogen	0	0	0	0	0	0
Renewables	**103**	**179**	**282**	**421**	**527**	**591**
Hydro	74	88	95	104	111	115
Wind	3	20	50	95	113	118
PV	0	18	57	93	125	141
Biomass	23	37	49	67	85	99
Geothermal	3	15	24	44	64	82
Solar thermal	0	0	0	0	0	1
Ocean energy	0	1	7	18	29	35
Distribution losses	51	53	53	52	50	49
Own consumption electricity	62	64	64	58	35	21
Electricity for hydrogen production	0	0	0	0	5	7
Final energy consumption (electricity)	**1,010**	**989**	**940**	**905**	**869**	**815**
Fluctuating RES (PV, Wind, Ocean)	3	39	114	206	267	294
Share of fluctuating RES	0.2%	3.5%	10.8%	20.3%	27.8%	33.0%
RES share	**9.1%**	**16.2%**	**26.7%**	**41.5%**	**55.0%**	**66.3%**
'Efficiency' savings (compared to Ref.)	**0**	**65**	**149**	**266**	**383**	**498**

table 11.8: japan: heat supply

PJ/a	2007	2015	2020	2030	2040	2050
District heating plants	**25**	**41**	**80**	**162**	**177**	**131**
Fossil fuels	19	29	51	74	50	26
Biomass	7	12	26	71	90	71
Solar collectors	0	0	0	1	1	1
Geothermal	0	0	3	16	35	33
Heat from CHP	**0**	**38**	**128**	**263**	**421**	**535**
Fossil fuels	0	28	73	136	172	161
Biomass	0	9	48	103	158	209
Geothermal	0	1	6	24	91	165
Fuel cell (hydrogen)	0	0	0	0	0	0
Direct heating[1]	**4,678**	**4,685**	**4,319**	**3,709**	**2,952**	**2,272**
Fossil fuels	4,555	4,440	3,847	2,921	2,002	1,210
Biomass	92	113	124	180	231	256
Solar collectors	23	79	164	286	331	360
Geothermal[2]	9	53	183	322	388	446
Total heat supply[1]	**4,703**	**4,764**	**4,526**	**4,133**	**3,550**	**2,937**
Fossil fuels	4,573	4,497	3,971	3,130	2,225	1,397
Biomass	99	134	198	354	479	535
Solar collectors	23	79	164	287	332	361
Geothermal[2]	9	54	193	362	515	644
Fuel cell (hydrogen)	0	0	0	0	0	0
RES share (including RES electricity)	**2.8%**	**5.6%**	**12.3%**	**24.3%**	**37.3%**	**52.4%**
'Efficiency' savings (compared to Ref.)	**0**	**381**	**754**	**1,179**	**1,752**	**2,291**

1) including cooling. 2) including heat pumps

table 11.9: japan: CO_2 emissions

MILL t/a	2007	2015	2020	2030	2040	2050
Condensation power plants	**460**	**474**	**400**	**278**	**171**	**97**
Coal	220	248	190	91	35	2
Lignite	0	0	0	0	0	0
Gas	143	153	153	152	120	90
Oil	96	72	55	33	16	4
Diesel	2	1	1	1	1	0
Combined heat & power production	**0**	**4**	**10**	**19**	**23**	**21**
Coal	0	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	4	10	19	23	21
Oil	0	0	0	0	0	0
CO_2 emissions power generation (incl. CHP public)	**460**	**478**	**410**	**297**	**194**	**118**
Coal	220	248	190	91	35	2
Lignite	0	0	0	0	0	0
Gas	143	157	163	172	143	111
Oil & diesel	98	73	56	34	17	4
CO_2 emissions by sector	**1,301**	**1,270**	**1,083**	**801**	**513**	**298**
% of 1990 emissions	114%	111%	95%	70%	45%	26%
Industry	210	197	176	153	123	91
Other sectors	170	170	141	89	46	16
Transport	244	246	210	162	109	58
Power generation (incl. CHP public)	460	475	403	283	179	105
Other conversion	217	181	154	114	56	28
Population (Mill.)	127.4	126	124	117	110	102
CO_2 emissions per capita (t/capita)	**10.2**	**10.1**	**8.8**	**6.8**	**4.7**	**2.9**

table 11.10: japan: installed capacity

GW	2007	2015	2020	2030	2040	2050
Power plants	**226**	**230**	**248**	**261**	**274**	**266**
Coal	50	51	39	19	9	1.1
Lignite	0	0	0	0	0	0
Gas	55	63	61	62	62	59
Oil	46	38	29	21	13	4.1
Diesel	3.2	2.5	2.0	1.5	1.0	0.8
Nuclear	48	19	8.9	2.0	0	0
Biomass	3.1	4.8	5.4	5.9	5.8	5.3
Hydro	19	21	23	25	26	27
Wind	1.5	11	23	34	38	37
PV	0.01	17	51	80	104	113
Geothermal	0.6	2.4	3.3	5.8	7.3	8.4
Solar thermal power plants	0	0	0	0	0.1	0.3
Ocean energy	0	0.3	2.0	5.1	8.3	10
Combined heat & power production	**0**	**1.8**	**6.1**	**13**	**21**	**26**
Coal	0	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	1.5	3.9	8.3	12	12
Oil	0	0	0	0	0	0
Biomass	0	0.4	2.0	4.3	7.5	11
Geothermal	0	0	0.1	0.4	1.6	3.0
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0.5	2.6	5.2	9.2	13
Autoproducers	0	1.4	3.4	7.9	11	13
Total generation	**226**	**232**	**254**	**274**	**295**	**292**
Fossil	154	156	135	112	96	77
Coal	50	51	39	19	9	1.1
Lignite	0	0	0	0	0	0
Gas	55	64	64	70	73	71
Oil	46	38	29	21	13	4.1
Diesel	3.2	2.5	2.0	1.5	1.0	0.8
Nuclear	48	19	9	2	0	0
Hydrogen	0	0	0	0	0	0
Renewables	**24**	**56**	**110**	**161**	**199**	**215**
Hydro	19	21	23	25	26	27
Wind	1.5	11	23	34	38	37
PV	0.01	17	51	80	104	113
Biomass	3.1	5.1	7.4	10	13	17
Geothermal	0.6	2.4	3.4	6.2	9.0	11
Solar thermal	0	0	0	0	0	0
Ocean energy	0	0.3	2.0	5.1	8.3	10
Fluctuating RES (PV, Wind, Ocean)	1.5	27	76	119	150	160
Share of fluctuating RES	0.7%	11.8%	29.9%	43.5%	51.0%	54.7%
RES share	**10.7%**	**24.3%**	**43.2%**	**58.5%**	**67.5%**	**73.6%**

table 11.11: japan: primary energy demand

PJ/a	2007	2015	2020	2030	2040	2050
Total	**21,767**	**20,899**	**19,003**	**16,332**	**13,610**	**11,310**
Fossil	**18,162**	**17,814**	**15,622**	**12,374**	**8,998**	**6,181**
Hard coal	4,782	4,296	3,232	1,627	746	236
Lignite	0	0	0	0	0	0
Natural gas	3,680	4,327	4,505	4,633	3,804	2,803
Crude oil	9,699	9,191	7,885	6,114	4,448	3,142
Nuclear	**2,879**	**1,473**	**696**	**156**	**0**	**0**
Renewables	**726**	**1,612**	**2,685**	**3,803**	**4,613**	**5,129**
Hydro	266	317	342	374	400	414
Wind	9	72	180	342	407	425
Solar	23	144	369	622	783	874
Biomass	310	647	1,084	1,355	1,538	1,632
Geothermal	118	429	685	1,045	1,381	1,658
Ocean Energy	0	4	25	65	104	126
RES share	**3.3%**	**7.7%**	**14.1%**	**23.3%**	**33.9%**	**45.3%**
'Efficiency' savings (compared to Ref.)	**0**	**1,734**	**3,773**	**6,234**	**8,526**	**10,052**

table 11.12: japan: final energy demand

PJ/a	2007	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**14,311**	**14,429**	**13,562**	**12,193**	**10,607**	**9,045**
Total (energy use)	**12,541**	**12,659**	**11,793**	**10,423**	**8,837**	**7,275**
Transport	**3,450**	**3,634**	**3,370**	**2,843**	**2,286**	**1,761**
Oil products	3,382	3,418	2,888	2,203	1,461	754
Natural gas	0	6	29	66	72	66
Biofuels	0	129	326	328	336	399
Electricity	68	81	127	233	399	515
RES electricity	6	13	34	97	219	342
Hydrogen	0	0	0	12	19	27
RES share Transport	**0.2%**	**3.9%**	**10.7%**	**15.1%**	**24.7%**	**43.0%**
Industry	**4,154**	**4,069**	**3,815**	**3,599**	**3,239**	**2,870**
Electricity	1,219	1,206	1,109	1,045	954	885
RES electricity	111	195	296	433	525	587
District heat	1	31	76	178	233	251
RES district heat	0	8	29	89	148	183
Coal	788	629	453	251	158	88
Oil products	1,239	1,156	1,041	922	677	471
Gas	793	882	909	886	821	678
Solar	0	27	58	109	125	133
Biomass and waste	114	122	128	131	160	196
Geothermal	0	16	40	77	111	167
Hydrogen	0	0	0	0	0	0
RES share Industry	**5.4%**	**9.0%**	**14.5%**	**23.3%**	**33.0%**	**44.2%**
Other Sectors	**4,937**	**4,957**	**4,607**	**3,981**	**3,312**	**2,645**
Electricity	2,350	2,273	2,147	1,963	1,768	1,522
RES electricity	215	368	573	814	973	1,010
District heat	24	46	126	234	348	395
RES district heat	6	14	50	128	239	306
Coal	25	21	17	10	0	0
Oil products	1,450	1,427	1,112	594	259	94
Gas	1,055	1,093	964	738	417	101
Solar	23	52	105	177	206	226
Biomass and waste	1	17	24	86	115	104
Geothermal	9	28	114	179	200	202
RES share Other Sectors	**5.1%**	**9.7%**	**18.8%**	**34.8%**	**52.3%**	**69.9%**
Total RES	**486**	**989**	**1,777**	**2,654**	**3,366**	**3,873**
RES share	**3.9%**	**7.8%**	**15.1%**	**25.5%**	**38.1%**	**53.2%**
Non energy use	**1,770**	**1,770**	**1,770**	**1,770**	**1,770**	**1,770**
Oil	1,737	1,737	1,737	1,737	1,737	1,737
Gas	16	16	16	16	16	16
Coal	16	16	16	16	16	16

japan: advanced energy [r]evolution scenario

table 11.13: japan: electricity generation

TWh/a	2007	2015	2020	2030	2040	2050
Power plants	**1,123**	**1,036**	**970**	**962**	**883**	**819**
Coal	272	274	116	19	5	0
Lignite	0	0	0	0	0	0
Gas	328	434	374	350	251	108
Oil	153	115	78	54	9	0
Diesel	3	3	2	2	1	1
Nuclear	264	0	0	0	0	0
Biomass	23	35	38	39	39	39
Hydro	74	88	101	110	114	115
Wind	3	44	140	179	200	228
PV	0	26	64	111	135	156
Geothermal	3	17	49	80	93	120
Solar thermal power plants	0	0	0	0	0	1
Ocean energy	0	1	9	19	35	50
Combined heat & power production	**0**	**10**	**58**	**87**	**107**	**138**
Coal	0	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	8	18	28	31	31
Oil	0	0	0	0	0	0
Biomass	0	2	38	52	56	69
Geothermal	0	0	2	6	18	35
Hydrogen	0	0	0	1	2	4
CHP by producer						
Main activity producers	0	2	26	34	44	65
Autoproducers	0	8	32	53	63	73
Total generation	**1,123**	**1,046**	**1,028**	**1,049**	**990**	**957**
Fossil	757	834	587	452	297	140
Coal	272	274	116	19	5	0
Lignite	0	0	0	0	0	0
Gas	328	442	391	378	282	139
Oil	153	115	78	54	9	0
Diesel	3	3	2	2	1	1
Nuclear	264	0	0	0	0	0
Hydrogen	0	0	0	1	2	4
Renewables	**103**	**213**	**440**	**596**	**690**	**813**
Hydro	74	88	101	110	114	115
Wind	3	44	140	179	200	228
PV	0	26	64	111	135	156
Biomass	23	37	76	91	95	108
Geothermal	3	17	51	86	111	155
Solar thermal	0	0	0	0	0	1
Ocean energy	0	1	9	19	35	50
Distribution losses	51	0	0	47	46	43
Own consumption electricity	62	0	0	52	28	16
Electricity for hydrogen production	0	0	0	0	6	17
Final energy consumption (electricity)	**1,010**	**931**	**917**	**950**	**909**	**880**
Fluctuating RES (PV, Wind, Ocean)	3	71	213	309	370	434
Share of fluctuating RES	0.2%	6.7%	20.7%	29.4%	37.4%	45.4%
RES share	**9.1%**	**20.3%**	**42.8%**	**56.8%**	**69.8%**	**85.0%**
'Efficiency' savings (compared to Ref.)	**0**	**126**	**210**	**282**	**401**	**513**

table 11.14: japan: heat supply

PJ/a	2007	2015	2020	2030	2040	2050
District heating plants	**25**	**42**	**124**	**163**	**166**	**134**
Fossil fuels	19	29	68	68	42	20
Biomass	7	12	49	72	71	59
Solar collectors	0	0	1	1	7	9
Geothermal	0	0	6	21	46	46
Heat from CHP	**0**	**39**	**249**	**359**	**479**	**616**
Fossil fuels	0	26	62	97	104	89
Biomass	0	13	165	203	209	233
Geothermal	0	1	21	56	159	283
Fuel cell (hydrogen)	0	0	1	4	7	11
Direct heating[1]	**4,678**	**4,683**	**4,153**	**3,612**	**2,905**	**2,188**
Fossil fuels	4,555	4,376	3,380	2,482	1,640	730
Biomass	92	132	234	255	245	216
Solar collectors	23	99	231	383	415	489
Geothermal[2]	9	75	307	491	591	669
Hydrogen	0	0	0	0	14	83
Total heat supply[1]	**4,703**	**4,764**	**4,526**	**4,133**	**3,550**	**2,937**
Fossil fuels	4,573	4,431	3,510	2,647	1,786	839
Biomass	99	158	448	530	525	508
Solar collectors	23	99	232	385	421	499
Geothermal[2]	9	76	334	568	796	998
Fuel cell (hydrogen)	0	0	1	4	21	94
RES share (including RES electricity)	**2.8%**	**7.0%**	**22.4%**	**35.9%**	**49.5%**	**70.9%**
'Efficiency' savings (compared to Ref.)	**0**	**382**	**754**	**1,179**	**1,752**	**2,291**

1) including cooling. 2) including heat pumps

table 11.15: japan: CO_2 emissions

MILL t/a	2007	2015	2020	2030	2040	2050
Condensation power plants	**460**	**479**	**301**	**194**	**107**	**42**
Coal	220	221	93	16	4	0
Lignite	0	0	0	0	0	0
Gas	143	185	158	144	97	41
Oil	96	72	49	33	6	0
Diesel	2	1	1	1	1	0
Combined heat & power production	**0**	**4**	**9**	**13**	**14**	**12**
Coal	0	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	4	9	13	14	12
Oil	0	0	0	0	0	0
CO_2 emissions power generation (incl. CHP public)	**460**	**483**	**309**	**207**	**121**	**54**
Coal	220	221	93	16	4	0
Lignite	0	0	0	0	0	0
Gas	143	189	166	157	111	53
Oil & diesel	98	73	50	34	6	1
CO_2 emissions by sector	**1,301**	**1,247**	**866**	**620**	**361**	**147**
% of 1990 emissions	114%	109%	76%	54%	32%	13%
Industry	210	195	158	129	94	51
Other sectors	170	165	111	66	37	13
Transport	244	237	176	137	83	23
Power generation (incl. CHP public)	460	480	304	199	113	46
Other conversion	217	170	117	89	34	15
Population (Mill.)	127.4	126	124	117	110	102
CO_2 emissions per capita (t/capita)	**10.2**	**9.9**	**7.0**	**5.3**	**3.3**	**1.4**

table 11.16: japan: installed capacity

GW	2007	2015	2020	2030	2040	2050
Power plants	**226**	**233**	**272**	**310**	**315**	**315**
Coal	50	46	19	3.2	1.0	0
Lignite	0	0	0	0	0	0
Gas	55	63	59	62	60	54
Oil	46	46	39	36	18	0.4
Diesel	3.2	2.5	2.0	1.5	1.0	0.8
Nuclear	48	0	0.0	0	0	0
Biomass	3.1	4.7	5.2	5.4	5.6	6.3
Hydro	19	21	24	26	27	27
Wind	1.5	23	56	64	68	71
PV	0.01	24	57	96	112	125
Geothermal	0.6	2.8	6.9	11	13	16
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	0	0.3	2.6	5.4	10	14
Combined heat & power production	**0**	**1.8**	**12**	**16**	**20**	**28**
Coal	0	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	1.4	3.4	6.1	7.1	10
Oil	0	0	0	0	0	0
Biomass	0	0.4	8.1	8.8	9.4	12
Geothermal	0	0	0.4	1.1	3.0	5.6
Hydrogen	0	0	0	0.2	0.4	0.7
CHP by producer						
Main activity producers	0	0.5	6.7	7.3	8.8	13
Autoproducers	0	1.4	5.3	9.0	11	15
Total generation	**226**	**235**	**284**	**327**	**335**	**343**
Fossil	154	158	123	108	87	65
Coal	50	46	19	3.2	1.0	0
Lignite	0	0	0	0	0	0
Gas	55	64	63	68	67	64
Oil	46	46	39	36	18	0.4
Diesel	3.2	2.5	2.0	1.5	1.0	0.8
Nuclear	48	0	0.0	0	0	0
Hydrogen	0	0	0	0.2	0.4	0.7
Renewables	**24**	**76**	**161**	**218**	**248**	**277**
Hydro	19	21	24	26	27	27
Wind	1.5	23	56	64	68	71
PV	0.01	24	57	96	112	125
Biomass	3.1	5.2	13	14	15	18
Geothermal	0.6	2.8	7.4	12	16	22
Solar thermal	0	0	0	0	0.1	0.3
Ocean energy	0	0.3	2.6	5.4	10	14
Fluctuating RES (PV, Wind, Ocean)	1.5	47	116	165	190	210
Share of fluctuating RES	0.7%	20.0%	40.7%	50.6%	56.7%	61.4%
RES share	**10.7%**	**32.5%**	**56.6%**	**66.7%**	**74.0%**	**80.8%**

table 11.17: japan: primary energy demand

PJ/a	2007	2015	2020	2030	2040	2050
Total	**21,767**	**19,484**	**17,534**	**15,774**	**13,264**	**11,114**
Fossil	**18,162**	**17,650**	**13,280**	**10,333**	**7,112**	**4,015**
Hard coal	4,782	3,391	1,505	336	109	27
Lignite	0	0	0	0	0	0
Natural gas	3,680	5,251	4,979	4,653	3,311	1,732
Crude oil	9,699	9,008	6,796	5,343	3,692	2,256
Nuclear	**2,879**	**0**	**0**	**0**	**0**	**0**
Renewables	**726**	**1,834**	**4,254**	**5,441**	**6,152**	**7,098**
Hydro	266	317	364	396	410	414
Wind	9	157	504	644	720	821
Solar	23	196	470	786	927	1,083
Biomass	310	663	1,479	1,604	1,611	1,628
Geothermal	118	499	1,404	1,942	2,358	2,972
Ocean Energy	0	4	32	68	126	180
RES share	**3.3%**	**9.4%**	**24.3%**	**34.5%**	**46.4%**	**63.9%**
'Efficiency' savings (compared to Ref.)	**0**	**3,149**	**5,242**	**6,793**	**8,873**	**10,248**

table 11.18: japan: final energy demand

PJ/a	2007	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**14,311**	**14,086**	**12,950**	**11,941**	**10,308**	**8,597**
Total (energy use)	**12,541**	**12,316**	**11,181**	**10,171**	**8,538**	**6,828**
Transport	**3,450**	**3,514**	**3,020**	**2,693**	**2,086**	**1,391**
Oil products	3,382	3,292	2,410	1,853	1,103	267
Natural gas	0	6	39	62	66	65
Biofuels	0	124	314	327	336	346
Electricity	68	91	258	435	550	676
RES electricity	6	19	110	247	384	575
Hydrogen	0	0	0	16	32	37
RES share Transport	**0.2%**	**4.1%**	**14.0%**	**21.7%**	**35.5%**	**68.5%**
Industry	**4,154**	**4,028**	**3,743**	**3,563**	**3,198**	**2,847**
Electricity	1,219	1,166	1,031	1,015	923	875
RES electricity	111	237	442	576	644	744
District heat	1	31	134	222	264	341
RES district heat	0	8	86	145	207	295
Coal	788	587	315	123	45	10
Oil products	1,239	1,153	973	824	585	208
Gas	793	915	942	905	736	522
Solar	0	27	93	152	193	273
Biomass and waste	114	122	156	157	161	150
Geothermal	0	29	98	165	276	381
Hydrogen	0	0	0	0	14	87
RES share Industry	**5.4%**	**10.5%**	**23.4%**	**33.6%**	**46.6%**	**67.3%**
Other Sectors	**4,937**	**4,774**	**4,418**	**3,915**	**3,254**	**2,589**
Electricity	2,350	2,093	2,007	1,936	1,734	1,477
RES electricity	215	425	860	1,100	1,210	1,255
District heat	24	48	237	330	353	397
RES district heat	6	14	141	199	271	352
Coal	25	7	0	0	0	0
Oil products	1,450	1,384	714	305	120	26
Gas	1,055	1,086	999	735	440	137
Solar	23	75	148	231	240	234
Biomass and waste	1	45	144	150	130	103
Geothermal	9	35	168	228	238	215
RES share Other Sectors	**5.1%**	**12.5%**	**33.1%**	**48.7%**	**64.2%**	**83.4%**
Total RES	**486**	**1,160**	**2,761**	**3,687**	**4,321**	**5,030**
RES share	**3.9%**	**9.4%**	**24.7%**	**36.2%**	**50.6%**	**73.7%**
Non energy use	**1,770**	**1,770**	**1,770**	**1,770**	**1,770**	**1,770**
Oil	1,737	1,737	1,737	1,737	1,737	1,737
Gas	16	16	16	16	16	16
Coal	16	16	16	16	16	16

japan: total new investment by technology

table 11.19: japan: total investment

MILLION $	2011-2020	2021-2030	2031-2040	2041-2050	2007-2050	2007-2050 AVERAGE PER YEAR
Reference scenario						
Conventional (fossil & nuclear)	**89,757**	**130,748**	**128,931**	**93,703**	**501,531**	**11,661**
Renewables	**27,275**	**19,674**	**17,880**	**15,186**	**95,416**	**2,219**
Biomass	4,531	3,254	1,429	1,415	13,835	322
Hydro	5,316	2,742	2,654	2,693	16,060	373
Wind	5,220	5,089	5,350	3,930	21,950	510
PV	8,924	6,484	5,848	4,646	32,318	752
Geothermal	2,116	890	534	991	4,861	113
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Energy [R]evolution						
Conventional (fossil & nuclear)	**60,533**	**115,851**	**47,624**	**2,309**	**284,610**	**6,619**
Renewables	**198,085**	**90,753**	**142,378**	**88,939**	**535,556**	**12,455**
Biomass	9,327	3,702	5,082	0	21,318	496
Hydro	9,660	4,038	3,514	2,926	22,793	530
Wind	25,533	13,182	25,665	10,136	76,877	1,788
PV	115,188	41,698	63,933	29,399	256,633	5,968
Geothermal	20,384	6,242	7,958	7,312	42,226	982
Solar thermal power plants	0	0	346	722	1,068	25
Ocean energy	6,791	7,699	6,702	8,474	29,665	690
Advanced Energy [R]evolution						
Conventional (fossil & nuclear)	**60,112**	**74,959**	**47,206**	**3,842**	**244,412**	**5,684**
Renewables	**307,569**	**103,238**	**193,236**	**123,960**	**743,404**	**17,288**
Biomass	8,851	3,149	5,111	2,243	22,560	525
Hydro	12,021	4,022	2,958	2,510	24,167	562
Wind	65,906	9,797	59,527	11,749	149,339	3,473
PV	133,087	54,922	63,222	39,738	297,386	6,916
Geothermal	41,750	10,309	8,726	22,404	83,519	1,942
Solar thermal power plants	0	0	346	722	1,068	25
Ocean energy	8,643	6,999	9,505	13,589	38,735	901

notes

energy
[r]evolution

GREENPEACE

Greenpeace is a global organisation that uses non-violent direct action to tackle the most crucial threats to our planet's biodiversity and environment. Greenpeace is a non-profit organisation, present in 40 countries across Europe, the Americas, Africa, Asia and the Pacific. It speaks for 2.8 million supporters worldwide, and inspires many millions more to take action every day. To maintain its independence, Greenpeace does not accept donations from governments or corporations but relies on contributions from individual supporters and foundation grants.

Greenpeace has been campaigning against environmental degradation since 1971 when a small boat of volunteers and journalists sailed into Amchitka, an area west of Alaska, where the US Government was conducting underground nuclear tests. This tradition of 'bearing witness' in a non-violent manner continues today, and ships are an important part of all its campaign work.

greenpeace japan
NF building 2F 8-13-11
Nishi-Shinjuku, Shinjuku,
Tokyo, Japan
t +81 3 5338 9800 f +81 3 5338 9817
www.greenpeace.org/japan

EREC

european renewable energy council - [EREC]
Created in April 2000, the European Renewable Energy Council (EREC) is the umbrella organisation of the European renewable energy industry, trade and research associations active in the sectors of bioenergy, geothermal, ocean, small hydro power, solar electricity, solar thermal and wind energy. EREC thus represents the European renewable energy industry with an annual turnover of €70 billion and employing 550,000 people.

EREC is composed of the following non-profit associations and federations: AEBIOM (European Biomass Association); EGEC (European Geothermal Energy Council); EPIA (European Photovoltaic Industry Association); ESHA (European Small Hydro power Association); ESTIF (European Solar Thermal Industry Federation); EUBIA (European Biomass Industry Association); EWEA (European Wind Energy Association); EUREC Agency (European Association of Renewable Energy Research Centers); EREF (European Renewable Energies Federation); EU-OEA (European Ocean Energy Association); ESTELA (European Solar Thermal Electricity Association).

EREC European Renewable Energy Council
Renewable Energy House, 63-67 rue d'Arlon
B-1040 Brussels, Belgium
t +32 2 546 1933 f+32 2 546 1934
erec@erec.org **www.erec.org**

image ICE MELTING ON A BERG ON THE GREENLANDIC COAST. GREENPEACE AND AN INDEPENDENT NASA-FUNDED SCIENTIST COMPLETED MEASUREMENTS OF MELT LAKES ON THE GREENLAND ICE SHEET THAT SHOW ITS VULNERABILITY TO WARMING TEMPERATURES. **front cover images** WIND TURBINES CREATING CLEAN ENERGY IN FUKUSHIMA JAPAN © STUDIOCASPAR/ISTOCK. A CLOSE-UP OF THE SOLAR PANEL OF A TRAFFIC SIGNAL IN YOKOHAMA, JAPAN. © JOEL-T/ISTOCK. WAVES OF JAPAN © BANOL2007/DREAMSTIME