energy
[r]evolution

A SUSTAINABLE EU 27 ENERGY OUTLOOK

EREC
EUROPEAN RENEWABLE
ENERGY COUNCIL

GREENPEACE

report 2012 EU 27 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?”**

partners

Greenpeace International, European Renewable Energy Council (EREC)

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image LA DEHESA, 50 MW PARABOLIC THROUGH SOLAR THERMAL POWER PLANT WITH MOLTEN SALTS STORAGE IN SPAIN. COMPLETED IN FEBRUARY 2011, IT IS LOCATED IN LA GAROVILLA AND IT IS OWNED BY RENOVABLES SAMCA. WITH AN ANNUAL PRODUCTION OF 160 MILLION KWH, LA DEHESA WILL BE ABLE TO COVER THE ELECTRICITY NEEDS OF MORE THAN 45,000 HOMES, PREVENTING THE EMISSION OF 160,000 TONNES OF CARBON. THE 220 H PLANT HAS 225,792 MIRRORS ARRANGED IN ROWS AND 672 SOLAR COLLECTORS WHICH OCCUPY A TOTAL LENGTH OF 100KM. BADAJOZ.

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for further information about the global, regional and national scenarios please visit the Energy [R]evolution website: **www.energyblueprint.info/**
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contents

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.

list of figures

2

3

4

5

6

7

8

9

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

list of tables

2

3

4

5

6

8

9

10

list of maps

8

introduction

"NOT LEAST IN TIMES OF TIGHT PUBLIC BUDGETS, CREDIBLE LONG-TERM COMMITMENTS ARE NEEDED. TARGETS HAVE PROVEN TO BE A KEY ELEMENT FOR TRIGGERING THE VITAL INVESTMENTS WHICH ARE NEEDED FOR A TRANSITION TO A SUSTAINABLE ENERGY SYSTEM."

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image BURBO BANK OFFSHORE WINDPARK 7 KILOMETERS OFF CROSBY BEACH. TECHNICIAN DAN SIMMONS WORKING ON TOP OF A WINDMILL. THE 25 WIND TURBINES OF TYPE SIEMENS SWT 3.6 107 A 3.6 MEGAWATT AND ARE OPERATED BY DONG ENERGY.

This edition of the EU 27 Energy [R]evolution comes at a time of profound changes and challenges in the energy market. At the 25th anniversary of the Chernobyl catastrophe yet another nuclear incident underlined the urgent need to rethink energy strategies. The Fukushima disaster triggered a surge in global renewable energy and energy efficiency deals and made some governments change their energy approach altogether. However, while the use of renewable forms of energy increased, the global economic crisis showed its impact: the Eurozone debt crisis, overall decreasing investments and resulting high unemployment, falling energy demand and decreasing global carbon prices.

At EU level, total gross inland consumption fell from about 75,362 PJ/a in 2008 to 73,352 PJ/a in 2010, while consumption of renewable energy rose from 6,000 PJ/a to 7,200 PJ/a in the same period. Renewable energy provided 12.5% of gross final energy consumption in Europe in 2010, exceeding the 2011/2012 interim target (10.7%) set out in the Renewable Energy Directive. This overall growth of renewable energy reflects the continued maturing of these technologies, with deployment progressing from support driven markets to new competitive segments. Ultimately, the objective is to be competitive in a fair and liberalised market, and to deliver the many benefits of renewable energy in the most cost-effective way.

While support schemes and incentives need to be adjusted and updated regularly, any retroactive changes to support schemes in EU member states are detrimental to investor confidence and significantly increase investment risks. Such increased risks lead to very high costs of capital, raising the costs of projects and ultimately undermining their competitiveness. Clear administrative procedures, stable and reliable support and easier access to capital are therefore vital for achieving the EU's binding 2020 target.

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.

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This publication shows that the Energy [R]evolution scenario creates half a million more jobs by 2020 than the Reference scenario, where little is done to support a shift to renewable energy. About 1.4 million jobs will all significantly contribute to a reduction in greenhouse gas (GHG) emissions. Renewable energy and increased energy efficiency are the most straightforward means of both reducing emissions and improving security of energy supply.

In 2009, EU leaders agreed a GHG emissions reduction of 80-95% below 1990 levels in 2050. However, credible energy and climate action to back up this commitment in a concrete way is yet to be delivered. With today´s policies the EU is set to fail in meeting its long-term ambition. The European Commission estimates that a continuation of current trends and policies would result in only a 40% reduction in GHG emissions by 2050.

The EU's climate and energy policies need to be geared up to reach significantly higher GHG reductions by 2050, while increasing energy security and competitiveness for the benefit of European citizens. Future energy and climate policies must therefore make clear that high-carbon investments are expensive and will remain so in the future. Not least in times of tight public budgets, credible long-term commitments are needed.

Targets have proven to be a key element for triggering the vital investments which are needed for a transition to a sustainable energy system. This is why a 2030 target of at least 45% renewable energy is needed.

The report supports one of the findings of the Energy Roadmap 2050, tabled by the European Commission in December 2011, which was to identify renewables, efficiency and infrastructure as the common elements across different "decarbonisation scenarios" that need to be promoted in all cases – the so-called "no-regrets" options.

The EU 27 Energy Revolution 2012 presents a blueprint for how to achieve a more sustainable energy system in Europe now and for generations to come. Such a profound change translates into a wide variety of skilled domestic green jobs in a Europe struggling with record levels of unemployment. At the same time, renewable energy technologies are becoming increasingly competitive with conventional fuels (which have been heavily subsidised for decades), which will, in turn, save energy consumers significantly in the long run, at a time when financial stringency and planning has become an imperative for citizens at large.

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OCTOBER 2012

executive summary

> "THE SCALE OF THE CHALLENGE REQUIRES A COMPLETE TRANSFORMATION OF THE WAY WE PRODUCE, CONSUME AND DISTRIBUTE ENERGY, WHILE MAINTAINING ECONOMIC GROWTH."

image GEMASOLAR, A 15 MWE SOLAR-ONLY POWER TOWER PLANT. ITS 16-HOUR MOLTEN SALT STORAGE SYSTEM CAN DELIVER POWER AROUND THE CLOCK.

The expert consensus is that a fundamental shift in the way we consume and generate energy must begin immediately and be well underway within the next ten years in order to avert the worst impacts of climate change.[1] The scale of the challenge requires a complete transformation of the way we produce, consume and distribute energy, while maintaining economic growth. The five key principles behind this Energy [R]evolution will be to:

- Implement renewable solutions, especially through decentralised energy systems and grid expansions
- 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, reduce grid loads and energy losses in distribution. Investments in 'climate infrastructure' such as smart interactive grids and transmission grids to transport large quantities of offshore wind and concentrated 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 who currently do not have access to electricity.

The Reference scenario is based on the Current Policies scenarios published by the International Energy Agency (IEA) in World Energy Outlook 2011 (WEO 2011).[2] It only takes existing international energy and environmental policies into account. As the IEA's projections only extend to 2035, they have been extended by extrapolating their key macroeconomic and energy indicators forward to 2050. This provides a baseline for comparison with the Energy [R]evolution scenario.

the energy [r]evolution – key results

Renewable energy sources account for 9.6% of Europe's primary energy demand in 2009. The main source is biomass, which is mostly used in the heat sector.

For electricity generation renewables contribute about 19% and for heat supply, around 14%, above all biomass. but increasingly from geothermal heat pumps and solar thermal collectors. About 76% of the primary energy supply in 2009 came from fossil fuels and 14% from nuclear energy.

reference

[1] IPCC – SPECIAL REPORT RENEWABLES, CHAPTER 1, MAY 2011.
[2] INTERNATIONAL ENERGY AGENCY (IEA), 'WORLD ENERGY OUTLOOK 2011', OECD/IEA 2011.

image TEST WINDMILL N90 2500, BUILT BY THE GERMAN COMPANY NORDEX, IN THE HARBOUR OF ROSTOCK. THIS WINDMILL PRODUCES 2.5 MEGA WATT AND IS TESTED UNDER OFFSHORE CONDITIONS. TWO TECHNICIANS WORKING INSIDE THE TURBINE.

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The Energy [R]evolution scenario describes development pathways to a sustainable energy supply for the 27 countries in the European Union, listed as one of the world's economic regions in the International Energy Agency's modelling. The scenario projects what is needed to acheive the urgently needed CO_2 reduction target and a nuclear phase-out, without unconventional oil resources. The results of the Energy [R]evolution scenario would be:

- **Curbing energy demand:** European energy demand is projected by combining population development, GDP growth and energy intensity. Under the Reference scenario, total primary energy demand in EU 27 increases by 5% from the current 69,700 PJ/a to 73,400 PJ/a in 2050 (including net electricity imports). The energy demand in 2050 in the Energy [R]evolution scenario decreases by 35% compared to current consumption and it is expected by 2050 to reach 45,500 PJ/a.
- **Controlling power demand:** Under the Energy [R]evolution scenario, electricity demand in industry as well as in the residential and service sectors is expected to decrease after 2015. Because of the growing shares of electric vehicles, heat pumps and hydrogen generation however, total electricity demand increases to 3,296 TWh/a in 2050, still 16% below the Reference case.
- **Reducing heating demand:** Efficiency gains in the heat supply sector are larger than in the electricity sector. Under the Energy [R]evolution scenario, final demand for heat supply can even be reduced significantly. Compared to the Reference scenario, consumption equivalent to 8,710 PJ/a is avoided through efficiency measures by 2050. As a result of energy-related renovation of the existing stock of residential buildings, as well as the introduction of low energy standards and 'passive houses' for new buildings, enjoyment of the same comfort and energy services will be accompanied by a much lower future energy demand.
- **Development of industrial energy demand:** The energy demand in the industrial sector will grow in both scenarios until 2015. While the economic growth rates in the Reference and the Energy [R]evolution scenario are identical, the growth of the overall energy demand is different due to a faster increase of energy intensity in the Energy [R]evolution case. Decoupling economic growth from energy demand is key to reaching a sustainable energy supply by 2050; the Energy [R]evolution scenario requires 25% less energy per € GDP than the Reference case.
- **Electricity generation:** A dynamically growing renewable energy market compensates for phasing out nuclear energy and fewer fossil fuel-fired power plants and reduces the number of fossil fuel-fired power plants required for grid stabilisation. By 2050, 96% of the electricity produced in EU 27 will come from renewable energy sources. 'New' renewables – mainly wind, solar thermal energy and PV – will contribute 75% of electricity generation. The Energy [R]evolution scenario projects an immediate market development with high annual growth rates achieving a renewable electricity share of 44% by 2020 and 67% by 2030. The installed capacity of renewables will reach 989 GW in 2030 and 1,480 GW by 2050.
- **Future costs of electricity generation:** Under the Energy [R]evolution scenario, the costs of electricity generation increase slightly compared to the Reference scenario. However, this difference will be less than 0.7 €cents/kWh up to 2020. Because of the lower CO_2 intensity of electricity generation, electricity generation costs will become increasingly favorable under the Energy [R]evolution scenario and by 2050 costs will be 4.8 €cents/kWh below those in the Reference version.
- **The future electricity bill:** Under the Reference scenario, the unchecked growth in demand together with an increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's € 300 billion per year to more than € 568 billion in 2050. The Energy [R]evolution scenario not only complies with EU 27´s CO_2 reduction targets but also helps to stabilise energy costs. Increased energy efficiency and shifting energy supply to renewables lead to long-term costs for electricity supply that are 16% lower than in the Reference scenario, although this includes costs for efficiency measures of up to 3 €cents/kWh.
- **Future investment in power generation:** The Energy [R]evolution will require initial investment higher than in the Reference case. The resulting higher electricity generation costs under the Energy [R]evolution scenario will, however, be compensated by reduced requirement for fuels in other sectors such as heating and transport. Under the Reference version, the levels of investment in conventional power plants add up to almost 35% while approximately 65% would be invested in renewable energy and cogeneration (CHP) until 2050. Under the Energy [R]evolution scenario, however, the EU would shift almost 96% of the entire investment towards renewables and cogeneration. Until 2030, the fossil fuel share of power sector investment would be focused mainly on CHP plants. The average annual investment in the power sector under the Energy [R]evolution scenario between today and 2050 would be approximately € 99 billion, €38 billion annually more than in the Reference scenario.
- **Fuel costs savings:** Because renewable energy has no fuel costs, the fuel cost savings in the Energy [R]evolution scenario reach a total of € 3,010 billion up to 2050, or € 75 billion per year. The total fuel cost savings based, on the assumed energy price path, would therefore cover the total additional investments compared to the Reference scenario twice over. 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 would continue to be a burden on national economies.
- **Heating supply:** Renewables currently provide 14% of EU 27's energy demand for heat supply, the main contribution coming from the use of biomass. The lack of district heating networks is a severe structural barrier to the large scale utilization of geothermal and solar thermal energy. In the Energy [R]evolution scenario, renewables provide 43% of EU 27's total heat demand in 2030 and 91% in 2050. For direct heating, solar collectors, geothermal as well as biomass/biogas

energy are increasingly substituting for fossil fuel-fired systems. The introduction of strict efficiency measures, for example strict building standards and ambitious support programs for renewable heating systems, are needed to achieve economies of scale within the next 5 to 10 years.

- **Future investments in the heat sector:** The heat sector in the Energy [R]evolution scenario would require a major revision of current investment strategies in heating technologies. In particular, the less common technologies such as solar, geothermal and heat pumps need a significant increase in installations if their potential is to be tapped for the heat sector. Installed capacity needs to be increased by a factor of 90 for solar thermal and by a factor of 230 for geothermal and heat pumps. Capacities of biomass technologies, which are already relatively widespread would remain a pillar of heat supply, assuming the use of sustainably sourced biomass. Renewable heating technologies vary greatly, from low tech biomass stoves and unglazed solar collectors to very sophisticated enhanced geothermal systems and solar thermal district heating plants with seasonal storage. Thus, it can only roughly be calculated that the Energy [R]evolution scenario requires approximately €74 billion per year to be invested in renewable heating technologies until 2050, including investments for replacement after the economic lifetime of the plants.

- **Future employment in the energy sector:** The Energy [R]evolution scenario results in more energy sector jobs in EU 27 at every stage of the projection. There are 1.5 million energy sector jobs in the Energy [R]evolution in 2015, and 0.9 million in the Reference scenario. By 2020, there are 1.4 million jobs in the Energy [R]evolution scenario, 500,000 more than in the Reference case. Jobs in the coal sector decline in both scenarios, leading to an overall decline of 34% in energy sector jobs in the Reference scenario.

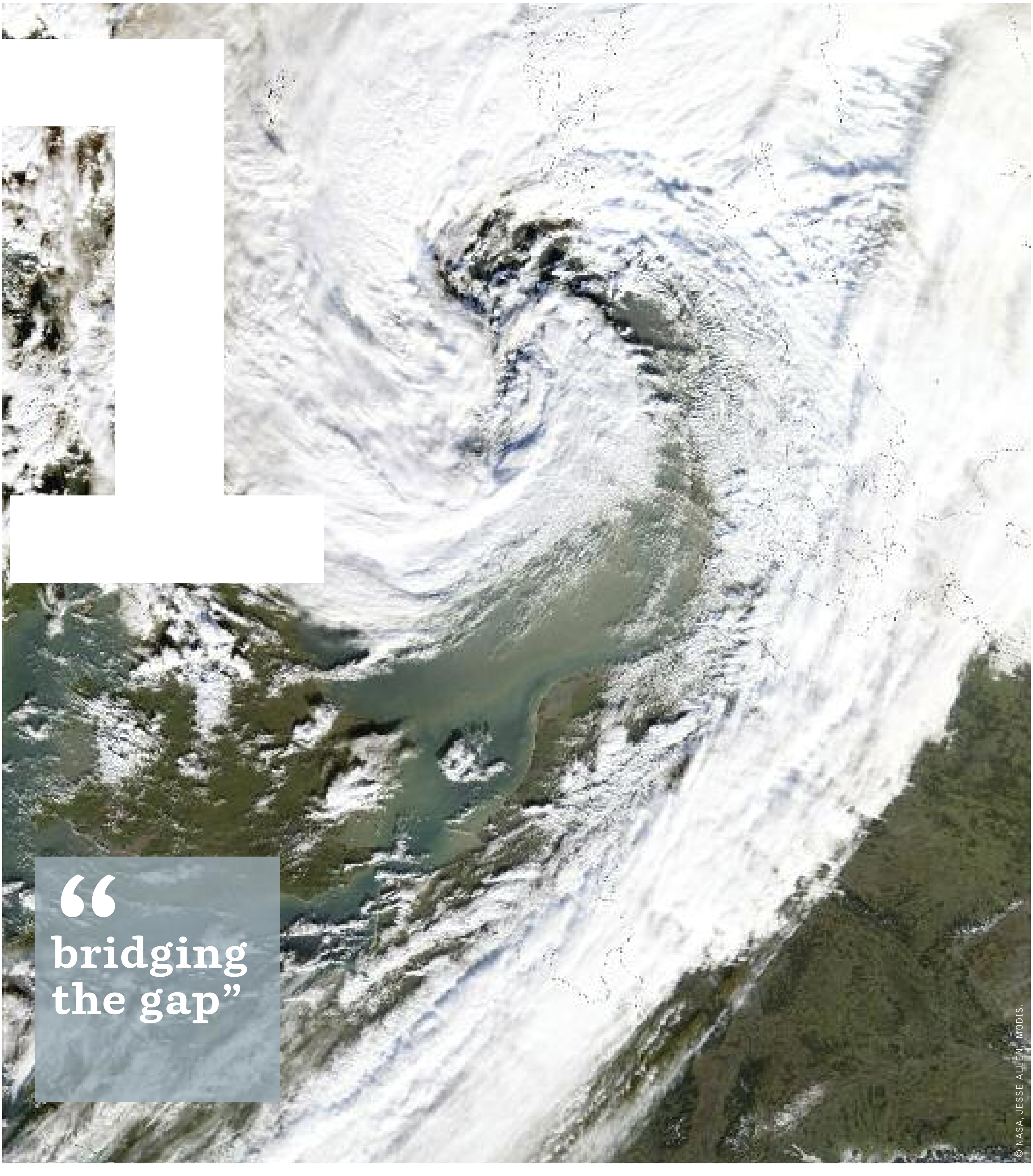
- **Transport:** In the transport sector, it is assumed under the Energy [R]evolution scenario that a total energy demand reduction of about 7,100 PJ/a can be achieved by 2050, saving 53% compared to the Reference scenario. This reduction can be achieved by the introduction of highly efficient vehicles, shifting a considerable amount of goods from road to rail, replacing domestic and intra-EU air passenger transport by high-speed rail services as much as possible and changes in mobility-related behavior patterns. By implementing a mix of increased public transport as attractive alternatives to individual cars, the car stock grows more slowly and annual person kilometers are lower 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 kilometers travelled lead to significant energy savings. In 2030, electricity will provide 12% of the transport sector's total energy demand in the Energy [R]evolution, while in 2050 the share will be 50%.

- **Primary energy consumption:** Under the Energy [R]evolution scenario, overall primary energy demand will be reduced by 40% in 2050 compared to the Reference scenario. Around 85% of the remaining demand will be covered by renewable energy sources. The Energy [R]evolution scenario phases out coal and oil about 10 to 15 years faster than the previous Energy [R]evolution scenario published in 2010. This is made possible mainly by the replacement of coal power plants with renewables and a faster introduction of highly efficient electric vehicles in the transport sector to replace internal combustion engines. This leads to an overall renewable primary energy share of 43% in 2030 and 85% in 2050.

- **Development of CO_2 emissions:** While CO_2 emissions in EU 27 will decrease by 10% in the Reference scenario, under the Energy [R]evolution scenario they will decrease by 95%, from around 3,500 million tonnes in 2009 to 197 million tonnes in 2050. Annual per capita emissions will drop from 7.1 tonnes to 3.5 tonnes in 2030 and 0.4 tonnes in 2050. Despite the phasing out of nuclear energy and increasing demand, CO_2 emissions will decrease in the electricity sector. In the long run, efficiency gains and the increased use of renewable electricity in vehicles will reduce emissions in the transport sector. With a share of 17% of CO_2 emissions in 2050, the power sector will drop below transport and other sectors as the largest sources of emissions. By 2050, EU 27's CO_2 emissions are 5% of 1990 levels.

climate and energy policy

EU CLIMATE AND ENERGY POLICY RECOMMENDATIONS



© NASA, JESSE ALLEN, MODIS.

image THE CLOUDS OVER NORTHERN EUROPE HAVE THE MENACING CURL OF A LOW PRESSURE SYSTEM ASSOCIATED WITH SEVERE WINTER STORMS. THIS PARTICULAR STORM LASHED THE UNITED KINGDOM, SCANDINAVIA, NORTHERN GERMANY, AND RUSSIA WITH HURRICANE-FORCE WINDS AND INTENSE RAINS. ACCORDING TO NEWS REPORTS, 14 PEOPLE DIED IN THE STORM, MANY FROM BEING HIT BY FALLING TREES OR BLOWING DEBRIS. THE STORM BROUGHT SEVERE FLOODS TO NORTHERN ENGLAND AND SCOTLAND, SUBMERSING THE ENGLISH TOWN OF CARLISLE ENTIRELY.

1.1 eu climate and energy policy recommendations

The Energy [R]evolution presents European decision-makers with a cost-effective and sustainable pathway for our economy, while tackling the challenges of climate change and the security of energy supply.

A fully renewable and efficient energy system would allow Europe to develop a sound energy economy, create high quality jobs, boost technology development, secure global competitiveness and trigger industrial leadership.

At the same time, the drive towards renewables and the smart use of energy would deliver the necessary greenhouse gas emissions cuts in the upper range of 80 to 95% by 2050 compared with 1990 levels, which Europe will have to realise in the fight against climate change.

But the Energy [R]evolution will not happen without much needed political leadership: The European Union and its member states will have to set the framework for a sustainable energy pathway. The next step on this road is the adoption of a 2030 climate and energy package with ambitious targets on emission reductions, renewable energy and energy savings.

A continuation of the successful triple targets for 2030 will provide industry certainty, mobilize investment in renewable and energy saving technologies and secure the necessary climate ambition.

At present, a wide range of energy-market failures still discourage the shift towards a clean energy system. It is high time to remove these barriers to increase energy savings and facilitate the replacement of fossil fuels with clean and abundant renewable energy sources.

European decision-makers should demonstrate commitment to a clean energy future, create the regulatory conditions for an efficient and renewable energy system, and stimulate governments, businesses, industries and citizens to opt for renewable energy and its smart use.

Greenpeace and EREC propose four steps that the European Union and its member states should take to realise the Energy [R]evolution.

1. Adopt legally binding targets for emission reductions, energy savings and renewable energy

Commit to legally binding emission reductions of at least 30% by 2020 To contribute to limiting global temperature increase below two degrees Celsius (2° C) the EU should reduce its greenhouse gas emissions domestically by at least 30% by 2020 compared to 1990 levels. For 2030, the Energy [R]evolution scenario shows that the energy sectors, including power generation, heating and cooling as well as transport, can make a significant contribution with a 56% greenhouse gas emissions reduction.

Moreover, the EU should provide substantial additional finance to assist developing countries mitigate climate change with clean energy technologies and forest protection.

Set a legally binding target of 45% renewable energy for 2030 With the adoption of the Renewable Energy Directive, European member states have committed to legally binding targets, adding up to a share of at least 20% renewable energy in the EU by 2020. The Energy [R]evolution scenarios demonstrate that even more is possible. To reap the full benefits that renewable energy offers the economy, employment, energy security, technological leadership and emission reductions, the EU should set legally binding national targets that add up to a 45% share of renewables across Europe in 2030.

Set a legally binding target for energy savings for 2030 Saving energy makes sense both from an environmental and an economic perspective. A high level of energy efficiency is fundamental for climate action and competitiveness. An ambitious, binding energy savings target for 2030 is necessary to move towards a resource-efficient energy system.

2. Remove barriers to a renewable and efficient energy system

Reform the electricity market and network management After decades of state subsidies to conventional energy sources, the entire electricity market and network have been developed to suit centralised nuclear and fossil production. Current ownership structures, price mechanisms, transmission and congestion management practices and technical requirements hinder the optimal integration renewable energy technologies, particularly those of a variable and decentralised nature.

As an important step towards the reform of the electricity market, all European governments should secure full ownership unbundling of transmission and distribution system operations from power production and supply activities. This is the effective way to provide fair market access and overcome existing discriminatory practices against new market entrants, such as renewable energy producers.

A modernisation of the power grid system is urgently required to allow for the cost-effective connection and integration of renewable power sources. The European Union and its governments should ensure the implementation of the guidelines proposed under the trans-European energy infrastructure regulation. These conditions are necessary to develop grid connections for renewable energy, including offshore, as well as for smart grid management and active demand side management.

To facilitate this modernisation, the Agency for the Cooperation of Energy Regulators (ACER) should be strengthened and the mandate of national energy regulators should be reviewed.

Both ACER and the European Network of Transmission System Operators for Electricity (ENTSO-E) should develop a strategic interconnection plan until 2050 which enables the development of a fully renewable electricity supply.

In parallel, electricity market regulation should ensure that investments in balancing capacity and flexible power production facilitate the integration of renewable power sources, while phasing out inflexible 'baseload' power supply and preventing the introduction of supporting payments in the form of capacity payments.

Phase out all subsidies and other support measures for environmentally damaging energy and transport technologies While the EU is striving for a liberalised market for electricity production, government support is still propping up conventional energy technologies, hindering the uptake of renewable energy sources and energy savings. For example, the nuclear power sector in Europe still benefits from direct subsidies, government loan

image PART-MADE WIND TURBINES FOR AN OFFSHORE WIND FARM AT MIDDELGRUNDEN, CLOSE TO COPENHAGEN, DENMARK

guarantees, export credit guarantees, government equity input and subsidised in-kind support. In addition, the sector continues to profit from guaranteed cheap loans under the Euratom Loan Facility and related loans by the European Investment Bank.

Apart from these financial advantages, the nuclear sector profits from cost-limitations for decommissioning of power stations and radioactive waste management (e.g. in Slovakia and the UK), government bail-outs of insufficient reserves for decommissioning and waste management (in the UK), and government financing of R&D and education infrastructure (on a national level and under Euratom). Liability coverage for installations in the nuclear energy sector is so low that damage of any major accident will have to be covered almost completely by state funds. The total level of these financial advantages is still four times the financial support given to the renewable energy sector, according to the European Commission.[3]

Also fossil fuels continue to receive large financial benefits that contradict the development of a clean power market. Spain, Germany, Poland and Romania still subsidise their coal sectors with support or at least acceptance from the side of the European Commission, although these subsidies should be phased out under the Treaty of the European Union.

New EU funds for fossil fuel technologies have been made available in recent years to promote carbon capture and storage technology. Spending money on carbon capture and storage is diverting funds away from renewable energy and energy savings. Even if carbon capture becomes technically feasible and capable of long-term storage, it would come at a high cost and still would not bring the urgently needed shift away from fossil fuels in the power production system.

In the transport sector, the most energy intensive modes, road and aviation, receive hundreds of billions in subsidies and tax exemptions. The EIB has long favoured these modes of transportation, especially in Central and Eastern Europe, cementing Europe's high carbon transport system.

Phase out nuclear power and close existing loopholes for nuclear waste The safety of European nuclear power plants is of serious concern. The post-Fukushima stress test of Europe's nuclear reactors have identified defects and revealed unacceptable failures in risk management. European governments should develop a credible phase-out plan for nuclear power in Europe, starting with the oldest and most risky reactors.

The European Union and its member states should bring the management of nuclear waste in line with general EU waste policies in order to make the polluter pays principle fully effective. This means that loopholes under which certain forms of radioactive waste are excluded from waste rules have to be closed. Over 90% of radioactive waste is produced by the nuclear power sector – a nuclear phase-out policy as proposed in the Energy [R]evolution scenario is therefore a logical component of a coherent EU waste policy.

3. Implement effective policies for a sustainable energy economy

Update the EU Emission Trading Scheme The EU Emissions Trading Scheme (ETS) can be an important climate mitigation tool. But the effectiveness ETS is currently undermined due to a large surplus of emission allowances. The European Commission estimates that by 2020 companies participating in the ETS will have accumulated a surplus of around two billion allowances (about the same size as their annual emissions). In order to reinvigorate the ETS, the auction of a significant portion of the emission allowance auctions must be postponed, followed by decision to permanently retire these allowances. Alternatively, the ETS emission reduction trajectory between 2021 and 2030 should be adjusted so to accommodate or 'eat up' the surplus of allowances.

To provide the right market signals and the economic incentives for the transition of our energy system along the whole production and consumption chain, all allowances under the ETS should be auctioned rather than being given out for free. Auctioning reduces the total cost of European climate action because it is the most economically efficient allocation methodology, eliminating windfall profits from free allowances.

Furthermore, the EU ETS should be a driver for domestic emission reductions. The required domestic reductions must not be replaced by purchasing offset credits in third countries. Strict quantitative limits and quality criteria on offsetting should guarantee real emission cuts.

Effectively implement the EU's fuel standard Another flagship climate change mitigation measure, the EU's low carbon fuel standard, should be implemented across fuel production from both renewable and fossil energy sources. The agreed target of reducing the carbon intensity of transport fuels by 6% between 2010 and 2020 will only be met if all direct and indirect lifecycle emissions are properly accounted for. In a first phase, fuels should be distinguished on the basis of the feedstock they are produced from (e.g. crude oil, tar sands, natural gas or rapeseed), whilst a methodology for further differentiation is being developed.

Support renewable energy and apply the Renewable Energy Directive With the adoption of the Renewable Energy Directive in 2009, European member states committed to legally binding targets, adding up to a share of at least 20% renewable energy in the EU by 2020 and to a framework for the support of clean energy. Since then, many member states have experienced significant growth in the deployment of renewable energy and current member state plans submitted to the Commission indicate that the EU might even exceed its 2020 target. Most governments have implemented a form of support policy to compensate for market failures and to help maturing renewable energy technologies to realise their full potential. However, some support systems have shown to be more effective in promoting renewable energy than others.

In the electricity sector, feed-in tariffs or premium systems, if designed well, have proven to be the most successful and cost effective instruments to promote the broad uptake of renewable power technologies. Under a feed-in system, a certain price is guaranteed for the electricity produced from different renewable sources. A premium model provides for a certain premium paid on top of the market price.

Today, at least 45% of the EU`s energy demand is used for heating and cooling. The Renewable Energy Directive created a renewable energy for heating and cooling obligation in new and

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reference

[3] COM(2011)31 RENEWABLE ENERGY: PROGRESSING TOWARDS THE 2020 TARGET.

refurbished buildings. Investment subsidies and tax credits are among the instruments available to support renewable heating and cooling. Yet the role of renewable heating and cooling technologies in the decarbonisation of the energy sector remains insufficiently addressed in most member states.

In order to empower the sector and make use of the widely untapped potential, an action plan for renewable heating and cooling is needed. Such a plan should include an assessment of the EU´s heating and cooling demand as well as best-practice examples on how to support the sector.

The support of renewable energy in the transport sector should focus primarily on the use and development of sustainable renewable energy solutions, including renewable electricity in electric road vehicles and trains. At the same time, a clear signal must be sent to the markets that the future of green transport does not include those biofuels that are socially and environmentally unsustainable.

The continued implementation of the Renewable Energy Directive is central to sustaining the growth of renewable energy in the EU and achieving the 20% target in 2020. The Commission should ensure the progress of member states towards their national targets, including the timely reporting and revision of National Renewable Energy Action Plans.

Create a robust sustainability framework for bioenergy Member states plan to use significant quantities of bioenergy to meet their renewable targets. The availability of sustainable bioenergy is limited and therefore the European Union and individual governments should ensure this scarce resource is used in the most effective manner. The European Union and individual governments should therefore ensure the full and timely implementation of sustainability criteria for biofuels and biomass, and address related indirect land use change (ILUC) impacts.

Implement the Energy Efficiency Directive and set energy efficiency standards for vehicles, consumer appliances, buildings and power production The EU has set itself to achieve a 20% energy efficiency target by 2020, compared to business-as-usual. The Commission should ensure that the Energy Efficiency Directive is implemented robustly and without delay by member states to ensure maximum energy savings are attained. Additional measures should be proposed as soon as possible to bridge the remaining gap to the 20% target, and binding targets should be adopted if member states fail to deliver.

A large part of energy savings can be achieved through efficiency standards for vehicles, consumer products and buildings. However, current EU legislation in this field represents an incoherent patchwork of measures, which does not add up to a clear and consistent division of responsibility and fails to deliver on the EU's energy savings potential. Efforts should be stepped up in each area. With regard to road vehicles, the EU should regulate for an average of 60 g CO_2/km for new passenger cars by 2025, ensure an equivalent level of improvements in light commercial vehicles, and rapidly introduce fuel efficiency regulation for trucks.

Initiate robust and harmonised EU green taxation A harmonisation and strengthening of taxes on carbon emissions and energy use should be implemented in all EU member states, in particular for sectors not covered by the EU ETS (such as transport and agriculture). Taxing energy use is crucial to achieve energy security and lower the consumption of natural resources. Green taxation would also deliver more jobs, because labour-intensive production would gain a competitive advantage. This effect would even be stronger if member states used revenues of green taxation to reduce labour costs (e.g. by reducing taxes on income).

4. Ensure that the transition is financed

Put climate action and sustainable energy at the centre of the Multiannual Financial Framework Ambitious emission reductions in the EU are technically and economically feasible, and can even deliver significant net benefits for the European economy. However, before the Energy [R]evolution starts paying off, major investments are required. EU member states in Central and Eastern Europe can face additional difficulties in mobilising the required private and public investments. The 2014-2020 Multiannual Financial Framework should "mainstream" the political priorities of climate action and sustainable energy, thus ensuring future EU budgets can allocate the necessary funds to energy system modernisation, energy infrastructure and energy efficiency technology.

Support innovation and research in energy saving technologies and renewable energy Innovation will play an important role in making the Energy [R]evolution more attractive. Direct public support is often necessary to speed up the deployment of new technologies. The European Union, national governments, as well as public finance institutions should ensure that current renewable energy and efficiency initiatives are successful and support additional investments in research and development for more efficient appliances and building techniques, new types of renewable energy production such as tidal and wave power, smart grid technology, as well as low emitting transport options. These include the development of better batteries for electric vehicles and freight transport management programmes.

Alongside support to facilitate the maturing or existing renewable energy and efficiency technologies, research and innovation are required also for truly sustainable technologies for the aviation and shipping sectors, as well as heavy road-transport. While substantial efficiency improvements and a shift from air- and road-based transportation to shipping and trains can help reduce the impact of transportation, the availability of sustainable renewable energy technologies is currently limited. Innovations, such as second generation biofuels and sails or hydrogen, could become part of the solution.

Create an Industrial Innovation Fund Energy-intensive industry sectors such as the steel, cement and paper sector have a significant unused potential for energy savings of at least 35% and emission reductions of close to 95% by 2050. The EU must provide the right policy framework to leverage investments in cleaner and more efficient production processes while strengthening industrial competitiveness.

To push innovation and deployment of green and efficient technologies in energy intensive sectors to a larger scale, a portion of the ETS auctioning revenue should go to an Industrial Innovation Fund dedicated to cleaner and innovate production processes (e.g. magnesium-based cement production, coke-free steel production). Complementary regulation, such as CO_2 standards and phase out pathways for high-carbon production must be introduced, so to ensure finance is followed by performance.

the energy [r]evolution concept

KEY PRINCIPLES

THE "3 STEP IMPLEMENTATION"

THE NEW ELECTRICITY GRID

CASE STUDY GERMANY

2

> “smart use, generation and distribution are at the core of the concept”

© NASA / JEFF SCHMALTZ,

image CENTRAL AND EASTERN EUROPE.

The expert consensus is that a fundamental shift in the way we consume and generate energy must begin immediately and be well underway within the next ten years in order to avert the worst impacts of climate change.[4] The scale of the challenge requires a complete transformation of the way we produce, consume and distribute energy, while maintaining economic growth. Nothing short of such a revolution will enable us to limit global warming to a rise in temperature of lower than 2°C, above which the impacts become devastating. This chapter explains the basic principles and strategic approach of the Energy [R]evolution concept, which have formed the basis for the scenario modelling since the very first Energy [R]evolution scenario published in 2005. However, this concept has been constantly improved as technologies develop and new technical and economical possibilities emerge.

Current electricity generation relies mainly on burning fossil fuels in very large power stations which generate carbon dioxide and also waste much of their primary input energy. More energy is lost as the power is moved around the electricity network and is converted from high transmission voltage down to a supply suitable for domestic or commercial consumers. The system is vulnerable to disruption: localised technical, weather-related or even deliberately caused faults can quickly cascade, resulting in widespread blackouts. Whichever technology generates the 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 therefore there are changes both to the way that energy is produced and distributed.

2.1 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 we emit almost 30 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 3.5 Gigatonnes (Gt) by 2050 and phase out over 80% of fossil fuels by 2050.

2. **Equity and fair access to energy** 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 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 global 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 0.5 and 1 tonne 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.[5]

   Just as climate change is real, so is the renewable energy sector. Sustainable, decentralised energy systems produce fewer carbon emissions, are cheaper and are less dependent 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.

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references

[4] IPCC – SPECIAL REPORT RENEWABLES, CHAPTER 1, MAY 2011.
[5] REN 21, RENEWABLE ENERGY STATUS REPORT 2012, JUNE 2012.

image WIND TURBINES AT THE NAN WIND FARM IN NAN'AO. GUANGDONG PROVINCE HAS ONE OF THE BEST WIND RESOURCES IN CHINA AND IS ALREADY HOME TO SEVERAL INDUSTRIAL SCALE WIND FARMS.


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2.2 the "3 step implementation"

In 2009, renewable energy sources accounted for 13% of the world's primary energy demand. Biomass, which is mostly used for heating, was the main renewable energy source. The share of renewable energy in electricity generation was 18%. About 81% of primary energy supply today still comes from fossil fuels.[6]

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

Within this decade, the power sector will decide how new electricity demand will be met, either by fossil and nuclear fuels or by the efficient use of renewable energy. The Energy [R]evolution scenario puts forward a policy and technical model for renewable energy and cogeneration combined with energy efficiency to meet the world's needs.

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.

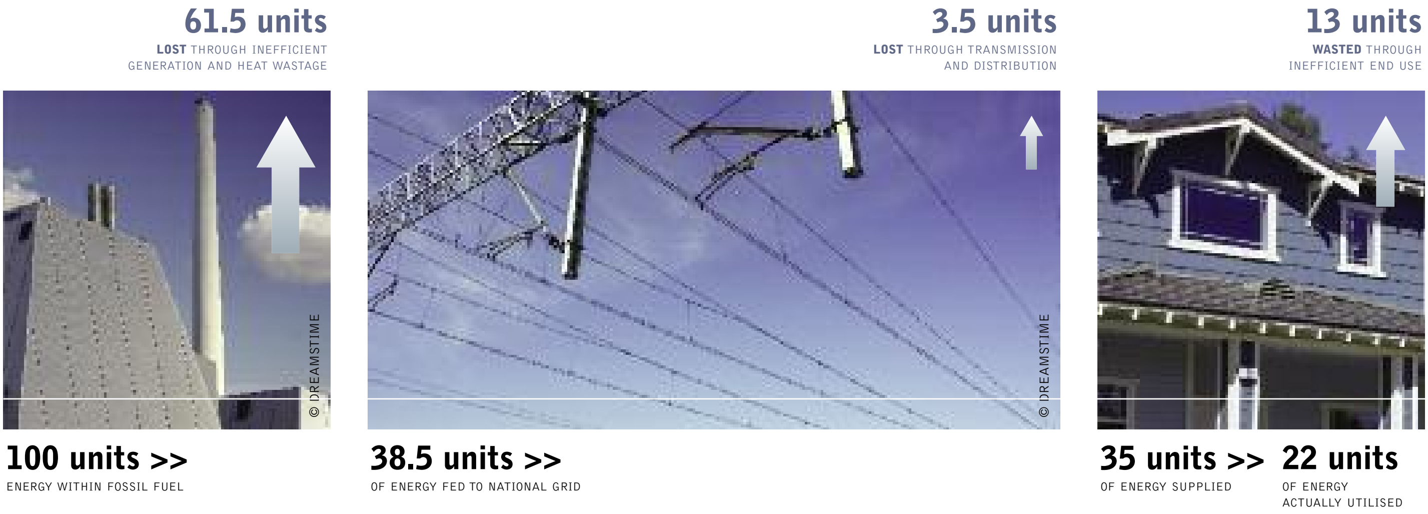
A transition phase is required to build up the necessary infrastructure because it is not possible to switch directly from a large scale fossil and nuclear fuel based energy system to a full renewable energy supply. Whilst remaining firmly committed to the promotion of renewable sources of energy, we appreciate that conventional natural gas, used in appropriately scaled cogeneration plants, is valuable as a transition fuel, and can also 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 valuable means of achieving emissions reductions. 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 and equity The Energy [R]evolution makes an 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.

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 currently use energy in the most inefficient way and can reduce their consumption drastically without the loss of either housing comfort or information and entertainment electronics. The global Energy [R]evolution scenario depends on energy saved in OECD countries to meet 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 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 2.1: centralised generation systems waste more than two thirds of their original energy input



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reference

[6] 'IEA WORLD ENERGY OUTLOOK 2011, PARIS NOVEMBER 2011.

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 Energy [R]evolution scenario makes extensive use of Decentralised Energy (DE). This term refers to energy generated at or near the point of use.

Decentralised energy is connected to a local distribution network system, supplying homes and offices, rather than the high voltage transmission system. Because electricity generation is closer to consumers, any waste heat from combustion processes can be piped to nearby buildings, a system known as cogeneration or combined heat and power. This means that for a fuel like gas, all the input energy is used, not just a fraction as with traditional centralised fossil fuel electricity plant.

Decentralised energy 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 for domestic users to provide sustainable, low emission heating. Some consider decentralised energy technologies 'disruptive' because they do not fit the existing electricity market and system. However, with appropriate changes they can grow exponentially with overall benefit and diversification for the energy sector.

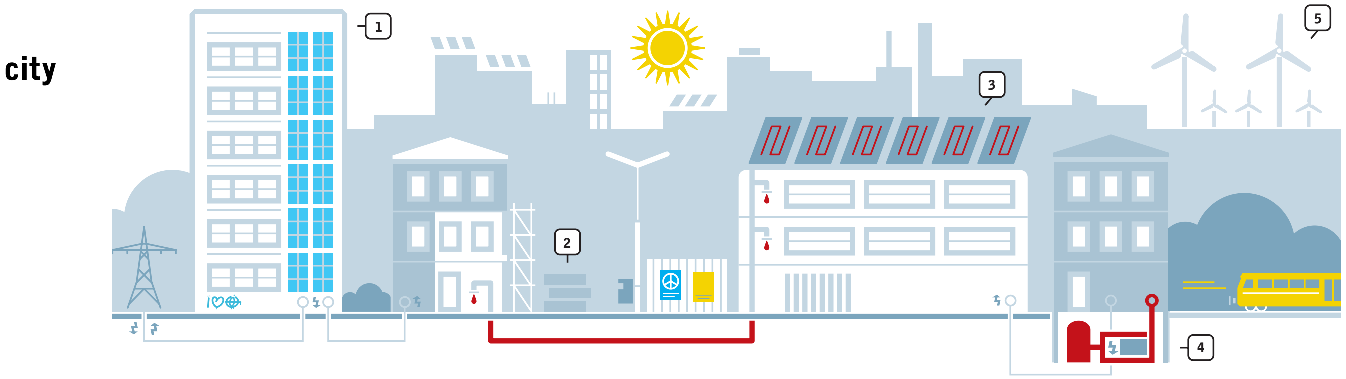
A huge proportion of global energy in 2050 will be produced by decentralised energy sources, although large scale renewable energy supply will still be needed for an energy revolution. Large offshore wind farms and concentrating solar power (CSP) plants in the sunbelt regions of the world will therefore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

Cogeneration (CHP) 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 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.

figure 2.2: **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.



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.

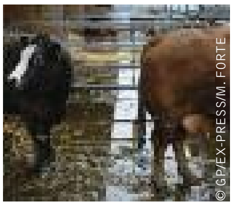


image COWS FROM A FARM WITH A BIOGAS PLANT IN ITTIGEN BERN, SWITZERLAND. THE FARMER PETER WYSS PRODUCES ON HIS FARM WITH A BIOGAS PLANT, GREEN ELECTRICITY WITH DUNG FROM COWS, LIQUID MANURE AND WASTE FROM FOOD PRODUCTION.

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Renewable heating In the heat supply sector, the contribution of renewable energy 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.

Transport Before new technologies including hybrid and electric cars can seriously enter the transport sector, other electricity users need to make large efficiency gains. 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 and only for heavy duty vehicles, ships and aviation. In contrast to previous versions of Energy [R]evolution scenarios, biofuels are entirely banned now for use in private cars.[7] 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 requires a balanced and timely mobilisation of all technologies. Such a mobilisation depends on the resource availability, cost reduction potential and technological maturity. When combined with technology-driven solutions, lifestyle changes - like simply driving less and using more public transport – have a huge potential to reduce greenhouse gas emissions.

New business model The 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.

Today's power supply value chain is broken down into clearly defined players but a global renewable power supply will inevitably change this division of roles and responsibilities. Table 2.1 provides an overview of how the value chain would change in a revolutionised energy mix.

The current model is a relatively small number of large power plants that are owned and operated by utilities or their subsidiaries, generating electricity for the population. Under the Energy [R]evolution scenario, around 60 to 70% of electricity will be made by small but numerous decentralised power plants. Ownership will shift towards more private investors, the manufacturer of renewable energy technologies and EPC companies (engineering, procurement and construction) away from centralised utilities. In turn, the value chain for power companies will shift towards project development, equipment manufacturing and operation and maintenance.

table 2.1: power plant value chain

TASK & MARKET PLAYER	PROJECT DEVELOPMENT	MANUFACTURE OF GEN. EQUIPMENT	INSTALLATION	OWNER OF THE POWER PLANT	OPERATION & MAINTENANCE	FUEL SUPPLY	TRANSMISSION TO THE CUSTOMER
CURRENT SITUATION POWER MARKET	Coal, gas and nuclear power stations are larger than renewables. Average number of power plants needed per 1 GW installed only 1 or 2 projects.			Relatively view power plants owned and sometimes operated by utilities.		A few large multinational oil, gas and coal mining companies dominate: today approx 75-80% of power plants need fuel supply.	Grid operation will move towards state controlled grid companies or communities due to liberalisation.
Market player							
Power plant engineering companies	■	■	■				
Utilities				■	■		
Mining companies						■	
Grid operator							■
2020 AND BEYOND POWER MARKET	Renewable power plants are small in capacity, the amount of projects for project development, manufacturers and installation companies per installed 1 GW is bigger by an order of magnitude. In the case of PV it could be up to 500 projects, for onshore wind still 25 to 50 projects.			Many projects will be owned by private households or investment banks in the case of larger projects.		By 2050 almost all power generation technologies - accept biomass - will operate without the need of fuel supply.	Grid operation will move towards state controlled grid companies or communities due to liberalisation.
Market player							
Renewable power plant engineering companies	■	■	■		■		
Private & public investors				■			
Grid operator							■

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reference
7 SEE CHAPTER 9.

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

The future pattern under the Energy [R]evolution will see more and more renewable energy companies, such as wind turbine manufacturers, 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.

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 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, providing 'baseload' power. Until now, renewable energy has been seen as an additional slice of the energy mix and had had adapt to the grid's operating conditions. If the Energy [R]evolution scenario is to be realised, this will have to change.

Because renewable energy relies mostly on natural resources, which are not available at all times, some critics say this makes it unsuitable for large portions of energy demand. Existing practice in a number of countries has already shown that this is false.

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 current and emerging 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'.[8] Further adaptations to how the grid network operates will allow integration of even larger quantities of renewable capacity.

Changes to the grid required to support decentralised energy Most grids around the world have large power plants in the middle connected by high voltage alternating current (AC) power lines and smaller distribution network carries power to final consumers. The centralised grid model was designed and planned up to 60 years ago, and brought great benefit to cities and rural areas. However the system is very wasteful, with much energy lost in transition. A system based on renewable energy, requiring lots of smaller generators, some with variable amounts of power output will need a new architecture.

The overall concept of a smart grid is one that balances fluctuations in energy demand and supply to share out power effectively among users. New measures to manage demand, forecasting the weather for storage needs, plus advanced communication and control technologies will help deliver electricity effectively.

Technological opportunities Changes to the power system by 2050 will create huge business opportunities for the information, communication and technology (ICT) sector. A smart grid has power supplied from a diverse range of sources and places and it relies on the collection and analysis of a lot of data. Smart grids require software, hardware and data networks capable of delivering data quickly, and responding to the information that they contain. Several important ICT players are racing to smarten up energy grids across the globe and hundreds of companies could be involved with smart grids.

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.

2.3 the new electricity grid

In the future power generators will be smaller and distributed throughout the grid, which 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 the large generators of the future are massive wind farms already being built in Europe's North Sea and plans for large areas of concentrating solar mirrors to generate energy in Southern Europe.

The challenge ahead will require 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 (see Figure 2.3, page 25).

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reference

[8] 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.

image GEMASOLAR IS A 15 MWE SOLAR-ONLY POWER TOWER PLANT, EMPLOYING MOLTEN SALT TECHNOLOGIES FOR RECEIVING AND STORING ENERGY. IT'S 16 HOUR MOLTEN SALT STORAGE SYSTEM CAN DELIVER POWER AROUND THE CLOCK. IT RUNS AN EQUIVALENT OF 6,570 FULL HOURS OUT OF 8,769 TOTAL. FUENTES DE ANDALUCÍA SEVILLE, SPAIN.

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box 2.2: definitions and technical terms

The electricity 'grid' is the collective name for all the cables, transformers and infrastructure that transport electricity from power plants to the end users.

Micro grids supply local power needs. Monitoring and control infrastructure are embedded inside distribution networks and use local energy generation resources. An example of a microgrid would be a combination of solar panels, micro turbines, fuel cells, energy efficiency and information/ communication technology to manage the load, for example on an island or small rural town.

Smart grids balance demand out over a region. A 'smart' electricity grid connects decentralised renewable energy sources and cogeneration and distributes power highly efficiently. Advanced types of control and management technologies for the electricity grid can also make it run more efficiently overall. For example, smart electricity meters show real-time use and costs, allowing big energy users to switch off or turn down on a signal from the grid operator, and avoid high power prices.

Super grids transport large energy loads between regions. This refers to interconnection - typically based on HVDC technology - between countries or areas with large supply and large demand. An example would be the interconnection of all the large renewable based power plants in the North Sea.

Baseload is the concept that there must be a minimum, uninterruptible supply of power to the grid at all times, traditionally provided by coal or nuclear power. The Energy [R]evolution challenges this, and instead relies on a variety of 'flexible' energy sources combined over a large area to meet demand. Currently, 'baseload' is part of the business model for nuclear and coal power plants, where the operator can produce electricity around the clock whether or not it is actually needed.

Constrained power refers to when there is a local oversupply of free wind and solar power which has to be shut down, either because it cannot be transferred to other locations (bottlenecks) or because it is competing with inflexible nuclear or coal power that has been given priority access to the grid. Constrained power is available for storage once the technology is available.

Variable power is electricity produced by wind or solar power depending on the weather. Some technologies can make variable power dispatchable, e.g. by adding heat storage to concentrated solar power.

Dispatchable is a type of power that can be stored and 'dispatched' when needed to areas of high demand, e.g. gas-fired power plants or hydro power plants.

Interconnector is a transmission line that connects different parts of the electricity grid. Load curve is the typical pattern of electricity through the day, which has a predictable peak and trough that can be anticipated from outside temperatures and historical data.

Node is a point of connection in the electricity grid between regions or countries, where there can be local supply feeding into the grid as well.

2.3.1 hybrid systems

While grid in the developed world supplies power to nearly 100% of the population, many rural areas in the developing world rely on unreliable grids or polluting electricity, for example from stand-alone diesel generators. This is also very expensive for small communities.

The standard approach of extending the grid used in developed countries is often not economic in rural areas of developing countries where potential electricity use is low and there are long distances to existing grid.

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.

Finance can often be an issue for relatively poor rural communities wanting to install such hybrid renewable systems. Greenpeace's funding model, the Feed-in Tariff Support Mechanism (FTSM), allows projects to be bundled together so the financial package is 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. In terms of project planning, it is essential that the communities themselves are directly involved in the process.

2.3.2 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 concept of baseload power towards a mix of flexible and dispatchable renewable power plants. 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.

What is a smart grid? 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 consist of tens of thousands of generation units such as solar panels, wind turbines and other renewable generation, partly within the distribution network, partly concentrated in large power plants such as offshore wind parks. The 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 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 requires a completely new power system architecture, which will need substantial amounts of further work to fully emerge.[9] Figure 2.3 shows 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. Some features of smart grids could be:

Managing level and timing of demand for electricity. Changes to pricing schemes can give consumers financial incentives to reduce or shut off their supply at periods of peak consumption, a system that 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.

Advances in communications technology. In Italy, for example, 30 million 'smart meters' 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.

Creating Virtual Power Plants (VPP). Virtual power plants interconnect 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.[10] 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 monitors (and anticipates through weather forecasts) when the wind turbines and solar modules will be generating electricity. Biogas and pumped storage units are used to make up the difference, either delivering electricity as needed in order to balance short term fluctuations or temporarily storing it.[11] Together, the combination ensures sufficient electricity supply to cover demand.

Electricity storage options. Pumped storage is the most established technology for storing energy from a type of hydroelectric power station. 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. Pumped storage has been successfully used for many decades all over the world. In 2007, the European Union had 38 GW of pumped storage capacity, representing 5% of total electrical capacity.

references

[9] 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.

[10] SEE ALSO HTTP://WWW.KOMBIKRAFTWERK.DE/INDEX.PHP?ID=27.

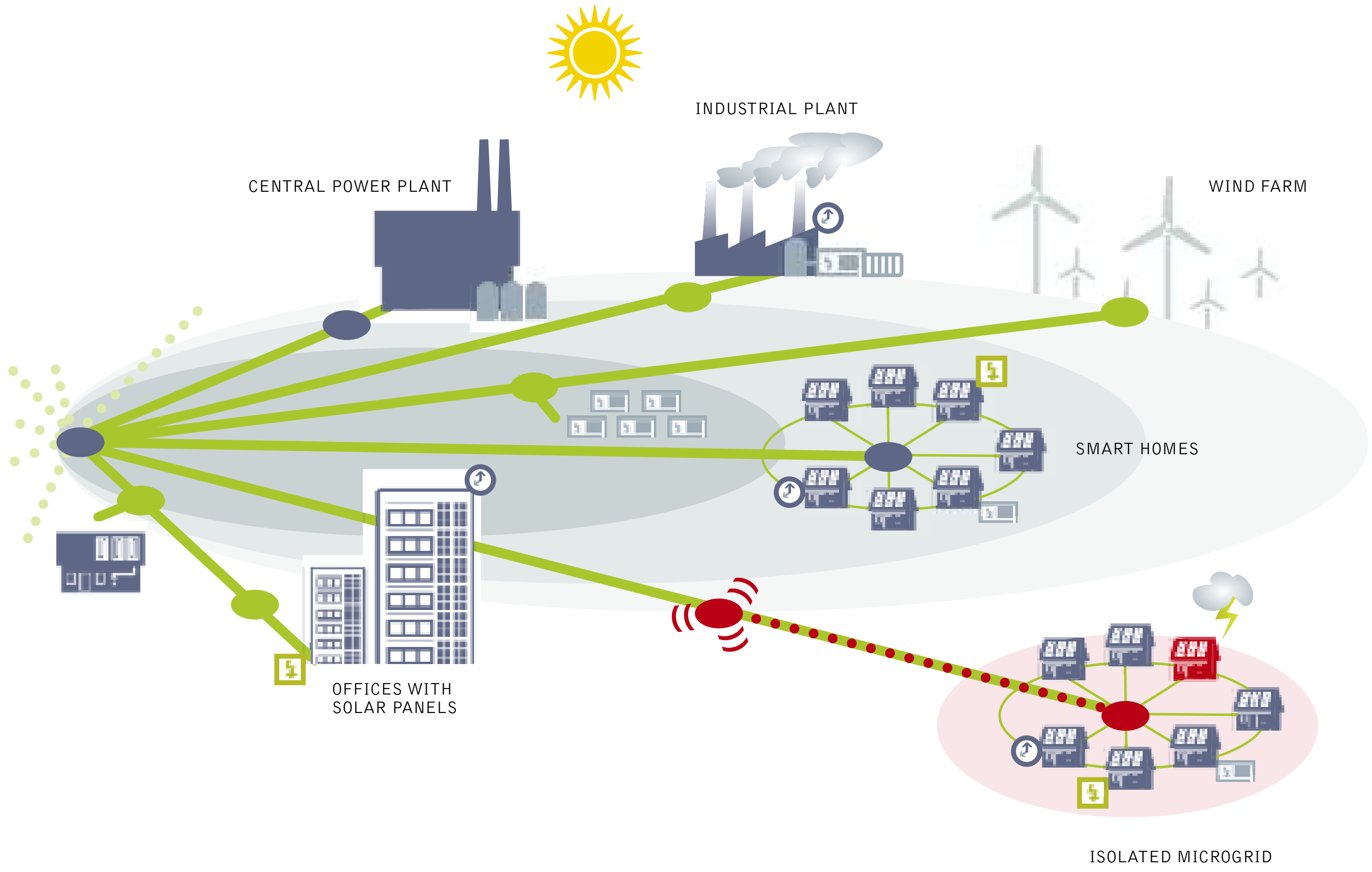
[11] SEE ALSO HTTP://WWW.SOLARSERVER.DE/SOLARMAGAZIN/ANLAGEJANUAR2008_E.HTML.

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

© GP/MARTIN ZAKORA

figure 2.3: **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.



● **PROCESSORS**
EXECUTE SPECIAL PROTECTION SCHEMES IN MICROSECONDS

SMART APPLIANCES
CAN SHUT OFF IN RESPONSE TO FREQUENCY FLUCTUATIONS

GENERATORS
ENERGY FROM SMALL GENERATORS AND SOLAR PANELS CAN REDUCE OVERALL DEMAND ON THE GRID

DISTURBANCE IN THE GRID

● **SENSORS (ON 'STANDBY')**
– DETECT FLUCTUATIONS AND DISTURBANCES, AND CAN SIGNAL FOR AREAS TO BE ISOLATED

DEMAND MANAGEMENT
USE CAN BE SHIFTED TO OFF-PEAK TIMES TO SAVE MONEY

STORAGE ENERGY GENERATED AT OFF-PEAK TIMES COULD BE STORED IN BATTERIES FOR LATER USE

SENSORS ('ACTIVATED')
– DETECT FLUCTUATIONS AND DISTURBANCES, AND CAN SIGNAL FOR AREAS TO BE ISOLATED

Vehicle-to-Grid. 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 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.

2.3.3 the super grid

Greenpeace simulation studies Renewables 24/7 (2010) and Battle of the Grids (2011) have shown that extreme situations with low solar radiation and little wind in many parts of Europe are not frequent, but they can occur. The power system, even with massive amounts of renewable energy, must be adequately designed to cope with such an event. A key element in achieving this is through the construction of new onshore and offshore super grids.

The Energy [R]evolution scenario assumes that about 70% of all generation is distributed and located close to load centres. The remaining 30% will be large scale renewable generation such as large offshore wind farms or large arrays of concentrating solar power plants. A North Sea offshore super grid, for example, would enable the efficient integration of renewable energy into the power system across the whole North Sea region, linking the UK, France, Germany, Belgium, the Netherlands, Denmark and Norway. By aggregating power generation from wind farms spread across the whole area, periods of very low or very high power flows would be reduced to a negligible amount. A dip in wind power generation in one area would be balanced by higher production in another area, even hundreds of kilometres away. Over a year, an installed offshore wind power capacity of 68.4 GW in the North Sea would be able to generate an estimated 247 TWh of electricity.[12]

2.3.4 baseload blocks progress

Generally, coal and nuclear plants run as so-called base load, meaning they work most of the time at maximum capacity regardless of how much electricity consumers need. When demand is low the power is wasted. When demand is high additional gas is needed as a backup.

However, coal and nuclear cannot be turned down on windy days so wind turbines will get switched off to prevent overloading the system. The recent global economic crisis triggered a drop in energy demand and revealed system conflict between inflexible base load power, especially nuclear, and variable renewable sources, especially wind power, with wind operators told to shut off their generators. In Northern Spain and Germany, this uncomfortable mix is already exposing the limits of the grid capacity. If Europe continues to support nuclear and coal power alongside a growth in renewables, clashes will occur more and more, creating a bloated, inefficient grid.

Despite the disadvantages stacked against renewable energy it has begun to challenge the profitability of older plants. After construction costs, a wind turbine is generating electricity almost for free and without burning any fuel. Meanwhile, coal and nuclear plants use expensive and highly polluting fuels. Even where nuclear plants are kept running and wind turbines are switched off, conventional energy providers are concerned. Like any commodity, oversupply reduces prices across the market. In energy markets, this affects nuclear and coal too. We can expect more intense conflicts over access to the grids over the coming years.

box 2.3: do we need baseload power plants?[13]

Power from some renewable plants, such as wind and solar, varies during the day and week. Some see this as an insurmountable problem, because up until now we have relied on coal or nuclear to provide a fixed amount of power at all times. In current policy-making there is a struggle to determine which type of infrastructure or management we choose and which energy mix to favour as we move away from a polluting, carbon intensive energy system. Some important facts include:

- electricity demand fluctuates in a predictable way.
- smart management can work with big electricity users, so their peak demand moves to a different part of the day, evening out the load on the overall system.
- electricity from renewable sources can be stored and 'dispatched' to where it is needed in a number of ways, using advanced grid technologies.

Wind-rich countries in Europe are already experiencing conflict between renewable and conventional power. In Spain, where a lot of wind and solar is now connected to the grid, gas power is stepping in to bridge the gap between demand and supply. This is because gas plants can be switched off or run at reduced power, for example when there is low electricity demand or high wind production. As we move to a mostly renewable electricity sector, gas plants will be needed as backup for times of high demand and low renewable production. Effectively, a kWh from a wind turbine displaces a kWh from a gas plant, avoiding carbon dioxide emissions. Renewable electricity sources such as thermal solar plants (CSP), geothermal, hydro, biomass and biogas can gradually phase out the need for natural gas. (See Case Studies, section 2.4 for more). The gas plants and pipelines would then progressively be converted for transporting biogas.

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references

[12] GREENPEACE REPORT, 'NORTH SEA ELECTRICITY GRID [R]EVOLUTION', SEPTEMBER 2008.

[13] BATTLE OF THE GRIDS, GREENPEACE INTERNATIONAL, FEBRUARY 2011.

image GREENPEACE OPENS A SOLAR ENERGY WORKSHOP IN BOMA. A MOBILE PHONE GETS CHARGED BY A SOLAR ENERGY POWERED CHARGER.

© GP/PHILIP REYNAERS

figure 2.4: **a typical load curve throughout europe, shows electricity use peaking and falling on a daily basis**

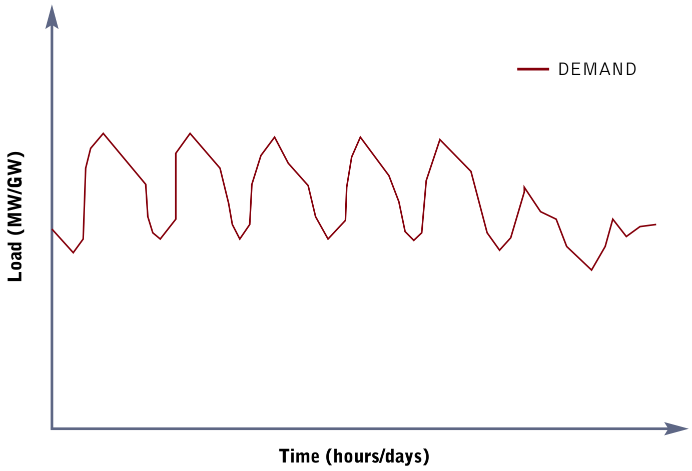
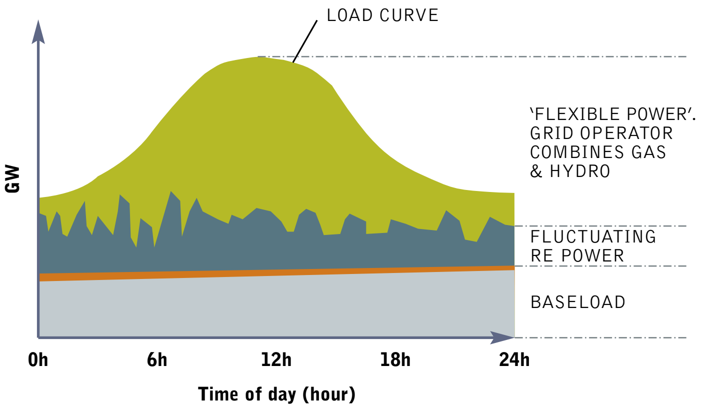


figure 2.5: **the evolving approach to grids**

Current supply system

- Low shares of fluctuating renewable energy
- The 'base load' power is a solid bar at the bottom of the graph.
- Renewable energy forms a 'variable' layer because sun and wind levels changes throughout the day.
- Gas and hydro power which can be switched on and off in response to demand. This is sustainable using weather forecasting and clever grid management.
- With this arrangement there is room for about 25 percent variable renewable energy.

To combat climate change much more than 25 percent renewable electricity is needed.



Supply system with more than 25 percent fluctuating renewable energy > base load priority

- This approach adds renewable energy but gives priority to base load.
- As renewable energy supplies grow they will exceed the demand at some times of the day, creating surplus power.
- To a point, this can be overcome by storing power, moving power between areas, shifting demand during the day or shutting down the renewable generators at peak times.

Does not work when renewables exceed 50 percent of the mix, and can not provide renewable energy as 90- 100% of the mix.

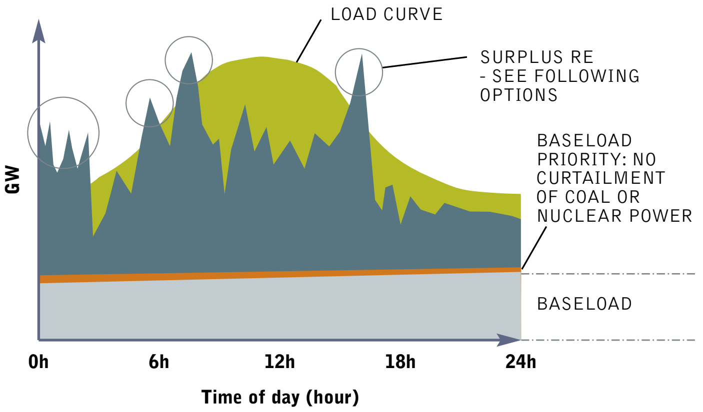
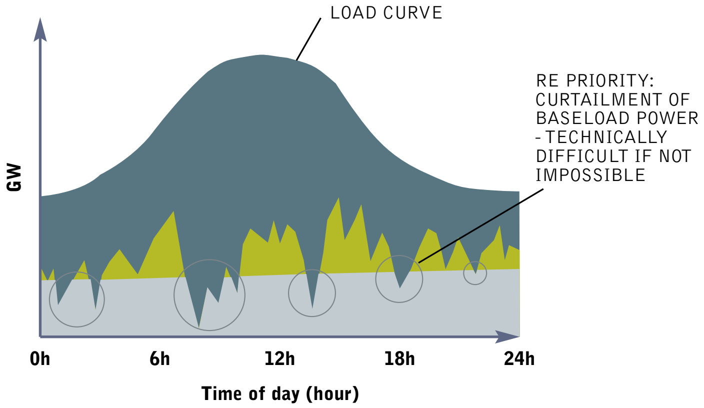


figure 2.5: the evolving approach to grids *continued*

Supply system with more than 25 percent fluctuating renewable energy – renewable energy priority

- This approach adds renewables but gives priority to clean energy.
- If renewable energy is given priority to the grid, it "cuts into" the base load power.
- Theoretically, nuclear and coal need to run at reduced capacity or be entirely turned off in peak supply times (very sunny or windy).
- There are technical and safety limitations to the speed, scale and frequency of changes in power output for nuclear and coal-CCS plants.

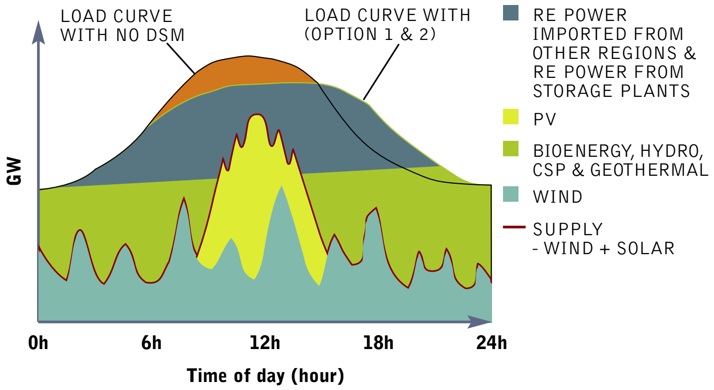
Technically difficult, not a solution.



The solution: an optimised system with over 90% renewable energy supply

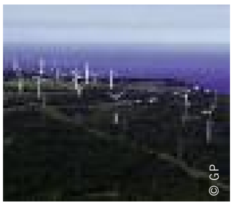
- A fully optimised grid, where 100 percent renewables operate with storage, transmission of electricity to other regions, demand management and curtailment only when required.
- Demand-side management (DSM) effectively moves the highest peak and 'flattens out' the curve of electricity use over a day.

Works!



One of the key conclusions from Greenpeace research is that in the coming decades, traditional power plants will have less and less space to run in baseload mode. With increasing penetration of variable generation from wind and photovoltaic in the electricity grid, the remaining part of the system will have to run in more 'load following' mode, filling the immediate gap between demand and production. This means the economics of base load plants like nuclear and coal will change fundamentally as more variable generation is introduced to the electricity grid.

image LE NORDAIS WINDMILL PARK, ONE OF THE MOST IMPORTANT IN AMERICA, LOCATED ON THE GASPÈ PENINSULA IN CAP-CHAT, QUEBEC, CANADA.



2.4 case study: a year after the german nuclear phase out

On 30 May 2011, the German environment minister, Norbert Röttgen, announced the Germany would close its eight oldest nuclear plants and phase out the remaining nine reactors by 2022. The plan is to replace most of the generating capacity of these nine reactors with renewables. The experience so far gives a real example of the steps needed for a global Energy [R]evolution at a national scale.

2.4.1 target and method

The German government expects renewables to generate 35% of German electricity by 2020.[14] The German Federal Environment Agency believes that the phase out would be technically feasible from 2017, requiring only 5 GW of additional combined heat-and-power or combined cycle gas plant (other than those already under construction) to meet peak time demand.[15]

2.4.2 carbon dioxide emissions trends

The German energy ambassador, Dr. Georg Maue, reported to a meeting in the British Parliament in February 2012 that Germany was still on track to meet its CO_2 reduction targets of 40% by 2020 and 80% by 2050 from 1990 levels. Figures for Germany's 2011 greenhouse gas emissions were not available for this report, although the small growth in use of lignite fuels is likely to have increased emissions in the short term.

However, the decision to phase out nuclear energy has renewed the political pressure to deliver a secure climate-friendly energy policy and ensure Germany still meets its greenhouse targets. The Energiewende ('energy transition') measures include €200 billion investment in renewable energy over the next decade, a major push on energy efficiency and an accelerated roll out of infrastructure to support the transition.[16] Germany has also become an advocate for renewables at the European level.[17] In the longer-term, by deploying a large amount of renewable capability Germany should be able to continue reducing its emissions at this accelerated rate and its improved industrial production should make it more viable for other countries to deliver greater and faster emissions reductions.

2.4.3 shortfall from first round of closures

The oldest eight nuclear reactors were closed immediately and based on figures available it looks like the 'shortfall' will be covered by a mix of lower demand, increasing renewable energy supply, and a small part by fossil-fuelled power.

In 2011 only 18% of the country's energy generation came from nuclear.[18] In the previous year, nuclear energy's contribution had already fallen from 22% to 18%, a shortfall covered mostly by renewable electricity which increased from 16% to 20% in the same period, while use of lignite (a greenhouse-intensive fossil fuel) increased from 23% to 25%.

In the first half of 2011, Germany was a net exporter of electricity (Figure 2.9), exporting 29 billion kWh and importing 24 kWh.[19] Complete figures for electricity imports and exports in the second half of 2011 are not yet available, once nuclear reactors were decommissioned, however it is known that Germany exported electricity to France during a cold spell in February 2012.[20]

Inside Germany, the demand for energy is falling.[21] Between 2010 and 2011 energy demand dropped by 5%, because the mild weather reduced demand for gas heating. While the British government is planning for electricity demand in the UK to double by 2050, the German government expects a cut of 25% from 2008 levels.[22] Total energy demand is expected to halve over the same time period.

2.4.4 the renewable energy sector in germany

Germany has successfully increased the share of renewable energy constantly over the last twenty years (see Figures 2.6 and 2.7), and the sector was employing over 350,000 employees by the end of 2011. The back bone of this development has been the Renewable Energy Act (Erneuerbare Energien Gesetz – EEG); a feed-in law which guarantees a fixed tariff per kWh for 20 years. The tariffs are different for each technology and between smaller and larger, to reflect their market penetration rates.

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references

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[16] HTTP://WWW.ERNEUERBARE-ENERGIEN.DE/INHALT/47872/3860/

[17] HTTP://WWW.ERNEUERBARE-ENERGIEN.DE/INHALT/48192/3860/

[18] THE GERMAN ASSOCIATION OF ENERGY AND WATER INDUSTRIES (BDEW), 16 DECEMBER 2011. HTTP://WWW.BDEW.DE/INTERNET.NSF/ID/EN_?OPEN&CCM=900010020010

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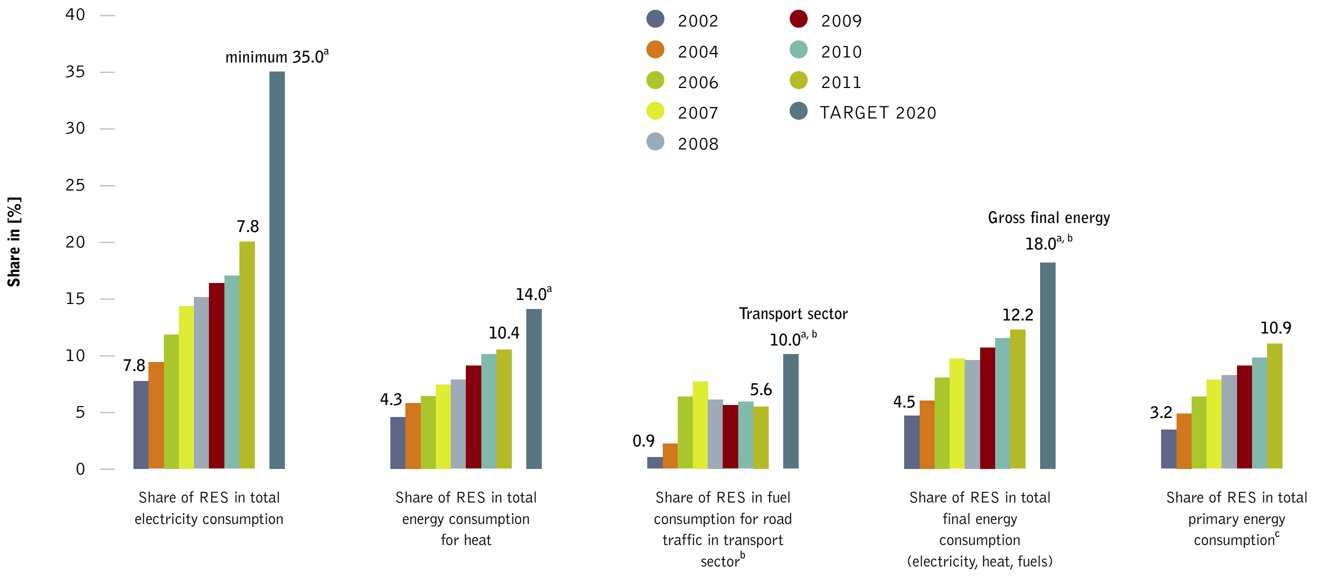
[21] HTTP://WWW.AG-ENERGIEBILANZEN.DE/COMPONENTEN/DOWNLOAD.PHP?FILEDATA=1329148695.PDF&FILENAME=AGEB_PRESSEDIENST_09_2011EN.PDF&MIMETYPE=APPLICATION/PDF

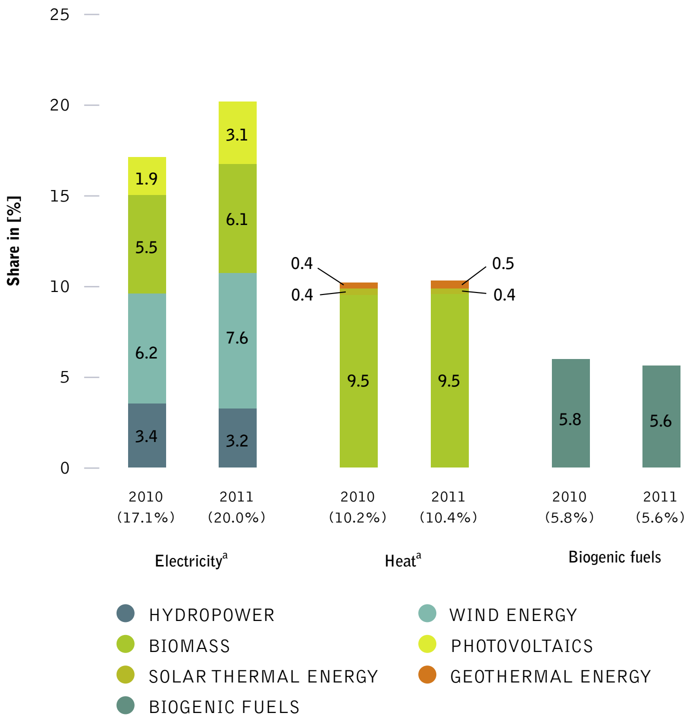
[22] HTTP://WWW.BMU.DE/FILES/ENGLISH/PDF/APPLICATION/PDF/ENERGIEKONZEPT_BUNDESREGIERUNG_EN.PDF (PAGE 5)

figure 2.6: renewable energy sources as a share of energy supply in germany



source
a TARGETS OF THE GERMAN GOVERNMENT, RENEWABLE ENERGY SOURCES ACT (EEG). RENEWABLE ENERGY SOURCES HEAT ACT (EEWärmeG). EU-DIRECTIVE 2009/28/EC.
b TOTAL CONSUMPTION OF ENGINE FUELS, EXCLUDING FUEL IN AIR TRAFFIC.
c CALCULATED USING EFFICIENCY METHOD; SOURCE: WORKING GROUP ON ENERGY BALANCES e.V. (AGEB); RES: RENEWABLE ENERGY SOURCES; SOURCE: BMU-KI III 1 ACCORDING TO WORKING GROUP ON RENEWABLE ENERGY-STATISTICS (AGEE-STAT); AS AT: MARCH 2012; ALL FIGURES PROVISIONAL.

figure 2.7: renewable energy sources in total final energy consumption in germany 2011/2010



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a BIOMASS: SOLID AND LIQUID BIOMASS, BIOGAS, SEWAGE AND LANDFILL GAS, BIOGENIC SHARE OF WASTE; ELECTRICITY FROM GEOTHERMAL ENERGY NOT PRESENTED DUE TO NEGLIBLE QUANTITIES PRODUCED; DEVIATIONS IN THE TOTALS ARE DUE TO ROUNDING; SOURCE: BMU-KI III 1 ACCORDING TO WORKING GROUP ON RENEWABLE ENERGY-STATISTICS (AGEE-STAT); AS AT: MARCH 2012; ALL FIGURES PROVISIONAL.

2.4.5 energy and climate targets

The German government agreed on short, medium and long term – binding - targets for renewable, energy efficiency and greenhouse gas reduction (Table 2.2).

2.4.6 details of the german nuclear phase-out plan

The following figure shows where the nuclear power stations are located and when they will be shut down. The last nuclear reactor will be closed down in 2022.

2.4.7 no 'blackouts'

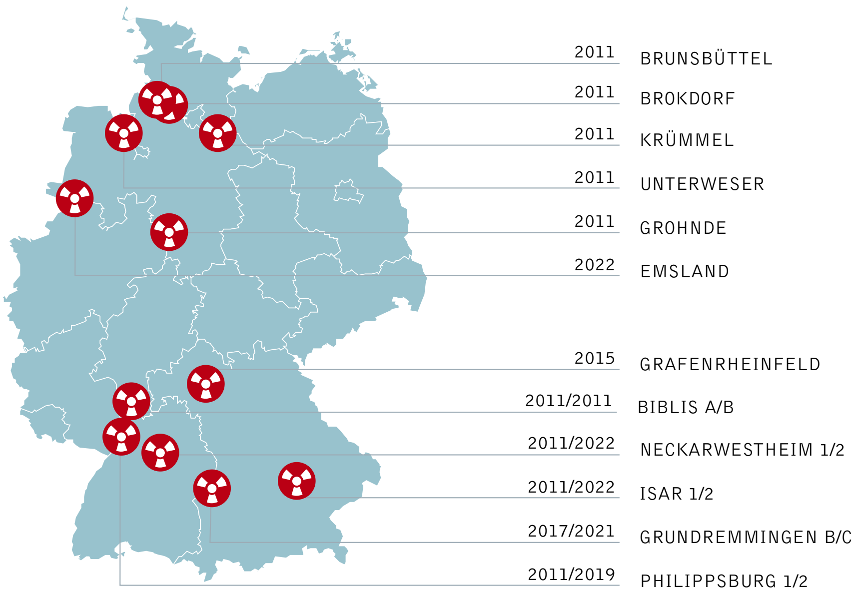
The nuclear industry has implied there would be a "black-out" in winter 2011 - 2012, or that Germany would need to import electricity from neighbouring countries, when the first set of reactors were closed. Neither event happened, and Germany actually remained a net- export of electricity during the first winter. The table below shows the electricity flow over the borders.

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.

table 2.2: german government short, medium and long term binding targets

	CLIMATE	RENEWABLE ENERGIES		EFFICIENCY		
	GREENHOUSE GASES (VS 1990)	SHARE OF ELECTRICITY	OVERALL SHARE (Gross final energy consumption)	PRIMARY ENERGY CONSUMPTION	ENERGY PRODUCTIVITY	BUILDING MODERNISATION
2020	- 40%	35%	18%	-20%		
2030	- 55%	50%	30%	↓	Increase to 2.1% annum	Double the rate 1%-2%
2040	- 70%	65%	45%			
2040	- 85-95%	80%	60%	-50%		

figure 2.8: phase out of nuclear energy

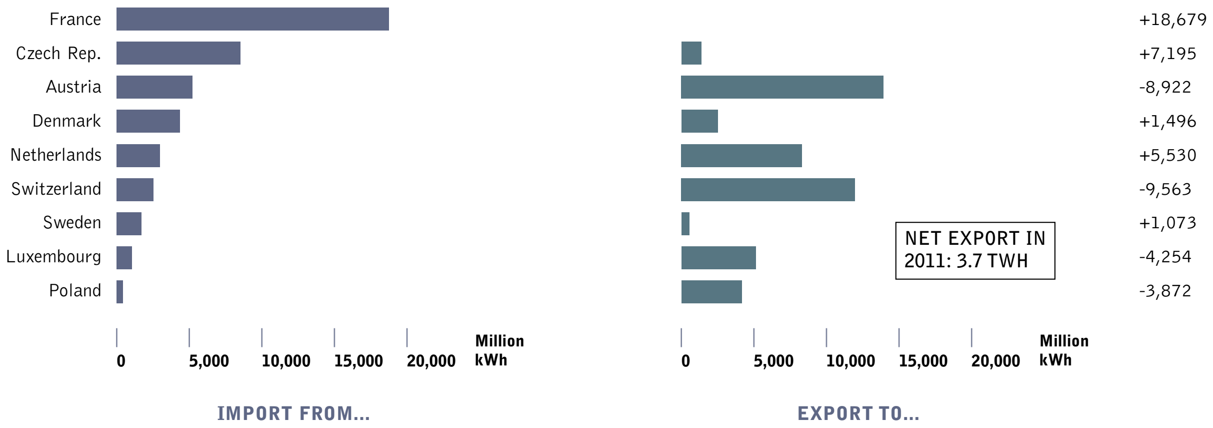


- Seven oldest plants plus Krümmel: immediate decommissioning
- Gradual phasing out of nuclear power by 2022
- Shutdown years: 2015, 2017, 2019, 2021, 2022

source UMWELTBUNDESAMT (UBA) 2012, GERMAN MINISTRY FOR ENVIRONMENT

figure 2.9: electricity imports/exports germany

JANUARY TO NOVEMBER 2011. (VOLUME MEASURE IN MILLION KWH)



implementing the energy [r]evolution

> “investments in renewables are investments in the future.”

© JACQUES DESCLOITRES, MODIS RAPID RESPONSE TEAM, NASA/GSFC

image AT THE END OF FEBRUARY SNOW IS MELTING IN NORTHWESTERN EUROPE, HINTING AT THE SPRING THAT IS COMING. IN THE FALSE-COLOR IMAGE, WATER IS BLACK AND DARK BLUE. SNOW IS LIGHT BLUE, AND CLOUDS ARE A LIGHTER SHADE OF BLUE. VEGETATION IS BRIGHT GREEN.

image GEOTHERMAL ACTIVITY NEAR HOLSSELSNALAR CLOSE TO REYKJAVIK, ICELAND.


© GP/NICK COBBING

3.1 renewable energy project planning basics

The renewable energy market works significantly different than the coal, gas or nuclear power market. The table below provides an overview of the ten steps from "field to an operating power plant" for renewable energy projects in the current market situation. Those steps are similar for each renewable energy technology, however step 3 and 4 are especially important for wind and solar projects. In developing countries the government and the mostly state-owned utilities might directly or indirectly take responsibilities of the project developers. The project developer might also work as a subdivision of a state-owned utility.

table 3.1: how does the current renewable energy market work in practice?

STEP	WHAT WILL BE DONE?	WHO?	NEEDED INFORMATION / POLICY AND/OR INVESTMENT FRAMEWORK
Step 1: Site identification	Identify the best locations for generators (e.g. wind turbines) and pay special attention to technical and commercial data, conservation issues and any concerns that local communities may have.	P	Resource analysis to identify possible sites Policy stability in order to make sure that the policy is still in place once Step 10 has been reached. Without a certainty that the renewable electricity produced can be fed entirely into the grid to a reliable tariff, the entire process will not start.
Step 2: Securing land under civil law	Secure suitable locations through purchase and lease agreements with land owners.	P	Transparent planning, efficient authorisation and permitting.
Step 3: Determining site specific potential	Site specific resource analysis (e.g. wind measurement on hub height) from independent experts. This will NOT be done by the project developer as (wind) data from independent experts is a requirement for risk assessments by investors.	P + M	See above.
Step 4: Technical planning/ micrositing	Specialists develop the optimum configuration or sites for the technology, taking a wide range of parameters into consideration in order to achieve the best performance.	P	See above.
Step 5: Permit process	Organise all necessary surveys, put together the required documentation and follow the whole permit process.	P	Transparent planning, efficient authorisation and permitting.
Step 6: Grid connection planning	Electrical engineers work with grid operators to develop the optimum grid connection concept.	P + U	Priority access to the grid. Certainty that the entire amount of electricity produced can be feed into the grid.
Step 7: Financing	Once the entire project design is ready and the estimated annual output (in kWh/a) has been calculated, all permits are processed and the total finance concept (incl. total investment and profit estimation) has been developed, the project developer will contact financial institutions to either apply for a loan and/or sell the entire project.	P + I	Long term power purchase contract. Prior and mandatory access to the grid. Site specific analysis (possible annual output).
Step 8: Construction	Civil engineers organise the entire construction phase. This can be done by the project developer or another. EPC (Engineering, procurement & construction) company – with the financial support from the investor.	P + I	Signed contracts with grid operator. Signed contract with investors.
Step 9: Start of operation	Electrical engineers make sure that the power plant will be connected to the power grid.	P + U	Prior access to the grid (to avoid curtailment).
Step 10: Business and operations management	Optimum technical and commercial operation of power plants/farms throughout their entire operating life – for the owner (e.g. a bank).	P + U + I	Good technology & knowledge (A cost-saving approach and "copy + paste engineering" will be more expensive in the long-term).

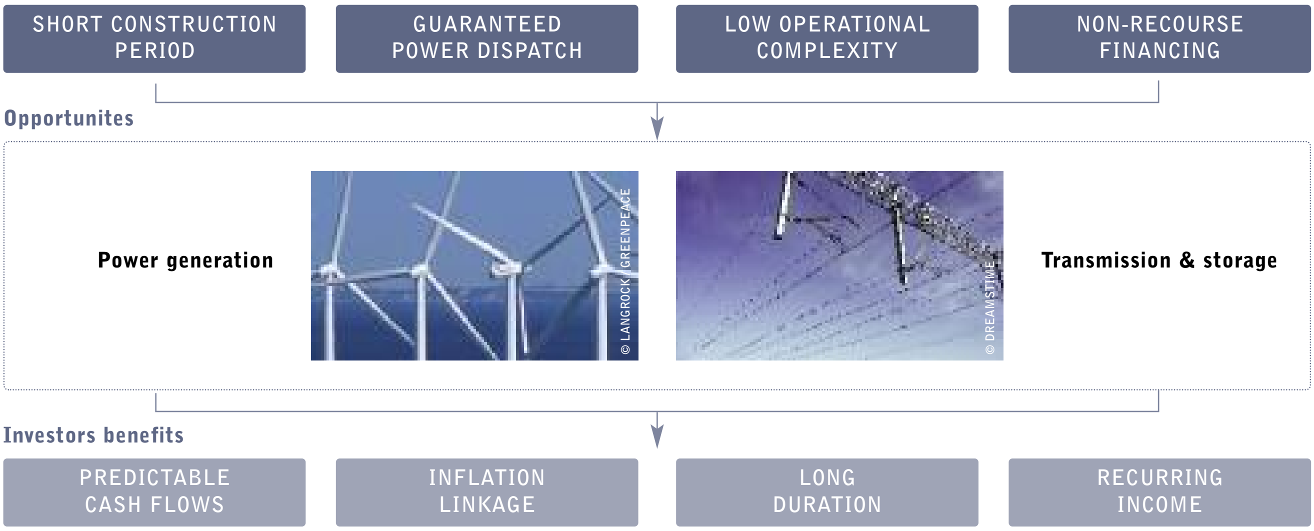
P = Project developer, **M** = Meteorological Experts, **I** = Investor, **U** = utility.

3.2 renewable energy financing basics

The Swiss RE Private Equity Partners have provided an introduction to renewable energy infrastructure investing (September 2011) which describes what makes renewable energy projects different from fossil-fuel based energy assets from a finance perspective:

- Renewable energy projects have short construction periods compared to conventional energy generation and other infrastructure assets. Renewable projects have limited ramp-up periods, and construction periods of one to three years, compared to ten years to build large conventional power plants.
- The Renewable Energy Directive granted priority of dispatch to renewable energy producers. Under this principle, grid operators are usually obliged to connect renewable power plants to their grid and for retailers or other authorised entities to purchase all renewable electricity produced.
- Renewable projects present relatively low operational complexity compared to other energy generation assets or other infrastructure asset classes. Onshore wind and solar PV projects in particular have well established operational track records. This is obviously less the case for biomass or offshore wind plants.
- Renewable projects typically have non-recourse financining, through a mix of debt and equity. In contrast to traditional corporate lending, project finance relies on future cash flows for interest and debt repayment, rather than the asset value or the historical financial performance of a company. Project finance debt typically covers 70–90% of the cost of a project, is non-recourse to the investors, and ideally matches the duration of the underlying contractual agreements.
- Renewable power typically has predictable cash flows and it is not subject to fuel price volatility because the primary energy resource is generally freely available. Contractually guaranteed tariffs, as well as moderate costs of erecting, operating and maintaining renewable generation facilities, allow for high profit margins and predictable cash flows.
- Renewable electricity remuneration mechanisms often include some kind of inflation indexation, although incentive schemes may vary on a case-by-case basis. For example, several tariffs in the EU are indexed to consumer price indices and adjusted on an annual basis (e.g. Italy). In projects where specific inflation protection is not provided (e.g. Germany), the regulatory framework allows selling power on the spot market, should the power price be higher than the guaranteed tariff.
- Renewable power plants have expected long useful lives (over 20 years). Transmission lines usually have economic lives of over 40 years. Renewable assets are typically underpinned by long-term contracts with utilities and benefit from governmental support and manufacturer warranties.
- Renewable energy projects deliver attractive and stable sources of income, only loosely linked to the economic cycle. Project owners do not have to manage fuel cost volatility and projects generate high operating margins with relatively secure revenues and generally limited market risk.
- The widespread development of renewable power generation will require significant investments in the electricity network. As discussed in Chapter 2 future networks (smart grids) will have to integrate an ever-increasing, decentralised, fluctuating supply of renewable energy. Furthermore, suppliers and/or distribution companies will be expected to deliver a sophisticated range of services by embedding digital grid devices into power networks.

figure 3.1: **return characteristics of renewable energies**



source
SWISS RE PRIVATE EQUITY PARTNERS.

image A LARGE SOLAR SYSTEM OF 63M² RISES ON THE ROOF OF A HOTEL IN CELERINA, SWITZERLAND. THE COLLECTOR IS EXPECTED TO PRODUCE HOT WATER AND HEATING SUPPORT AND CAN SAVE ABOUT 6,000 LITERS OF OIL PER YEAR. THUS, THE CO_2 EMISSIONS AND COMPANY COSTS CAN BE REDUCED.

Risk assessment and allocation is at the centre of project finance. Accordingly, project structuring and expected return are directly related to the risk profile of the project. The four main risk factors to consider when investing in renewable energy assets are:

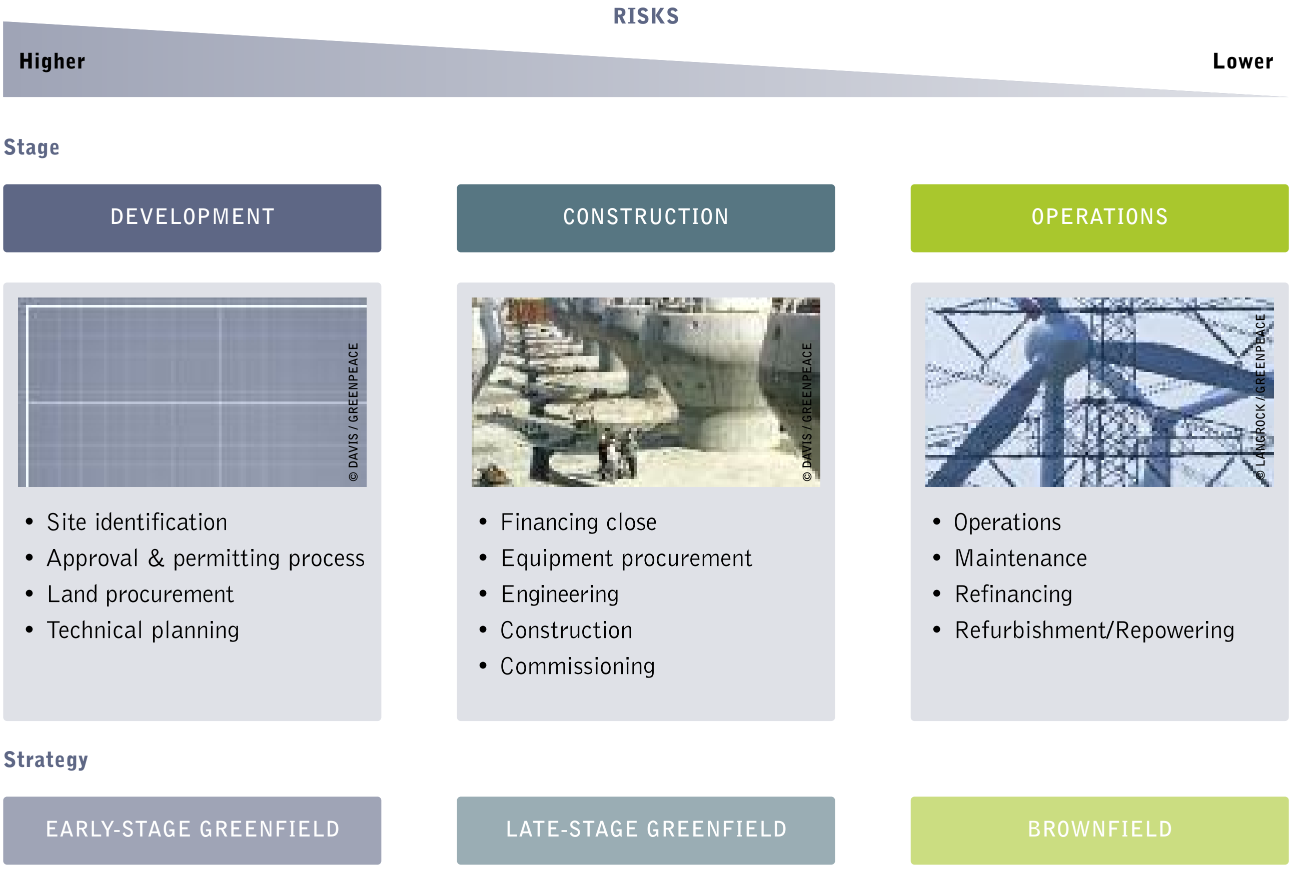
- **Regulatory risks** refer to adverse changes in laws and regulations, unfavourable tariff setting and change or breach of contracts. As long as renewable energy relies on government policy dependent tariff schemes, it will remain vulnerable to changes in regulation. However a diversified investment across regulatory jurisdictions, geographies, and technologies can help mitigate those risks.
- **Construction risks** relate to the delayed or costly delivery of an asset, the default of a contracting party, or an engineering/design failure. Construction risks are less prevalent for renewable energy projects because they have relatively simple design. However, construction risks can be mitigated by selecting high-quality and experienced turnkey partners, using proven technologies and established equipment suppliers as well as agreeing on retentions and construction guarantees.
- **Financing risks** refer to the inadequate use of debt in the financial structure of an asset. This comprises the abusive use of leverage, the exposure to interest rate volatility as well as the need to refinance at less favourable terms.
- **Operational risks** include equipment failure, counterparty default and reduced availability of the primary energy source (e.g. wind, heat, radiation). For renewable assets a lower than forecasted resource availability will result in lower revenues and profitability so this risk can damage the business case. For instance, abnormal wind regimes in Northern Europe over the last few years have resulted in some cases in breach of coverage ratios and in the inability of some projects to pay dividends to shareholders.

figure 3.2: overview risk factors for renewable energy projects

REGULATORY RISKS	CONSTRUCTION RISKS
FINANCING RISKS	OPERATIONAL RISKS

source
SWISS RE PRIVATE EQUITY PARTNERS.

figure 3.3: investment stages of renewable energy projects



DEVELOPMENT
- Site identification
- Approval & permitting process
- Land procurement
- Technical planning

CONSTRUCTION
- Financing close
- Equipment procurement
- Engineering
- Construction
- Commissioning

OPERATIONS
- Operations
- Maintenance
- Refinancing
- Refurbishment/Repowering

source
SWISS RE PRIVATE EQUITY PARTNERS.

3.2.1 overcoming barriers to finance and investment for renewable energy

table 3.2: categorisation of barriers to renewable energy investment

CATEGORY	SUB-CATEGORY	EXAMPLE BARRIERS
Barriers to finance	Cost barriers	Costs of renewable energy to generate Market failures (e.g. insufficient carbon price) Energy prices Technical barriers Competing technologies (gas, nuclear, CCS and coal)
	Insufficient information and experience	Overrated risks Lack of experienced investors Lack of experienced project developers Weak finance sectors in some countries
	Financial structure	Up-front investment cost Costs of debt and equity Leverage Risk levels and finance horizon Equity/credit/bond options Security for investment
	Project and industry scale	Relative small industry scale Smaller project scale
	Investor confidence	Confidence in long term policy Confidence in short term policy Confidence in the renewable energy market
Other investment barriers	Government renewable energy policy and law	Renewable energy targets Feed-in tariffs Framework law stability Local content rules
	System integration and infrastructure	Access to grid Energy infrastructure Overall national infrastructure quality Energy market Contracts between generators and users
	Lock-in of existing technologies	Subsidies to other technologies Grid lock-in Skills lock-in Lobbying power
	Permitting and planning regulation	Favourability Transparency Public support
	Government economic position and policy	Monetary policy e.g. interest rates Fiscal policy e.g. stimulus and austerity Currency risks Tariffs in international trade
	Skilled human resources	Lack of training courses
	National governance and legal system	Political stability Corruption Robustness of legal system Litigation risks Intellectual property rights Institutional awareness

Despite the relatively strong growth in renewable energies in some countries, there are still many barriers which hinder the rapid uptake of renewable energy needed to achieve the scale of development required. The key barriers to renewable energy investment identified by Greenpeace through a literature review[23] and interviews with renewable energy sector financiers and developers are shown in Figure 3.4.

There are broad categories of common barriers to renewable energy development that are present in many countries, however the nature of the barriers differs significantly. At the local level, political and policy support, grid infrastructure, electricity markets and planning regulations have to be negotiated for new projects.

image SOVARANI KOYAL LIVES IN SATJELLIA ISLAND AND IS ONE OF THE MANY PEOPLE AFFECTED BY SEA LEVEL RISE: "NOWADAYS, HEAVY FLOODS ARE GOING ON HERE. THE WATER LEVEL IS INCREASING AND THE TEMPERATURE TOO. WE CANNOT LIVE HERE, THE HEAT IS BECOMING UNBEARABLE. WE HAVE RECEIVED A PLASTIC SHEET AND HAVE COVERED OUR HOME WITH IT. DURING THE COMING MONSOON WE SHALL WRAP OUR BODIES IN THE PLASTIC TO STAY DRY. WE HAVE ONLY A FEW GOATS BUT WE DO NOT KNOW WHERE THEY ARE. WE ALSO HAVE TWO CHILDREN AND WE CANNOT MANAGE TO FEED THEM."

It is uncertainty of policy that is holding back investment more than an absence of policy support mechanisms. In the short term, investors aren't confident rules will remain unaltered and aren't confident that renewable energy goals will be met in the longer term, let alone increased.

When investors are cautious about taking on these risks, it drives up investment costs and the difficulty in accessing finance is a barrier to renewable energy project developers. Contributing factors include a lack of information and experience among investors and project developers, involvement of smaller companies and projects and a high proportion of up-front costs.

Grid access and grid infrastructure are also major barriers to developers, because they are not certain they will be able to sell all the electricity they generate in many countries, during project development.

Both state and private utilities are contributing to blocking renewable energy through their market power and political power, maintaining 'status quo' in the grid, electricity markets for centralised coal and nuclear power and lobbying against pro-renewable and climate protection laws.

The sometimes higher cost of renewable energy relative to competitors is still a barrier, though many are confident that it will be overcome in the coming decades. The Special Report on Renewable Energy Sources and Climate Change Mitigation (SRREN) identifies cost as the most significant barrier to investment[24] and while it exists, renewable energy will rely on policy intervention by governments in order to be competitive, which creates additional risks for investors. It is important to note though, that in some regions of the world specific renewable technologies are broadly competitive with current market energy prices (e.g. onshore wind in Europe).

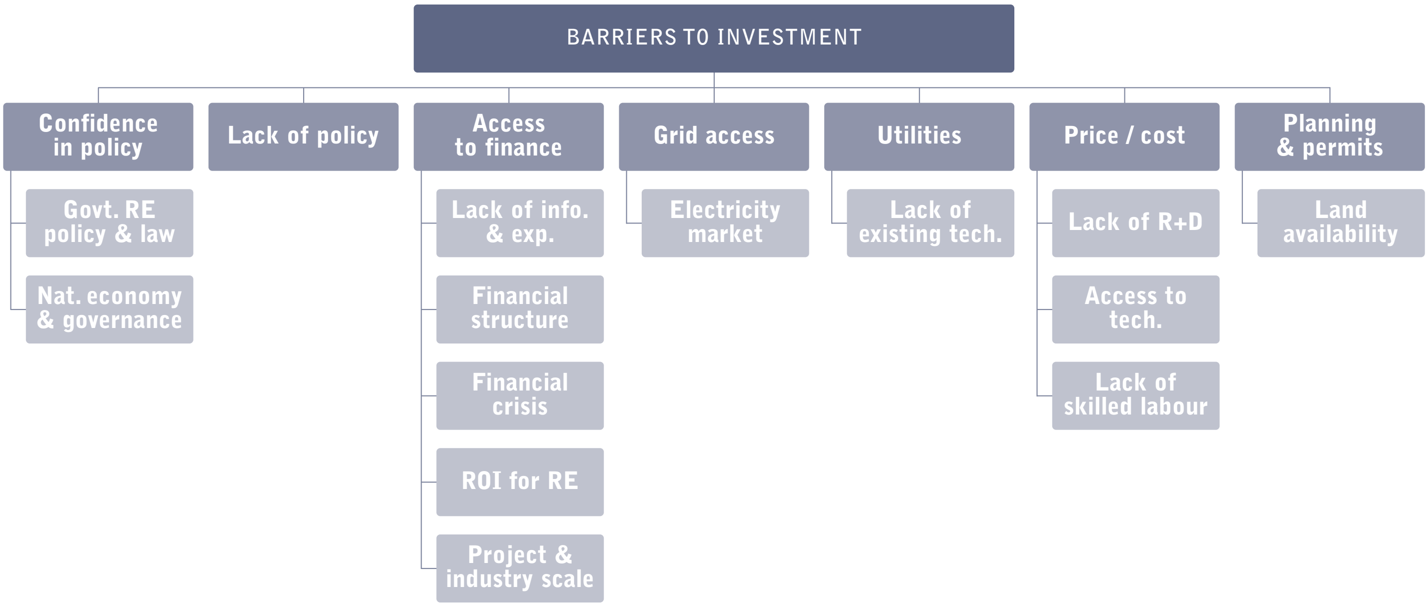
Concerns over planning and permit issues are significant, though vary significantly in their strength and nature depending on the jurisdiction.

3.2.2 how to overcome investment barriers for renewable energy

To see an Energy [R]evolution will require a mix of policy measures, finance, grid, and development. In summary:

- Additional and improved policy support mechanisms for renewable energy are needed in all countries and regions.
- Building confidence in the existing policy mechanisms may be just as important as making them stronger, particularly in the short term.
- Improved policy mechanisms can also lower the cost of finance, particularly by providing longer durations of revenue support and increasing revenue certainty.[25]
- Access to finance can be increased by greater involvement of governments and development banks in programs like loan guarantees and green bonds as well as more active private investors.
- Grid access and infrastructure needs to be improved through investment in smart, decentralised grids.
- Lowering the cost of renewable energy technologies directly will require industry development and boosted research and development.
- A smoother pathway for renewable energy needs to be established through planning and permit issues at the local level.

figure 3.4: key barriers to renewable energy investment



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[24] INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC) (2011) SPECIAL REPORT ON RENEWABLE ENERGY SOURCES AND CLIMATE CHANGE MITIGATION (SRREN). 15TH JUNE 2011. CHP. 11, P.24.

[25] CLIMATE POLICY INITIATIVE (2011):THE IMPACTS OF POLICY ON THE FINANCING OF RENEWABLE PROJECTS: A CASE STUDY ANALYSIS, 3 OCTOBER 2011.

scenario for a future energy supply

> “towards a sustainable energy supply system.”

© NASA

image BLUSTERY WEATHER SPREADS ACROSS EUROPE BLASTING EVEN THE NORMALLY BALMY SPAIN WITH SNOW AND FREEZING TEMPERATURES. THE SNOW IS CENTERED ON THREE AREAS: THE CANTABRIAN MOUNTAINS ON THE NORTHERN COAST, THE CENTER OF THE COUNTRY NEAR THE CAPITAL, MADRID, AND IN THE PYRENEES MOUNTAINS ON THE FRENCH BORDER. THE SNOW IS TURQUOISE, WHILE CLOUD IS WHITE.

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

Moving from principles to action for energy supply that mitigates against climate change requires a long-term perspective. Energy infrastructure takes time to build up; new energy technologies take time to develop. Policy shifts often also need many years to take effect. In most world regions the transformation from fossil to renewable energies will require additional investment and higher supply costs over about twenty years. However, there will be tremendous economic benefits in the long term, due to much lower consumption of increasingly expensive, rare or imported fuels. Any analysis that seeks to tackle energy and environmental issues therefore needs to look ahead at least half a century.

Scenarios are necessary to describe possible development paths, to give decision-makers a broad overview and indicate how far they can shape the future energy system. Two scenarios are used here to show the wide range of possible pathways in each world region for a future energy supply system:

- **Reference scenario**, reflecting a continuation of current trends and policies.
- The **Energy [R]evolution scenario**, designed to achieve a set of environmental policy targets.

The Reference scenario is based on the Current Policies scenarios published by the International Energy Agency (IEA) in World Energy Outlook 2011 (WEO 2011).[26] It only takes existing international energy and environmental policies into account. Its assumptions include, for example, continuing progress in electricity and gas market reforms, the liberalisation of cross-border energy trade and recent policies designed to combat environmental pollution. The Reference scenario does not include additional policies to reduce greenhouse gas emissions. As the IEA's projections only extend to 2035, they have been extended by extrapolating their key macroeconomic and energy indicators forward to 2050. This provides a baseline for comparison with the Energy [R]evolution scenario.

The global Energy [R]evolution scenario has a key target to reduce worldwide carbon dioxide emissions from energy use down to a level of below 4 Gigatonnes per year by 2050 in order to hold the increase in average global temperature under +2°C. A second objective is the global phasing out of nuclear energy. The Energy [R]evolution scenarios published by Greenpeace in 2007, 2008 and 2010 included 'basic' and 'advanced' scenarios, the less ambitious target was for 10 Gigatonnes CO_2 emissions per year by 2050. However, this 2012 revision only focuses on the more ambitious "advanced" Energy [R]evolution scenario first published in 2010.

This global carbon dioxide emission reduction target translates into a carbon budget for Europe (EU 27): the basis of this Energy [R]evolution for Europe (EU 27). To achieve the target, the scenario includes significant efforts to fully exploit the large potential for energy efficiency, using currently available best practice technology. At the same time, all cost-effective renewable energy sources are used for heat and electricity generation as well as the production of biofuels. The general framework parameters for population and GDP growth remain unchanged from the Reference scenario.

Efficiency in use of electricity and fuels in industry and "other sectors" has been completely re-evaluated using a consistent approach based on technical efficiency potentials and energy intensities. The resulting consumption pathway is close to the projection of the earlier editions. One key difference for the new Energy [R]evolution scenario is it incorporates stronger efforts to develop better technologies to achieve CO_2 reduction. There is lower demand factored into the transport sector (compared to the basic scenario in 2008 and 2010), from a change in driving patterns and a faster uptake of efficient combustion vehicles and a larger share of electric and plug-in hybrid vehicles after 2025. This scenario contains a lower use of biofuels for private vehicles following the latest scientific reports that indicate that biofuels might have a higher greenhouse gas emission footprint than fossil fuels. Current EU sustainability standards for biofuels are insufficient to avoid competition with food growing and to avoid deforestation.

The new Energy [R]evolution scenario also foresees a shift in the use of renewables from power to heat, thanks to the enormous and diverse potential for renewable power. Assumptions for the heating sector include a fast expansion of the use of district heat and more electricity for process heat in the industry sector. More geothermal heat pumps are also included, which leads to a higher overall electricity demand, when combined with a larger share of electric cars for transport. A faster expansion of solar and geothermal heating systems is also assumed. Hydrogen generated by electrolysis and renewable electricity is introduced in this scenario as third renewable fuel in the transport sector after 2025, complementary to biofuels and direct use of renewable electricity. Hydrogen is also applied as a chemical storage medium for electricity from renewables and used in industrial combustion processes and cogeneration for provision of heat and electricity, as well, and for short periods also reconversion into electricity. Hydrogen generation can have high energy losses, however the limited potentials of biofuels and probably also battery electric mobility makes it necessary to have a third renewable option. Alternatively, this renewable hydrogen could be converted into synthetic methane or liquid fuels depending on economic benefits (storage costs vs. additional losses) as well as technology and market development in the transport sector (combustion engines vs. fuel cells).

In all sectors, the latest market development projections of the renewable energy industry[27] have been taken into account. The fast introduction of electric vehicles, combined with the implementation of smart grids and fast expansion of super grids allows a high share of fluctuating renewable power generation (photovoltaic and wind) to be employed. In the global secenario, renewable energy would pass 30% of the global energy supply just after 2020. The EU 27 Energy [R]evolution scenario shows that renewable energy would pass 20% of the EU's energy supply before 2020.

The quantities of biomass power generators and large hydro power remain limited in the new Energy [R]evolution scenarios, for reasons of ecological sustainability.

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reference

[26] INTERNATIONAL ENERGY AGENCY (IEA), 'WORLD ENERGY OUTLOOK 2011', OECD/IEA 2011.

[27] SEE EREC ('RE-THINKING 2050'), GWEC, EPIA ET AL.

These scenarios by no means claim to predict the future; they simply describe and compare two potential development pathways out of the broad range of possible 'futures'. The Energy [R]evolution scenarios are designed to indicate the efforts and actions required to achieve their ambitious objectives and to illustrate the options we have at hand to change our energy supply system into one that is truly sustainable.

4.1 scenario background

The scenarios in this report were jointly commissioned by Greenpeace and the European Renewable Energy Council from the Systems Analysis group of the Institute of Technical Thermodynamics, part of the German Aerospace Center (DLR). The supply scenarios were calculated using the MESAP/PlaNet simulation model adopted in the previous Energy [R]evolution studies.[28] The new energy demand projections were developed from the University of Utrecht, Netherlands, based on an analysis of the future potential for energy efficiency measures in 2012. The biomass potential calculated for previous editions, judged according to Greenpeace sustainability criteria, has been developed by the German Biomass Research Centre in 2009 and has been further reduced for precautionary principles. The future development pathway for car technologies is based on a special report produced in 2012 by the Institute of Vehicle Concepts, DLR for Greenpeace International. Finally the Institute for Sustainable Futures (ISF) analysed the employment effects of the Energy [R]evolution and Reference scenarios.

4.1.1 status and future projections for renewable heating technologies

EREC and DLR undertook detailed research about the current renewable heating technology markets, market forecasts, cost projections and state of the technology development. The cost projection as well as the technology option have been used as an input information for this new Energy [R]evolution scenario.

4.2 population development

Future population development is an important factor in energy scenario building because population size affects the size and composition of energy demand, directly and through its impact on economic growth and development. The Energy [R]evolution scenario uses the UNEP World Population Prospect 2010 projection for population development.

table 4.1: population development projections
(IN MILLIONS)

	2009	2015	2020	2025	2030	2040	**2050**
EU 27	499	506	511	514	516	515	**512**

source UNEP WORLD POPULATION PROSPECT 2010.

4.3 economic growth

Economic growth is a key driver for energy demand. Since 1971, each 1% increase in global Gross Domestic Product (GDP) has been accompanied by a 0.6% increase in primary energy consumption. The decoupling of energy demand and GDP growth is therefore a prerequisite for an energy revolution. Most global energy/economic/environmental models constructed in the past have relied on market exchange rates to place countries in a common currency for estimation and calibration. This approach has been the subject of considerable discussion in recent years, and an alternative has been proposed in the form of purchasing power parity (PPP) exchange rates. Purchasing power parities compare the costs in different currencies of a fixed basket of traded and non-traded goods and services and yield a widely-based measure of the standard of living. This is important in analysing the main drivers of energy demand or for comparing energy intensities among countries.

Although PPP assessments are still relatively imprecise compared to statistics based on national income and product trade and national price indexes, they are considered to provide a better basis for a scenario development.[29] Thus all data on economic development in WEO 2011 refers to purchasing power adjusted GDP. However, as WEO 2011 only covers the time period up to 2035, the projections for 2035-2050 for the Energy [R]evolution scenario are based on our own estimates.

Prospects for GDP growth have decreased considerably since the previous study, due to the financial crisis at the beginning of 2009, although underlying growth trends continue much the same. GDP growth in all regions is expected to slow gradually over the coming decades. World GDP is assumed to grow on average by 3.8% per year over the period 2009-2030, compared to 3.1% from 1971 to 2007, and on average by 3.1% per year over the entire modelling period (2009-2050). China and India are expected to grow faster than other regions, followed by the Middle East, Africa, remaining Non-OECD Asia, and Eastern Europe/Eurasia. The Chinese economy will slow as it becomes more mature, but will nonetheless become the largest in the world in PPP terms early in the 2020s. GDP in Europe (EU 27) is assumed to grow by on average 1.6% per year over the projection period.

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[29] NORDHAUS, W, 'ALTERNATIVE MEASURES OF OUTPUT IN GLOBAL ECONOMIC-ENVIRONMENTAL MODELS: PURCHASING POWER PARITY OR MARKET EXCHANGE RATES?', REPORT PREPARED FOR IPCC EXPERT MEETING ON EMISSION SCENARIOS, US-EPA WASHINGTON DC, JANUARY 12-14, 2005.


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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.

table 4.2: gdp development projections

(AVERAGE ANNUAL GROWTH RATES)

REGION	2009-2020	2020-2035	2035-2050	**2009-2050**
World	4.2%	3.2%	2.2%	3.1%
OECD Americas	2.7%	2.3%	1.2%	2.0%
OECD Asia Oceania	2.4%	1.4%	0.5%	1.3%
Europe (EU 27)	2.1%	1.8%	1.0%	1.6%
Eastern Europe/ Eurasia	4.2%	3.2%	1.9%	3.0%
India	7.6%	5.8%	3.1%	5.3%
China	8.2%	4.2%	2.7%	4.7%
Non OECD Asia	5.2%	3.2%	2.6%	3.5%
Latin America	4.0%	2.8%	2.2%	2.9%
Middle East	4.3%	3.7%	2.8%	3.5%
Africa	4.5%	4.4%	4.2%	4.4%

source 2009-2035: IEA WEO 2011 AND 2035-2050: DLR, PERSONAL COMMUNICATION (2012)

4.4 oil and gas price projections

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 €28 per barrel (/bbl) was assumed in 2030. More recent projections of oil prices by 2035 in the IEA's WEO 2011 range from €80/bbl in the 450 ppm scenario up to €116/bbl in current policies scenario.

Since the first Energy [R]evolution study was published in 2007, however, the actual price of oil has reached over €83/bbl for the first time, and in July 2008 reached a record high of more than €116/bbl. Although oil prices fell back to €83/bbl in September 2008 and around €66/bbl in April 2010, prices have increased to more than €91/bbl in early 2012. Thus, the projections in the IEA Current Policies 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 slightly higher than the IEA WEO 2011 "Current Policies" case extrapolated forward to 2050 (see Table 4.3).

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 €20-25/GJ by 2050.

table 4.3: development projections for fossil fuel and biomass prices in € 2010

FOSSIL FUEL	UNIT	2000	2005	2007	2008	2010	2015	2020	2025	2030	2035	2040	2050
Crude oil imports													
Historic prices (from WEO)	barrel	29	42	63	98	65							
WEO "450 ppm scenario"	barrel					65	80	80	80	80	80		
WEO Current policies	barrel					65	88	88	88	112	116		
Energy [R]evolution 2012	barrel					65	93	93	93	126	126	126	126
Natural gas imports													
Historic prices (from WEO)													
United States	GJ	4.20	1.94	2.71		3.84							
Europe	GJ	3.10	3.77	5.27		6.55							
Japan LNG	GJ	5.11	3.79	5.30		9.61							
WEO 2011 "450 ppm scenario"													
United States	GJ					3.84	5.15	5.68	6.98	7.32	6.81		
Europe	GJ					6.55	8.21	8.56	8.56	8.47	8.21		
Japan LNG	GJ					9.61	10.39	10.48	10.48	10.57	10.57		
WEO 2011 Current policies													
United States	GJ					3.84	5.33	6.12	6.72	7.32	7.86		
Europe	GJ					6.55	8.56	9.61	10.39	11.00	11.35		
Japan LNG	GJ					9.61	11.09	11.78	12.40	12.92	13.27		
Energy [R]evolution 2012													
United States	GJ					3.84	7.03	8.97	10.39	12.06	13.61	15.18	19.89
Europe	GJ					6.55	11.77	13.89	15.08	16.17	17.30	18.45	21.82
Japan LNG	GJ					9.61	13.42	15.79	17.07	18.31	19.55	20.79	24.64
OECD steam coal imports													
Historic prices (from WEO)	tonne	34.76	41.38	57.93	100.96	81.93							
WEO 2011 "450 ppm scenario"	tonne					81.93	82.76	76.96	68.69	61.24	56.27		
WEO 2011 Current policies	tonne					81.93	86.89	90.20	93.51	96.00	97.65		
Energy [R]evolution 2012	tonne						104.85	115.03	134.31	141.51	150.04	164.69	170.73
Biomass (solid)													
Energy [R]evolution 2012													
OECD Europe	GJ			6.21		6.46	6.88	7.71	8.04	8.38	8.51	8.63	8.81
OECD Asia Oceania & North America	GJ			2.76		2.85	2.94	3.19	3.39	3.61	3.77	3.94	4.36
Other regions	GJ			2.27		2.35	2.68	2.94	3.14	3.35	3.61	3.86	4.10

source IEA WEO 2009 & 2011 own assumptions and 2035-2050: DLR, Extrapolation (2012).

4.5 cost of CO_2 emissions

The costs 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, and a broad range of future estimates has been made in studies. Other projections have assumed higher CO_2 costs than than those included in this Energy [R]evolution study (57 $€_{2010}/tCO_2$)[30], reflecting estimates of the total external costs of CO_2 emissions. The CO_2 cost estimates in the 2010 version of the global Energy [R]evolution were rather conservative (42 $€_{2008}/t$). CO_2 costs are applied in Kyoto Protocol Non-Annex B countries only from 2030 on.

table 4.4: assumptions on CO_2 emissions cost development for Annex-B and Non-Annex-B countries of the UNFCCC.

($€_{2010}/tCO_2$)

COUNTRIES	2010	2015	2020	2030	2040	2050
Annex-B countries	0	11	19	30	42	57
Non-Annex-B countries	0	0	0	30	42	57

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

Further cost reduction potentials are assumed for fuel power technologies in use today for coal, gas, lignite and oil. Because they are at an advanced stage of market development the potential for cost reductions is limited, and will be achieved mainly through an increase in efficiency.[31]

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

CCS means 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 special report on CCS assesses costs at €12-62 per ton of captured CO_2[32], while a 2007 US Department of Energy report found installing carbon capture systems to most modern plants resulted in a near doubling of costs.[33] These costs are estimated to increase the price of electricity in a range from 21-91%.[34]

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.[35] 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.[36]

The Intergovernmental Panel on Climate Change (IPCC) estimates a cost range for pipelines of € 0.8 – 6.6/tonne 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 € 5 million. The same report estimates that a dedicated interstate pipeline network in North Carolina would cost upwards of € 4 billion due to the limited geological sequestration potential in that part of the country.[37] Storage and subsequent monitoring and verification costs are estimated by the IPCC to range from € 0.4-6.6/tCO_2 (for storage) and € 0.1-0.25/tCO_2. The overall cost of CCS could therefore be a major barrier to its deployment. [38]

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

Table 4.5 summarises our assumptions on the technical and economic parameters of future fossil-fuelled power plant technologies. Based on estimates from WEO 2010, we assume that further technical innovation will not prevent an increase of future investment costs because raw material costs and technical complexity will continue to increase. Also, improvements in power plant efficiency are outweighed by the expected increase in fossil fuel prices, which would increase electricity generation costs significantly.

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image SATELLITE IMAGE OF JAPAN'S DAI ICHI POWER PLANT SHOWING DAMAGE AFTER THE EARTHQUAKE AND TSUNAMI OF 2011.

table 4.5: development of efficiency and investment costs for selected new power plant technologies

POWER PLANT		2009	2015	2020	2030	2040	2050
Coal-fired condensing power plant	Max. efficiency (%)	45	46	48	50	52	53
	Investment costs (€2010/kW)	1,085	1,046	1,029	1,004	987	953
	CO_2 emissions a)(g/kWh)	744	728	697	670	644	632
Lignite-fired condensing power plant	Max. efficiency (%)	41	43	44	44.5	45	45
	Investment costs (€2010/kW)	1,278	1,219	1,192	1,167	1,141	1,116
	CO_2 emissions a)(g/kWh)	975	929	908	898	888	888
Natural gas combined cycle	Max. efficiency (%)	57	59	61	62	63	64
	Investment costs (€2010/kW)	587	569	556	530	503	477
	CO_2 emissions a)(g/kWh)	354	342	330	325	320	315

source
WEO 2010, DLR 2010 a) CO_2 emissions refer to power station outputs only; life-cycle emissions are not considered.

4.7 cost projections for renewable energy technologies

The different renewable energy technologies available today all have different technical maturity, costs and development potential. Whereas hydro power has been widely used for decades, other technologies, such as the gasification of biomass or ocean energy, 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 coordination with the grid network. But although in many cases renewable energy technologies are 'distributed' - their output being generated and delivered locally to the consumer – in the future we can also have large-scale applications like offshore wind parks, photovoltaic power plants or concentrating solar power stations.

It is possible to develop a wide spectrum of options to market maturity, using the individual advantages of the different technologies, and linking them with each other, and integrating them step by step into the existing supply structures. This approach will 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 environmental and social costs of conventional power production are not reflected in market prices. It is expected, however that large cost reductions can come from technical advances, manufacturing improvements and large-scale production, unlike conventional technologies. The dynamic trend of cost developments over time plays a crucial role in identifying economically sensible expansion strategies for scenarios spanning several decades.

To identify long-term cost developments, learning curves have been applied to the model calculations to reflect how the cost of a particular technology can change in relation to the cumulative production volumes. For many technologies, the learning factor (or progress ratio) is 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 Energy [R]evolution scenario are derived from a review of learning curve studies, for example by Lena Neij and others[39], from the analysis of recent technology foresight and road mapping studies, including the European Commission funded NEEDS project (New Energy Externalities Developments for Sustainability)[40] 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 different sectors of the renewable energy industry.

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[40] WWW.NEEDS-PROJECT.ORG.

4.7.1 photovoltaics (PV)

The worldwide photovoltaics (PV) market has been growing at over 40% per annum in recent years and the contribution is starting to make a significant contribution to electricity generation. Photovoltaics are important because of its decentralised / centralised character, its flexibility for use in an urban environment and huge potential for cost reduction. The PV industry has been increasingly exploiting this potential during the last few years, with installation prices more than halving in the last few years. Current development 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 costs reducing by 20% each time the installed capacity doubles, indicating a high rate of technical learning. Assuming a globally installed capacity of 1,500 GW by between 2030 and 2040 in the Energy [R]evolution scenario, and with an electricity output of 2,600 TWh/a, we can expect that generation costs of around 4-8 €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.

4.7.2 concentrating solar power (CSP)

Solar thermal 'concentrating' power stations (CSP) can only use direct sunlight and are therefore dependent on very sunny locations. Southern Europe has a technical potential for this technology which far exceeds local demand. The various solar thermal technologies have 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 10,000C°, which is then used to run a combined gas and steam turbine.

Thermal storage systems are a way for CSP electricity generators to reduce 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 5-8 €cents/kWh can be achieved. This presupposes rapid market introduction in the next few years.

table 4.6: photovoltaics (PV) cost assumptions

INCLUDING ADDITIONAL COSTS FOR GRID INTEGRATION OF UP TO 25% OF PV INVESTMENT

SCENARIO	2009	2015	2020	2030	2040	2050
E[R]						
Investment costs (€/kWp)	2,817	1,733	1,246	967	785	799
O & M costs €/(kW/a)	40	29	16	11	11	11

O & M = Operation and maintenance.

table 4.7: concentrating solar power (CSP) cost assumptions

INCLUDING COSTS FOR HEAT STORAGE AND ADDITIONAL SOLAR FIELDS

SCENARIO	2009	2015	2020	2030	2040	2050
E[R]						
Investment costs (€/kWp)	8,667	6,501	5,000	4,334	3,982	3,630
O & M costs €/(kW/a)	335	260	200	173	159	145

O & M = Operation and maintenance.

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

4.7.3 wind power

Within a short period of time, the dynamic development of wind power has resulted in the establishment of a flourishing global market. In Europe, favorable policy incentives were the early drivers for the global wind market. The boom in demand for wind power technology has nonetheless led to supply constraints. As a consequence, the cost of new systems has increased. The industry is continuously expanding production capacity, however, so it is already resolving the bottlenecks in the supply chain. Taking into account market development projections, learning curve analysis and industry expectations, we assume that investment costs for wind turbines will reduce by 25% for onshore and 50% for offshore installations up to 2050.

4.7.4 biomass

The crucial factor for the economics of using biomass for energy is the cost of the feedstock, which today ranges from a negative 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 has a wide range of applications, is still relatively expensive. In the long term it is expected that using wood gas both in micro CHP units (engines and fuel cells) and in gas-and-steam power plants will have the most favorable electricity production costs. 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 –although its climate benefit is disputed. 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 could 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.

table 4.8: wind power cost assumptions

INCLUDING ADDITIONAL COSTS FOR GRID INTEGRATION OF UP TO 25% OF INVESTMENT

SCENARIO	2009	2015	2020	2030	2040	2050
E[R]						
Wind turbine offshore						
Investment costs (€/kWp)	4,875	4,171	2,871	2,275	2,056	1,767
O & M costs €/(kW · a)	173	155	122	99	94	81
Wind turbine onshore						
Investment costs (€/kWp)	1,422	1,125	975	967	972	1,016
O & M costs €/(kW/a)	51	42	41	42	44	46

O & M = Operation and maintenance.

table 4.9: biomass cost assumptions

SCENARIO	2009	2015	2020	2030	2040	2050
E[R]						
Biomass power plant						
Investment costs (€/kWp)	2,653	2,329	2,199	2,124	2,037	1,994
O & M costs €/(kW · a)	160	140	132	127	123	120
Biomass CHP						
Investment costs (€/kWp)	4,500	3,815	3,337	2,914	2,686	2,551
O & M costs €/(kW/a)	315	268	234	204	189	179

O & M = Operation and maintenance.

4.7.5 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 widened potential sites. 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, could make it possible to produce geothermal electricity anywhere. Advanced heat and power cogeneration plants will also improve the economics of geothermal electricity.

A large part of the costs for a geothermal power plant come from deep underground drilling, so further development of innovative drilling technology is expected. Assuming a global average market growth for geothermal power capacity of 15% per year up to 2020, adjusting to 12% beyond 2030, the result would be a cost reduction potential of 7% by 2050:

- for conventional geothermal power, from 12 €cents/kWh to about 7 €cents/kWh;
- for EGS, despite the presently high figures (about 17 – 25 €cents/kWh), electricity production costs - depending on the payments for heat supply - are expected to come down to around 6 €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, can deliver of heating and cooling at any time anywhere, and can be used for thermal energy storage.

4.7.6 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 research and development, 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 20-80 €cents/kWh[41], and for initial tidal stream farms in the range of 11-22 €cents/kWh. Generation costs of 7-8 €cents/kWh are expected by 2030. 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 long 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.[42]

table 4.10: geothermal cost assumptions

SCENARIO	2009	2015	2020	2030	2040	2050
E[R]						
Geothermal power plant						
Investment costs (€/kWp)	11,159	9,318	7,042	4,821	4,007	3,446
O & M costs €/(kW/ a)	504	406	316	240	224	212

O & M = Operation and maintenance.

table 4.11: ocean energy cost assumptions

SCENARIO	2009	2015	2020	2030	2040	2050
E[R]						
Ocean energy power plant						
Investment costs (€/kWp)	5,466	3,489	2,492	1,733	1,439	1,281
O & M costs €/(kW/a)	219	140	100	69	58	51

O & M = Operation and maintenance.

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[42] WWW.NEEDS-PROJECT.ORG.

image ANDASOL 1 SOLAR POWER STATION IS EUROPE'S FIRST COMMERCIAL PARABOLIC TROUGH SOLAR POWER PLANT. IT WILL SUPPLY UP TO 200,000 PEOPLE WITH CLIMATE-FRIENDLY ELECTRICITY AND SAVE ABOUT 149,000 TONNES OF CARBON DIOXIDE PER YEAR COMPARED WITH A MODERN COAL POWER PLANT.

4.7.7 hydro power

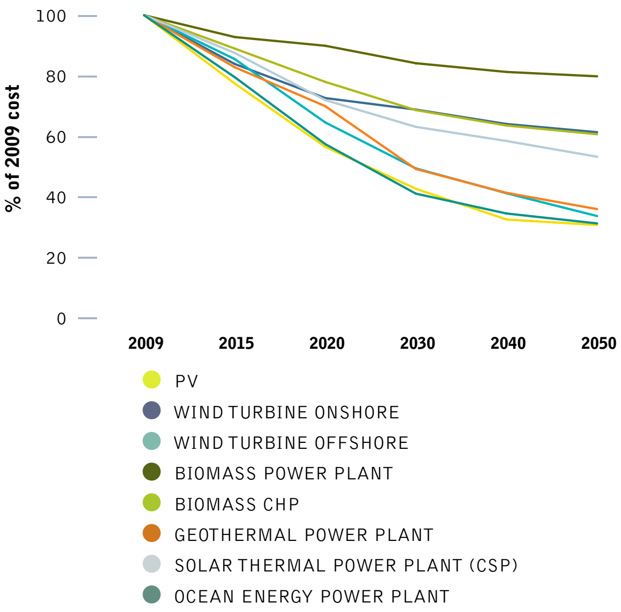
Hydropower is a mature technology with a significant part of its global resource already exploited. There is still, however, some potential left both for new schemes (especially small scale run-of-river projects with little or no reservoir impoundment) and for repowering of existing sites. There is likely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

table 4.12: hydro power cost assumptions

SCENARIO	2009	2015	2020	2030	2040	2050
E[R]						
Investment costs (€/kWp)	2,457	2,568	2,647	2,766	2,866	2,953
O & M costs €/(kW/a)	98	103	106	111	115	118

O & M = Operation and maintenance.

figure 4.1: future development of investment costs for renewable energy technologies (NORMALISED TO 2010 COST LEVELS)



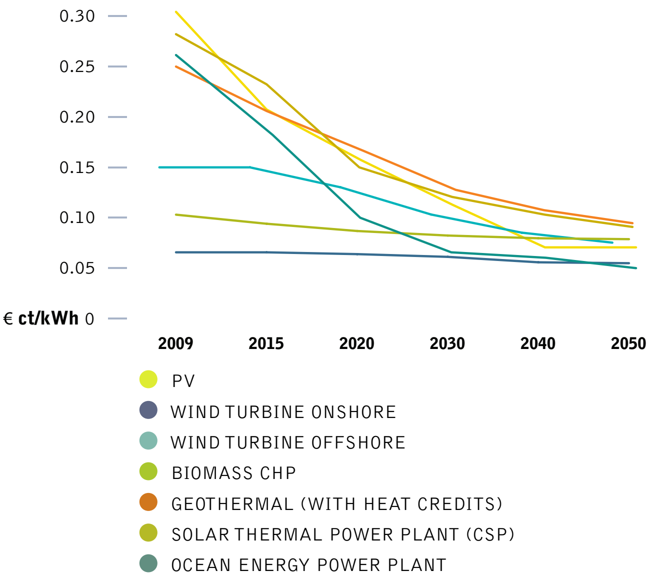
4.7.8 summary of renewable energy cost development

Figure 4.1 summarises the cost trends for renewable power technologies derived from the respective learning curves. It is important to note that the expected cost reduction is not a function of time, but of cumulative capacity (production of units), so dynamic market development is required. Most of the technologies will be able to reduce their specific investment costs to between 30% and 60% of current 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 4.2. Generation costs today are around 7 to 29 €cents/kWh for the most important technologies, including photovoltaic. In the long term, costs are expected to converge at around 5 to 10 €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 4.2: expected development of electricity generation costs from fossil fuel and renewable options

EXAMPLE FOR OECD EUROPE



4.8 cost projections for renewable heating technologies

Renewable heating has the longest tradition of all renewable technologies. EREC and DLR carried out a survey on costs of renewable heating technologies in Europe, which analyses installation costs of renewable heating technologies, ranging from direct solar collector systems to geothermal and ambient heat applications and biomass technologies. The report shows that some technologies are already mature and compete on the market – especially simple heating systems in the domestic sector. However, more sophisticated technologies, which can provide higher shares of heat demand from renewable sources, are still under development and rather expensive. Market barriers slow down the further implementation and cost reduction of renewable heating systems, especially for heating networks. Nevertheless, significant learning rates can be expected if renewable heating is increasingly implemented as projected in the Energy [R]evolution scenario.

4.8.1 solar thermal technologies

Solar collectors depend on direct solar irradiation, so the yield strongly depends on the location. In very sunny regions, simple thermosiphon systems can provide total hot water demand in households at around 400 €/m^2 installation costs. In parts of Europe with less sun, where additional space heating is needed, installation cost for pumped systems are twice as high. In these areas, economies of scales can decrease solar heating costs significantly. Large scale solar collector system are known from 250-600 €/m^2, depending on the share of solar energy in the whole heating system and the level of storage required.

4.8.2 deep geothermal applications

Deep geothermal heat from aquifers or reservoirs can be used directly in hydrothermal heating plants to supply heat demand close to the plant or in a district heating network for several different types of heat. Due to the high drilling costs deep geothermal energy is mostly feasible for large applications in combination with heat networks. It is already economic feasible and has been in use for a long time, where aquifers can be found near the surface. In Europe deep geothermal applications are being developed for heating purposes at investment costs from 500€/kWth (shallow) to 3000 €/kWth (deep), with the costs strongly dependent on the drilling depth.

4.8.3 heat pumps

Heat pumps typically provide hot water or space heat for heating systems with relatively low supply temperature or can serve as a supplement to other heating technologies. They have become increasingly popular for underfloor heating in buildings. Economies of scale are less important than for deep geothermal, so there is focus on small household applications with investment costs from 500-1,600 €/kW for ground water systems and higher costs from 1,200-3,000 €/kW for ground source or aerothermal systems.

4.8.4 biomass applications

There is broad portfolio of modern technologies for heat production from biomass, ranging from small scale single room stoves to heating or CHP-plants in MW scale. Investments costs show a similar variety: simple log wood stoves can be obtained from 100 €/kW, more sophisticated automated heating systems that cover the whole heat demand of a building are significantly more expensive. Log wood or pellet boilers range from 400-1200 €/kW, with large applications being cheaper than small systems.

Economy of scales apply to heating plants above 500kW, with investment cost between 400 and 700 €/kW. Heating plants can deliver process heat or provide whole neighbourhoods with heat. Even if heat networks demand additional investment, there is great potential to use solid biomass for heat generation in both small and large heating centers linked to local heating networks.

Heat from cogeneration (CHP) is another option with a broad range of technologies at hand. It is a very varied energy technology – applying to co-firing in large coal-fired cogeneration plants; biomass gasification combined with CHP or biogas from wet residues. But the costs for heat are often mainly dependent on the power production.

Main biomass input into renewable heating today is solid biomass – wood in various specifications from waste wood and residues to pellets from short rotation forestry. Biomass costs are as versatile: In Europe biomass costs ranged from 1-6 €/GJ for sawmill products, over 2-7 €/GJ for log wood to 6-18 €/GJ for wood pellets.[43]

Cost reductions expected vary strongly within each technology sector, depending on the maturity of a specific technology. E.g. Small wood stoves will not see significant cost reductions, while there is still learning potential for automated pellet heating systems. Cost for simple solar collectors for swimming pools might be already optimised, whereas integration in large systems is neither technological nor economical mature. Table 4.13 shows average development pathways for a variety of heat technology options.

table 4.13: overview over expected investment costs pathways for heating technologies (IN €2010/KWTH

	2015	2020	2030	2040	2050
Geothermal distict heating*	2,000	1,900	1,700	1,508	1,328
Heat pumps	1,500	1,455	1,369	1,288	1,212
Small solar collector systems	886	849	759	670	570
Large solar collector systems	714	684	612	540	460
Solar district heating*	814	814	814	814	814
Small biomass heating systems	700	679	639	601	566
Large biomass heating systems	500	485	456	429	404
Biomass district heating*	500	485	456	429	404

* WITHOUT NETWORK

references

[43] OLSON, O. ET AL. (2010): WP3-WOOD FUEL PRICE STATISTICS IN EUROPE - D.31. SOLUTIONS FOR BIOMASS FUEL MARKET BARRIERS AND RAW MATERIAL AVAILABILITY. EUBIONET3. UPPSALA, SWEDEN, SWEDISH UNIVERSITY OF AGRICULTURAL SCIENCES.

image A SATELLITE IMAGE OF EYJAFJALLAJOKULL VOLCANO ERUPTION, ICELAND, 2010.

4.9 assumptions for fossil fuel phase out

More than 80% of the current energy supply is based on fossil fuels. Oil dominates the entire transport sector; oil and gas make up the heating sector and coal is the most-used fuel for power. Each sector has different renewable energy and energy efficiency technologies combinations which depend on the locally available resources, infrastructure and to some extent, lifestyle. The renewable energy technology pathways use in this scenario are based on currently available "off-the-shelf" technologies, market situations and market projections developed from renewable industry associations such as the Global Wind Energy Council, the European Photovoltaic Industry Association and the European Renewable Energy Council, the DLR and Greenpeace International.

In line with this modeling, the Energy [R]evolution needs to map out a clear pathway to phase-out oil in the short term and gas in the mid to long term. This pathway has been identified on the basis of a detailed analysis of the global conventional oil resources, current infrastructure of those industries, the estimated production capacities of existing oil wells and the investment plans know by end 2011. Those remaining fossil fuel resources between 2012 and 2050 form the oil pathway, so no new deep sea and arctic oil exploration, no oil shale and tar sand mining for two reasons:

- First and foremost, to limit carbon emissions to save the climate.
- Second, financial resources must flow from 2012 onwards in the development of new and larger markets for renewable energy technologies and energy efficiency to avoid "locking-in" new fossil fuel infrastructure.

4.9.1 oil – production decline assumptions

Figure 4.3 shows the remaining production capacities with an annual production decline between 2.5% and 5% and the additional production capacities assuming all new projects planned for 2012 to 2020 will go ahead. Even with new projects, the amount of remaining conventional oil is very limited and therefore a transition towards a low oil demand pattern is essential.

4.9.2 coal – production decline assumptions

While there is an urgent need for a transition away from oil and gas to avoid "locking-in" investments in new production wells, the climate is the clearly limiting factor for the coal resource, not its availability. All existing coal mines – even without new expansions of mines – could produce more coal, but its burning puts the world on a catastrophic climate change pathway.

figure 4.3: global oil production 1950 to 2011 and projection till 2050

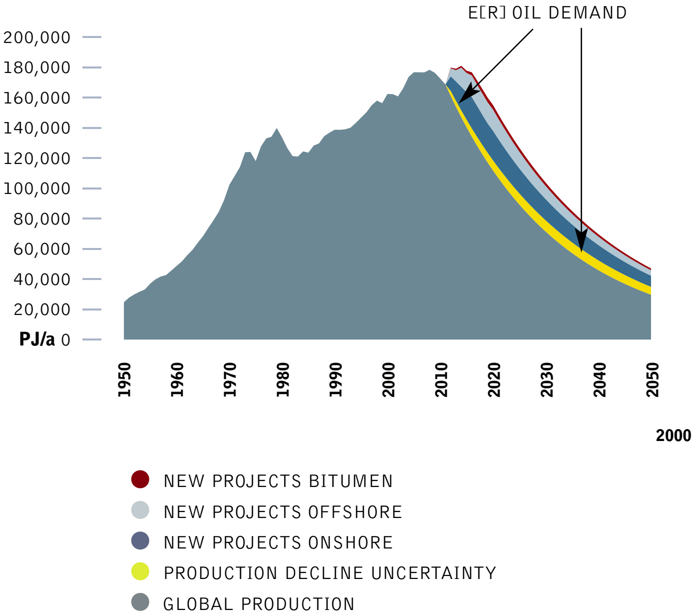
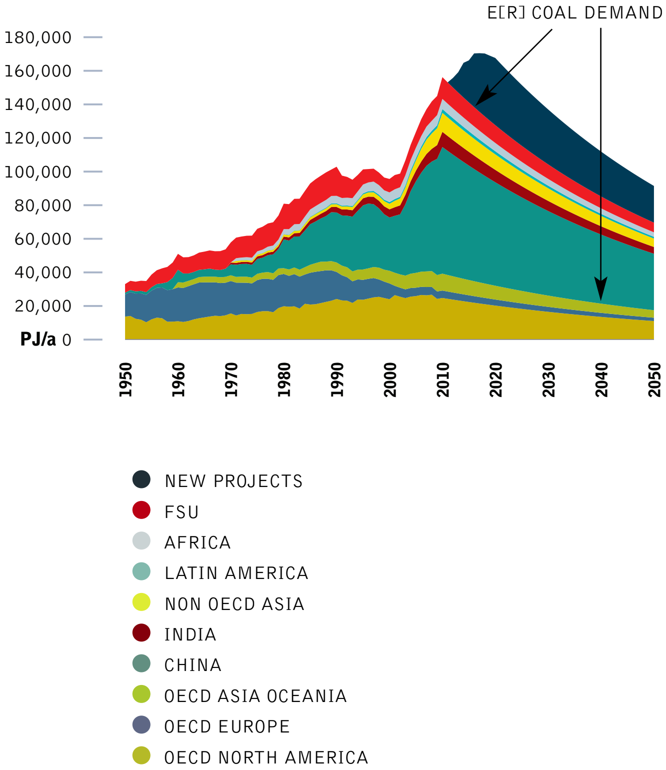


figure 4.4: coal scenario: base decline of 2% per year and new projects



4.10 review: greenpeace scenario projections of the past

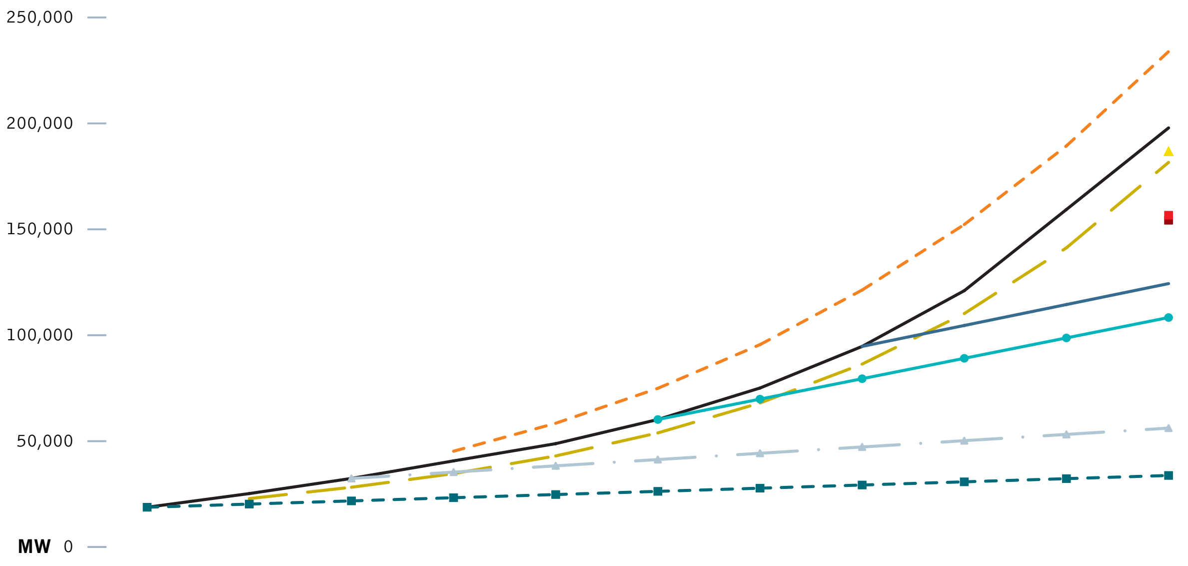
Greenpeace has published numerous projections in cooperation with renewable industry associations and scientific institutions in the past decade. This section provides an overview of the projections between 2000 and 2011 and compares them with real market developments and projections of the IEA World Energy Outlook – our Reference scenario.

4.10.1 the development of the global wind industry

Greenpeace and the European Wind Energy Association published "Windforce 10" for the first time in 1999– a global market projection for wind turbines until 2030. Since then, an updated prognosis has been published every second year. Since 2006 the report has been renamed to "Global Wind Energy Outlook" with a new partner – the Global Wind Energy Council (GWEC) – a new umbrella organisation of all regional wind industry associations. Figure 4.5 shows the projections made each year between 2000 and 2010 compared to the real market data. The graph also includes the first two Energy [R]evolution (ER) editions (published in 2007 and 2008) against the IEA's wind projections published in World Energy Outlook (WEO) 2000, 2002, 2005 and 2007.

The projections from the "Wind force 10" and "Windforce 12" were calculated by BTM consultants, Denmark. The "Windforce 10" (2001 - 2011) projection for the global wind market was actually 10% lower than the actual market development. All following editions where around 10% above or below the real market. In 2006, the new "Global Wind Energy Outlook" had two different scenarios, a moderate and an advanced wind power market projections calculated by GWEC and Greenpeace International. The figures here show only the advanced projections, as the moderate were too low. However, these very projections were the most criticised at the time, being called "over ambitious" or even "impossible".

figure 4.5: wind power: short term prognosis vs real market development - global cummulative capacity



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
REAL	17,400	23,900	31,100	39,431	47,620	59,091	74,052	93,820	120,291	158,864	197,637
WF 10 (1999)		21,510	26,901	33,371	41,781	52,715	66,929	85,407	109,428	140,656	181,252
WF 12 (2002)				44,025	57,306	73,908	94,660	120,600	151,728	189,081	233,905
GWEO 2006 (Advanced)											153,759
GWEO 2008 (Advanced)											186,309
ER 2007											156,149
ER 2008											163,855
ADVANCED ER 2010											
IEA WEO 2000 (REF)	17,400	18,910	20,420	21,930	23,440	24,950	26,460	27,970	29,480	30,990	32,500
IEA WEO 2002 (REF)			31,100	34,088	37,075	40,063	43,050	46,038	49,025	52,013	55,000
IEA WEO 2005 (REF)						59,091	68,781	78,471	88,161	97,851	107,541
IEA WEO 2007 (REF)								93,820	103,767	113,713	123,660

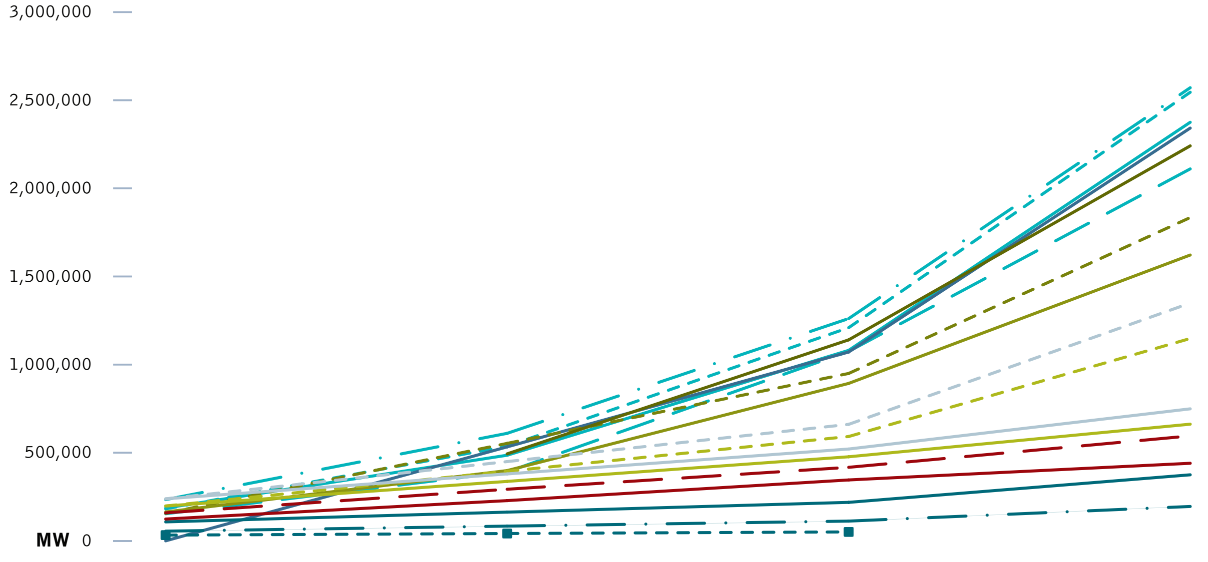
image A PRAWN SEED FARM ON MAINLAND INDIA'S SUNDARBANS COAST LIES FLOODED AFTER CYCLONE AILA. INUNDATING AND DESTROYING NEARBY ROADS AND HOUSES WITH SALT WATER.


© GP/PETER CATON

In contrast, the IEA "Current Policy" projections seriously under estimated the wind industry's ability to increase manufacturing capacity and reduce costs. In 2000, the IEA published projections of global installed capacity for wind turbines of 32,500 MW for 2010. This capacity had been connected to the grid by early 2003, only two-and-a-half years later. By 2010, the global wind capacity was close to 200,000 MW; around six times more than the IEA's assumption a decade earlier.

Only time will tell if the GPI/DLR/GWEC longer-term projections for the global wind industry will remain close to the real market. However the International Energy Agency's World Energy Outlook projections over the past decade have been constantly increased and keep coming close to our progressive growth rates.

figure 4.6: wind power: long term market projects until 2030



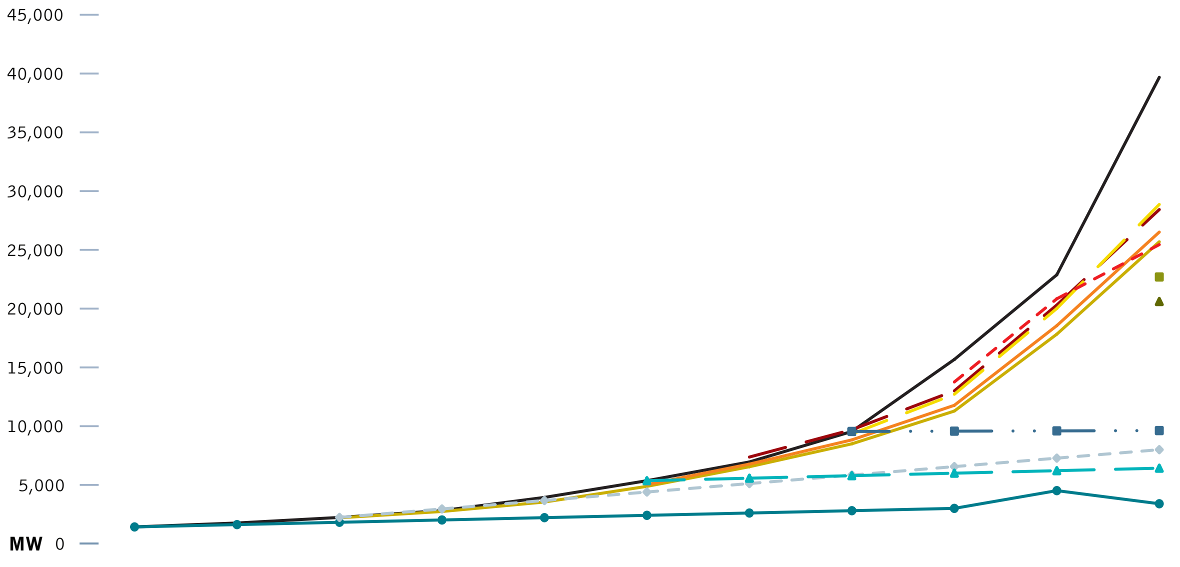
	2010	2015	2020	2030
WF 10 (1999)	181,252	537,059	1,209,466	2,545,232
WF 12 (2002)	233,905	610,000	1,261,157	2,571,000
GWEO 2006 (Advanced)	153,759	391,077	1,074,835	2,110,401
GWEO 2008 (Advanced)	186,309	485,834	1,080,886	2,375,000
GWEO 2008 (Advanced)	0	533,233	1,071,415	2,341,984
E[R] 2007	156,149	552,973	949,796	1,834,286
E[R] 2008	163,855	398,716	893,317	1,621,704
ADVANCED E[R] 2010		493,542	1,140,492	2,241,080
IEA WEO 2000 (REF)	32,500	41,550	50,600	
IEA WEO 2002 (REF)	55,000	83,500	112,000	195,000
IEA WEO 2005 (REF)	107,541	162,954	218,367	374,694
IEA WEO 2007 (REF)	123,660	228,205	345,521	440,117
IEA WEO 2009 (REF)	158,864	292,754	417,198	595,365
IEA WEO 2010 (REF)	197,637	337,319	477,000	662,000
IEA WEO 2010 (450ppm)	197,637	394,819	592,000	1,148,000
IEA WEO 2011 (REF)	238,351	379,676	521,000	749,000
IEA WEO 2011 (450ppm)	238,351	449,676	661,000	1,349,000

4.10.2 the development of the global solar photovoltaic industry

Inspired by the successful work with the European Wind Energy Association (EWEA), Greenpeace began working with the European Photovoltaic Industry Association to publish "Solar Generation 10" – a global market projection for solar photovoltaic technology up to 2020 for the first time in 2001. Since then, six editions have been published and EPIA and Greenpeace have continuously improved the calculation methodology with experts from both organisations.

Figure 4.7 shows the actual projections for each year between 2001 and 2010 compared to the real market data, against the first two Energy [R]evolution editions (published in 2007 and 2008) and the IEA's solar projections published in World Energy Outlook (WEO) 2000, 2002, 2005 and 2007. The IEA did not make specific projections for solar photovoltaic in the first editions analysed in the research, instead the category "Solar/Tidal/Other" are presented in Figure 4.7 and 4.8.

figure 4.7: **photovoltaics: short term prognosis vs real market development - global cummulative capacity**



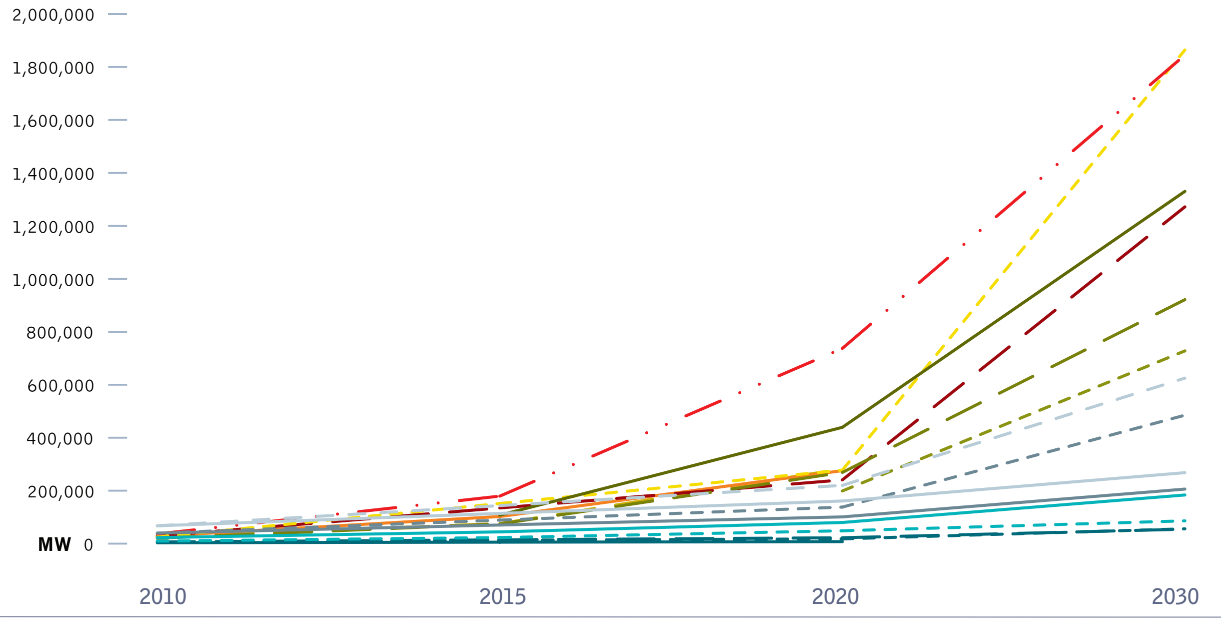
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
— REAL	1,428	1,762	2,236	2,818	3,939	5,361	6,956	9,550	15,675	22,878	39,678
— SG I 2001			2,205	2,742	3,546	4,879	6,549	8,498	11,285	17,825	25,688
— SG II 2004						5,026	6,772	8,833	11,775	18,552	26,512
- - - SG III 2006							7,372	9,698	13,005	20,305	28,428
- - - SG IV 2007 (Advanced)								9,337	12,714	20,014	28,862
- - - SG V 2008 (Advanced)									13,760	20,835	25,447
- - - SG VI 2010 (Advanced)											36,629
■ ER 2007											22,694
▲ ER 2008											20,606
● ADVANCED ER 2010											
—●— IEA WEO 2000 (REF)	1,428	1,625	1,822	2,020	2,217	2,414	2,611	2,808	3,006	4,516	3,400
- ◆ - IEA WEO 2002 (REF)			2,236	2,957	3,677	4,398	5,118	5,839	6,559	7,280	8,000
- ▲ - IEA WEO 2005 (REF)						5,361	5,574	5,787	6,000	6,213	6,425
·· ■ IEA WEO 2007 (REF)								9550	9,575	9,600	9,625

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.

In contrast to the wind projections, all the SolarGeneration projections have been too conservative. The total installed capacity in 2010 was close to 40,000 MW about 30% higher than projected in SolarGeneration published ten years earlier. Even SolarGeneration 5, published in 2008, under-estimated the possible market growth of photovoltaic in the advanced scenario. In contrast, the IEA WEO 2000 estimations for 2010 were reached in 2004.

The long-term projections for solar photovoltaic are more difficult than for wind because the costs have dropped significantly faster than projected. For some OECD countries, solar has reached grid parity with fossil fuels in 2012 and other solar technologies, such as concentrated solar power plants (CSP), are also headed in that direction. Therefore, future projections for solar photovoltaic do not just depend on cost improvements, but also on available storage technologies. Grid integration can actually be a bottle-neck to solar that is now expected much earlier than estimated.

figure 4.8: photovoltaic: long term market projects until 2030



	2010	2015	2020	2030
SG I 2001	25,688		207,000	
SG II 2004	26,512	75,600	282,350	
SG III 2006	28,428	102,400	275,700	
SG IV 2007 (Advanced)	28,862	134,752	240,641	1,271,773
SG V 2008 (Advanced)	25,447	151,486	277,524	1,864,219
SG VI 2010 (Advanced)	36,629	179,442	737,173	1,844,937
ER 2007	22,694		198,897	727,816
ER 2008	20,606	74,325	268,789	921,332
ADVANCED ER 2010		107,640	439,269	1,330,243
IEA WEO 2000 (REF)	3,400	5,500	7,600	
IEA WEO 2002 (REF)	8,000	13,000	18,000	56,000
IEA WEO 2005 (REF)	6,425	14,356	22,286	54,625
IEA WEO 2007 (REF)	9,625	22,946	48,547	86,055
IEA WEO 2009 (REF)	22,878	44,452	79,878	183,723
IEA WEO 2010 (REF)	39,678	70,339	101,000	206,000
IEA WEO 2010 (450ppm)	39,678	88,839	138,000	485,000
IEA WEO 2011 (REF)	67,300	114,150	161,000	268,000
IEA WEO 2011 (450ppm)	67,300	143,650	220,000	625,000

4.11 how does the energy [r]evolution scenario compare to other scenarios?

The International Panel on Climate Change (IPCC) published a ground-breaking new "Special Report on Renewables" (SRREN) in May 2011. This report showed the latest and most comprehensive analysis of scientific reports on all renewable energy resources and global scientifically accepted energy scenarios. The Energy [R]evolution was among three scenarios chosen as an indicative scenario for an ambitious renewable energy pathway. The following summarises the IPCC's view.

Four future pathways, the following models were assessed intensively:

- International Energy Agency World Energy Outlook 2009, (IEA WEO 2009)
- Greenpeace Energy [R]evolution 2010, (ER 2010)
- ReMIND-RECIPE
- MiniCam EMF 22

The World Energy Outlook of the International Energy Agency was used as an example baseline scenario (least amount of development of renewable energy) and the other three treated as "mitigation scenarios", to address climate change risks. The four scenarios provide substantial additional information on a number of technical details, represent a range of underlying assumptions and follow different methodologies. They provide different renewable energy deployment paths, including Greenpeace's "optimistic application path for renewable energy assuming that . . . the current high dynamic (increase rates) in the sector can be maintained".

The IPCC notes that scenario results are determined partly by assumptions, but also might depend on the underlying modelling architecture and model specific restrictions. The scenarios analysed use different modelling architectures, demand projections and technology portfolios for the supply side. The full results are provided in Table 4.14, but in summary:

- The IEA baseline has a high demand projection with low renewable energy development.
- ReMind-RECIPE, MiniCam EMF 22 scenarios portrays a high demand expectation and significant increase of renewable energy is combined with the possibility to employ CCS and nuclear.
- The ER 2010 relies on and low demand (due to a significant increase of energy efficiency) combined with high renewable energy deployment, no CCS employment and a global nuclear phase-out by 2045.

Both population increase and GDP development are major driving forces on future energy demand and therefore at least indirectly determining the resulting shares of renewable energy. The IPCC analysis shows which models use assumptions based on outside inputs and what results are generated from within the models. All scenarios take a 50% increase of the global population into account on baseline 2009. Regards gross domestic product (GDP), all assume or calculate a significant increase in terms of the GDP. The IEA WEO 2009 and the ER 2010 model uses forecasts of International Monetary Fund (IMF 2009) and the Organisation of Economic Co-Operation and Development (OECD) as inputs to project GSP. The other two scenarios calculate GDP from within their model.

table 4.14: overview of key parameter of the illustrative scenarios based on assumptions that are exogenous to the models respective endogenous model results

CATEGORY		STATUS QUO	BASELINE		CAT III+IV (>450-660PPM)		CAT I+II (<440 PPM)		CAT I+II (<440 PPM)	
SCENARIO NAME			IEA WEO 2009		ReMind		MiniCam		ER 2010	
MODEL					ReMind		EMF 22		MESAP/PlaNet	
	UNIT	2007	2030	2050(1)	2030	2050	2030	2050	2030	2050
Technology pathway										
Renewables			al	all	generec solar	generec solar	generec solar - no ocean energy	>no ocean energy	all	all
CCS			+	+	+	+	+	+	-	-
Nuclear			+	+	+	+	+	+	+	-
Population	billion	6.67	8.31	8.31	8.32	9.19	8.07	8.82	8.31	9.15
GDP/capita	k$\$_{2005}$/capita	10.9	17.4	17.4	12.4	18.2	9.7	13.9	17.4	24.3
Input/Indogenous model results										
Energy demand (direct equivalent)	EJ/yr	469	674	674	590	674	608	690	501	466
Energy intensity	MJ/$\$_{2005}$	6.5	4.5	4.5	5.7	4.0	7.8	5.6	3.3	1.8
Renewable energy	%	13	14	14	32	48	24	31	39	77
Fossil & industrial CO_2 emissions	Gt CO_2/y	27.4	38.5	38.5	26.6	15.8	29.9	12.4	18.4	3.3
Carbon intensity	kg CO_2/GJ	58.4	57.1	57.1	45.0	23.5	49.2	18.0	36.7	7.1

source
DLR/IEA 2010: IEA World Energy Outlook 2009 does not cover the years 2031 till 2050. As the IEA's projection only covers a time horizon up to 2030 for this scenario exercise, an extrapolation of the scenario has been used which was provided by the German Aerospace Agency (DLR) by extrapolating the key macroeconomic and energy indicators of the WEO 2009 forward to 2050 (Publication filed in June 2010 to Energy Policy).

key results of the EU 27 energy [r]evolution scenario

ENERGY DEMAND BY SECTOR

ELECTRICITY GENERATION

FUTURE COSTS OF ELECTRICITY GENERATION

FUTURE INVESTMENTS IN THE POWER SECTOR

HEATING SUPPLY

FUTURE INVESTMENTS IN THE HEAT SECTOR

FUTURE EMPLOYMENT IN THE ENERGY SECTOR

TRANSPORT

DEVELOPMENT OF CO_2 EMISSIONS

PRIMARY ENERGY CONSUMPTION

5

> “renewable energy should become the central pillar of our future energy supply”
>
> **ANGELA MERKEL**
> CHANCELLOR
> OF GERMANY

© NASA/JESSE ALLEN

image SPRING RUN-OFF FILLS THE RIVERS OF CENTRAL EUROPE. MELTING SNOW HAS SWOLLEN THE DANUBE RIVER AND ITS TRIBUTARIES. HEAVY SNOWS BLANKETED THIS REGION FOR MUCH OF THE WINTER. AS WINTER DREW TO A CLOSE IN FEBRUARY AND MARCH, PRECIPITATION TOTALS SOARED ABOVE AVERAGE AND ABOVE THE PREVIOUS YEAR’S TOTALS, WHICH WERE ALSO SLIGHTLY ABOVE AVERAGE.

5.1 energy demand by sector

The future development pathways for Europe's energy demand are shown in Figure 5.1 for the Reference and the Energy [R]evolution scenario. Under the Reference scenario, total primary energy demand in EU 27 (the 27 countries in the European Union economic region) increases by 5% from the current 69,700 PJ/a to around 73,400 PJ/a in 2050 (including net electricity imports). The energy demand in 2050 in the Energy [R]evolution scenario decreases by 35% compared to current consumption and it is expected by 2050 to reach 45,500 PJ/a.

Under the Energy [R]evolution scenario, electricity demand in the industry as well as in the residential and service sectors is expected to decrease after 2015 (see Figure 5.2). Because of the growing shares of electric vehicles, heat pumps and hydrogen generation however, electricity demand increases to 3,296 TWh/a in 2050, still 16% below the Reference case.

Efficiency gains in the heat supply sector are larger than in the electricity sector. Under the Energy [R]evolution scenario, final demand for heat supply can even be reduced significantly (see Figure 5.4). Compared to the Reference scenario, consumption equivalent to 8,710 PJ/a is avoided through efficiency measures by 2050. As a result of energy-related renovation of the existing stock of residential buildings, as well as the introduction of low energy standards and 'passive houses' for new buildings, enjoyment of the same comfort and energy services will be accompanied by a much lower future energy demand.

figure 5.1: total final energy demand by sector under the reference scenario and the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

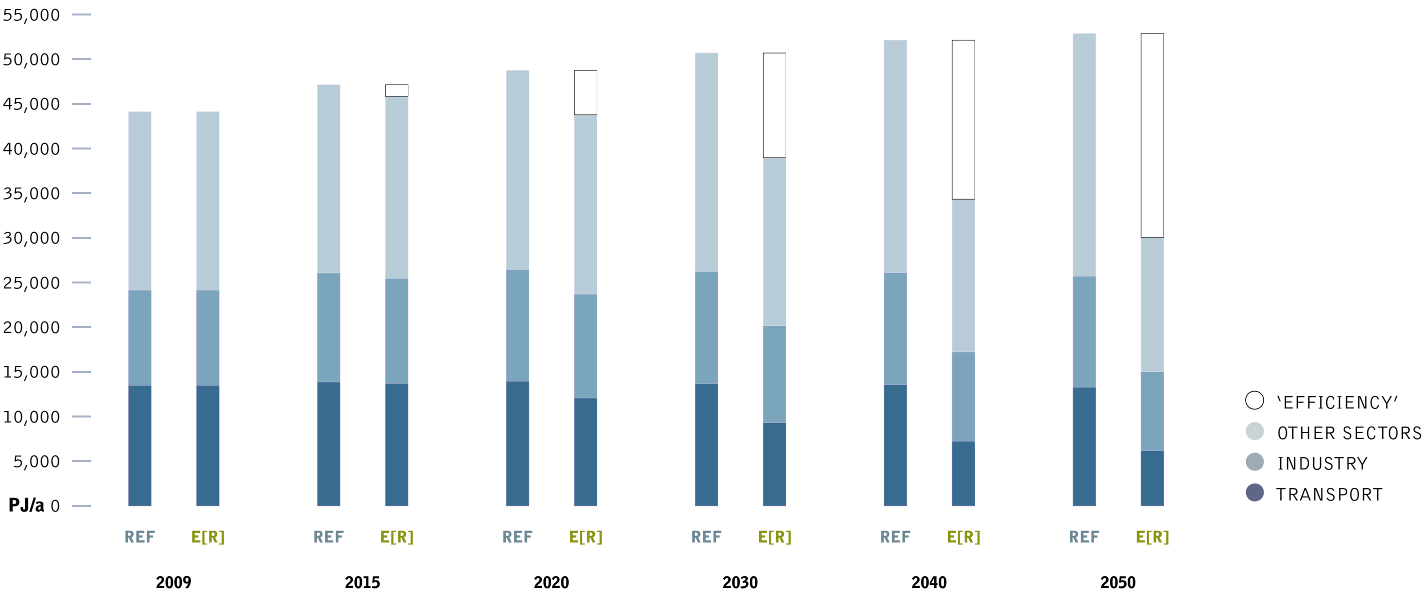


image PLANT NEAR REYKJAVIK WHERE ENERGY IS PRODUCED FROM THE GEOTHERMAL ACTIVITY.

image WORKERS EXAMINE PARABOLIC TROUGH COLLECTORS IN THE PS10 SOLAR TOWER PLANT AT SAN LUCAR LA MAYOR OUTSIDE SEVILLE, SPAIN, 2008.

figure 5.2: development of electricity demand by sector in the energy [r]evolution scenario

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

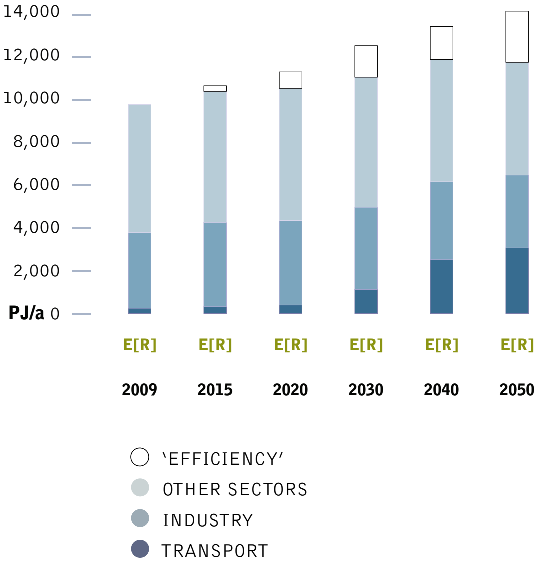


figure 5.4: development of heat demand by sector in the energy [r]evolution scenario

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

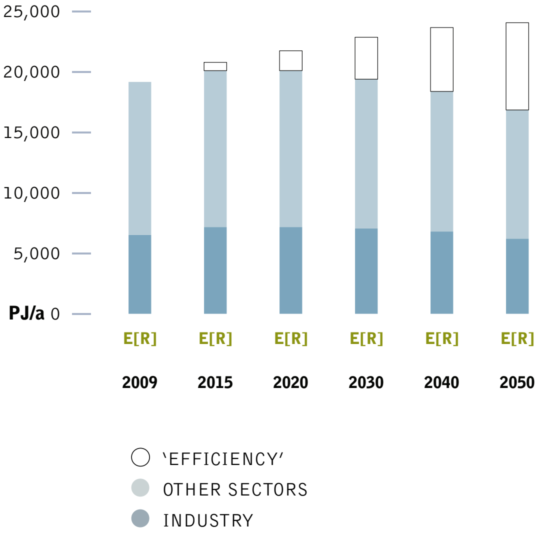
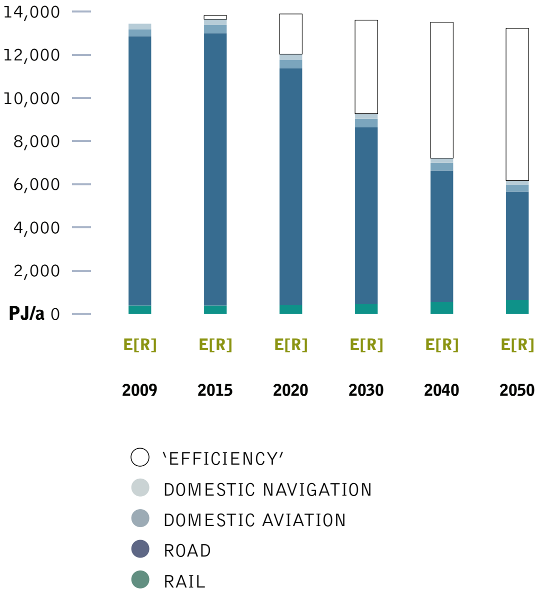


figure 5.3: development of the transport demand by sector in the energy [r]evolution scenario



5.2 electricity generation

The development of the electricity supply market under the Energy [R]evolution scenario is characterised by a dynamically growing renewable energy market. This 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, 96% of the electricity produced in EU 27 will come from renewable energy sources. 'New' renewables – mainly wind, solar thermal energy and PV – will contribute 75% of electricity generation. The Energy [R]evolution scenario projects an immediate market development with high annual growth rates achieving a renewable electricity share of 44% already by 2020 and 67% by 2030. The installed capacity of renewables will reach 989 GW in 2030 and 1,480 GW by 2050.

Table 5.1 shows the comparative evolution of the different renewable technologies in EU 27 over time. Up to 2020 hydro and wind will remain the main contributors of the growing market share. After 2020, the continuing growth of wind will be complemented by electricity from biomass, photovoltaics and solar thermal (CSP) energy. The Energy [R]evolution scenario will lead to a high share of fluctuating power generation sources (photovoltaic, wind and ocean) of 40% by 2030, therefore the expansion of smart grids, demand side management (DSM) and storage capacity e.g. from the increased share of electric vehicles will be used for a better grid integration and power generation management.

table 5.1: renewable electricity generation capacity under the reference scenario and the energy [r]evolution scenario

IN GW

		2009	2020	2030	2040	2050
Hydro	REF	146	155	161	164	168
	E[R]	146	151	155	161	165
Biomass	REF	20	29	36	42	47
	E[R]	20	35	47	57	72
Wind	REF	75	189	243	275	298
	E[R]	75	246	368	458	492
Geothermal	REF	1	2	2	3	4
	E[R]	1	6	25	45	56
PV	REF	14	77	110	137	163
	E[R]	14	213	345	498	570
CSP	REF	0	2	4	5	6
	E[R]	0	11	31	62	81
Ocean energy	REF	0	0	2	11	16
	E[R]	0	3	18	36	44
Total	**REF**	**256**	**455**	**558**	**636**	**702**
	E[R]	**256**	**666**	**989**	**1,316**	**1,480**

figure 5.5: electricity generation structure under the reference scenario and the energy [r]evolution scenario

(INCLUDING ELECTRICITY FOR ELECTROMOBILITY, HEAT PUMPS AND HYDROGEN GENERATION)

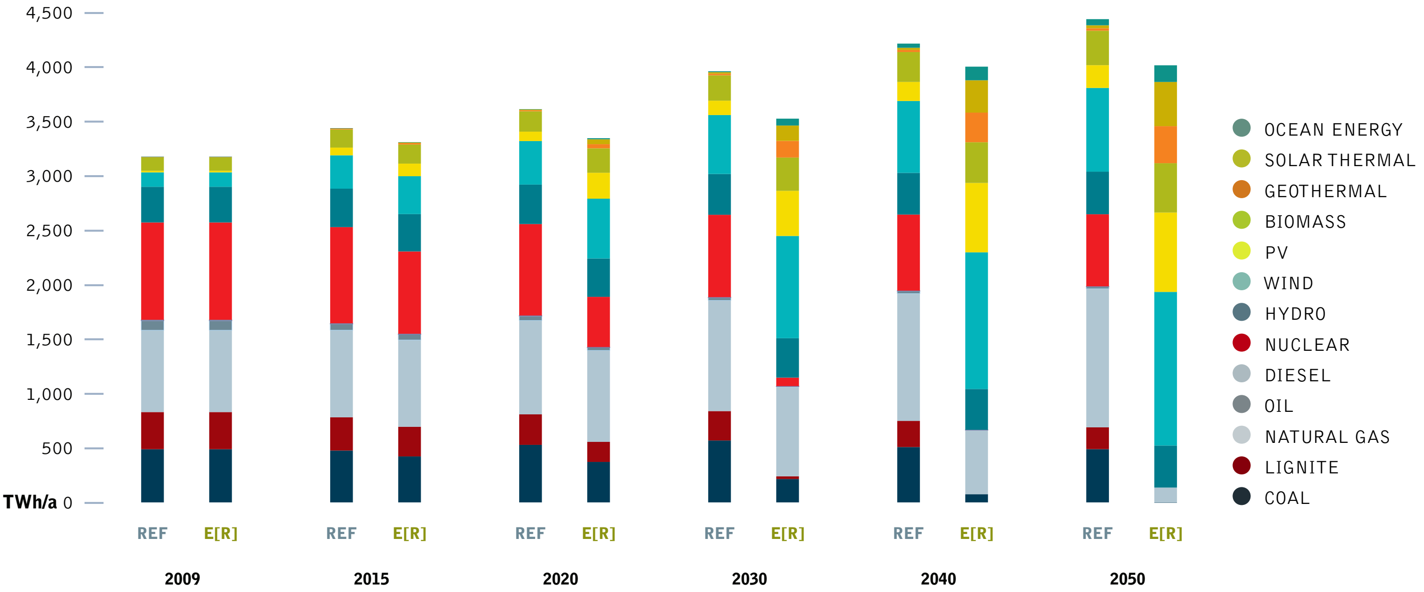


image OFFSHORE WINDFARM, MIDDELGRUNDEN, COPENHAGEN, DENMARK.

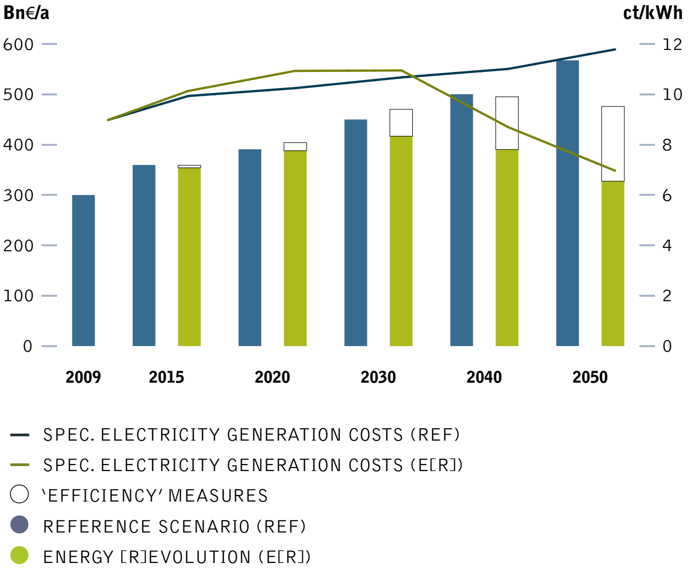
image MAN USING METAL GRINDER ON PART OF A WIND TURBINE MAST IN THE VESTAS FACTORY, CAMBELTOWN, SCOTLAND, GREAT BRITAIN.

5.3 future costs of electricity generation

Figure 5.6 shows that the introduction of renewable technologies under the Energy [R]evolution scenario slightly increases the costs of electricity generation in EU 27 compared to the Reference scenario. This difference will be less than 0.7 €cents/kWh up to 2020, however. Because of the lower CO_2 intensity of electricity generation, electricity generation costs will become favourable under the Energy [R]evolution scenario and by 2050 costs will be 4.8 €cents/kWh below those in the Reference version.

Under the Reference scenario, the 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 €300 billion per year to more than €568 billion in 2050. Figure 5.6 shows that the Energy [R]evolution scenario not only complies with EU 27´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 16% lower than in the Reference scenario, although costs for efficiency measures of up to 3 cents/kWh are taken into account.

figure 5.6: total electricity supply costs and specific electricity generation costs under two scenarios



5.4 future investments in the power sector

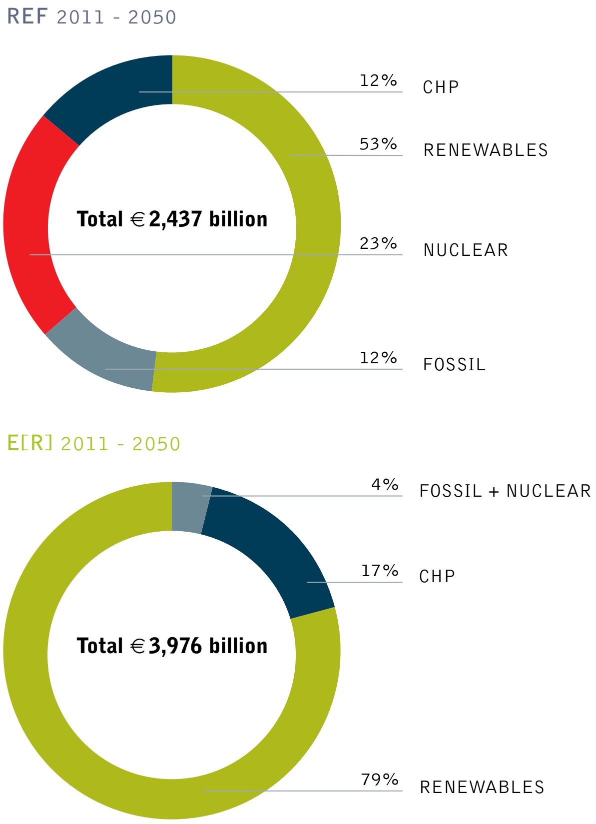
It would require about €4,000 billion in investment for the Energy [R]evolution scenario to become reality (including investments for replacement after the economic lifetime of the plants) - approximately €1,540 billion or €38 billion annually more than in the Reference scenario (€2,437 billion). Under the

Under the Reference scenario, the levels of investment in conventional power plants add up to almost 35% while approximately 65% would be invested in renewable energy and cogeneration (CHP) until 2050.

Under the Energy [R]evolution scenario, however, the EU 27 countries would shift almost 96% of their entire energy investment towards renewables and cogeneration. Until 2030, the fossil fuel share of power sector investment would be focused mainly on CHP plants. The average annual investment in the power sector under the Energy [R]evolution scenario between today and 2050 would be approximately €99 billion.

Because renewable energy has no fuel costs, the fuel cost savings in the Energy [R]evolution scenario reach a total of €3,010 billion up to 2050, or €75 billion per year. The total fuel cost savings based, on the assumed energy price path, would therefore cover the total additional investments compared to the Reference scenario twice over. 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.

figure 5.7: investment shares - reference scenario versus energy [r]evolution scenario



5.5 heating supply

Renewables currently provide 14% of EU 27's energy demand for heat supply, the main contribution coming from the use of biomass. The lack of district heating networks is a severe structural barrier to the large scale utilisation of geothermal and solar thermal energy. In the Energy [R]evolution scenario, renewables provide 43% of EU 27's total heat demand in 2030 and 91% in 2050.

- Energy efficiency measures can decrease the current total demand for heat supply by at least 20%, in spite of growing population and economic activities and improving living standards.
- For direct heating, solar collectors, biomass/biogas as well as geothermal energy are increasingly substituting for fossil fuel-fired systems.
- The introduction of strict efficiency measures e.g. via strict building standards and ambitious support programs for renewable heating systems are needed to achieve economies of scale within the next five to ten years.

Table 5.2 shows the development of the different renewable technologies for heating in EU 27 over time. Up to 2020, biomass will remain the main contributor of the growing market share. After 2020, the continuing growth of solar collectors and a growing share of geothermal heat pumps will reduce the dependence on fossil fuels.

table 5.2: renewable heating capacities under the reference scenario and the energy [r]evolution scenario

IN GW

		2009	2020	2030	2040	2050
Biomass	REF	2,630	3,288	3,917	4,468	4,931
	E[R]	2,630	3,301	3,197	3,034	2,898
Solar collectors	REF	52	101	189	323	448
	E[R]	52	833	2,605	4,246	5,389
Geothermal	REF	61	122	180	197	225
	E[R]	61	979	2,654	4,486	5,669
Hydrogen	REF	0	0	0	0	0
	E[R]	0	0	2	80	490
Total	**REF**	**2,744**	**3,511**	**4,285**	**4,987**	**5,604**
	E[R]	**2,744**	**5,113**	**8,458**	**11,847**	**14,445**

figure 5.8: heat supply structure under the reference scenario and the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

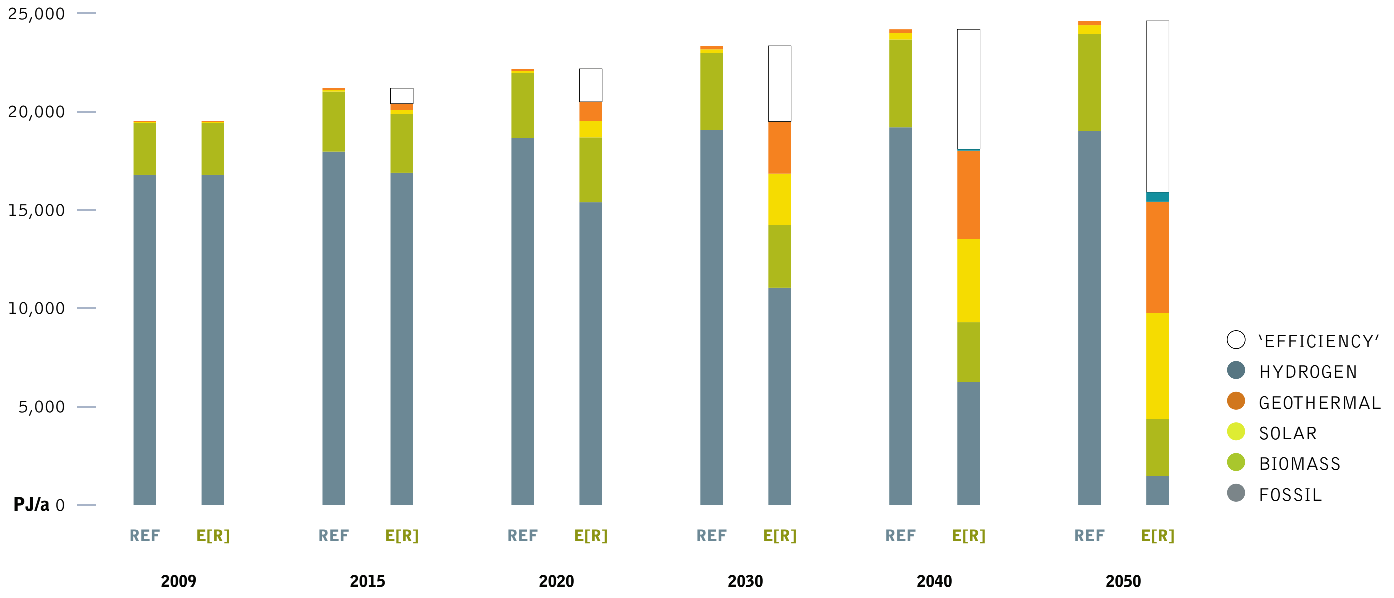


image INSTALLATION AND TESTING OF A WINDPOWER STATION IN RYSUMER NACKEN NEAR EMDEN WHICH IS MADE FOR OFFSHORE USAGE ONSHORE. A WORKER CONTROLS THE SECURITY LIGHTS AT DARK.

image THE MARANCHON WIND FARM IS ONE OF THE LARGEST IN EUROPE WITH 104 GENERATORS, AND IS OPERATED BY IBERDROLA.

5.6 future investments in the heat sector

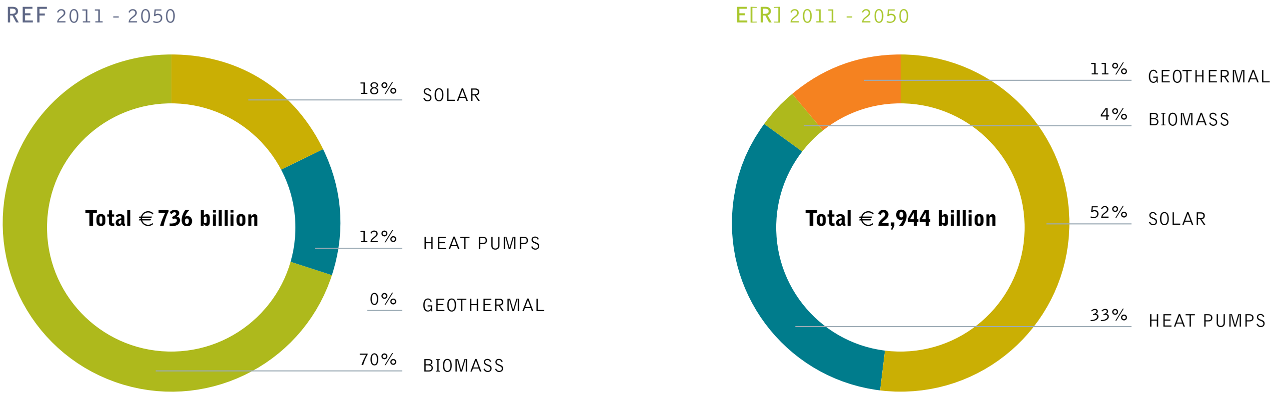
Also in the heat sector the Energy [R]evolution scenario would require a major revision of current investment strategies in heating technologies. Especially the less common solar, geothermal and heat pump technologies need enormous increase in installations, if these potentials are to be tapped for the heat sector. Installed capacity need to be increased by a factor of 90 for solar thermal and even by a factor of 230 for geothermal and heat pumps. Capcities of biomass technologies, which are already rather wide spread still need to remain a pillar of heat supply.

Renewable heating technologies vary greatly, from low tech biomass stoves and unglazed solar collectors to very sophisticated enhanced geothermal systems and solar thermal district heating plants with seasonal storage.Thus, it can only roughly be calculated that the Energy [R]evolution scenario requires approximately €2,944 billion to be invested in renewable heating technologies until 2050, including investments for replacement after the economic lifetime of the plants - approximately €74 billion per year. Due to a lack of regional information on costs for conventional heating systems and fuel prices, total investments and fuel cost savings for the heat supply in the scenarios have not been estimated.

table 5.3: renewable heat generation capacities under the reference scenario and the energy [r]evolution scenario IN GW

		2009	2020	2030	2040	2050
Biomass	REF	386	481	574	651	708
	E[R]	386	438	388	325	271
Geothermal	REF	1	1	1	1	0
	E[R]	1	24	88	135	187
Solar thermal	REF	17	33	62	105	146
	E[R]	17	244	761	1,190	1,475
Heat pumps	REF	11	22	33	36	41
	E[R]	11	122	263	397	483
Total	**REF**	**415**	**537**	**669**	**793**	**896**
	E[R]	**415**	**828**	**1,499**	**2,046**	**2,416**

figure 5.9: investments for renewable heat generation technologies under the reference scenario and the energy [r]evolution scenario


REF 2011 - 2050

E[R] 2011 - 2050

5.8 transport

In the transport sector, it is assumed under the Energy [R]evolution scenario energy demand reduction of about 7,100 PJ/a can be achieved by 2050, saving 53% compared to the Reference scenario. Energy demand will therefore decrease between 2009 and 2050 by 54% to 6,200 PJ/a. 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. By implementing a mix of increased public transport as attractive alternatives to individual cars, the car stock grows more slowly and annual person kilometres are lower 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 lead to significant energy savings. In 2030, electricity will provide 12% of the transport sector's total energy demand in the Energy [R]evolution, while in 2050 the share will be 50%.

table 5.4: **transport energy demand by mode under the reference scenario and the energy [r]evolution scenario**

(WITHOUT ENERGY FOR PIPELINE TRANSPORT) IN PJ/A

		2009	2020	2030	2040	2050
Rail	REF	384	391	396	407	412
	E[R]	384	405	448	545	628
Road	REF	12,473	12,804	12,408	12,241	11,910
	E[R]	12,473	10,965	8,190	6,090	5,034
Domestic aviation	REF	324	426	519	582	629
	E[R]	324	405	400	361	324
Domestic navigation	REF	259	272	280	278	272
	E[R]	259	254	233	211	188
Total	**REF**	**13,440**	**13,892**	**13,603**	**13,509**	**13,223**
	E[R]	**13,440**	**12,029**	**9,271**	**7,207**	**6,174**

figure 5.10: **final energy consumption for transport under the reference scenario and the energy [r]evolution scenario**

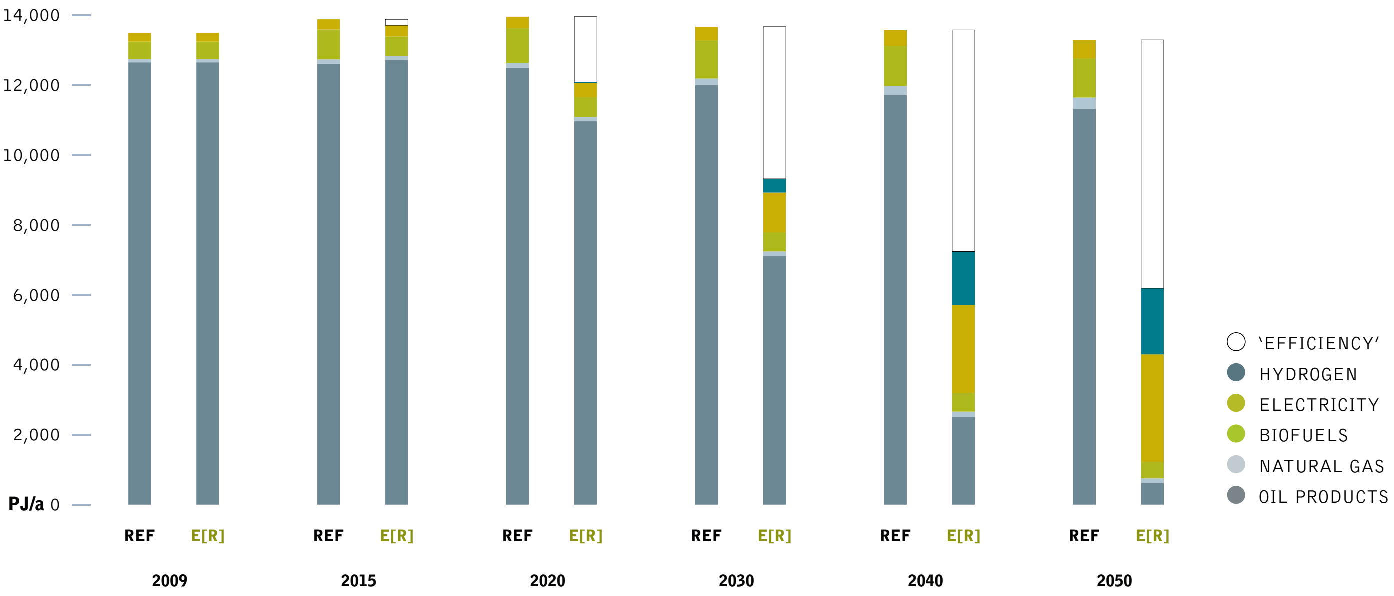


image THE PIONEERING REYKJANES GEOTHERMAL POWER PLANT USES STEAM AND BRINE FROM A RESERVOIR AT 290 TO 320°C, WHICH IS EXTRACTED FROM 12 WELLS THAT ARE 2,700 METERS DEEP. THIS IS THE FIRST TIME THAT GEOTHERMAL STEAM OF SUCH HIGH TEMPERATURE HAS BEEN USED FOR ELECTRICAL GENERATION. THE REYKJANES GEOTHERMAL POWER PLANT GENERATES 100 MWE FROM TWO 50 MWE TURBINES, WITH AN EXPANSION PLAN TO INCREASE THIS BY AN ADDITIONAL 50 MWE BY THE END OF 2010.

image RENEWABLE ENERGY FACILITIES ON A FORMER US-BASE IN MORBACH, GERMANY. MIXTURE OF WIND, BIOMASS AND SOLAR POWER RUN BY THE JUWI GROUP.


© STEVE MORGAN/GP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5.9 development of CO_2 emissions

While CO_2 emissions in EU 27 will decrease by 10% in the Reference scenario, under the Energy [R]evolution scenario they will decrease from around 3,500 million tonnes in 2009 to 197 million tonnes in 2050. Annual per capita emissions will drop from 7.1 tonnes to 3.5 tonnes in 2030 and 0.4 tonnes in 2050. Despite the phasing out of nuclear energy and increasing demand, CO_2 emissions will decrease in the electricity sector. In the long run efficiency gains and the increased use of renewable electricity in vehicles will reduce emissions in the transport sector. With a share of 17% of CO_2 emissions in 2050, the power sector will drop below transport and other sectors as the largest sources of emissions. By 2050, EU 27's CO_2 emissions are 5% of 1990 levels.

5.10 primary energy consumption

Taking into account the assumptions discussed above, the resulting primary energy consumption under the Energy [R]evolution scenario is shown in Figure 5.12. Compared to the Reference scenario, overall primary energy demand will be reduced by 40% in 2050. Around 85% of the remaining demand will be covered by renewable energy sources.

The Energy [R]evolution scenario phases out coal and oil about 10 to 15 years faster than the previous Energy [R]evolution scenario published in 2010. This is made possible mainly by the replacement of coal power plants with renewables and a faster introduction of very efficient electric vehicles in the transport sector to replace oil combustion engines. This leads to an overall renewable primary energy share of 43% in 2030 and 85% in 2050. Nuclear energy is phased out just after 2030.

figure 5.12: development of CO_2 emissions by sector under the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

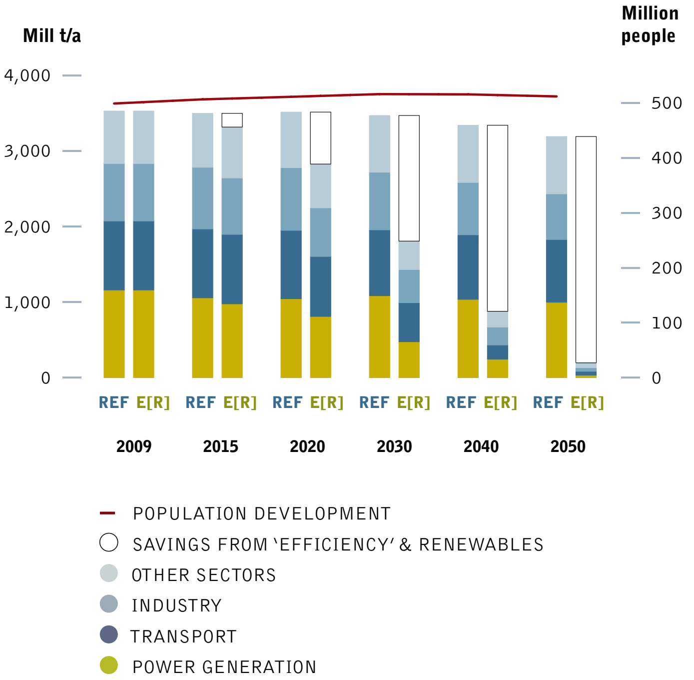

figure 5.11: primary energy consumption under the reference scenario and the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

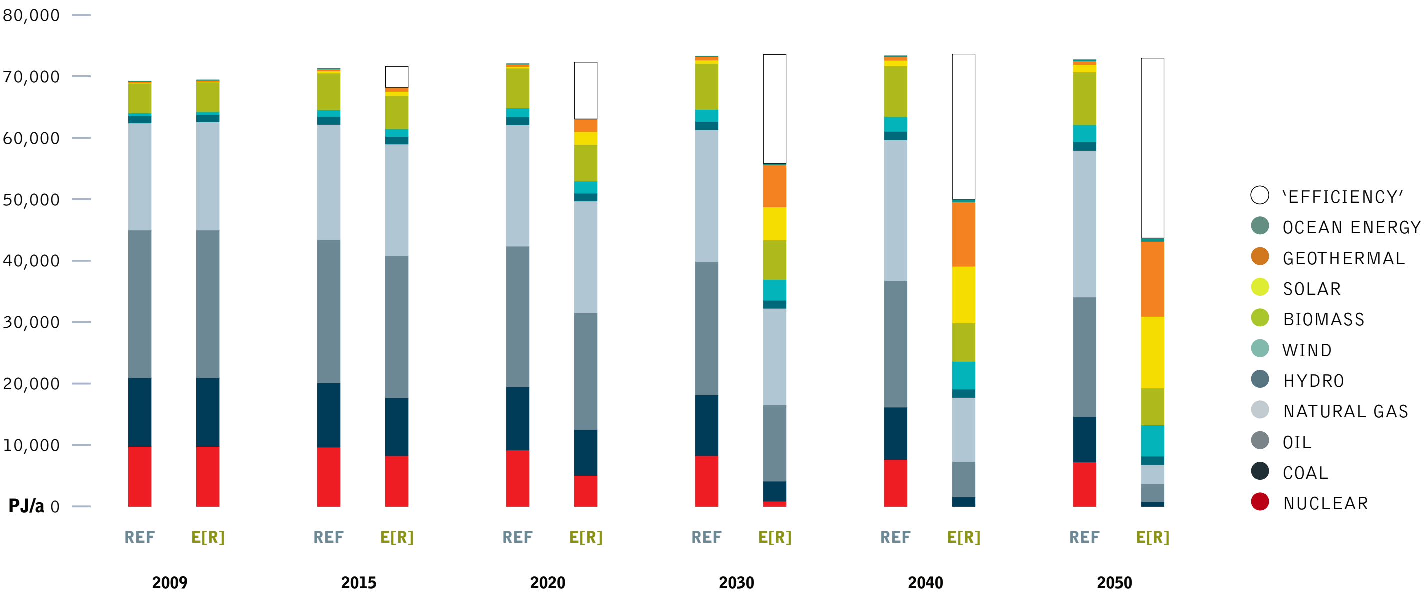

table 5.6: investment costs for electricity generation and fuel cost savings under the energy [r]evolution scenario compared to the reference scenario

INVESTMENT COSTS	EURO	2011 - 2020	2021 - 2030	2031 - 2040	2041 - 2050	2011 - 2050	2011 - 2050 AVERAGE PER ANNUM
DIFFERENCE E[R] VERSUS REF							
Conventional (fossil & nuclear)	billion €	-216.0	-234.6	-173.1	-173.1	-766.3	-19.2
Renewables	billion €	471.3	550.4	701.6	701.6	2,304.7	57.6
Total	billion €	**255.4**	**315.8**	**528.5**	**528.5**	**1,538.4**	**38.5**
CUMULATED FUEL COST SAVINGS							
SAVINGS CUMULATIVE E[R] VERSUS REF							
Fuel oil	billion €/a	11.5	32.8	46.6	43.0	133.9	3.3
Gas	billion €/a	37.3	166.8	560.4	1,458.2	2,222.8	55.6
Hard coal	billion €/a	27.0	118.7	186.6	236.3	568.6	14.2
Lignite	billion €/a	4.5	21.8	30.1	28.3	84.7	2.1
Total	billion €/a	**80.4**	**340.0**	**823.7**	**1,765.7**	**3,009.9**	**75.2**

employment projections

METHODOLOGY TO CALCULATE JOBS

REGIONAL ADJUSTMENTS

COAL, GAS AND RENEWABLE TECHNOLOGY TRANDE

FUTURE EMPLOYMENT IN THE ENERGY SECTOR

EMPLOYMENT IN RENEWABLE HEATING SECTOR

6

> “economy and ecology goes hand in hand with new employment.”

© NASA

image THE CLOUDS CLEARED OVER MUCH OF EASTERN EUROPE, REVEALING SNOW TO THE EASTERN EDGE OF THE IMAGE. THE IMAGE ALSO PROVIDES A GLIMPSE OF SOUTHEASTERN EUROPE, INCLUDING THE BALKANS, WHERE WINTER BLIZZARDS RESULTED IN STATES OF EMERGENCY. NORTH OF THE BALKANS, THE STORMS DUMPED UP TO 12 INCHES OF SNOW IN VIENNA, AND PARTS OF THE CZECH REPUBLIC RECEIVED 16 INCHES OF SNOW, ACCORDING TO NEWS REPORTS.

6.1 methodology to calculate jobs

Greenpeace International and the European Renewable Energy Council have published four global Energy [R]evolution scenarios. These compare a low-carbon Energy [R]evolution scenario to a Reference scenario based on the International Energy Agency (IEA) "business as usual" projections (from the WEO series, for example International Energy Agency, 2007, 2011). The Institute for Sustainable Futures (ISF) analysed the employment effects of the 2008 and 2012 Energy [R]evolution global scenarios. The methodology used in the 2012 global analysis is used to calculate energy sector employment for the EU 27 Energy [R]evolution and Reference scenario.

Employment is projected for the EU 27 for both scenarios at 2015, 2020, and 2030 by using a series of employment multipliers and the projected electrical generation, electrical capacity, heat collector capacity, and the primary consumption of coal, gas and biomass (excluding gas used for transport). The results of the energy scenarios are used as inputs to the employment modelling.

Only direct employment is included, namely jobs in construction, manufacturing, operations and maintenance, and fuel supply associated with electricity generation and direct heat provision. Indirect jobs, induced jobs, and energy efficiency jobs are not included in the calculations. Indirect jobs generally include jobs in secondary industries which supply the primary industry sector, for example, catering and accommodation. Induced jobs are those resulting from spending wages earned in the primary industries.

A detailed description of the methodology is given in Rutovitz & Harris, 2012a.

Inputs for energy generation and demand for each scenario include:

- The amount of electrical and heating capacity that will be installed each year for each technology.
- The primary energy demand for coal, gas, and biomass fuels in the electricity and heating sectors.
- The amount of electricity generated per year from nuclear, oil, and diesel.

Inputs for each technology include:

- 'Employment factors', or the number of jobs per unit of capacity, separated into manufacturing, construction, operation and maintenance, and per unit of primary energy for fuel supply.
- For the 2020 and 2030 calculations, a 'decline factor' for each technology which reduces the employment factors by a certain percentage per year to reflect the employment per unit reduction as technology efficiencies improve.
- The percentage of local manufacturing and domestic fuel production in each region, in order to calculate the number of manufacturing and fuel production jobs in the region.
- The percentage of world trade which originates in the region for coal and gas fuels, and renewable traded components.

The electrical capacity increase and energy use figures from each scenario are multiplied by the employment factors for each of the technologies, and then adjusted for the proportion of fuel or manufacturing occurring locally. The calculation is summarised in Table 6.1.

table 6.1: **methodology overview**

MANUFACTURING (FOR LOCAL USE) = MW INSTALLED PER YEAR IN REGION × MANUFACTURING EMPLOYMENT FACTOR × % OF LOCAL MANUFACTURING
MANUFACTURING (FOR EXPORT) = MW EXPORTED PER YEAR × MANUFACTURING EMPLOYMENT FACTOR
CONSTRUCTION = MW INSTALLED PER YEAR × CONSTRUCTION EMPLOYMENT FACTOR
OPERATION & MAINTENANCE = CUMULATIVE CAPACITY × O&M EMPLOYMENT FACTOR
FUEL SUPPLY (NUCLEAR) = ELECTRICITY GENERATION × FUEL EMPLOYMENT FACTOR
FUEL SUPPLY (COAL, GAS & BIOMASS) = PRIMARY ENERGY DEMAND + EXPORTS × FUEL EMPLOYMENT FACTOR × % OF LOCAL PRODUCTION
HEAT SUPPLY = MW INSTALLED PER YEAR × EMPLOYMENT FACTOR FOR HEAT

JOBS = **MANUFACTURING** + **CONSTRUCTION** + **OPERATION & MAINTENANCE (O&M)** + **FUEL SUPPLY** + **FUEL SUPPLY**

EMPLOYMENT FACTOR AT 2020 OR 2030 = **2010 EMPLOYMENT FACTOR** × TECHNOLOGY DECLINE FACTOR$^{\text{(NUMBER OF YEARS AFTER 2010)}}$

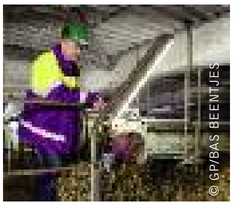

image THROUGH BURNING OF WOOD CHIPS THE POWER PLANT GENERATES ELECTRICITY, ENERGY OR HEAT. HERE WE SEE THE STOCK OF WOOD CHIPS WITH A CAPACITY OF 1000 M^{3} ON WHICH THE PLANT CAN RUN, UNMANNED, FOR ABOUT FOUR DAYS. LELYSTAD, THE NETHERLANDS.

Employment numbers are indicative only, as a large number of assumptions are required to make calculations. Quantitative data on present employment based on actual surveys is difficult to obtain, so it is not possible to calibrate the methodology against time series data, or even against current data in many regions. However, within the limits of data availability, the figures presented are indicative of electricity sector employment levels under the two scenarios. However, there are some significant areas of employment which are not included, including replacement of generating plant, and energy efficiency jobs.

Only a partial estimate of the jobs in heat supply is included, as biomass, gas, and coal jobs in this sector include only fuel supply jobs where heat is supplied directly (that is, not via a combined heat and power plant), while jobs in heat from geothermal and solar collectors primarily include manufacturing and installation. Insufficient data means it was not possible to include a comprehensive assessment for this sector.

6.2 coal, gas and renewable technology trade

It is assumed that all manufacturing for energy technologies occurs within the EU 27, Futher, it is assumed that the EU 27 accounts for 50% of world trade in renewable energy technologies.

Jobs in coal and gas supply have been allocated taking international trade into account. The proportion of coal imported in the Reference case is calculated from the Current Policies scenario from the World Energy Outlook 2011 (International Energy Agency, 2011). This is adjusted according to the ratio between the Reference scenario and the [R]evolution scenario coal consumption to derive the proportion of imports in the {R]evolution scenario.

The proportion of gas imported in the Reference scenario is calculated by subtracting the projected gas production from the Current Policies scenario (International Energy Agency, 2011) from the consumption projected in the Reference scenario. The proportion imported in the Energy [R]evolution scenario is then calculated using the ratio between the Reference scenario and the [R]evolution scenario consumption.

The proportion of coal or gas imports calculated for the Reference and [R]evolution scenarios are shown in Table 6.2.

6.3 employment factors

The employment factors used in the 2012 analysis are shown in Table 6.4, with the main source given in the notes.

Employment factors are adjusted to take into account the reduction in employment per unit of electrical capacity as technologies and production techniques mature. The learning rates assumed have a significant effect on the outcome of the analysis, and are given in Table 6.3 below. These declines rates are calculated directly from the cost data used in the Energy [R]evolution modelling (Teske et al., 2012). The factor for nuclear decommissioning has been taken as the average decline across all other technologies.

table 6.3: technology cost decline factors

	ANNUAL DECLINE IN JOB FACTORS		
	2010-2015	2015-2020	2020-30
Coal	0.3%	0.3%	0.5%
Lignite	0.4%	0.4%	0.4%
Gas	0.5%	0.5%	1.0%
Oil	0.4%	0.4%	0.8%
Diesel	0.0%	0.0%	0.0%
Nuclear	0.0%	0.0%	0.0%
Biomass	1.6%	1.1%	0.7%
Hydro-large	-0.6%	-0.6%	-0.9%
Hydro-small	-0.6%	-0.6%	-0.9%
Wind onshore	3.6%	2.8%	0.2%
Wind offshore	3.1%	7.2%	4.5%
PV	5.3%	6.4%	4.9%
Geothermal power	3.5%	5.4%	7.3%
Solar thermal power	5.6%	5.1%	2.8%
Ocean	4.8%	6.5%	7.0%
Coal CHP	0.3%	0.3%	0.5%
Lignite CHP	0.3%	0.3%	0.5%
Gas CHP	0.9%	1.0%	1.0%
Oil CHP	0.4%	0.4%	0.8%
Biomass CHP	2.0%	2.2%	2.2%
Geothermal CHP	2.6%	3.2%	4.5%
Nuclear decommissioning	1.6%	2.0%	1.8%
Geothermal - heat	0.0%	0.9%	0.9%
Solar thermal heat	Uses decline factor for solar thermal power		

table 6.2: EU 27 proportion of coal and gas imports: reference and [r]evolution scenarios

	REFERENCE				ENERGY [R]EVOLUTION			
	2010	2015	2020	2030	2010	2015	2020	2030
Coal imports	45%	50%	55%	66%	45%	50%	38%	0%
Gas imports	60%	66%	73%	79%	60%	64%	71%	72%

table 6.4: summary of employment factors used in EU 27 analysis 2012

FUEL	CONSTRUCTION TIMES *Years*	CONSTRUCTION /INSTALLATION *Job years/MW*	MANUFACTURING *Jobs years/MW*	OPERATION & MAINTENANCE *Jobs/MW*	FUEL – PRIMARY ENERGY DEMAND *Jobs/PJ*	
Coal	5	7.7	3.5	0.1	38	Note 1
Gas	2	1.7	1.0	0.08	22	Note 2
Nuclear	10	14	1.3	0.3	0.001 jobs per GWh (final energy demand)	Note 3
Biomass	2	14	2.9	1.5	32	Note 4
Hydro-large	2	6.0	1.5	0.3		Note 5
Hydro-small	2	15	5.5	2.4		Note 6
Wind onshore	2	2.5	6.1	0.2		Note 7
Wind offshore	4	7.1	11	0.2		Note 8
PV	1	11	6.9	0.3		Note 9
Geothermal	2	6.8	3.9	0.4		Note 10
Solar thermal	2	15	4.0	1.0		Note 11
Ocean	2	9.0	1.0	0.3		Note 12
Geothermal - heat	3.0 jobs/ MW (construction and manufacturing)					Note 13
Solar - heat	7.4 jobs/ MW (construction and manufacturing)					Note 14
Nuclear decommissioning	0.95 jobs per MW decommissioned					Note 15
Combined heat and power	CHP technologies use the factor for the technology, i.e. coal, gas, biomass, geothermal, etc, increased by a factor of 1.5 for O&M only.					
Oil and diesel	Use the employment factors for gas					

sources for employment factors

1. Coal: construction, manufacturing and operations and maintenance factors are from the JEDI model (National Renewable Energy Laboratory, 2011a). Jobs per PJ fuel have been derived using data from EURACOAL and the IEA (European Association for Coal and Lignite, 2011; International Energy Agency, 2012)

2. Gas, oil and diesel: Installation and manufacturing factors are from the JEDI model (National Renewable Energy Laboratory, 2011b). O&M factor is an average the figure from the 2010 report, the JEDI model (National Renewable Energy Laboratory, 2011b), a US study (National Commission on Energy Policy, 2009) and ISF research (Rutovitz & Harris, 2012b). The fuel factor per PJ is the weighted average of US, Canadian, and Russian employment in gas production, derived from US and Canadian information (America's Natural Gas Alliance, 2008; IHS Global Insight (Canada) Ltd, 2009; Zubov, 2012).

3. Nuclear: The construction factor is the average of two studies from the UK and one from the US (Cogent Sector Skills Council, 2010, 2011a; National Commission on Energy Policy, 2009). The manufacturing factor is the average of the two UK reports, while the O&M factor is the average of values from all three studies and ISF research (Rutovitz & Harris, 2012).The fuel factor was derived by ISF in 2009 (Rutovitz & Atherton, 2009).

4. Bioenergy: Employment factors for construction, manufacturing, and O&M use the average values of studies from Greece, the UK, Spain, USA, and one Europe wide (Kjaer, 2006; Moreno & López, 2008; Thornley, 2006; Thornley et al., 2009; Thornley, Rogers, & Huang, 2008; Tourkolias & Mirasgedis, 2011) Fuel employment per PJ primary energy is derived from five studies, all in Europe (Domac, Richards, & Risovic, 2005; EPRI, 2001; Hillring, 2002; Thornley, 2006; Upham & Speakman, 2007; Valente, Spinelli, & Hillring, 2011)

5. Hydro – large: Construction and manufacturing factors are from a US study (Navigant Consulting, 2009). O&M factor is an average of data from the US study (Navigant Consulting, 2009) and ISF research (Rutovitz, 2010; Rutovitz & Harris, 2012; Rutovitz & Ison, 2011).

6. Hydro – small: factors are the average a Canadian study, the JEDI model, a US study and a Spanish study (Moreno & López, 2008; National Renewable Energy Laboratory, 2011d; Navigant Consulting, 2009; Pembina Insitute, 2004)

7. Wind – onshore: The installation factor used is from the European Wind Energy Association. The manufacturing factor is derived using the employment per MW in turbine manufacture at Vestas from 2007 – 2011 (Vestas, 2011), adjusted for total manufacturing using the ratio used by the EWEA (European Wind Energy Association, 2009). The O&M factor is an average of eight reports from USA, Europe, the UK and Australia.

8. Wind – offshore: All factors are from a German report (Price Waterhouse Coopers, 2012).

9. Solar PV: The Solar PV installation employment factor is the average of five estimates in Germany and the US, while manufacturing is taken from the JEDI model (National Renewable Energy Laboratory, 2010a), a Greek study (Tourkolias & Mirasgedis, 2011), a Korean national report (Korea Energy Management Corporation (KEMCO) & New and Renewable Energy Center (NREC), 2012), and ISF research for Japan (Rutovitz & Ison, 2011).

10. Geothermal: The construction and O&M factors are the weighted averages from employment data reported for thirteen power stations totalling 1050 MW in the US, Canada, Greece and Australia (some of them hypothetical). The manufacturing factor is derived from a US study (Geothermal Energy Association, 2010).

11. Solar thermal power: The OECD Europe figure is used for the EU 27, and is higher than the overall OECD factors of 8.9 job years/MW (construction) and 0,5 jobs/MW (O&M). Overall OECD figures were derived from a weighted average of 19 reported power plants (3223 MW), while the OECD Europe figure includes only European data (951 MW).The manufacturing factor is unchanged from the 2010 analysis (European Renewable Energy Council, 2008, page 16).

12. Ocean: These factors are unchanged from the 2010 analysis. The construction factor used in this study is a combined projection for wave and tidal power derived from data for offshore wind power (Batten & Bahaj, 2007). A study of a particular wave power technology, Wave Dragon, provided the O&M factor (Soerensen, 2008).

13. Geothermal and heat pumps: One overall factor has been used for jobs per MW installed, from the US EIA annual reporting (US Energy Information Administration, 2010), adjusted to include installation using data from WaterFurnace (WaterFurnace, 2009)

14. Solar thermal heating: One overall factor has been used for jobs per MW installed, as this was the only data available on any large scale. This may underestimate jobs, as it may not include O&M. The global figure is derived from the IEA heating and cooling program report (International Energy Agency Solar Heating and Cooling Program, 2011).

15. Nuclear decommissioning: The weighted average decommissioning employment over the first 20 years from one UK study and two German studies is used (Cogent Sector Skills Council, 2009, 2011b; Wuppertal Institute for Climate Environment and Energy, 2007). See Section Fehler! Verweisquelle konnte nicht gefunden werden. for more details.

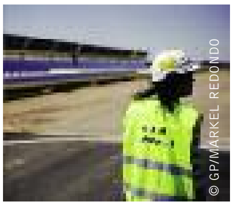

image A WORKER SURVEYS THE EQUIPMENT AT ANDASOL 1 SOLAR POWER STATION, WHICH IS EUROPE'S FIRST COMMERCIAL PARABOLIC TROUGH SOLAR POWER PLANT. ANDASOL 1 WILL SUPPLY UP TO 200,000 PEOPLE WITH CLIMATE-FRIENDLY ELECTRICITY AND SAVE ABOUT 149,000 TONNES OF CARBON DIOXIDE PER YEAR COMPARED WITH A MODERN COAL POWER PLANT.

6.4 future employment in the energy sector

The Energy [R]evolution scenario results in more energy sector jobs in EU 27 at every stage of the projection than the Reference scenario.

- There are 1.5 million energy sector jobs in the Energy [R]evolution in 2015, and 0.9 million in the Reference scenario.
- In 2020, there are 1.4 million jobs in the Energy [R]evolution, and 0.9 million in the Reference scenario.
- In 2030, there are 1.2 million jobs in the Energy [R]evolution, and 0.7 million in the Reference scenario.

Figure 6.1 shows the change in job numbers under both scenarios for each technology between 2010 and 2030. Jobs in the coal sector decline in both scenarios, leading to an overall decline of 34% in energy sector jobs in the Reference scenario.

Exceptionally strong growth in renewable energy leads to an increase of 32% in total energy sector jobs in the Energy [R]evolution scenario between 2010 and 2015. Renewable energy accounts for 76% of energy jobs by 2030, with biomass having the greatest share (21%), followed by solar PV, wind and solar heating.

figure 6.1: employment in the energy sector under the reference and energy [r]evolution scenarios

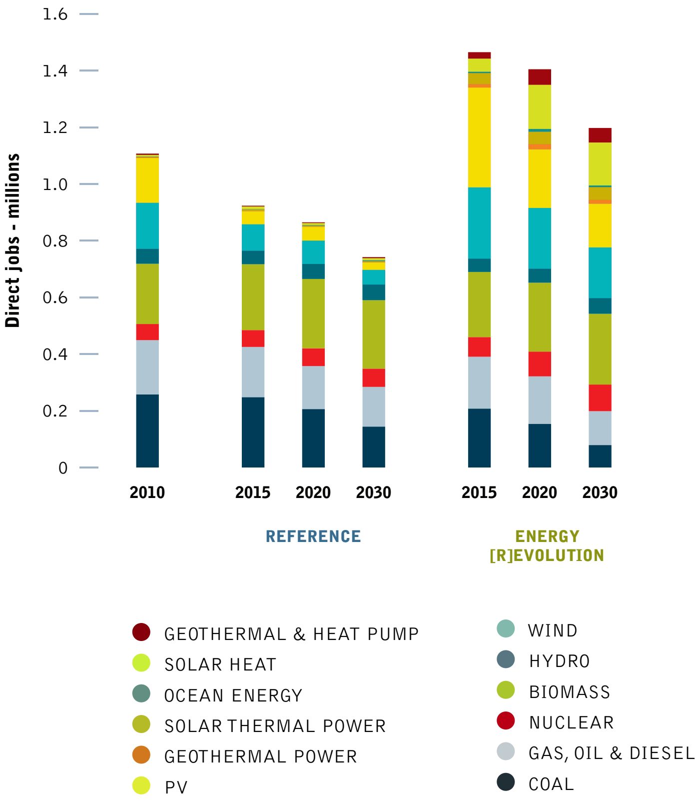

table 6.5: total employment in the energy sector THOUSAND JOBS

		REFERENCE			ENERGY [R]EVOLUTION		
	2010	2015	2020	2030	2015	2020	2030
Coal	261	251	208	146	210	156	80
Gas, oil & diesel	193	176	146	130	181	162	107
Nuclear	57	60	63	65	70	88	95
Renewable	607	443	448	397	1,014	1,005	914
Total Jobs (thousands)	**1,118**	**929**	**865**	**738**	**1,475**	**1,412**	**1,196**
Construction and installation	171	94	91	74	355	388	361
Manufacturing	186	86	67	36	387	332	257
Operations and maintenance	210	232	237	233	240	251	253
Fuel supply (domestic)	550	517	470	395	494	441	326
Coal and gas export	-	-	-	-	-	-	-
Total Jobs (thousands)	**1,118**	**929**	**865**	**738**	**1,475**	**1,412**	**1,196**

figure 6.2: employment in the energy sector by technology in 2010 and 2030

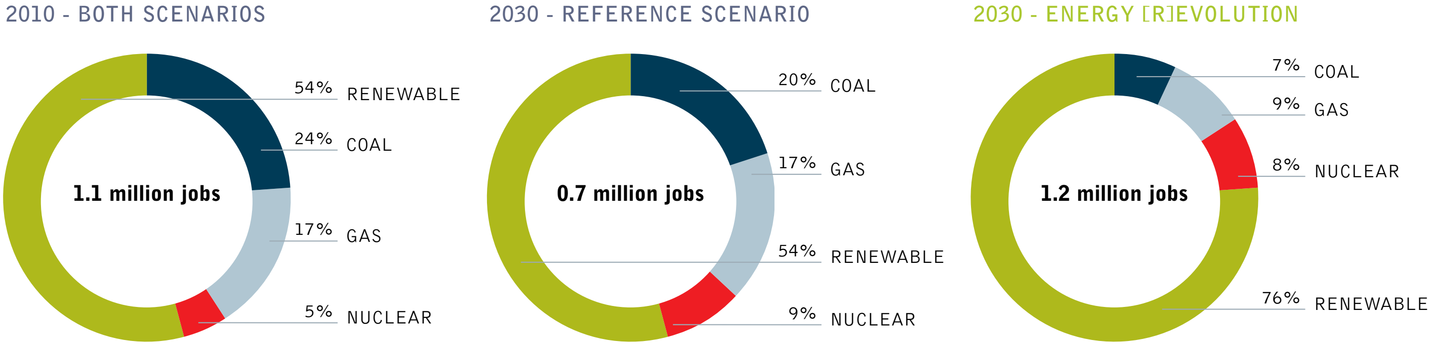

table 6.6: employment in the energy sector by technology, two scenarios THOUSAND JOBS

		REFERENCE			ENERGY [R]EVOLUTION		
By sector	2010	2015	2020	2030	2015	2020	2030
Construction and installation	165	86	84	66	307	238	216
Manufacturing	183	82	64	33	366	269	197
Operations and maintenance	210	232	237	233	240	251	253
Fuel supply (domestic)	550	517	470	395	494	441	326
Coal and gas export	-	-	-	-	-	-	-
Solar and geothermal heat	10	12	10	11	69	212	205
Total jobs (thousands)	**1,118**	**929**	**865**	**738**	**1,475**	**1,412**	**1,196**
By technology							
Coal	261	251	208	146	210	156	80
Gas, oil & diesel	193	176	146	130	181	162	107
Nuclear	57	60	63	65	70	88	95
Renewable	**607**	**443**	**448**	**397**	**1,014**	**1,005**	**914**
Biomass	*215*	*235*	*247*	*244*	*232*	*245*	*252*
Hydro	*53*	*48*	*52*	*56*	*47*	*51*	*56*
Wind	*164*	*94*	*83*	*52*	*254*	*216*	*180*
PV	*160*	*47*	*49*	*27*	*355*	*209*	*156*
Geothermal power	*1.8*	*1.0*	*0.9*	*0.7*	*11*	*17*	*14*
Solar thermal power	*2.6*	*5.9*	*4.4*	*3.2*	*40*	*45*	*45*
Ocean	*0.3*	*0.3*	*1.1*	*3.7*	*4.7*	*10*	*6*
Solar - heat	*6*	*9*	*7*	*8*	*47*	*157*	*153*
Geothermal & heat pump	*4.0*	*2.6*	*3.0*	*3.2*	*22*	*55*	*52*
Total jobs (thousands)	**1,118**	**929**	**865**	**738**	**1,475**	**1,412**	**1,196**

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

6.5 employment in the renewable heating sector

Employment in the renewable heat sector includes jobs in installation, manufacturing, and fuel supply. However, this analysis includes only jobs associated with fuel supply in the biomass sector, and jobs in installation and manucturing for direct heat from solar, geothermal and heat pumps. It will therefore be an underestimate of jobs in this sector.

6.5.1 employment in solar heating

In the Energy [R]evolution scenario, solar heating would provide 13% of total heat supply by 2030, and would employ approximately 153,000 people. Growth is much more modest in the Reference scenario, with solar heating providing less than 1% of heat supply, and employing approximately 8,000 people.

6.5.2 employment in geothermal and heat pump heating

In the Energy [R]evolution scenario, geothermal and heat pump heating would provide 14% of total heat supply by 2030, and would employ approximately 52,000 people. Growth is much more modest in the Reference scenario, with geothermal and heat pump heating providing less than 1% of heat supply, and employing approximately 3,000 people.

6.5.3 employment in biomass heat

In the Energy [R]evolution scenario, biomass heat would provide 16% of total heat supply by 2030, and would employ approximately 125,000 people. Growth is slightly higher in the Reference scenario, with biomass heat providing 17% of heat supply, and employing approximately 128,000 people.

table 6.7: solar heating: capacity, investment and direct jobs

			REFERENCE			ENERGY [R]EVOLUTION	
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	26	33	62	60	244	761
Heat supplied	PJ	80	101	189	196	833	2,605
Share of total supply	%	0.4%	0.5%	0.8%	1.0%	4%	13%
Market and investment							
Annual increase in capacity	GW	1.6	1.4	2.7	9	37	48
Employment in the energy sector							
Direct jobs in installation and manufacture	jobs	9,300	6,800	7,600	47,200	157,000	152,800

table 6.8: geothermal and heat pump heating: capacity, investment and direct jobs

			REFERENCE			ENERGY [R]EVOLUTION	
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	17	23	34	50	146	351
Heat supplied	PJ	-	122	180	320	979	2,654
Share of total supply	%	0%	0.6%	0.8%	1.6%	5%	14%
Market and investment							
Annual increase in capacity	GW	0.9	1.1	1.2	7.4	19	20
Employment in the energy sector							
Direct jobs in installation and manufacture	jobs	2,600	3,000	3,200	22,000	55,000	52,000

6.5.4 employment in solar photovoltaics

In the Energy [R]evolution scenario, solar photovoltaics would provide 12% of total electricity generation by 2030, and would employ approximately 156,000 people. Growth is much more modest in the Reference scenario, with solar photovoltaics providing 3% of generation, and employing approximately 27,000 people.

6.5.5 employment in solar thermal power

In the Energy [R]evolution scenario, solar thermal power would provide 4% of total electricity generation by 2030, and would employ approximately 45,000 people. Growth is much lower in the Reference scenario, with solar thermal power providing only 0.4% of generation, and employing approximately 3,000 people.

table 6.9: biomass heat: direct jobs in fuel supply

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Heat supplied	PJ	3,053	3,288	3,917	2,996	3,301	3,197
Share of total heat supply	%	14%	15%	17%	15%	16%	16%
Employment							
Direct jobs in fuel supply	jobs	120,000	125,000	128,000	129,000	136,000	125,000

table 6.10: solar photovoltaics: capacity, investment and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	67	77	110	109	213	345
Total generation	TWh	71	86	132	115	238	414
Share of total supply	%	2.1%	2.4%	3.3%	3.5%	7.1%	11.7%
Market and investment							
Annual increase in capacity	GW	8.1	2.2	3.1	16	21	13
Employment in the energy sector							
Direct jobs in construction, manufacturing, operation and maintenance	jobs	46,800	49,200	26,600	355,200	208,800	155,500

table 6.11: solar thermal power: capacity, investment and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	1	2	4	2	11	31
Total generation	TWh	2	8	14	7	45	141
Share of total supply	%	0.0%	0.2%	0.4%	0.2%	1%	4%
Market and investment							
Annual increase in capacity	GW	0.1	0.3	0.2	0.4	2	2
Employment in the energy sector							
Direct jobs in construction, manufacturing, operation and maintenance	jobs	5,900	4,400	3,200	39,900	45,000	45,100

image TESTING THE SCOTRENEWABLES TIDAL TURBINE OFF KIRWALL IN THE ORKNEY ISLANDS.

6.5.6 employment in geothermal power

In the Energy [R]evolution scenario, geothermal power would provide around 2% of total electricity generation by 2030, and would employ approximately 14,000 people. Growth is much more modest in the Reference scenario, with geothermal power providing less than 1% of generation, and employing approximately 700 people.

6.5.7 employment in wave and tidal power

In the Energy [R]evolution scenario, wave and tidal power would provide up to 2% of total electricity generation by 2030, and would employ approximately 6,000 people. Growth is much more modest in the Reference scenario, with wave and tidal power providing less than 1% of generation, and employing approximately 4,000 people.

table 6.12: geothermal power: capacity, investment and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	1	2	2	2	6	25
Total generation	TWh	9	10	15	13	38	153
Share of total supply	%	0.2%	0.3%	0.372%	0.3%	0.7%	2.3%
Market and investment							
Annual increase in capacity	GW	0.1	0.0	0.1	0	1	2
Employment in the energy sector							
Direct jobs in construction, manufacturing, operation and maintenance	jobs	1,000	900	700	11,400	17,500	14,100

table 6.13: wave and tidal power: capacity, investment and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	0.3	0.4	2.4	0.3	3	18
Total generation	TWh	1	1.5	9	1	10	63
Share of total supply	%	0.0%	0.0%	0.2%	0.0%	0.3%	1.8%
Market and investment							
Annual increase in capacity	GW	0.0	0.0	0.2	0.0	0.5	1.5
Employment in the energy sector							
Direct jobs in construction, manufacturing, operation and maintenance	jobs	300	1,100	3,700	4,700	9,700	6,400

6.5.8 employment in wind energy

In the Energy [R]evolution scenario, wind energy would provide 27% of total electricity generation by 2030, and would employ approximately 180,000 people. Growth is more modest in the Reference scenario, with wind energy providing 14% of generation, and employing approximately 52,000 people.

6.5.9 employment in biomass

In the Energy [R]evolution scenario, biomass would provide up to 9% of total electricity generation by 2030, and would employ approximately 252,000 people. Growth is slightly lower in the Reference scenario, with biomass providing approximately 6% of generation, and employing approximately 244,000 people.

table 6.14: wind energy: capacity, investment and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	157	189	243	171	246	368
Total generation	TWh	306	400	541	348	549	939
Share of total supply	%	9%	11%	14%	11%	16%	27%
Market and investment							
Annual increase in capacity	GW	14	7	5	17	15	13
Employment in the energy sector							
Direct jobs in construction, manufacturing, operation and maintenance	jobs	94,000	83,400	52,400	254,400	216,300	180,000

table 6.15: biomass: capacity, investment and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	26	29	36	28	35	47
Total generation	TWh	167	187	233	176	225	306
Share of total supply	%	4.9%	5.2%	5.9%	5.3%	6.7%	8.7%
Market and investment							
Annual increase in capacity	GW	1.0	0.5	0.7	1.3	1.4	1.1
Employment in the energy sector							
Direct jobs in construction, manufacturing, operation and maintenance	jobs	234,700	247,100	243,800	232,400	245,400	252,000

image WORKERS BUILD A WIND TURBINE IN A FACTORY IN PATHUM THANI, THAILAND. THE IMPACTS OF SEA-LEVEL RISE DUE TO CLIMATE CHANGE ARE PREDICTED TO HIT HARD ON COASTAL COUNTRIES IN ASIA, AND CLEAN RENEWABLE ENERGY IS A SOLUTION.

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6.5.10 employment in coal

Jobs in the coal sector drop signficantly in both the Reference scenario and the Energy [R]evolution scenario. In the Reference scenario coal employment drops by 105,000 jobs between 2015 and 2030, despite generation from coal increasing. This is in addition to a loss of 10,000 jobs from 2010 to 2015, driven by a 5% reduction in the projected output from coal powered generation.

Coal sector employment in the Energy [R]evolution scenario falls even more, reflecting a 65% reduction in coal generation between 2015 and 2030. Coal jobs in both scenarios include coal used for heat supply.

6.5.11 employment in gas, oil & diesel

Employment in the gas sector drops by 26% in the Reference scenario between 2015 and 2030, despite the fact that gas generation increases by 21%. In the Energy [R]evolution scenario employment falls by 41% while generation is reduced by only 3%. Employment losses are mainly in gas supply, as an increasing proportion is imported. Gas sector jobs in both scenarios include heat supply jobs from gas.

6.5.12 employment in nuclear energy

Employment in nuclear energy grows by 9% in the Reference scenario between 2015 and 2030, while generation falls by 14%.

In the Energy [R]evolution scenario generation is reduced by 90% between 2015 and 2030, representing a virtual phase out of nuclear power. Employment in the Energy [R]evolution increases by 35% from 2015 to 2030. This is because the accelerated closure of nuclear plants results in a signifcant increase in nuclear decomissioning employment. It is expected these jobs will persist for 20 - 30 years.

table 6.16: fossil fuels and nuclear energy: capacity, investment and direct jobs

Employment in the energy sector - fossil fuels and nuclear	UNIT	REFERENCE 2015	REFERENCE 2020	REFERENCE 2030	ENERGY [R]EVOLUTION 2015	ENERGY [R]EVOLUTION 2020	ENERGY [R]EVOLUTION 2030
coal	jobs	250,800	208,100	145,900	209,800	156,100	80,200
gas, oil & diesel	jobs	176,000	145,500	130,400	181,500	162,200	107,400
Nuclear energy	jobs	59,700	63,400	64,800	70,100	88,100	94,700
COAL							
Energy							
Installed capacity	GW	175	181	183	155	125	60
Total generation	TWh	781	808	839	694	556	240
Share of total supply	%	23%	22%	21%	21%	17%	7%
Market and investment							
Annual increase in capacity	GW	-2	1.4	-	-5.2	-5.0	-5.0
GAS, OIL & DIESEL							
Energy							
Installed capacity	GW	272	288	311	272	261	243
Total generation	TWh	863	908	1,046	854	871	828
Share of total supply	%	25%	25%	26%	26%	26%	23%
Market and investment							
Annual increase in capacity	GW	-	3.1	2.3	-1.2	-2.3	-1.4
NUCLEAR ENERGY							
Energy							
Installed capacity	GW	135	124	110	115	68	11
Total generation	TWh	883	840	757	756	461	78
Share of total supply	%	26%	23%	19%	23%	14%	2%
Market and investment							
Annual increase in capacity	GW	-1.2	-2.2	-1.4	-5.1	-9.5	-5.6

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the silent revolution – past and current market developments

POWER PLANT MARKETS

GLOBAL MARKET SHARES IN THE POWER PLANT MARKET AND THE EU 27 POSITION

DEVELOPMENT OF THE INSTALLED POWER PLANT CAPACITY IN EUROPE

7

> “the bright future for renewable energy is already underway.”

© NASA/JESSE ALLEN

technology SOLAR PARKS PS10 AND PS20, SEVILLE, SPAIN. THESE ARE PART OF A LARGER PROJECT INTENDED TO MEET THE ENERGY NEEDS OF SOME 180,000 HOMES — ROUGHLY THE ENERGY NEEDS OF SEVILLE BY 2013, WITHOUT GREENHOUSE GAS EMISSIONS.

A new 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 capacities between 2000 and 2010. However, it is too early to claim the end of the fossil fuel based power generation, because more than 475,000 MW of new coal power plants were built with embedded cumulative emissions of over 55 billion tonnes CO_2 over their technical lifetime.

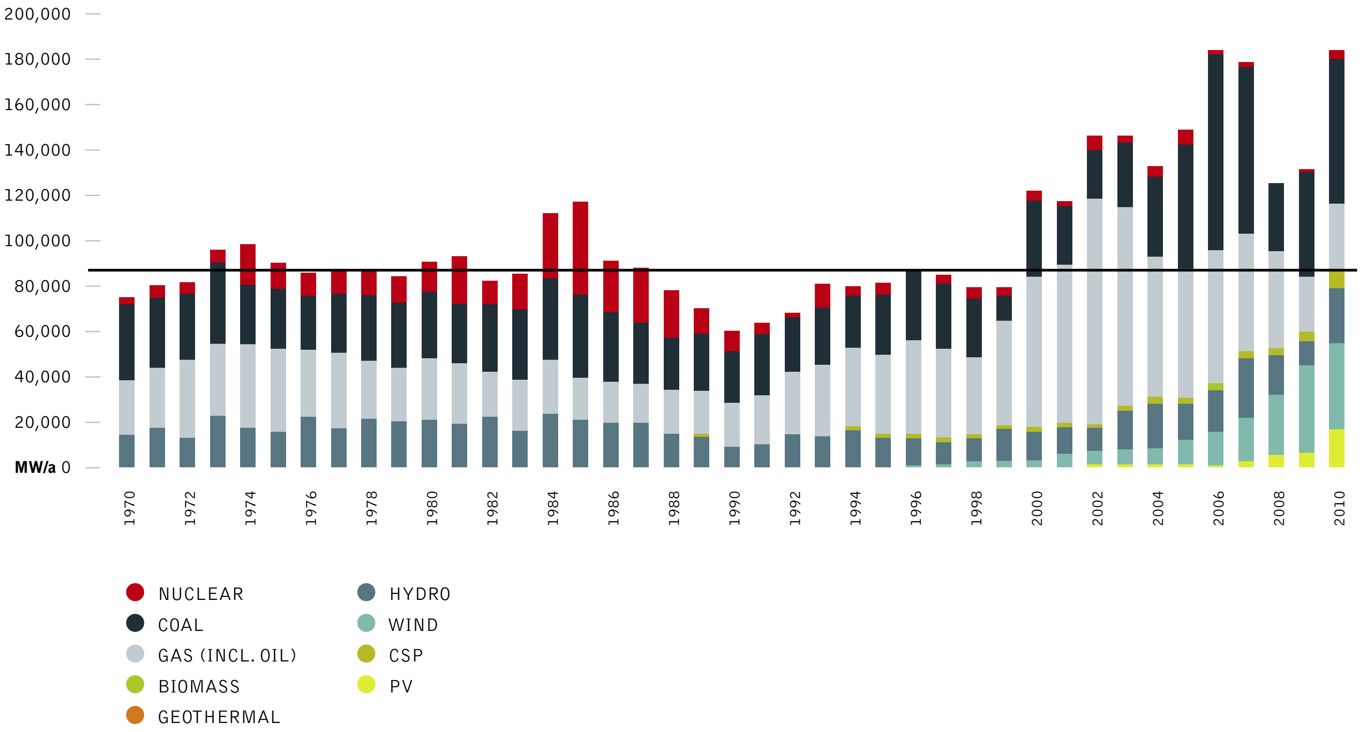
The global market volume of renewable energies constructed in 2010 was on average, equal to the total global energy market volume (all kinds) added each year between 1970 and 2000. There is a window of opportunity for new renewable energy installations to replace old plants in OECD countries and for electrification in developing countries. However, the window will close within the next few years without good renewable energy policies and legally binding CO_2 reduction targets.

Between 1970 and 1990, the OECD[44] global power plant market was dominated by countries that electrified their economies mainly with coal, gas and hydro power plants. The power sector 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 - and went into decline in following years, with no recent signs of growth.

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.

The economies of developing countries, especially in Asia, started growing during the 1990s, triggering a new wave of power plant projects. 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 (IPPs), who sell the electricity mainly to state-owned utilities. The majority of new power plant technology in liberalised power markets is fuelled by gas, except for in China which focused on building new coal power plants. Excluding China, the rest of the global power plant market has seen a phase-out of coal since the late 1990s with growing gas and renewable generation, particularly wind.

figure 7.1: global power plant market 1970-2010



source
Platts, IEA, Breyer, Teske.

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reference
44 ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT.

image NESJAVELLIR GEOTHERMAL PLANT GENERATES ELECTRICITY AND HOT WATER BY UTILIZING GEOTHERMAL WATER AND STEAM. IT IS THE SECOND LARGEST GEOTHERMAL POWER STATION IN ICELAND. THE STATION PRODUCES APPROXIMATELY 120MW OF ELECTRICAL POWER, AND DELIVERS AROUND 1,800 LITRES (480 US GAL) OF HOT WATER PER SECOND, SERVICING THE HOT WATER NEEDS OF THE GREATER REYKJAVIK AREA. THE FACILITY IS LOCATED 177 M (581 FT) ABOVE SEA LEVEL IN THE SOUTHWESTERN PART OF THE COUNTRY, NEAR THE HENGILL VOLCANO.

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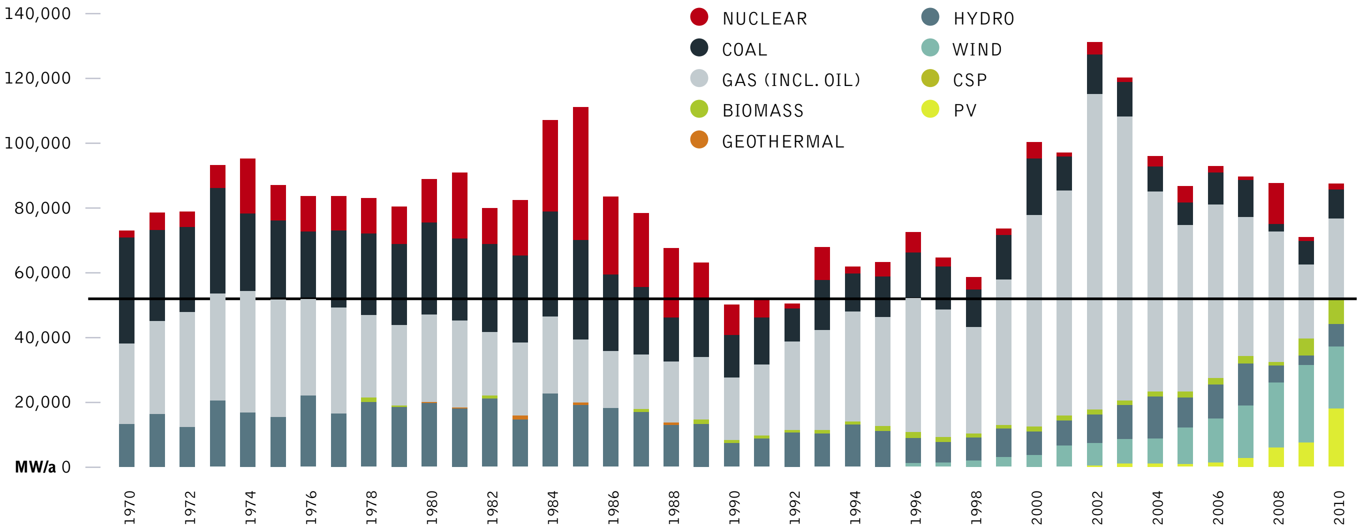
figure 7.2: global power plant market 1970-2010, excluding china



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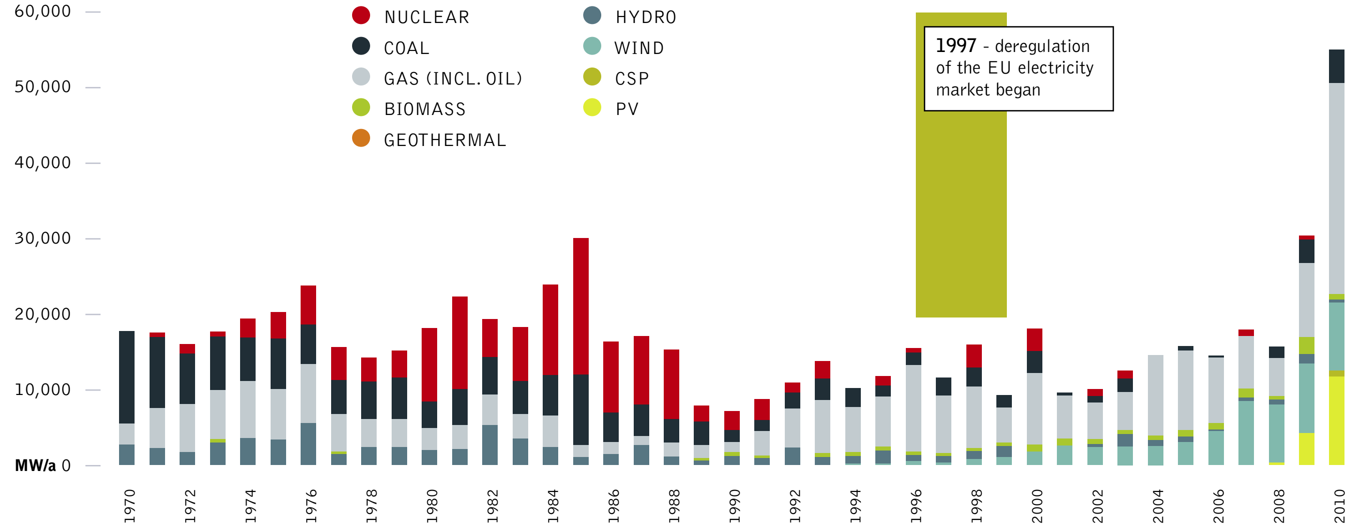
Platts, IEA, Breyer, Teske.

Europe: About five years after the US began deregulating the power sector, the European Community started a similar process with similar effect on the power plant market. 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 then. The growing share of renewables, especially wind and solar photovoltaic, are due to a legally-binding target and the associated feed-in laws which have been 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 because the aged power plant fleet in Europe needed re-powering.

figure 7.3: europe (eu 27): power plant market 1970-2010



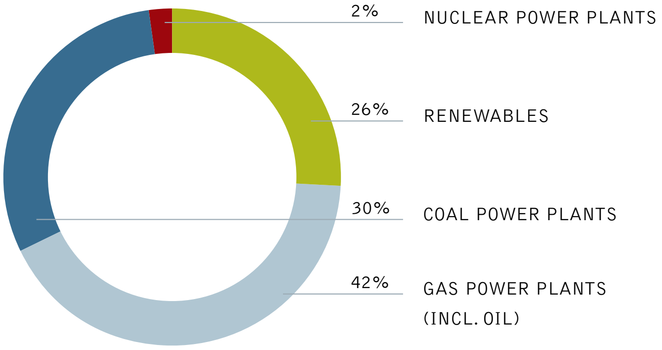
1997 - deregulation of the EU electricity market began

7.1 the global market shares in the power plant market and the EU 27 position: renewables gaining ground

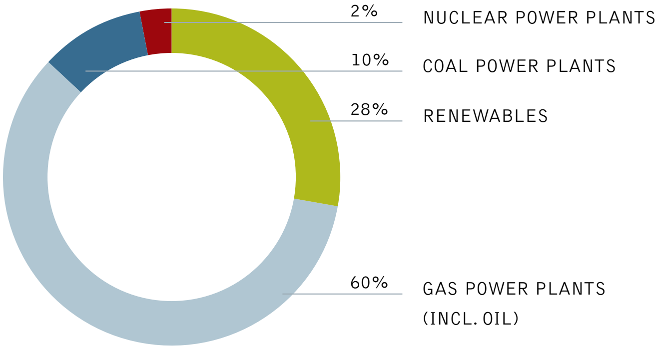
Since the year 2000, the wind power market gained a growing market share within the global power plant market. Initially only a handful of countries, namely Germany, Denmark and Spain, dominated the wind market, but the wind industry now has projects in over 70 countries around the world. Following the example of the wind industry, the solar photovoltaic industry experienced an equal growth since 2005. Between 2000 and 2010, 26% of all new power plants worldwide were renewable-powered – mainly wind – and 42% run on gas. So, two-thirds of all new power plants installed globally are gas power plants and renewable, with close to one-third as coal. Nuclear remains irrelevant on a global scale with just 2% of the global market share. About 430,000 MW of new renewable energy capacity has been installed over the last decade, while 475,000 MW of new coal, with embedded cumulative emissions of more than 55 billion tonnes CO_2 over their technical lifetime, came online – 78% or 375,000 MW in China.

figure 7.4: power plant market shares

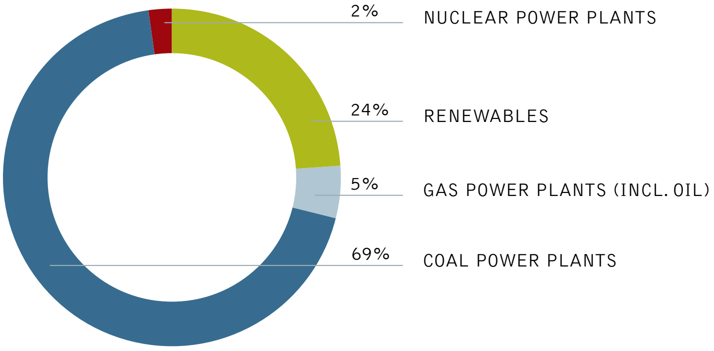
global power plant market shares 2000-2010



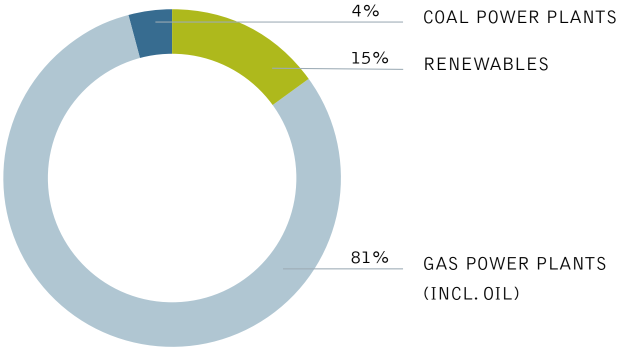
global power plant market shares 2000-2010 - excluding china



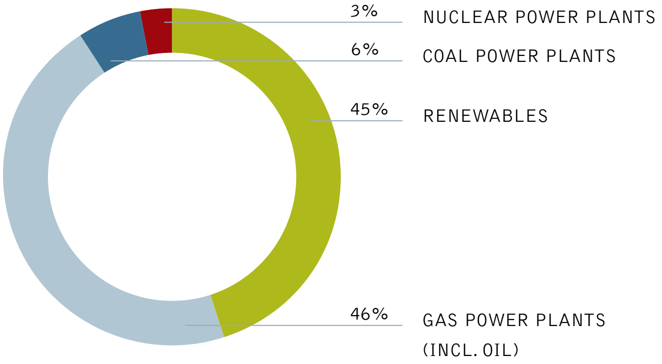
china: power plant market shares 2000-2010



usa: power plant market shares 2000-2010



EU 27: power plant market shares 2000-2010 - excluding china



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

image WITNESSES FROM FUKUSHIMA, JAPAN, KANAKO NISHIKATA, HER TWO CHILDREN KAITO AND FUU AND TATSUKO OGAWARA VISIT A WIND FARM IN KLENNOW IN WENDLAND.

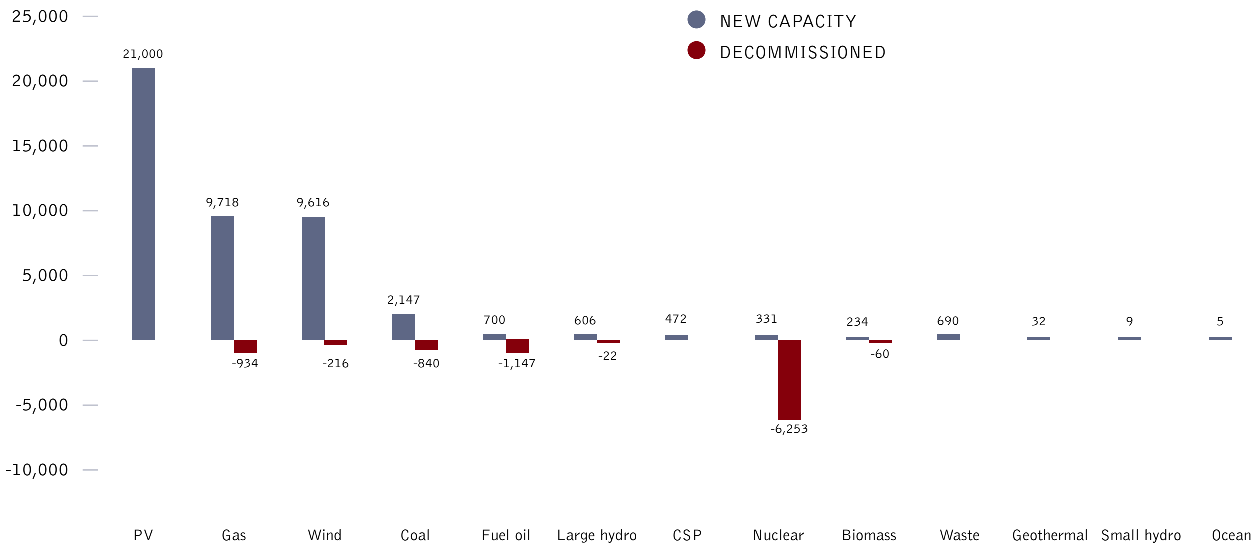

© MICHAEL LOEWA

The energy revolution has started on a global level already. This picture is even clearer when we look into the global market shares but exclude China, the only country with a massive expansion of coal. About 28% of all new power plants since 2000 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 also recently kick-started its wind market, and solar photovoltaics is expected to follow in the years to come.

7.2 development of the installed power plant capacity in europe (EU 27)

Figure 7.5 provides shows the new installed capacity and decommissioned power plant capacity. The trend away from nuclear towards renewable energy – especially wind and solar pv – and gas has been quite robust over recent years. However, in 2011 more coal power plants have been connected to the grid than decommissioned which will lead to high and long term carbon emissions.

figure 7.5: new installed capacity and decommissioned capacity in mw, 2011. total 35,468 mw.



source
EWEA 2012

energy resources and security of supply

GLOBAL

OIL

GAS

COAL

NUCLEAR

RENEWABLE ENERGY

8

> “the issue of security of supply is now at the top of the energy policy agenda.”

© NASA/JESSE ALLEN)

image POLAND’S ROSPUDA VALLEY IS A WETLAND AREA THAT COLLECTS DEAD PLANT MATERIAL. ALTHOUGH PEAT BOGS WERE ONCE COMMON IN COOL, TEMPERATE CLIMATES LIKE NORTHERN EUROPE’S, FEW HAVE SURVIVED THE CHANGES PEOPLE HAVE MADE TO THE LANDSCAPE FOR AGRICULTURE AND OTHER DEVELOPMENT. THE PEAT BOG IN ROSPUDA VALLEY IS ONE OF EUROPE’S LAST PRISTINE WETLANDS.

image AERIAL PHOTO OF THE ANDASOL 1 SOLAR POWER STATION, EUROPE'S FIRST COMMERCIAL PARABOLIC TROUGH SOLAR POWER PLANT. ANDASOL 1 WILL SUPPLY UP TO 200,000 PEOPLE WITH CLIMATE-FRIENDLY ELECTRICITY AND SAVE ABOUT 149,000 TONNES OF CARBON DIOXIDE PER YEAR COMPARED WITH A MODERN COAL POWER PLANT.

The issue of security of supply is at the top of the energy policy agenda. Concern is focused both on price security and the security of physical supply for countries with none if their own resources. At present around 80% of global energy demand is met by fossil fuels. The world is currently experiencing an unrelenting increase in energy demand in the face of 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.

Table 8.1 shows estimated deposits and current use of fossil energy sources. There is no shortage of fossil fuels; there might a shortage of conventional oil and gas. Reducing global fossil fuel consumption for reasons of resource scarcity alone is not mandatory, even though there may be substantial price fluctuations and regional or structural shortages as we have seen in the past.

The presently known coal resources and reserves alone probably amount to around 3,000 times the amount currently mined in a year. Thus, in terms of resource potential, current-level demand could be met for many hundreds of years to come. Coal is also relatively evenly spread across the globe; each continent holds considerable deposits. However, the supply horizon is clearly much lower for conventional mineral oil and gas reserves at 40–50 years. If some resources or deposits currently still classified as 'unconventional' are included, the resource potentials exceed the current consumption rate by far more than one hundred years. However, serious ecological damage is frequently associated with fossil energy mining, particularly of unconventional deposits in oil sands and oil shale.

Over the past few years, new commercial processes have been developed in the natural gas extraction sector, allowing more affordable access to gas deposits previously considered 'unconventional', many of which are more frequently found and evenly distributed globally than traditional gas fields. However, tight gas and shale gas extraction can potentially be accompanied by seismic activities and the pollution of groundwater basins and inshore waters. It therefore needs special regulations. It is expected that an effective gas market will develop using the existing global distribution network for liquid gas via tankers and loading terminals. With greater competitiveness regards price fixing, it is expected that the oil and gas prices will no longer be linked. Having more liquid gas in the energy mix (currently around 10% of overall gas consumption) significantly increases supply security, e.g. reducing the risks of supply interruptions associated with international pipeline networks.

Gas hydrates are another type of gas deposit found in the form of methane aggregates both in the deep sea and underground in permafrost. They are solid under high pressure and low temperatures. While there is the possibility of continued greenhouse gas emissions from such deposits as a consequence of arctic permafrost soil thaw or a thawing of the relatively flat Siberian continental shelf, there is also potential for extraction of this energy source. Many states, including the USA, Japan, India, China and South Korea have launched relevant research programmes. Estimates of global deposits vary greatly; however, all are in the zettajoule range, for example 70,000–700,000 EJ (Krey et al., 2009). The Global Energy Assessment report estimates the theoretical potential to be 2,650–2,450,000 EJ (GEA, 2011), i.e. possibly more than a thousand times greater than the current annual total energy consumption. Approximately a tenth (1,200–245,600 EJ) is rated as potentially extractable. The WBGU advised against applied research for methane hydrate extraction, as mining bears considerable risks and methane hydrates do not represent a sustainable energy source ('The Future Oceans', WBGU, 2006).

table 8.1: global occurances of fossil and nuclear sources

THERE ARE HIGH UNCERTAINTIES ASSOCIATED WITH THE ASSESSMENT OF RESERVES AND RESOURCES.

FUEL	HISTORICAL PRODUCTION UP TO 2008 (EJ)	PRODUCTION IN 2008 (EJ)	RESERVES (EJ)	RESOURCES (EJ)	FURTHER DEPOSITS (EJ)
Conventional oil	6,500	170	6,350	4,967	-
Unconventional oil	500	23	3,800	34,000	47,000
Conventional gas	3,400	118	6,000	8,041	-
Unconventional gas	160	12	42,500	56,500	490,000
Coal	7,100	150	21,000	440,000	-
Total fossil sources	**17,660**	**473**	**79,650**	**543,507**	**537,000**
Conventional uranium	1,300	26	2,400	7,400	-
Unconventional uranium	-	-	-	4,100	2,600,000

source

The representative figures shown here are WBGU estimates on the basis of the GEA, 2011.

table 8.2: overview of the resulting emissions if all fossil resources were burned

POTENTIAL EMISSIONS AS A CONSEQUENCE OF THE USE OF FOSSIL RESERVES AND RESOURCES. ALSO ILLUSTRATED IS THEIR POTENTIAL FOR ENDANGERING THE 2°C GUARD RAIL. THIS RISK IS EXPRESSED AS THE FACTOR BY WHICH, ASSUMING COMPLETE EXHAUSTION OF THE RESPECTIVE RESERVES AND RESOURCES, THE RESULTANT CO_2 EMISSIONS WOULD EXCEED THE 750 GT C02 BUDGET PERMISSIBLE FROM FOSSIL SOURCES UNTIL 2050.

FOSSIL FUEL	HISTORICAL PRODUCTION UP TO 2008 (GT CO_2)	PRODUCTION IN 2008 (GT CO_2)	RESERVES (GT CO_2)	RESOURCES (GT CO_2)	FURTHER DEPOSITS (GT CO_2)	TOTAL RESERVES, RESOURCES AND FURTHER OCCURENCES (GT CO_2)	FACTOR BY WHICH THESE EMISSIONS ALONE EXCEED THE 2°C EMISSIONS BUDGET
Conventional oil	505	13	493	386	-	879	1
Unconventional oil	39	2	295	2,640	3,649	6,584	9
Conventional gas	192	7	339	455	-	794	1
Unconventional gas	9	1	2,405	3,197	27,724	33,325	44
Coal	666	14	1,970	41,277	-	43,247	58
Total fossil fuels	**1,411**	**36**	**5,502**	**47,954**	**31,373**	**84,829**	**113**

source
GEA, 2011.

box 8.1: the energy [r]evolution fossil fuel pathway

The Energy [R]evolution scenario will phase-out fossil fuel not simply as they are depleted, but to achieve a greenhouse gas reduction pathway required to avoid dangerous climate change. Decisions new need to avoid a "lock-in" situation meaning that investments in new oil production will make it more difficult to change to a renewable energy pathway in the future. Scenario development shows that the Energy [R]evolution can be made without any new oil exploration and production investments in the arctic or deep sea wells. Unconventional oil such as Canada's tars and or Australia's shale oil is not needed to guarantee the supply oil until it is phased out under the Energy [R]evolution scenario (see chapter 3).

8.1 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 about one third 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.

8.1.1 the reserves chaos

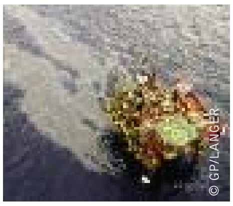
Public information about oil and gas reserves is strikingly inconsistent, and potentially unreliable for legal, commercial, historical and sometimes political reasons. The most widely available and quoted figures, those from the industry journals Oil and Gas Journal and World Oil, have limited value 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 represent 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 would require a regional assessment of the mean backdated (i.e. 'technical') discoveries.

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.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8.1.2 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.

The 'tar sands' are a heavy mixture of bitumen, water, sand and clay found beneath more than 54,000 square miles[45] of prime forest in northern Alberta, an area the size of England and Wales. Producing crude oil from this resource 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.

8.2 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 there is lower public concern about depletion than for 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.

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 ones have been almost constant since 1980 because discoveries have roughly matched production.

8.2.1 shale gas[46]

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.

Natural gas obtained from unconventional reserves (known as "shale gas" or "tight gas") requires the reservoir rock to be fractured using a process known as hydraulic fracturing or "fracking". Fracking is associated with a range of environmental impacts some of which are not fully documented or understood. In addition, it appears that the greenhouse gas "footprint" of shale gas production may be significantly greater than for conventional gas and is claimed to be even worse than for coal.

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. Even so, it is expected to increase.

Greenpeace is opposed to the exploitation of unconventional gas reserves and these resources are not needed to guarantee the needed gas supply under the Energy [R]evolution scenario.

8.3 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. 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.

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references

[45] THE INDEPENDENT, 10 DECEMBER 2007.

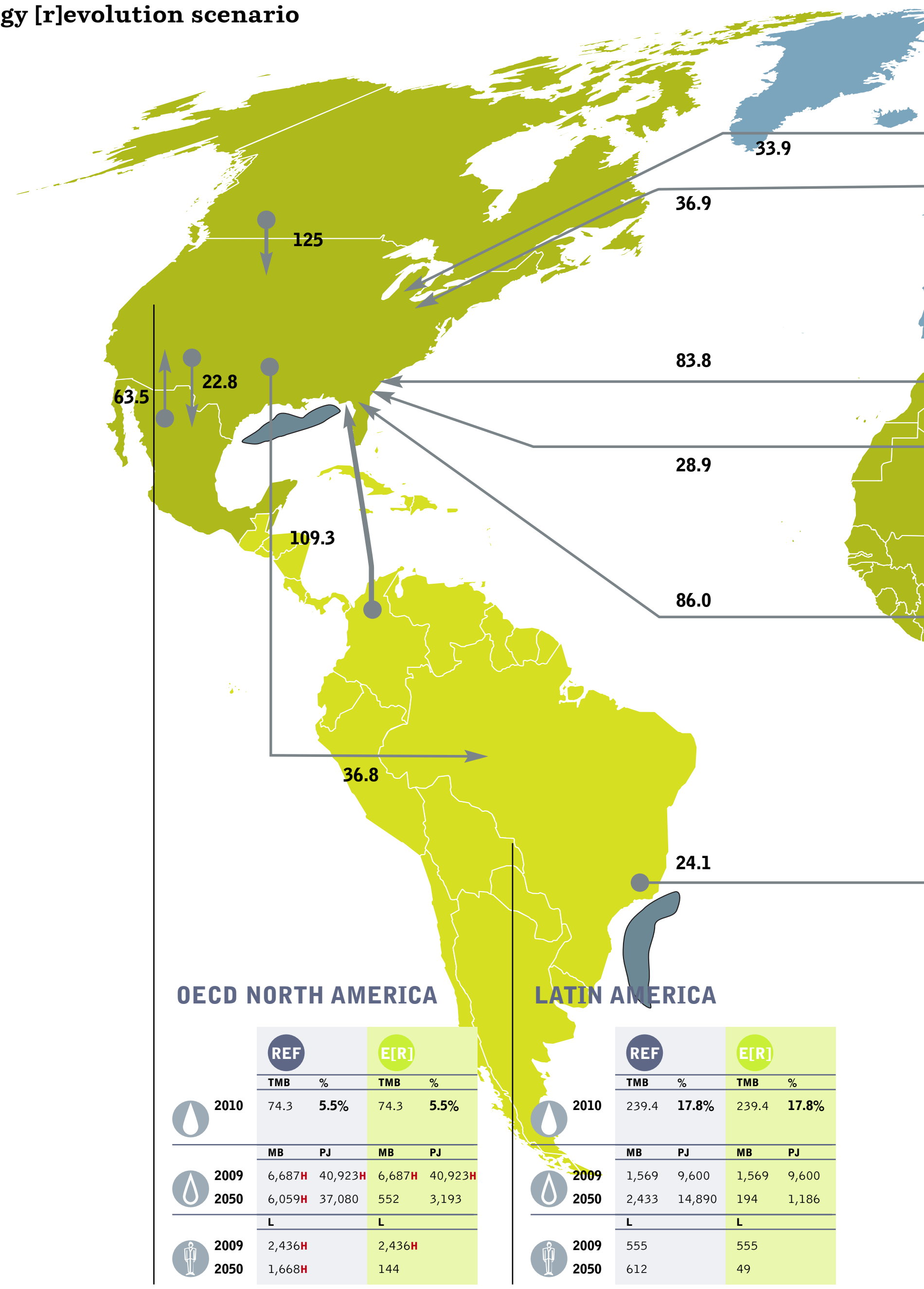
[46] INTERSTATE NATURAL GAS ASSOCIATION OF AMERICA (INGAA), "AVAILABILITY, ECONOMICS AND PRODUCTION POTENTIAL OF NORTH AMERICAN UNCONVENTIONAL NATURAL GAS SUPPLIES", NOVEMBER 2008.

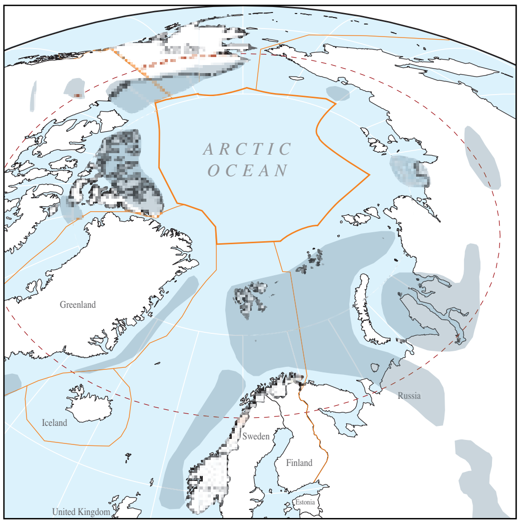
map 8.1: oil reference scenario and the energy [r]evolution scenario

WORLDWIDE SCENARIO

NON RENEWABLE RESOURCE

OIL





LEGEND - ARCTIC REGION

- POSSIBLE OIL & GAS EXPLORATION FIELDS
- 200 SEA MILE NATIONAL BOUNDARY

OECD NORTH AMERICA

		REF		E[R]	
		TMB	%	TMB	%
💧	2010	74.3	5.5%	74.3	5.5%
		MB	PJ	MB	PJ
💧	2009	6,687H	40,923H	6,687H	40,923H
	2050	6,059H	37,080	552	3,193
		L		L	
🧍	2009	2,436H		2,436H	
	2050	1,668H		144	

LATIN AMERICA

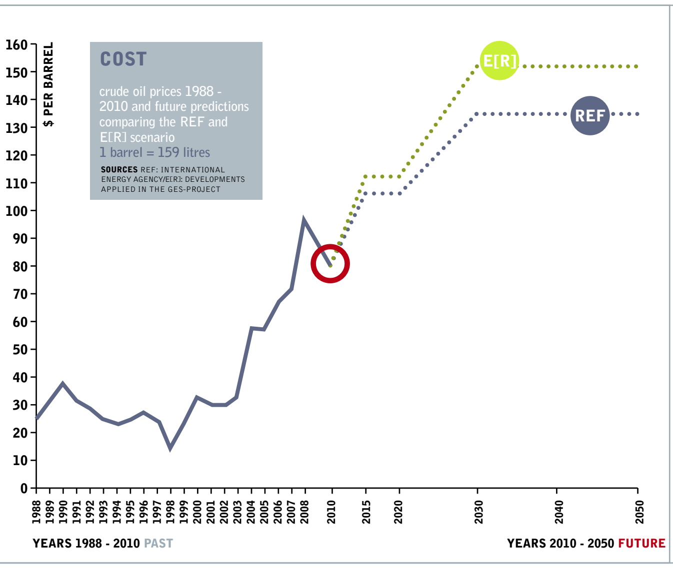
		REF		E[R]	
		TMB	%	TMB	%
💧	2010	239.4	17.8%	239.4	17.8%
		MB	PJ	MB	PJ
💧	2009	1,569	9,600	1,569	9,600
	2050	2,433	14,890	194	1,186
		L		L	
🧍	2009	555		555	
	2050	612		49	

LEGEND - WORLD MAP

- ● >60 ● 50-60 ● 40-50
- ● 30-40 ● 20-30 ● 10-20
- ● 5-10 ● 0-5 % RESOURCES GLOBALLY
- REF REFERENCE SCENARIO
- E[R] ENERGY [R]EVOLUTION SCENARIO
- POSSIBLE MAIN DEEP SEA OIL EXPLORATION FIELDS
- TRADE FLOWS (MILLION TONNES)
- **RESERVES TOTAL** THOUSAND MILLION BARRELS [TMB] | SHARE IN % OF GLOBAL TOTAL [END OF 2011]
- **CONSUMPTION PER REGION** MILLION BARRELS [MB] | PETA JOULE [PJ]
- **CONSUMPTION PER PERSON** LITERS [L]

0 1000 KM

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



COST

crude oil prices 1988 - 2010 and future predictions comparing the REF and E[R] scenario
1 barrel = 159 litres

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

OECD EUROPE

	REF		E[R]	
	TMB	%	TMB	%
2010	14.8	1.1%M	14.8	1.1%M
	MB	PJ	MB	PJ
2009	4,160	25,462	4,160	25,462
2050	3,621	22,163	497M	3,042M
	L		L	
2009	1,233		1,233	
2050	1,022M		140	

MIDDLE EAST

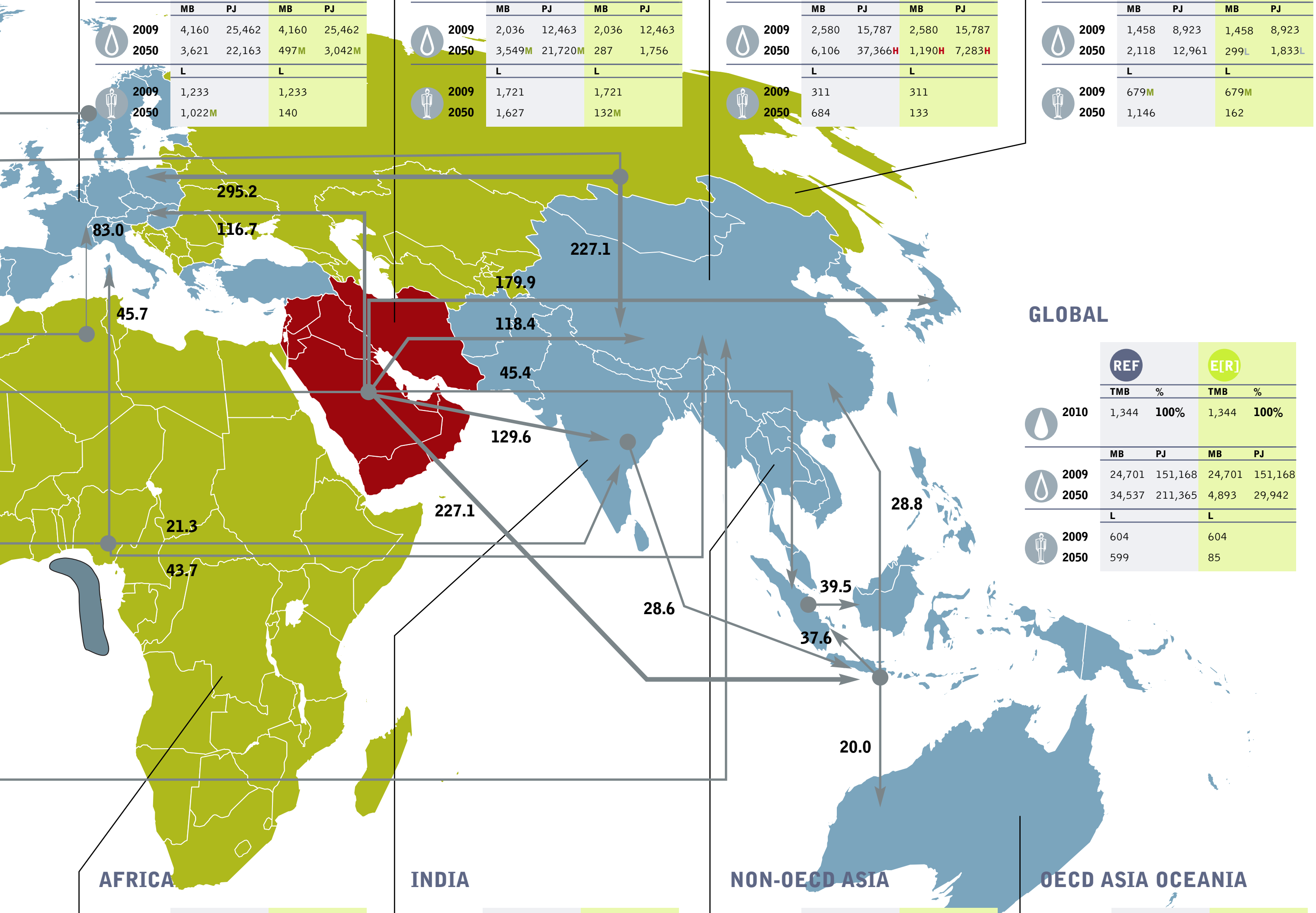
	REF		E[R]	
	TMB	%	TMB	%
2010	752.5H	56.0%H	752.5H	56.0%H
	MB	PJ	MB	PJ
2009	2,036	12,463	2,036	12,463
2050	3,549M	21,720M	287	1,756
	L		L	
2009	1,721		1,721	
2050	1,627		132M	

CHINA

	REF		E[R]	
	TMB	%	TMB	%
2010	14.8	1.1%	14.8	1.1%
	MB	PJ	MB	PJ
2009	2,580	15,787	2,580	15,787
2050	6,106	37,366H	1,190H	7,283H
	L		L	
2009	311		311	
2050	684		133	

EAST EUROPE/EURASIA

	REF		E[R]	
	TMB	%	TMB	%
2010	85.6	6.4%	85.6	6.4%
	MB	PJ	MB	PJ
2009	1,458	8,923	1,458	8,923
2050	2,118	12,961	299L	1,833L
	L		L	
2009	679M		679M	
2050	1,146		162	



GLOBAL

	REF		E[R]	
	TMB	%	TMB	%
2010	1,344	100%	1,344	100%
	MB	PJ	MB	PJ
2009	24,701	151,168	24,701	151,168
2050	34,537	211,365	4,893	29,942
	L		L	
2009	604		604	
2050	599		85	

AFRICA

	REF		E[R]	
	TMB	%	TMB	%
2010	132.1M	9.8%M	132.1M	9.8%M
	MB	PJ	MB	PJ
2009	1,039	6,359L	1,039	6,359
2050	1,640L	10,037L	555	3,398
	L		L	
2009	179		179	
2050	131L		44L	

INDIA

	REF		E[R]	
	TMB	%	TMB	%
2010	9.0	0.7%	9.0	0.7%
	MB	PJ	MB	PJ
2009	1,040L	6,366	1,040L	6,366L
2050	4,143	25,354	494	3,024
	L		L	
2009	146L		146L	
2050	397		47	

NON-OECD ASIA

	REF		E[R]	
	TMB	%	TMB	%
2010	16.0	1.2%	16.0	1.2%
	MB	PJ	MB	PJ
2009	1,738	10,634	1,738	10,634
2050	3,037	18,585	529	3,239
	L		L	
2009	283		283	
2050	321		56	

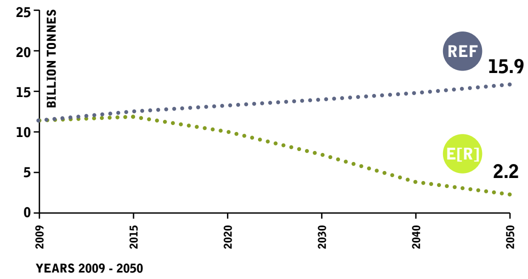
OECD ASIA OCEANIA

	REF		E[R]	
	TMB	%	TMB	%
2010	5.4L	0.4%L	5.4L	0.4%L
	MB	PJ	MB	PJ
2009	2,394M	14,651M	2,394	14,651
2050	1,832	11,209	325	1,990
	L		L	
2009	1,902		1,902	
2050	1,635		290H	

CO_2 EMISSIONS FROM OIL

comparison between the REF and E[R] scenario 2009 - 2050 billion tonnes

SOURCE GPI/EREC



RESERVES AND CONSUMPTION

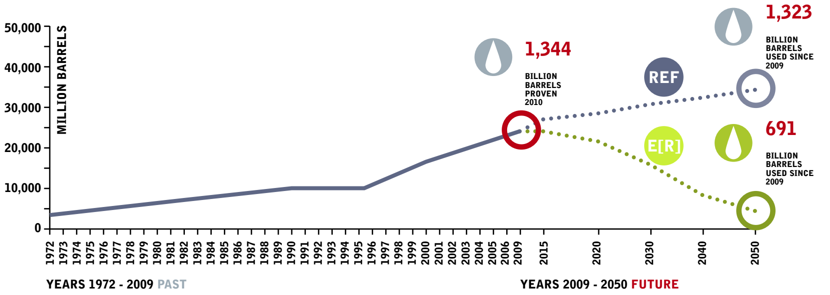
oil reserves versus global demand, production and consumption. global consumption comparison between the REF and E[R] scenario.

million barrels. 1 barrel = 159 litres

SOURCE BP 2011

REF global consumption

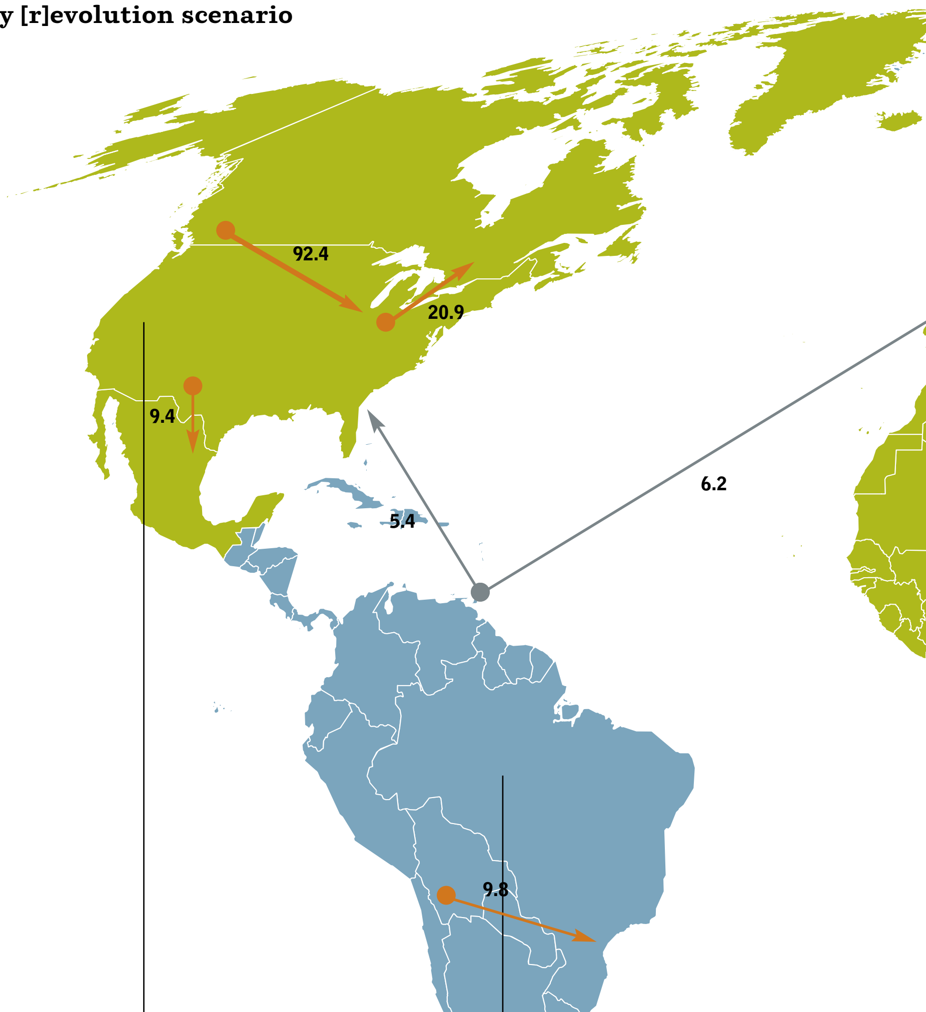
E[R] global consumption



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

map 8.2: gas reference scenario and the energy [r]evolution scenario

WORLDWIDE SCENARIO



OECD NORTH AMERICA

		REF		E[R]	
		tn m^3	%	tn m^3	%
	2010	9.9	**5.2%**	9.9	**5.2%**
		bn m^3	PJ	bn m^3	PJ
	2009	731**H**	27,790**H**	731**H**	27,790**H**
	2050	890**H**	33,814**H**	67	2,559
		m^3		m^3	
	2009	1,598		1,598	
	2050	1,496		113	

LATIN AMERICA

		REF		E[R]	
		tn m^3	%	tn m^3	%
	2010	7.4	**3.9%**	7.4	**3.9%**
		bn m^3	PJ	bn m^3	PJ
	2009	119	4,539	119	4,539
	2050	301	11,441	62	2,373
		m^3		m^3	
	2009	255		255	
	2050	499		104	

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] ENERGY [R]EVOLUTION SCENARIO

●→ **PIPELINE GAS TRADE FLOWS (BILLION CUBIC METRES)**

●→ **LNG TRADE FLOWS (BILLION CUBIC METRES)**

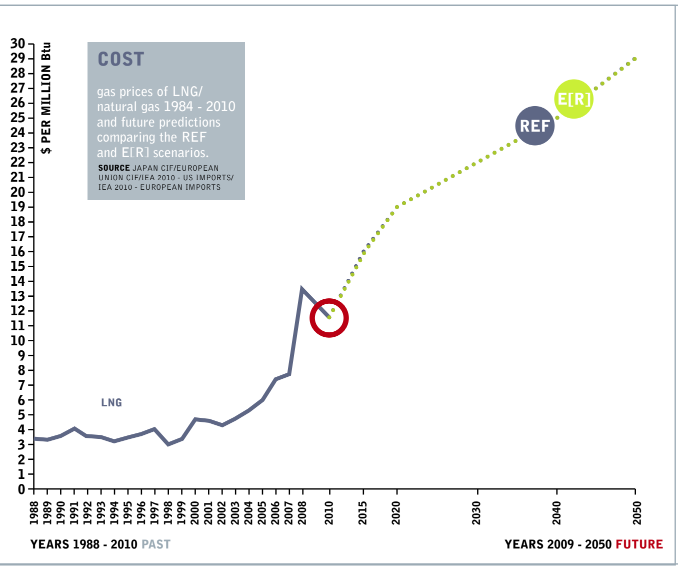
RESERVES TOTAL TRILLION CUBIC METRES [tn m^3] | SHARE IN % OF GLOBAL TOTAL [END OF 2011]

CONSUMPTION PER REGION BILLION CUBIC METRES [bn m^3] | PETA JOULE [PJ]

CONSUMPTION PER PERSON CUBIC METRES [m^3]

H HIGHEST | M MIDDLE | L LOWEST

0 1000 KM



COST

gas prices of LNG/ natural gas 1984 - 2010 and future predictions comparing the REF and E[R] scenarios.

SOURCE JAPAN CIF/EUROPEAN UNION CIF/IEA 2010 - US IMPORTS/ IEA 2010 - EUROPEAN IMPORTS

OECD EUROPE

	REF		E[R]	
	tn m^3	%	tn m^3	%
2010	13.6	**7.1%**	13.6	**7.1%**
	bn m^3	PJ	bn m^3	PJ
2009	480	18,249	480	18,249
2050	666	25,308	84	3,176
	m^3		m^3	
2009	865		865	
2050	1,110		139M	

MIDDLE EAST

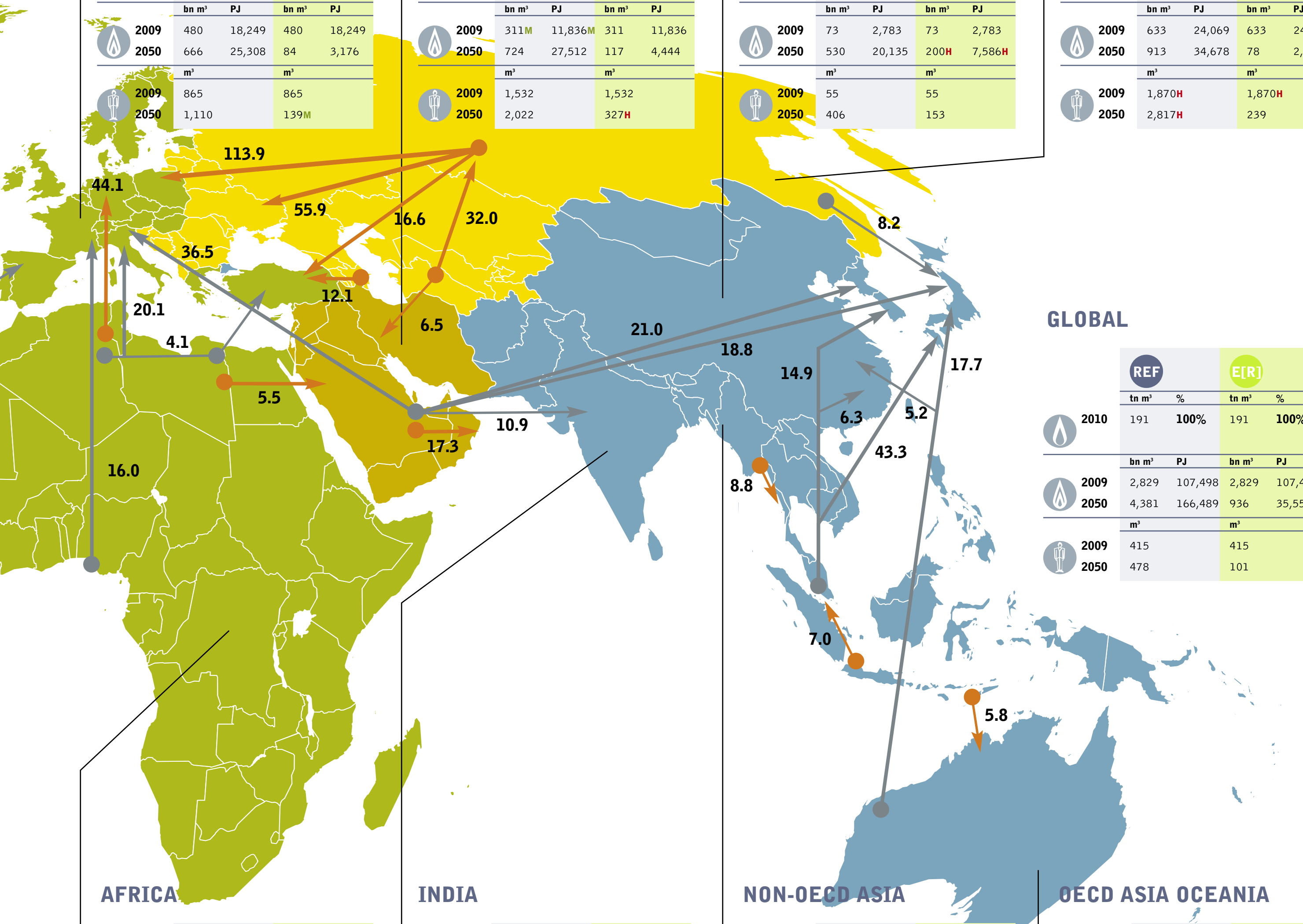
	REF		E[R]	
	tn m^3	%	tn m^3	%
2010	75.8H	**39.7%**H	75.8H	**39.7%**H
	bn m^3	PJ	bn m^3	PJ
2009	311M	11,836M	311	11,836
2050	724	27,512	117	4,444
	m^3		m^3	
2009	1,532		1,532	
2050	2,022		327H	

CHINA

	REF		E[R]	
	tn m^3	%	tn m^3	%
2010	2.8	**1.5%**	2.8	**1.5%**
	bn m^3	PJ	bn m^3	PJ
2009	73	2,783	73	2,783
2050	530	20,135	200H	7,586H
	m^3		m^3	
2009	55		55	
2050	406		153	

EAST EUROPE/EURASIA

	REF		E[R]	
	tn m^3	%	tn m^3	%
2010	53.3	**27.9%**	53.3	**27.9%**
	bn m^3	PJ	bn m^3	PJ
2009	633	24,069	633	24,069
2050	913	34,678	78	2,949
	m^3		m^3	
2009	1,870H		1,870H	
2050	2,817H		239	



GLOBAL

	REF		E[R]	
	tn m^3	%	tn m^3	%
2010	191	**100%**	191	**100%**
	bn m^3	PJ	bn m^3	PJ
2009	2,829	107,498	2,829	107,498
2050	4,381	166,489	936	35,557
	m^3		m^3	
2009	415		415	
2050	478		101	

AFRICA

	REF		E[R]	
	tn m^3	%	tn m^3	%
2010	14.7M	**7.7%**M	14.7M	**7.7%**M
	bn m^3	PJ	bn m^3	PJ
2009	91	3,452	91	3,452
2050	229	8,697	69	2,604
	m^3		m^3	
2009	91		91	
2050	104L		31L	

INDIA

	REF		E[R]	
	tn m^3	%	tn m^3	%
2010	1.5L	**0.8%**L	1.5L	**0.8%**L
	bn m^3	PJ	bn m^3	PJ
2009	53L	2,005L	53L	2,005L
2050	254	9,637	97M	3,700M
	m^3		m^3	
2009	44L		44L	
2050	150		58	

NON-OECD ASIA

	REF		E[R]	
	tn m^3	%	tn m^3	%
2010	8.7	**4.5%**	8.7	**4.5%**
	bn m^3	PJ	bn m^3	PJ
2009	178	6,757	178	6,757
2050	436M	16,561M	102	3,864
	m^3		m^3	
2009	170		170	
2050	302		70	

OECD ASIA OCEANIA

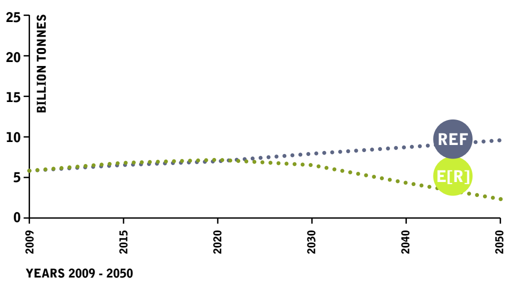
	REF		E[R]	
	tn m^3	%	tn m^3	%
2010	3.3	**1.7%**	3.3	**1.7%**
	bn m^3	PJ	bn m^3	PJ
2009	158	6,019	158	6,019
2050	211L	8,020L	61L	2,302L
	m^3		m^3	
2009	789M		789M	
2050	1,095M		314	

CO_2 EMISSIONS FROM GAS

comparison between the REF and E[R] scenario 2009 - 2050

billion tonnes

SOURCE GPI/EREC



RESERVES AND CONSUMPTION

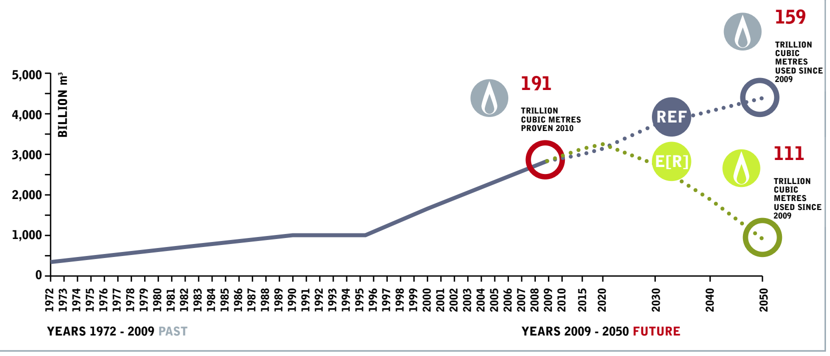
gas reserves versus global demand, production and consumption. global consumption comparison between the REF and E[R] scenario.

billion cubic metres

SOURCE 1970-2011 BP, 2009-2050 GPI/EREC

• • • • • • REF global consumption

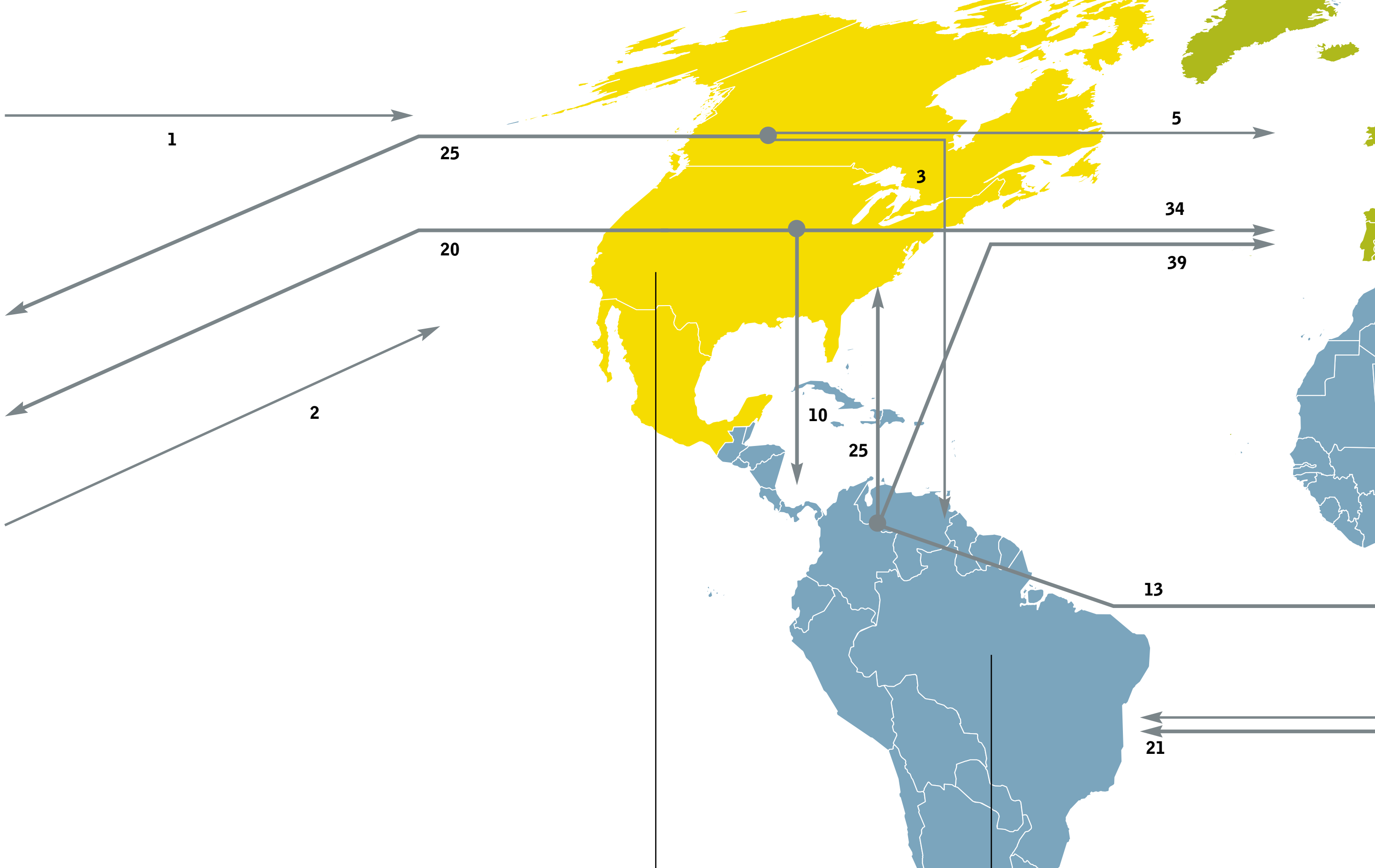
• • • • • • E[R] global consumption



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

map 8.3: coal reference scenario and the energy [r]evolution scenario

WORLDWIDE SCENARIO



NON RENEWABLE RESOURCE

COAL

OECD NORTH AMERICA

		REF		E[R]	
		mn t	%	mn t	%
RESERVES	2009	245,088 H	28.6% H	245,088 H	28.6% H
		mn t	PJ	mn t	PJ
CONSUMPTION	2009	1,701	21,335	1,701	21,335
	2050	1,145M	21,963	148	3,405
		t		t	
PER PERSON	2009	2.0		2.0	
	2050	1.6		0.2	

LATIN AMERICA

		REF		E[R]	
		mn t	%	mn t	%
RESERVES	2009	12,508	1.5%	12,508	1.5%
		mn t	PJ	mn t	PJ
CONSUMPTION	2009	37	737	37	737
	2050	80	1,741	38	873
		t		t	
PER PERSON	2009	0.1		0.1	
	2050	0.1		0.1M	

LEGEND

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

REF REFERENCE SCENARIO

E[R] ENERGY [R]EVOLUTION SCENARIO

0 1000 KM

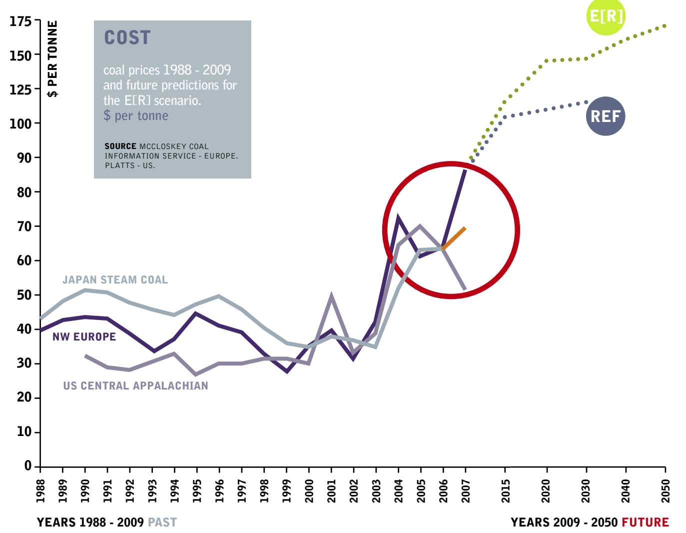
TRADE FLOWS (MILLION TONNES)

RESERVES TOTAL MILLION TONNES [mn t] | SHARE IN % OF GLOBAL TOTAL [END OF 2011]

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 - 2009 and future predictions for the E[R] scenario.
$ per tonne

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

OECD EUROPE

	REF		E[R]	
	mn t	%	mn t	%
2011	80,121 M	9.4%M	80,121	9.4%M
	mn t	PJ	mn t	PJ
2009	980	13,134M	980	13,134M
2050	630	9,417	38	874
	t		t	
2009	1.0		1.0	
2050	0.7		0.1M	

MIDDLE EAST

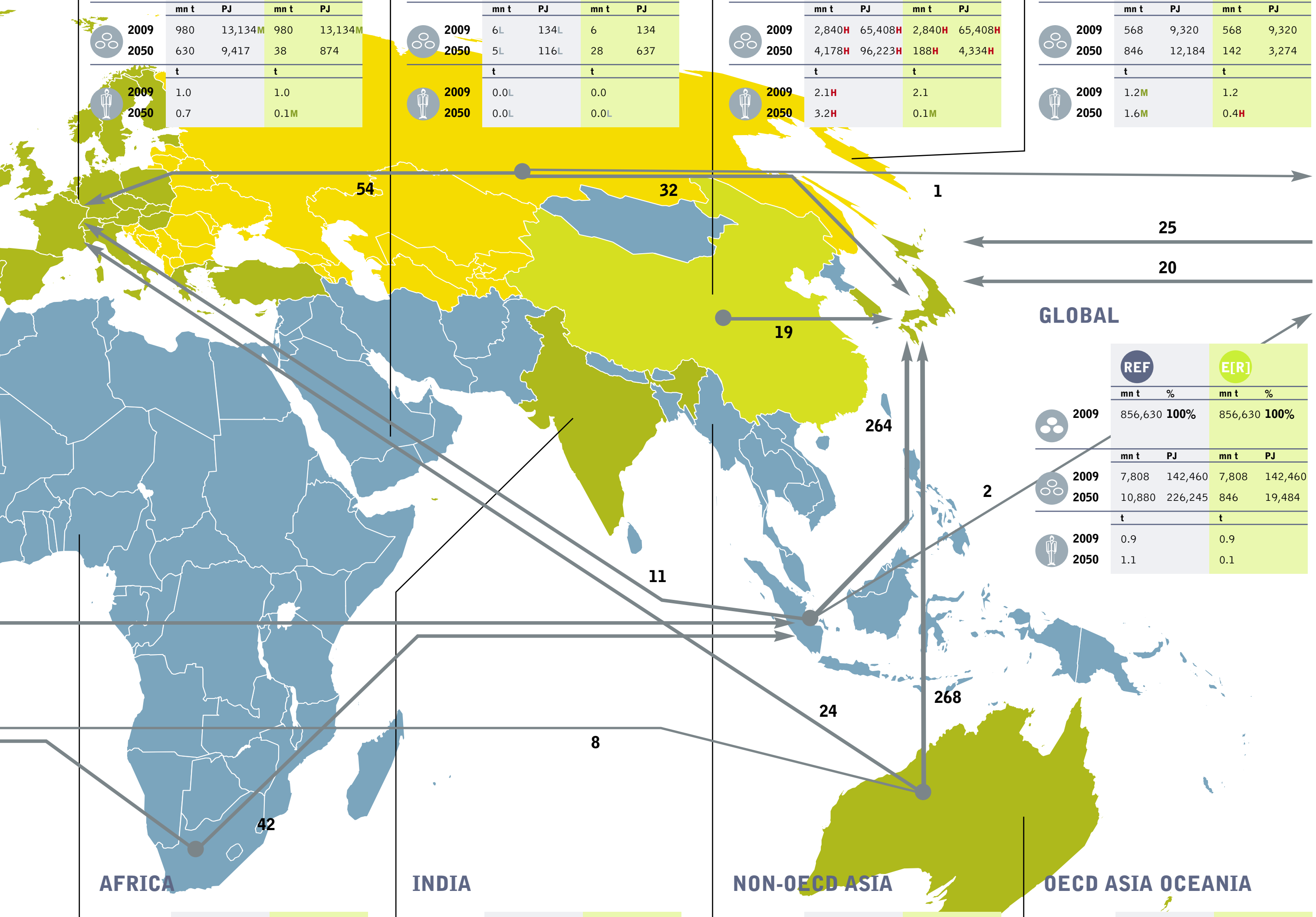
	REF		E[R]	
	mn t	%	mn t	%
2009	1,203L	0.1%L	1,203L	0.1%L
	mn t	PJ	mn t	PJ
2009	6L	134L	6	134
2050	5L	116L	28	637
	t		t	
2009	0.0L		0.0	
2050	0.0L		0.0L	

CHINA

	REF		E[R]	
	mn t	%	mn t	%
2009	114,500	13.4%	114,500	13.4%
	mn t	PJ	mn t	PJ
2009	2,840H	65,408H	2,840H	65,408H
2050	4,178H	96,223H	188H	4,334H
	t		t	
2009	2.1H		2.1	
2050	3.2H		0.1M	

EAST EUROPE/EURASIA

	REF		E[R]	
	mn t	%	mn t	%
2009	224,483	26.2%	224,483	26.2%
	mn t	PJ	mn t	PJ
2009	568	9,320	568	9,320
2050	846	12,184	142	3,274
	t		t	
2009	1.2M		1.2	
2050	1.6M		0.4H	



GLOBAL

	REF		E[R]	
	mn t	%	mn t	%
2009	856,630	100%	856,630	100%
	mn t	PJ	mn t	PJ
2009	7,808	142,460	7,808	142,460
2050	10,880	226,245	846	19,484
	t		t	
2009	0.9		0.9	
2050	1.1		0.1	

AFRICA

	REF		E[R]	
	mn t	%	mn t	%
2009	31,692	3.7%	31,692	3.7%
	mn t	PJ	mn t	PJ
2009	192	4,414	192	4,414
2050	586	13,493	40	921
	t		t	
2009	0.2		0.2	
2050	0.3		0.0L	

INDIA

	REF		E[R]	
	mn t	%	mn t	%
2009	60,600	7.1%M	60,600	7.1%M
	mn t	PJ	mn t	PJ
2009	593M	13,084	593M	13,084
2050	1,819	39,343	122M	2,803
	t		t	
2009	0.5		0.5	
2050	1.0M		0.1M	

NON-OECD ASIA

	REF		E[R]	
	mn t	%	mn t	%
2009	8,988	1.0%	8,988	1.0%
	mn t	PJ	mn t	PJ
2009	374	5,658	374	5,658
2050	1,199	23,445M	76	1,754M
	t		t	
2009	0.2		0.2	
2050	0.7		0.1M	

OECD ASIA OCEANIA

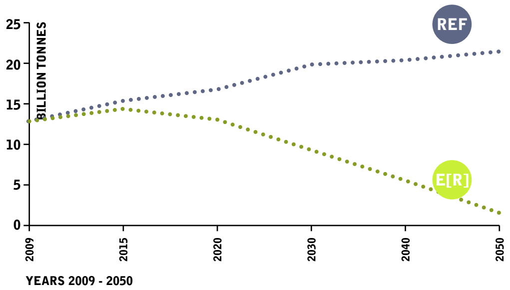
	REF		E[R]	
	mn t	%	mn t	%
2009	77,447	9%	77,447	9%
	mn t	PJ	mn t	PJ
2009	517	9,236	517	9,236
2050	392	8,319	26L	607L
	t		t	
2009	2.0		2.0	
2050	1.9		0.1M	

CO2 EMISSIONS FROM COAL

comparison between the REF and E[R] scenarios 2009 - 2050

billion tonnes

SOURCE GPI/EREC

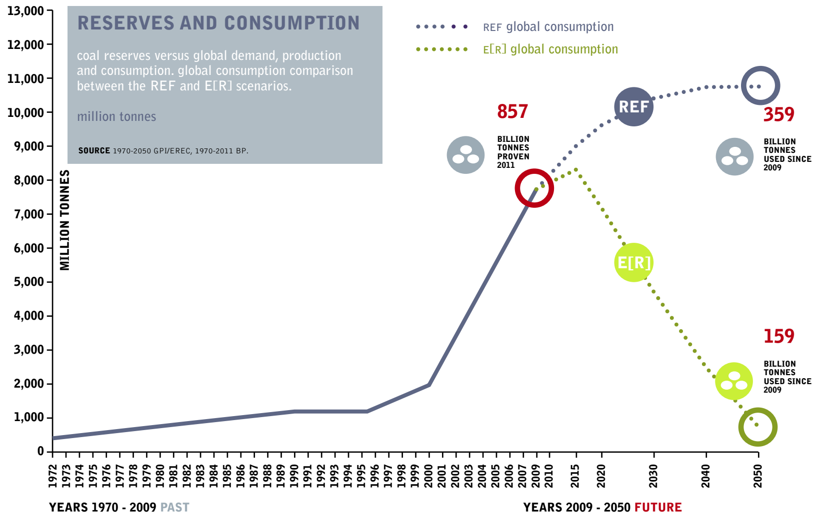


RESERVES AND CONSUMPTION

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

million tonnes

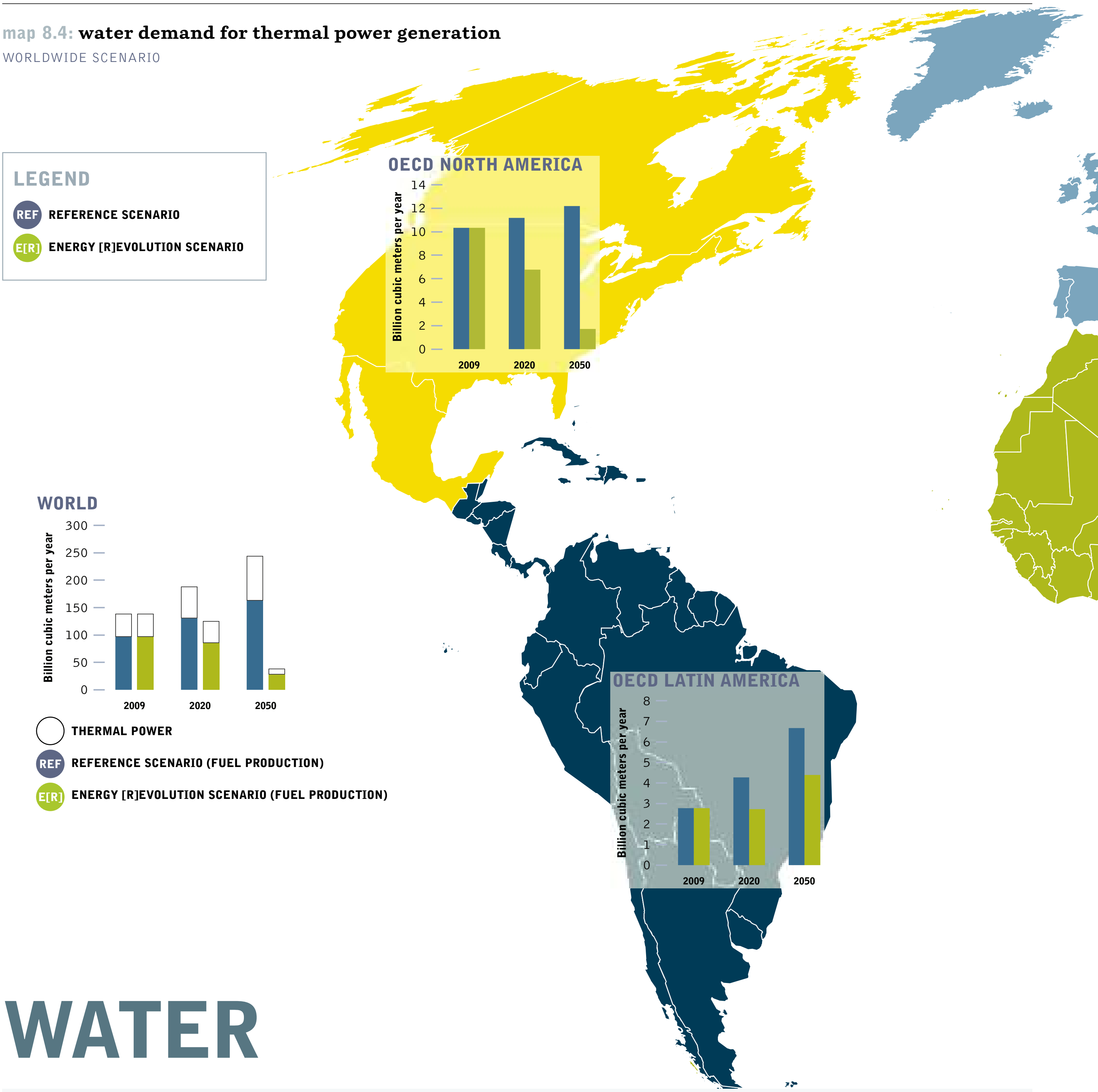
SOURCE 1970-2050 GPI/EREC, 1970-2011 BP.



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

map 8.4: **water demand for thermal power generation**

WORLDWIDE SCENARIO



WATER

The Energy [R]evolution is the first global energy scenario to quantify the water needs of different energy pathways. The water footprint of thermal power generation and fuel production is estimated by taking the production levels in each scenario and multiplying by technology-specific water consumption factors. Water consumption factors for power generation technologies are taken from U.S. Department of Energy and University of Texas and adjusted for projected region-specific thermal efficiencies of different operating power plant types.[i] Water footprints of coal, oil and gas extraction are based on data from Wuppertal Institute, complemented by estimates of water footprint of unconventional fossil fuels as well as first and second generation transport biofuels.[ii] As a detailed regional breakdown of fuel production by region is not available for the reference scenario, the water footprint of fuel production is only estimated on the global level.

Benefits of the Energy [R]evolution for water:

- Electric technologies with low to no water requirements – energy efficiency, wind and solar PV – substituted for thermal power generation with high water impacts.
- Reduced water use and contamination from fossil fuel production: no need for unconventional fossil fuels; lowered consumption of conventional coal and oil.
- Bioenergy is based on waste-derived biomass and cellulosic biomass requiring no irrigation (no food for fuel). As a result, water intensity of biomass use is a fraction of that in IEA scenarios.
- Energy efficiency programmes reduce water consumption in buildings and industry.

- Rapid CO_2 emission reductions protect water resources from catastrophic climate change.

Global water consumption for power generation and fuel production has almost doubled in the past two decades, and the trend is projected to continue. The OECD predicts that in a business-as-usual scenario, the power sector would consume 25% of the world's water in 2050 and be responsible for more than half of additional demand.[iii] The Energy [R]evolution pathway would halt the rise in water demand for energy, mitigating the pressures and conflicts on the world's already stressed water resources. Approximately 90 billion cubic meters of water would be saved in fuel production and thermal power generation by 2030, enough to satisfy the water needs of 1.3 billion urban dwellers, or to irrigate enough fields to produce 50 million tonnes of grain, equal to the average direct consumption of 300-500 million people.[iv]

references (water scenario)

i NATIONAL ENERGY TECHNOLOGY LABORATORY 2009: WATER REQUIREMENTS FOR EXISTING AND EMERGING THERMOELECTRIC PLANT TECHNOLOGIES. US DEPARTMENT OF ENERGY. AUGUST 2008 (APRIL 2009 REVISION); U.S. DEPARTMENT OF ENERGY 2006: ENERGY DEMANDS ON WATER RESOURCES. REPORT TO CONGRESS ON THE INTERDEPENDENCY OF ENERGY AND WATER. UNIVERSITY OF TEXAS & ENVIRONMENTAL DEFENSE FUND 2009: ENERGY-WATER NEXUS IN TEXAS.

ii WUPPERTAL INSTITUT: MATERIAL INTENSITY OF MATERIALS, FUELS, TRANSPORT SERVICES, FOOD. HTTP://WWW.WUPPERINST.ORG/UPLOADS/TX_WIBEITRAG/MIT_2011.PDF; WORLD ECONOMIC FORUM 2009: ENERGY VISION UPDATE 2009. THIRSTY ENERGY; HARTO ET AL: LIFE CYCLE WATER CONSUMPTION OF ALTERNATIVE, LOW-CARBON TRANSPORTATION ENERGY SOURCES. FUNDED BY ARIZONA WATER INSTITUTE.

iii OECD ENVIRONMENTAL OUTLOOK TO 2050: THE CONSEQUENCES OF INACTION. HTTP://WWW.OECD.ORG/DOCUMENT/11/0,3746,EN_2649_37465_49036555_1_1_1_37465,00.HTML

iv USING TYPICAL URBAN RESIDENTIAL WATER CONSUMPTION OF 200 LITERS/PERSON/DAY. AVERAGE GRAIN CONSUMPTION RANGES FROM 8 KG/PERSON/MONTH (US) TO 14 (INDIA).

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

table 8.3: assumptions on fossil fuel use in the global energy [r]evolution scenario

FOSSIL FUEL	2009	2015	2020	2030	2040	2050
Oil						
Reference (PJ/a)	151,168	167,159	173,236	185,993	197,522	211,365
Reference (million barrels/a)	24,701	27,314	28,306	30,391	32,275	34,537
E[R] (PJ/a)	151,168	151,996	133,712	95,169	53,030	29,942
E[R] (million barrels/a)	24,701	24,836	21,848	15,550	8,665	4,893
Gas						
Reference (PJ/a)	107,498	121,067	131,682	155,412	179,878	195,804
Reference (billion cubic metres = 10E9m/a)	2,829	3,186	3,465	4,090	4,734	5,153
E[R] (PJ/a)	107,498	120,861	124,069	106,228	73,452	35,557
E[R] (billion cubic metres = 10E9m/a)	2,829	3,181	3,265	2,795	1,933	936
Coal						
Reference (PJ/a)	142,460	169,330	186,742	209,195	224,487	226,245
Reference (million tonnes)	7,808	8,957	9,633	10,349	10,879	10,880
E[R] (PJ/a)	142,460	154,932	142,833	105,219	58,732	19,484
E[R] (million tonnes)	7,808	8,197	7,119	4,707	2,556	846

8.4 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. However, these will soon be used up. 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[47] 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.

---

reference

[47] 'URANIUM 2003: RESOURCES, PRODUCTION AND DEMAND'.

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


© PAUL LANGROCK/ZENIT/GP

8.5 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.

box 8.1: definition of types of energy resource potential[48]

Theoretical potential 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.

On average, the energy in the sunshine that reaches the earth is about one kilowatt per square metre worldwide. According to the IPCC Special Report Renewables (SRREN)[49] solar power is a renewable energy source gushing out at 7,900 times more than the energy currently needed in the world. In one day, the sunlight which reaches the earth produces enough energy to satisfy the world's current energy requirements for twenty years, even before other renewable energy sources such as wind and ocean energy are taken into account. Even though only a percentage of that potential is technically accessible, this is still enough to provide up to ten times more energy than the world currently requires.

Before looking at the part renewable energies can play in the range of scenarios in this report, it is worth understanding the upper limits of their regional potential and by when this potential can be exploited.

The overall technical potential of renewable energy is huge and several times higher than current total energy demand. Technical potential is defined as the amount of renewable energy output obtainable by full implementation of demonstrated technologies or practices that are likely to develop. It takes into account the primary resources, the socio-geographical constraints and the technical losses in the conversion process. Calculating renewable energy potentials is highly complex because these technologies are comparatively young and their exploitation involves changes to the way in which energy is both generated and distributed. The technical potential is dependent on a number of uncertainties, e.g. a technology breakthrough, for example, could have a dramatic impact, changing the technical potential assessment within a very short time frame. Further, because of the speed of technology change, many existing studies are based on out of date information. More recent data, e.g. significantly increased average wind turbine capacity and output, would increase the technical potentials still further.

table 8.4: renewable energy theoretical potential

RE	ANNUAL FLUX (EJ/a)	RATIO (ANNUAL ENERGY FLUX/ 2008 PRIMARY ENERGY SUPPLY)	TOTAL RESERVE
Bioenergy	1,548	3.1	-
Solar energy	3,900,000	7,900	-
Geothermal energy	1,400	2.8	-
Hydro power	147	0.3	-
Ocean energy	7,400	15	-
Wind energy	6,000	12	-

---

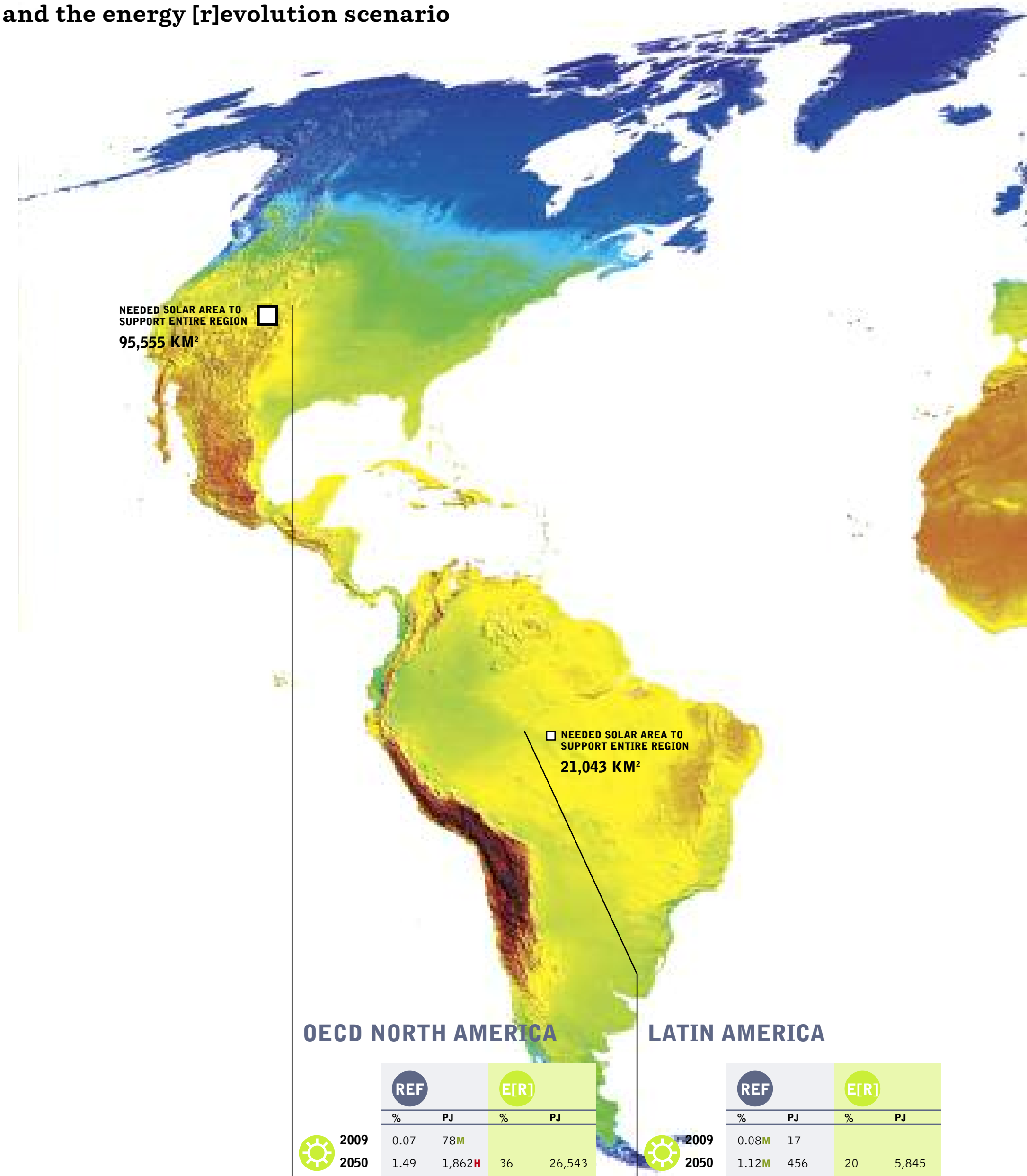
references

[48] WBGU (GERMAN ADVISORY COUNCIL ON GLOBAL CHANGE).

[49] IPCC, 2011: IPCC SPECIAL REPORT ON RENEWABLE ENERGY SOURCES AND CLIMATE CHANGE MITIGATION. PREPARED BY WORKING GROUP III OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE [O. EDENHOFER, R. PICHS-MADRUGA, Y. SOKONA, K. SEYBOTH, P. MATSCHOSS, S. KADNER, T. ZWICKEL, P. EICKEMEIER, G. HANSEN, S. SCHLÖMER, C. VON STECHOW (EDS)]. CAMBRIDGE UNIVERSITY PRESS, CAMBRIDGE, UNITED KINGDOM AND NEW YORK, NY, USA, 1075 PP.

map 8.5: solar reference scenario and the energy [r]evolution scenario

WORLDWIDE SCENARIO



NEEDED SOLAR AREA TO SUPPORT ENTIRE REGION ☐
95,555 KM²

☐ NEEDED SOLAR AREA TO SUPPORT ENTIRE REGION
21,043 KM²

OECD NORTH AMERICA

		REF		E[R]	
		%	PJ	%	PJ
☼	2009	0.07	78M		
	2050	1.49	1,862H	36	26,543
			kWh		kWh
🚶	2009		48		
	2050		896H		12,395H

LATIN AMERICA

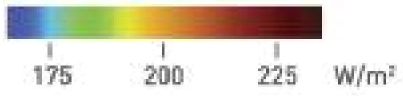
		REF		E[R]	
		%	PJ	%	PJ
☼	2009	0.08M	17		
	2050	1.12M	456	20	5,845
			kWh		kWh
🚶	2009		10		
	2050		211		2,691

RENEWABLE RESOURCE

SOLAR

LEGEND

Global Horizontal Irradiance



REF **REFERENCE SCENARIO**

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

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

🚶 **PRODUCTION PER PERSON** KILOWATT HOUR [kWh]

H HIGHEST | M MIDDLE | L LOWEST

0 1000 KM

OECD EUROPE

	REF		E[R]	
	%	PJ	%	PJ
2009	0.15M	115		
2050	1.84H	1,495	25	11,649
		kWh		kWh
2009		59M		
2050		722		5,395M

MIDDLE EAST

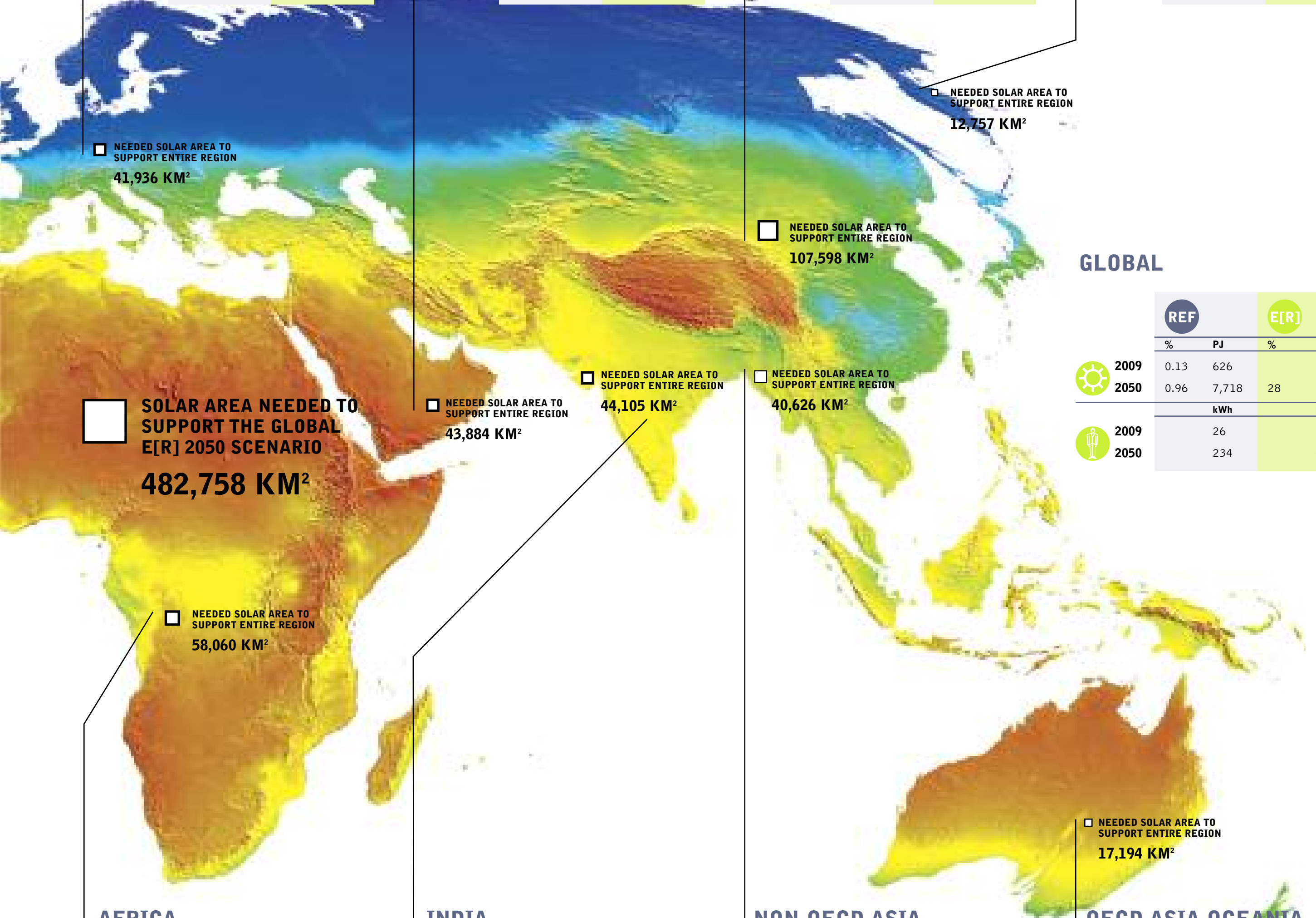
	REF		E[R]	
	%	PJ	%	PJ
2009	0.02	5		
2050	0.75	378	44H	12,190
		kWh		kWh
2009		7		
2050		297M		9,458

CHINA

	REF		E[R]	
	%	PJ	%	PJ
2009	0.31H	302H		
2050	0.72	1,305	29M	29,888H
		kWh		kWh
2009		63		
2050		254		6,362

EAST EUROPE/EURASIA

	REF		E[R]	
	%	PJ	%	PJ
2009	0.01L	3L		
2050	0.09L	64L	9L	3,544L
		kWh		kWh
2009		2		
2050		57		3,038



GLOBAL

	REF		E[R]	
	%	PJ	%	PJ
2009	0.13	626		
2050	0.96	7,718	28	134,099
		kWh		kWh
2009		26		
2050		234		4,062

AFRICA

	REF		E[R]	
	%	PJ	%	PJ
2009	0.01L	3L		
2050	1.26	707M	37	16,128
		kWh		kWh
2009		1L		
2050		98		2,044

INDIA

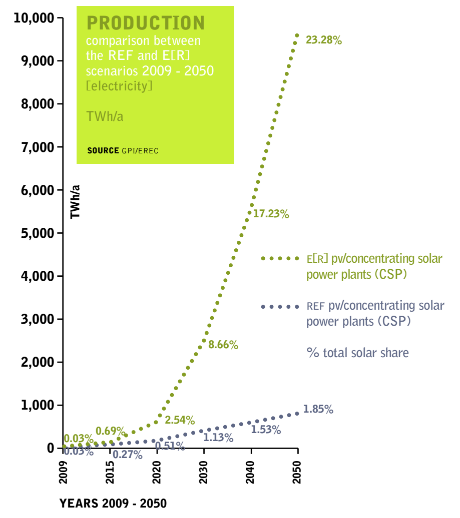
	REF		E[R]	
	%	PJ	%	PJ
2009	0.02	6		
2050	0.23	182	25	12,252M
		kWh		kWh
2009		1L		
2050		31L		2,011L

NON-OECD ASIA

	REF		E[R]	
	%	PJ	%	PJ
2009	0.02	5		
2050	0.42	309	24	11,285
		kWh		kWh
2009		1L		
2050		57		2,169

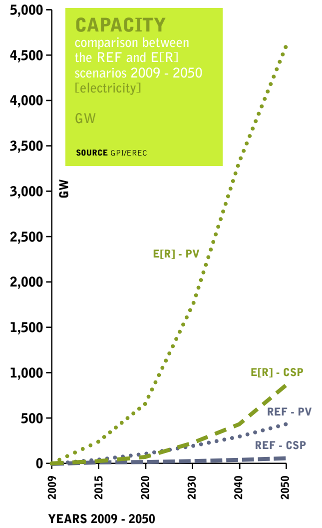
OECD ASIA OCEANIA

	REF		E[R]	
	%	PJ	%	PJ
2009	0.24	87		
2050	1.54	579	21	4,776
		kWh		kWh
2009		120H		
2050		894		6,885


PRODUCTION comparison between the REF and E[R] scenarios 2009 - 2050 [electricity]

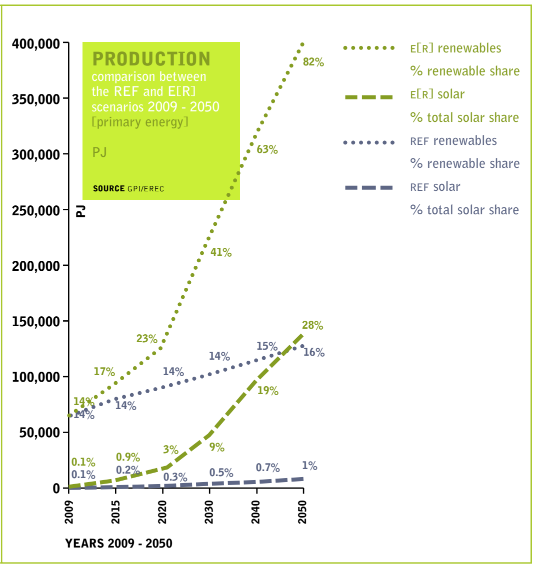
TWh/a

SOURCE GPI/EREC


CAPACITY comparison between the REF and E[R] scenarios 2009 - 2050 [electricity]

GW

SOURCE GPI/EREC


PRODUCTION comparison between the REF and E[R] scenarios 2009 - 2050 [primary energy]

PJ

SOURCE GPI/EREC

GREENPEACE
DESIGN WWW.ONEHEMISPHERE.SE **CONCEPT** SVEN TESKE/GREENPEACE INTERNATIONAL.
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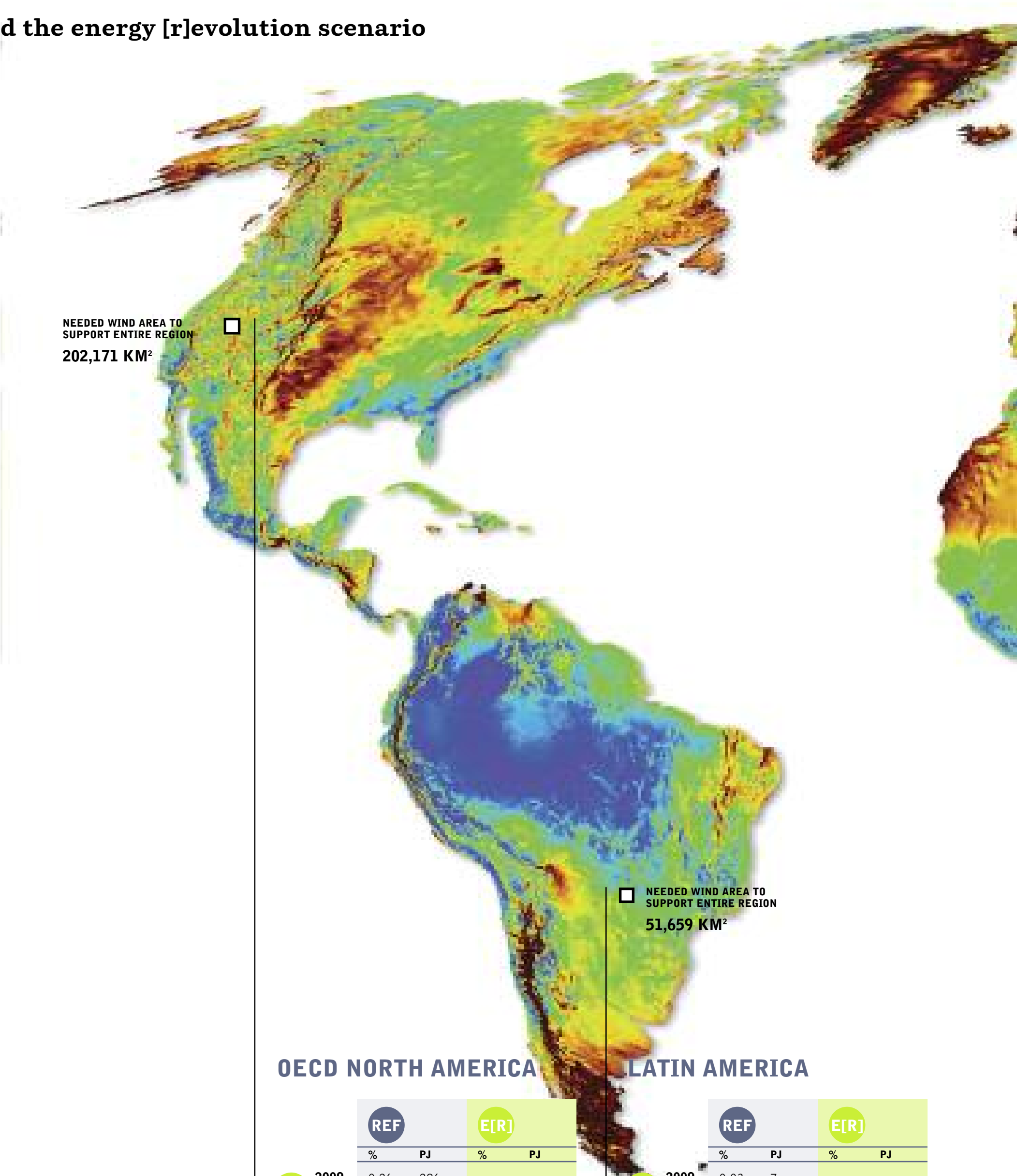
map 8.6: **wind reference scenario and the energy [r]evolution scenario**

WORLDWIDE SCENARIO



NEEDED WIND AREA TO SUPPORT ENTIRE REGION
202,171 KM²

NEEDED WIND AREA TO SUPPORT ENTIRE REGION
51,659 KM²

OECD NORTH AMERICA

		REF %	REF PJ	E[R] %	E[R] PJ
PRODUCTION PER REGION	**2009**	0.26	286		
	2050	1.72	2,157	12	9,001
			kWh		**kWh**
PRODUCTION PER PERSON	**2009**		177		
	2050		1,038		4,203

LATIN AMERICA

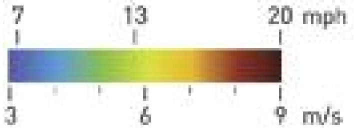
		REF %	REF PJ	E[R] %	E[R] PJ
PRODUCTION PER REGION	**2009**	0.03	7		
	2050	0.65	266	9	2,683
			kWh		**kWh**
PRODUCTION PER PERSON	**2009**		4		
	2050		123		1,235

RENEWABLE RESOURCE

WIND

LEGEND

5km wind map - Mean wind speed at 80m



REF **REFERENCE SCENARIO**

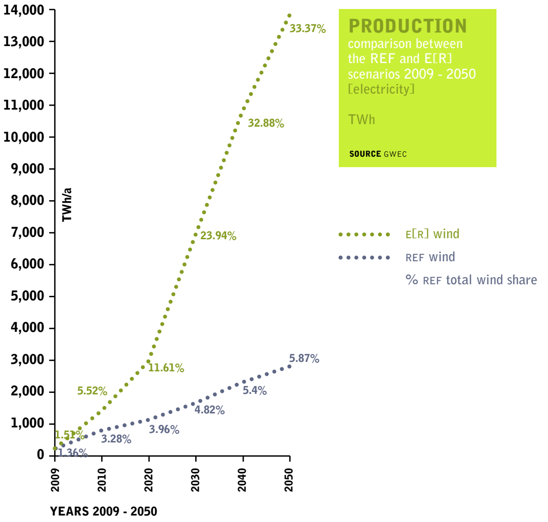
E[R] **ENERGY [R]EVOLUTION SCENARIO**

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

PRODUCTION PER PERSON KILOWATT HOUR [kWh]

H HIGHEST | M MIDDLE | L LOWEST

0 1000 KM



PRODUCTION
comparison between the REF and E[R] scenarios 2009 - 2050 [electricity]

TWh

SOURCE GWEC

OECD EUROPE

	REF %	REF PJ	E[R] %	E[R] PJ
2009	0.65H	485H		
2050	3.57H	2,894H	12	5,347
		kWh		kWh
2009		250H		
2050		1,399H		2,476

MIDDLE EAST

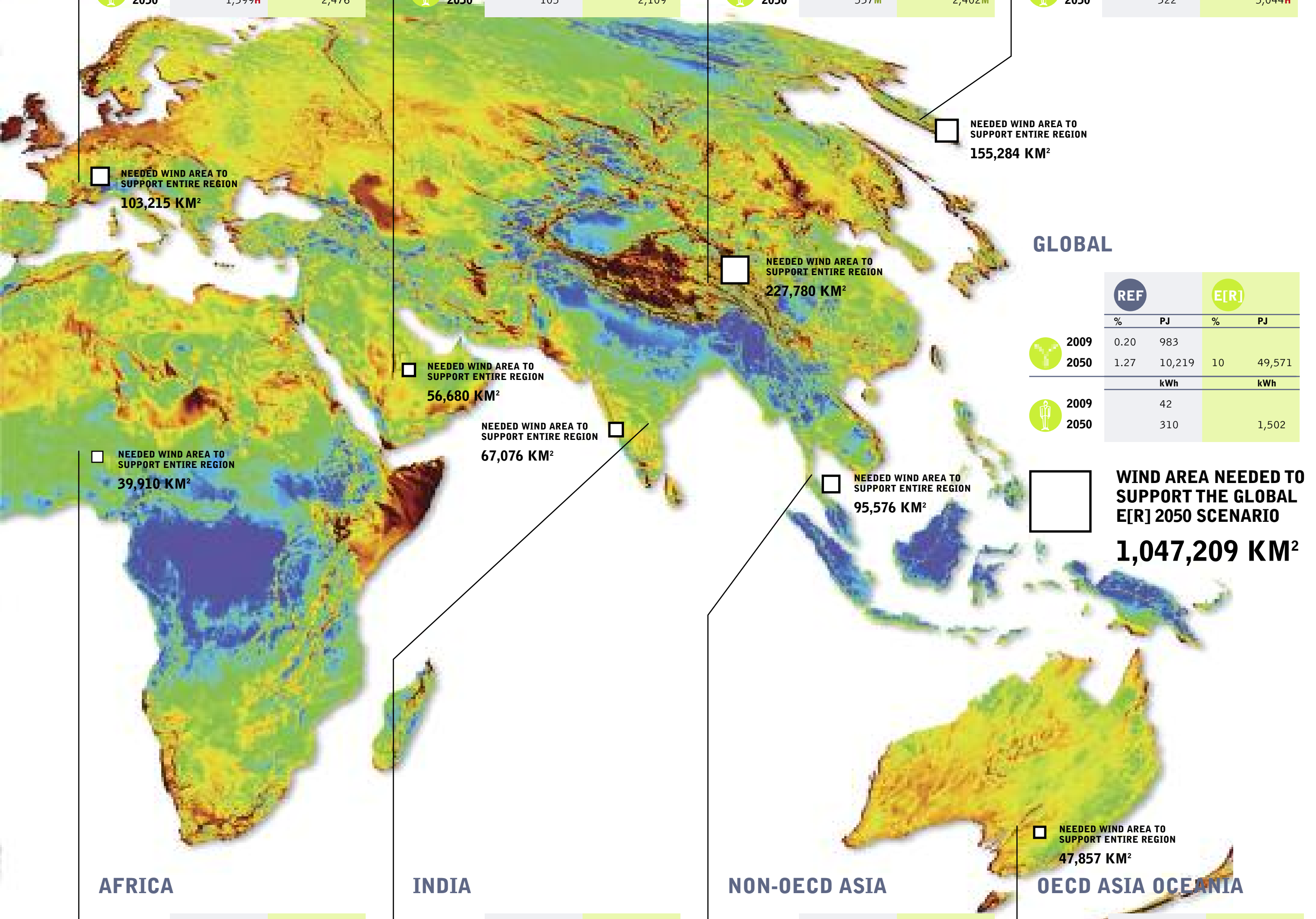
	REF %	REF PJ	E[R] %	E[R] PJ
2009	0.00L	1L		
2050	0.26L	133L	10M	2,718
		kWh		kWh
2009		1L		
2050		105		2,109

CHINA

	REF %	REF PJ	E[R] %	E[R] PJ
2009	0.10M	97M		
2050	1.52	2,756	11	11,284H
		kWh		kWh
2009		20		
2050		537M		2,402M

EAST EUROPE/EURASIA

	REF %	REF PJ	E[R] %	E[R] PJ
2009	0.00	2		
2050	0.52	360	16H	5,884
		kWh		kWh
2009		2		
2050		322		5,044H



NEEDED WIND AREA TO SUPPORT ENTIRE REGION
103,215 KM²

NEEDED WIND AREA TO SUPPORT ENTIRE REGION
56,680 KM²

NEEDED WIND AREA TO SUPPORT ENTIRE REGION
227,780 KM²

NEEDED WIND AREA TO SUPPORT ENTIRE REGION
155,284 KM²

NEEDED WIND AREA TO SUPPORT ENTIRE REGION
39,910 KM²

NEEDED WIND AREA TO SUPPORT ENTIRE REGION
67,076 KM²

NEEDED WIND AREA TO SUPPORT ENTIRE REGION
95,576 KM²

NEEDED WIND AREA TO SUPPORT ENTIRE REGION
47,857 KM²

GLOBAL

	REF %	REF PJ	E[R] %	E[R] PJ
2009	0.20	983		
2050	1.27	10,219	10	49,571
		kWh		kWh
2009		42		
2050		310		1,502

WIND AREA NEEDED TO SUPPORT THE GLOBAL E[R] 2050 SCENARIO

1,047,209 KM²

AFRICA

	REF %	REF PJ	E[R] %	E[R] PJ
2009	0.02	6		
2050	0.32	181	5L	2,207L
		kWh		kWh
2009		2		
2050		25L		280L

INDIA

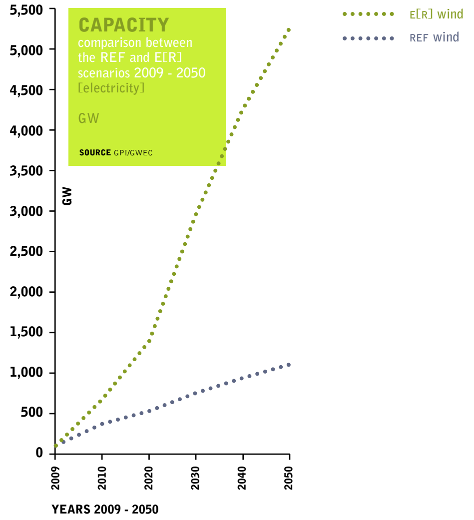
	REF %	REF PJ	E[R] %	E[R] PJ
2009	0.22	65		
2050	0.55	493	7	3,300
		kWh		kWh
2009		15		
2050		85		542

NON-OECD ASIA

	REF %	REF PJ	E[R] %	E[R] PJ
2009	0.01	3		
2050	0.79	583M	10M	4,590M
		kWh		kWh
2009		1L		
2050		107		882

OECD ASIA OCEANIA

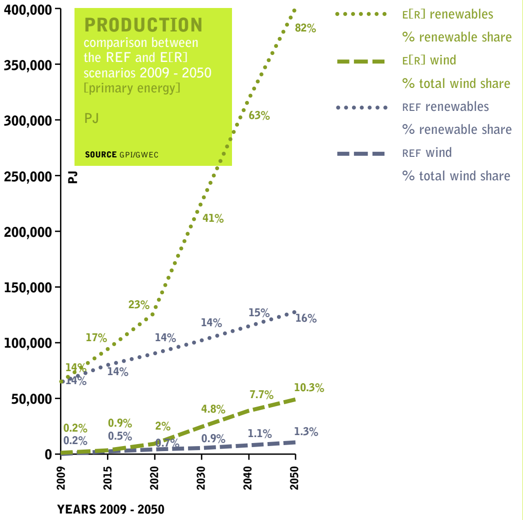
	REF %	REF PJ	E[R] %	E[R] PJ
2009	0.09	32		
2050	1.06M	396	11	2,556
		kWh		kWh
2009		45M		
2050		612		3,686



CAPACITY
comparison between the REF and E[R] scenarios 2009 - 2050 [electricity]

GW

SOURCE GPI/GWEC



PRODUCTION
comparison between the REF and E[R] scenarios 2009 - 2050 [primary energy]

PJ

SOURCE GPI/GWEC

DESIGN WWW.ONEHEMISPHERE.SE **CONCEPT** SVEN TESKE/GREENPEACE INTERNATIONAL.
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A wide range of estimates is provided in the literature but studies have consistently found that the total global technical potential for renewable energy is substantially higher than both current and projected future global energy demand. Solar has the highest technical potential amongst the renewable sources, but substantial technical potential exists for all forms. (SRREN, May 2011)

Taking into account the uncertainty of technical potential estimates, Figure 8.1 provides an overview of the technical potential of various renewable energy resources in the context of current global electricity and heat demand as well as global primary energy supply. Issues related to technology evolution, sustainability, resource availability, land use and other factors that relate to this technical potential are explored in the relevant chapters. The regional distribution of technical potential is addressed in map 8.7.

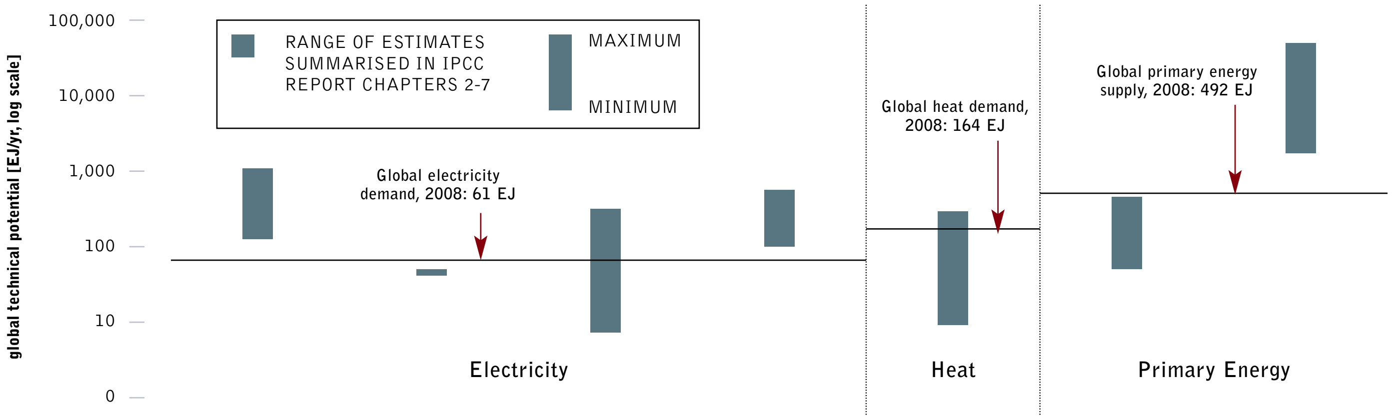
The various types of energy cannot necessarily be added together to estimate a total, because each type was estimated independently of the others (for example, the assessment did not take into account land use allocation; e.g. PV and concentrating solar power cannot occupy the same space even though a particular site is suitable for either of them).

Given the large unexploited resources which exist, even without having reached the full development limits of the various technologies, the technical potential is not a limiting factor to expansion of renewable energy generation. It will not be necessary nor desirable to exploit the entire technical potential.

Implementation of renewable energies must respect sustainability criteria in order to achieve a sound future energy supply. Public acceptance is crucial, especially bearing in mind that renewable energy technologies will be closer to consumers than today's more centralised power plants. Without public acceptance, market expansion will be difficult or even impossible.

In addition to the theoretical and technical potential discussions, this report also considers the economic potential of renewable energy sources that takes into account all social costs and assumes perfect information and the market potential of renewable energy sources. Market potential 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 existing and expected real-world market conditions shaped by policies, availability of capital and other factors. 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.

figure 8.1: ranges of global technical potentials of renewable energy sources

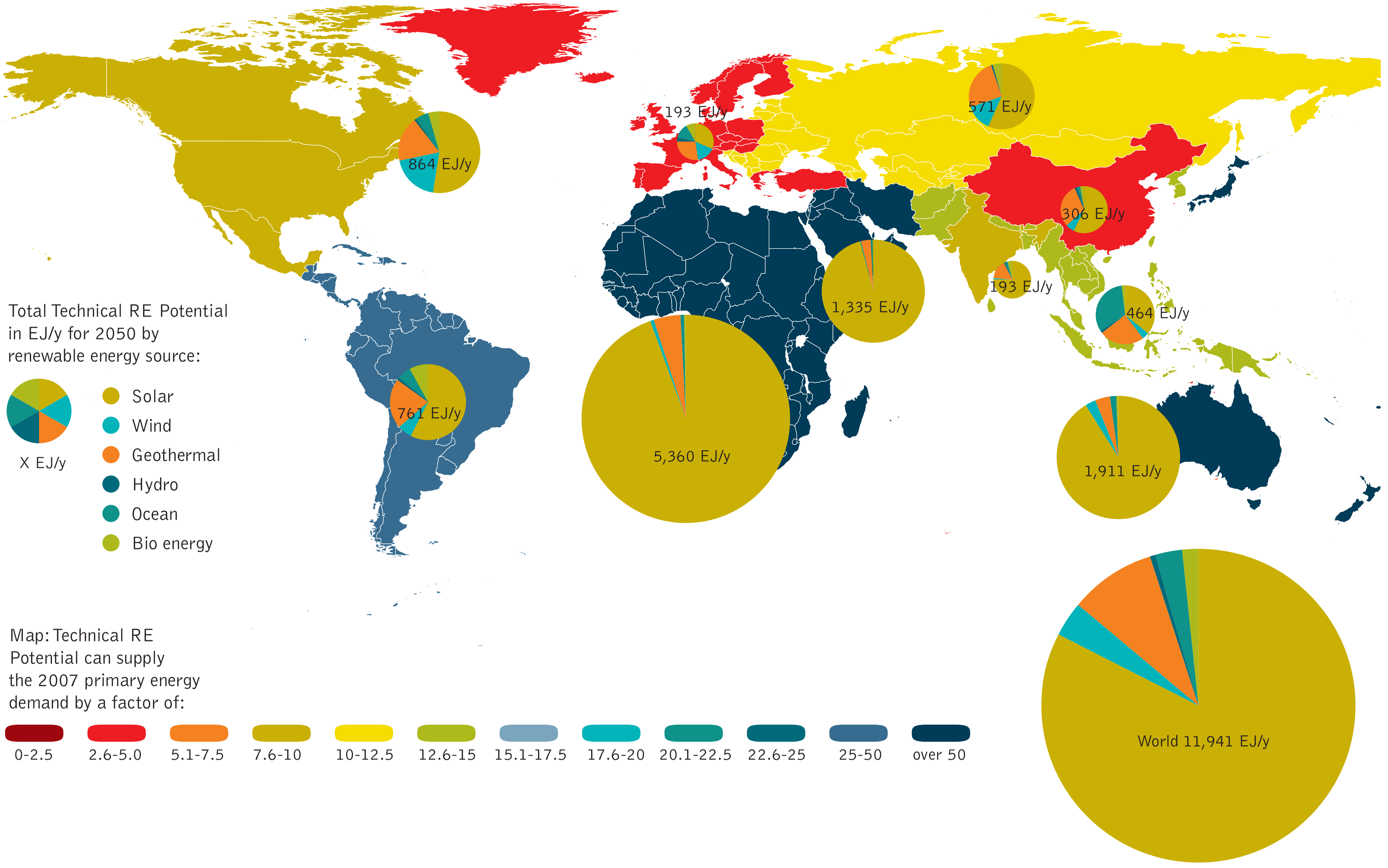


	GEOTHERMAL ENERGY	HYDROPOWER	OCEAN ENERGY	WIND ENERGY	GEOTHERMAL ENERGY	BIOMASS	DIRECT SOLAR ENERGY
Max (in EJ/yr)	1,109	52	331	580	312	500	49,837
Min (in EJ/yr)	118	50	7	85	10	50	1,575

source
IPCC/SRREN.

note
RANGES OF GLOBAL TECHNICAL POTENTIALS OF RE SOURCES DERIVED FROM STUDIES PRESENTED IN CHAPTERS 2 THROUGH 7 IN THE IPCC REPORT. BIOMASS AND SOLAR ARE SHOWN AS PRIMARY ENERGY DUE TO THEIR MULTIPLE USES. NOTE THAT THE FIGURE IS PRESENTED IN LOGARITHMIC SCALE DUE TO THE WIDE RANGE OF ASSESSED DATA.

map 8.7: regional renewable energy potential



source

IPCC/SRREN. RE POTENTIAL ANALYSIS: TECHNICAL RE POTENTIALS REPORTED HERE REPRESENT TOTAL WORLDWIDE AND REGIONAL POTENTIALS BASED ON A REVIEW OF STUDIES PUBLISHED BEFORE 2009 BY KREWITT ET AL. (2009). THEY DO NOT DEDUCT ANY POTENTIAL THAT IS ALREADY BEING UTILIZED FOR ENERGY PRODUCTION. DUE TO METHODOLOGICAL DIFFERENCES AND ACCOUNTING METHODS AMONG STUDIES, STRICT COMPARABILITY OF THESE ESTIMATES ACROSS TECHNOLOGIES AND REGIONS, AS WELL AS TO PRIMARY ENERGY DEMAND, IS NOT POSSIBLE. TECHNICAL RE POTENTIAL ANALYSES PUBLISHED AFTER 2009 SHOW HIGHER RESULTS IN SOME CASES BUT ARE NOT INCLUDED IN THIS FIGURE. HOWEVER, SOME RE TECHNOLOGIES MAY COMPETE FOR LAND WHICH COULD LOWER THE OVERALL RE POTENTIAL. SCENARIO DATA: IEA WEO 2009 REFERENCE SCENARIO (INTERNATIONAL ENERGY AGENCY (IEA), 2009; TESKE ET AL., 2010), REMIND-RECIPE 450PPM STABILIZATION SCENARIO (LUDERER ET AL., 2009), MINICAM EMF22 1ST-BEST 2.6 W/2 OVERSHOOT SCENARIO (CALVIN ET AL., 2009), ADVANCED ENERGY [R]EVOLUTION 2010 (TESKE ET AL., 2010.

8.6 biomass in the 2012 energy [r]evolution (4th edition)

The 2012 Energy [R]evolution (4th edn.) is an energy scenario which shows a possible pathway for the global energy system to move from fossil fuels dominated supply towards energy efficiency and sustainable renewable energy use. The aim is to only use sustainable bioenergy and reduce the use of unsustainable bioenergy in developing countries which is currently in the range of 30 to 40 EJ/a. The fourth edition of the Energy [R]evolution again decreases the amount of bioenergy used significantly due to sustainability reasons, and the lack of global environmental and social standards. The amount of bioenergy used in this report is based on bioenergy potential surveys which are drawn from existing studies, but not necessarily reflecting all the ecological assumptions that Greenpeace would use. It is intended as a coarse-scale, "order-of-magnitude" example of what the energy mix would look like in the future (2050) with largely phased-out fossil fuels. The rationale underpinning the use of biomass in the 2012 Energy [R]evolution is explained here but note the amount of bioenergy included in the Energy [R]evolution does not mean that Greenpeace per se agrees to the amount without strict criteria.

The Energy [R]evolution takes a precautionary approach to the future use of bioenergy. 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. 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 bio energies 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.

All energy production has some impact on the environment. What is important is to minimise the impact on the environment, through reduction in energy usage, increased efficiency and careful choice of renewable energy sources. Different sources of energy have different impacts and these impacts can vary enormously with scale. Hence, a range of energy sources are needed, each with its own limits of what is sustainable.

Biomass is part of the mix of a wide variety of non-finite fuels that, together, provide a practical and possible means to eliminate our dependency on fossil fuels. Thereby we can minimise greenhouse gas emissions, especially from fossil carbon, from energy production. 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. To ensure that biofuels are produced and used in ways which maximise its greenhouse gas saving potential, these accounting problems will need to be resolved in future. The Energy [R]evolution prioritises non-combustion resources (wind, solar etc.). Greenpeace does not consider biomass as carbon, or greenhouse gas neutral because of the time biomass takes to regrow and because of emissions arising from direct and indirect land use changes. The Energy [R]evolution scenario is an energy scenario, therefore only energy-related CO_2 emissions are calculated and no other GHG emissions can be covered, e.g. from agricultural practices. However, the Energy [R]evolution summarises the entire amount of bioenergy used in the energy model and indicates possible additional emissions connected to the use of biofuels. As there are many scientific publications about the GHG emission effects of bioenergy which vary between carbon neutral to higher CO_2 emissions than fossil fuels a range is given in the Energy [R]evolution.

Bioenergy in the Energy [R]evolution scenario is largely limited to that which can be gained from wood processing and agricultural (crop harvest and processing) residues as well as from discarded wood products. The amounts are based on existing studies, some of which apply sustainability criteria but do not necessarily reflect all Greenpeace's sustainability criteria. Large-scale biomass from forests would not be sustainable.[50] The Energy [R]evolution recognises that there are competing uses for biomass, e.g. maintaining soil fertility, use of straw as animal feed and bedding, use of woodchip in furniture and does not use the full potential. Importantly, the use of biomass in the 2012 Energy [R]evolution has been developed within the context of Greenpeace's broader bioenergy position to minimise and avoid the growth of bioenergy and in order to prevent use of unsustainable bioenergy. The Energy [R]evolution uses the latest available bioenergy technologies for power and heat generation, as well as transport systems. These technologies can use different types of fuel and biogas is preferred due to higher conversion efficiencies. Therefore the primary source for biomass is not fixed and can be changed over time. Of course, any individual bioenergy project developed in reality needs to be thoroughly researched to ensure our sustainability criteria are met.

Greenpeace supports the most efficient use of biomass in stationary applications. For example, the use of agricultural and wood processing residues in, preferably regional and efficient cogeneration power plants, such as CHP (combined heat and power plants).

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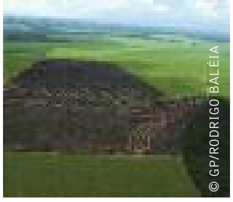
reference

[50] SCHULZE, E-D., KÖRNER, C., LAW, B.E .HABERL, H. & LUYSSAERT, S. 2012. LARGE-SCALE BIOENERGY FROM ADDITIONAL HARVEST OF FOREST BIOMASS IS NEITHER SUSTAINABLE NOR GREENHOUSE GAS NEUTRAL. GLOBAL CHANGE BIOLOGY BIOENERGY DOI: 10.1111/J.1757-1707.2012.01169.X.

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.

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


© LANGROCK/ZENIT/GP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8.6.1 how much biomass

Roughly 55 EJ/a of bioenergy was used globally in 2011[51] (approximately 10% of the world's energy[52]). The Energy [R]evolution assumes an increase to 80 EJ/a. in 2050. Currently, much biomass is used in low-efficiency traditional uses and charcoal.[53] The Energy [R]evolution assumes an increase in the efficiency of biomass usage for energy globally by 2050. In addition to efficiencies in burning, there are potentially better uses of local biogas plants from manure (in developing countries at least), better recovery of residues not suitable as feed and an increase in food production using ecological agriculture. The Energy [R]evolution assumes biofuels will only be used for heavy trucks, marine transport and – after 2035 – to a limited extent for aviation. In those sectors, there are currently no other technologies available – apart from some niche technologies which are not proven yet and therefore the only option to replace oil. No import/export of biomass between regions (e.g. Canada and Europe) is required for the Energy [R]evolution.

In the 2012 Energy [R]evolution, the bioenergy potential has not been broken down into various sources, because different forms of bioenergy (e.g. solid, gas, fluid) and technical development continues so the relative contribution of sources is variable. Dedicated biomass crops are not excluded, but are limited to current amounts of usage. Similarly, 10% of current tree plantations are already used for bioenergy[54], and the Energy [R]evolution assumes the same usage.

There have been several studies on the availability of biomass for energy production and the consequences for sustainability. Below are brief details of examples of such studies on available biomass. These are not Greenpeace studies, but serve to illustrate the range of estimates available and their principal considerations.

The Energy [R]evolution estimate of 80 EJ/yr is at the low end of the spectrum of estimates of available biomass. The Energy [R]evolution doesn't differentiate between forest and agricultural residues as there is too much uncertainty regarding the amounts available regionally now and in the future.

box 8.2: what is an exajoule?

- One exajoule (EJ) is a billion billion joules
- One exajoule is about equal to the energy content of 30 million tons of coal. It takes 60 million tons of dry biomass to generate one exajoule.
- Global energy use in 2009 was approximately 500 EJ

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references

[51] INTERNATIONAL ENERGY AGENCY 2011. WORLD ENERGY OUTLOOK 2011 HTTP://WWW.WORLDENERGYOUTLOOK.ORG/PUBLICATIONS/WEO-2011/

[52] IPCC, 2011: IPCC SPECIAL REPORT ON RENEWABLE ENERGY SOURCES AND CLIMATE CHANGE MITIGATION. PREPARED BY WORKING GROUP III OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE [O. EDENHOFER, R. PICHS-MADRUGA, Y. SOKONA, K. SEYBOTH, P. MATSCHOSS, S. KADNER, T. ZWICKEL, P. EICKEMEIER, G. HANSEN, S. SCHLÖMER, C. VON STECHOW (EDS)]. CAMBRIDGE UNIVERSITY PRESS, CAMBRIDGE, UNITED KINGDOM AND NEW YORK, NY, USA.

[53] IPCC, 2011: IPCC SPECIAL REPORT ON RENEWABLE ENERGY SOURCES AND CLIMATE CHANGE MITIGATION. PREPARED BY WORKING GROUP III OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE [O. EDENHOFER, R. PICHS-MADRUGA, Y. SOKONA, K. SEYBOTH, P. MATSCHOSS, S. KADNER, T. ZWICKEL, P. EICKEMEIER, G. HANSEN, S. SCHLÖMER, C. VON STECHOW (EDS)]. CAMBRIDGE UNIVERSITY PRESS, CAMBRIDGE, UNITED KINGDOM AND NEW YORK, NY, USA.

[54] FAO 2010. WHAT WOODFUELS CAN DO TO MITIGATE CLIMATE CHANGE. FAO FORESTRY PAPER 162. FAO, ROME . HTTP://WWW.FAO.ORG/DOCREP/013/I1756E/I1756E00.PDF

Current studies estimating the amount of biomass give the following ranges:

- IPCC (2011) pg. 223. Estimates "From the expert review of available scientific literature, potential deployment levels of biomass for energy by 2050 could be in the range of 100 to 300 EJ. However, there are large uncertainties in this potential such as market and policy conditions, and it strongly depends on the rate of improvement in the production of food and fodder as well as wood and pulp products."
- WWF (2011) Ecofys Energy Scenario (for WWF) found a 2050 total potential of 209 EJ per year with a share of waste/residue-based bioenergy of 101 EJ per year (for 2050), a quarter of which is agricultural residues like cereal straw. Other major sources include wet waste/residues like sugar beet/ potato, oil palm, sugar cane/cassava processing residues or manure (35 EJ), wood processing residues and wood waste (20 EJ) and non-recyclable renewable dry municipal solid waste (11 EJ).[55] However, it's not always clear how some of the numbers were calculated.
- Beringer et al. (2011) estimate a global bioenergy potential of 130-270 EJ per year in 2050 of which 100 EJ per year is waste/residue based.[56]
- WBGU (2009) estimate a global bioenergy potential of 80-170 EJ per year in 2050 of which 50 EJ per year is waste/residue based.[57]
- Deutsches Biomasse Forschungs Zentrum (DBFZ), 2008 did a survey for Greenpeace International where the sustainable bioenergy potentials for residuals have been estimated at 87.6 EJ/a and energy crops at a level of 10 to 15 EJ/a (depending on the assumptions for food production). The DBFZ technical and sustainable 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.

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 (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.

Greenpeace's vision of ecological agriculture means that low input agriculture is not an option, but a pre-requisite. This means strongly reduced dependence on capital intensive inputs. The shift to eco-agriculture increases the importance of agricultural residues as synthetic fertilisers are phased out and animal feed production and water use (irrigation and other) are reduced. We will need optimal use of residues as fertiliser, animal feed, and to increase soil organic carbon and the water retention function of the soils etc. to make agriculture more resilient to climate impacts (droughts, floods) and to help mitigate climate change.

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references

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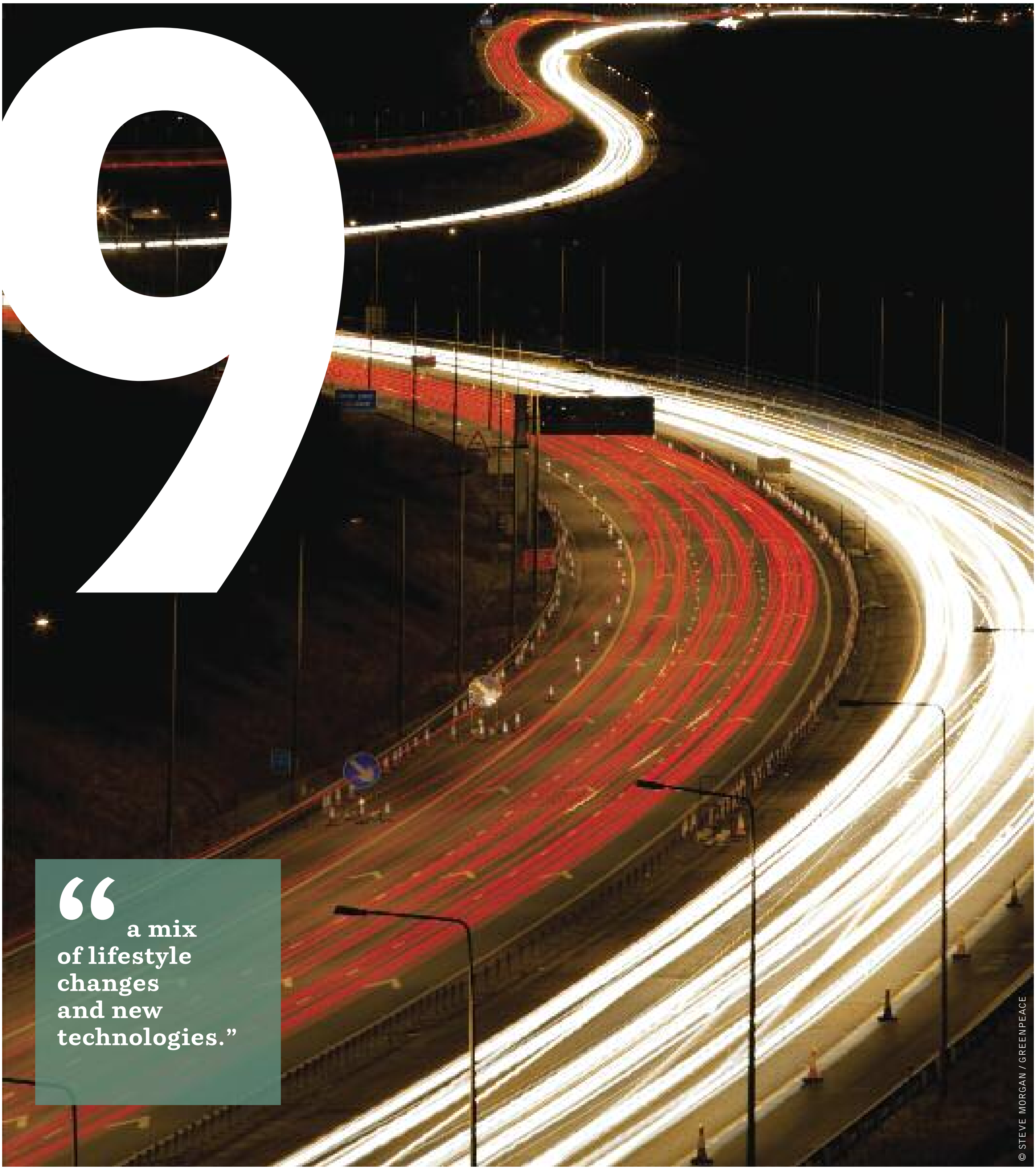
transport

9



> "a mix of lifestyle changes and new technologies."

© STEVE MORGAN / GREENPEACE

image CARS ON THE ROAD NEAR MANCHESTER. ROAD TRANSPORT IS ONE OF THE BIGGEST SOURCES OF POLLUTION IN THE UK, CONTRIBUTING TO POOR AIR QUALITY, CLIMATE CHANGE, CONGESTION AND NOISE DISTURBANCE. OF THE 33 MILLION VEHICLES ON OUR ROADS, 27 MILLION ARE CARS.

Sustainable transport is needed to reduce the level of greenhouse gases in the atmosphere, just as much as a shift to renewable electricity and heat production. Today, more than a quarter (27%) of energy use comes from the transport sector, including road and rail, as well as intra-European and domestic aviation and shipping. This chapter provides an overview of the measures required to develop a more energy efficient and sustainable transport system in the future, with a focus on:

- reducing transport demand,
- shifting transport modes (from high to low energy intensity), and
- energy efficiency improvements through technology development.

This section provides the assumptions for the EU 27 transport sector energy demand calculations used in the Reference and the Energy [R]evolution scenarios including projections for the passenger vehicle market (light-duty vehicles). But, some technologies will have to be adapted for greater energy efficiency. In other situations, a simple modification will not be enough. The transport of people in urban areas will have to be almost entirely re-organised and individual transport must be complemented or even substituted by public transport systems. Car sharing and public transport on demand are only the beginning of the transition needed for a system that carries more people more quickly and conveniently to their destination while using less energy. The Energy [R]evolution scenario is based on an analysis by the German DLR Institute of Vehicle Concepts of the entire global transport sector. This report outlines the key findings of the analysis' calculations for the EU 27.

9.1 the future of the transport sector

A detailed Reference scenario has been constructed, which includes detailed shares and energy intensity data per mode of transport up to 2050. Based on this Reference scenario, deviating transport performance and technical parameters have been applied to create the ambitious Energy [R]evolution scenario for reducing energy consumption. Traffic performance is assumed to decline for the high energy intensity modes and further energy reduction potentials were assumed to come from efficiency gains, alternative power trains and fuels.

International shipping and intercontinental air transport have been left out whilst calculating the baseline figures, because it spreads across all regions of the world and is difficult to assign to the EU 27. The total is therefore made up of light-duty vehicles (LDVs), heavy and medium-duty trucks (HDV and MDV), rail, domestic and intra-EU air transport and inland water transport. Although energy use from international marine bunkers (international shipping fuel suppliers) is not included in these calculations, it is still estimated to account for 9% of today's worldwide transport final energy demand and 7% by 2050. It is therefore very important to improve the energy efficiency of international shipping. Possible options are examined later in this chapter.

The definitions of the transport modes for the scenarios[59] are:

- Light-duty vehicles (LDV) are four-wheel vehicles used primarily for personal passenger road travel. These are typically cars, sports utility vehicles (SUVs), small passenger vans (up to eight seats) and personal pickup trucks. Light-duty vehicles are also simply called 'cars' within this chapter.

box 9.1: **eu transport policy**

Transport is the only major sector in the EU that has seen a continuous rise in GHG emissions. Emissions increased by 27% between 1990 and 2009, according to the EEA.[58] It is also the only sector that is still almost entirely dependent on fossil fuels. However, the EU's policy response has been slow. A reduction in transport demand is still seen as a worrying symptom of economic recession rather than a policy goal in itself, and progress on measures to promote a shift to more environmentally friendly transport modes, such as road pricing, has been slow. The European Commission's White Paper on Transport of 2011 fails to provide a credible blueprint on how to lower the climate impact of the EU's transport operations and replace fossil fuels with sustainable renewable energy.

Flagship measures include the EU's low carbon performance standards for transport fuels as well as road vehicles, including passenger cars and vans. The car standards in particular have helped to accelerate improvements significantly. The annual rate of emission reductions is now about twice what it was before the introduction of mandatory targets. However, for trucks no standards are in place yet. The EU's low carbon fuel standard, or Article 7a of the Fuel Quality Directive, is still not being fully implemented.

There has been little progress on aviation and shipping. While the aviation sector is covered by the EU Emissions Trading Scheme (ETS), the aviation industry continues to benefit from all kinds of economic support, such as VAT and fuel tax exemptions and regional airport subsidies. A European plan to manage shipping emissions has been pushed back despite an agreed deadline of 2011.

Besides regulation to reduce carbon emissions, the EU has also agreed a target to increase renewable energy use in transport to 10% by 2020. However, insufficient sustainability safeguards and erroneous carbon accounting rules have led member states to plan for large amounts of unsustainable biofuels to meet the target.

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reference

[58] EEA (2011).
[59] FULTON & EADS (2004).

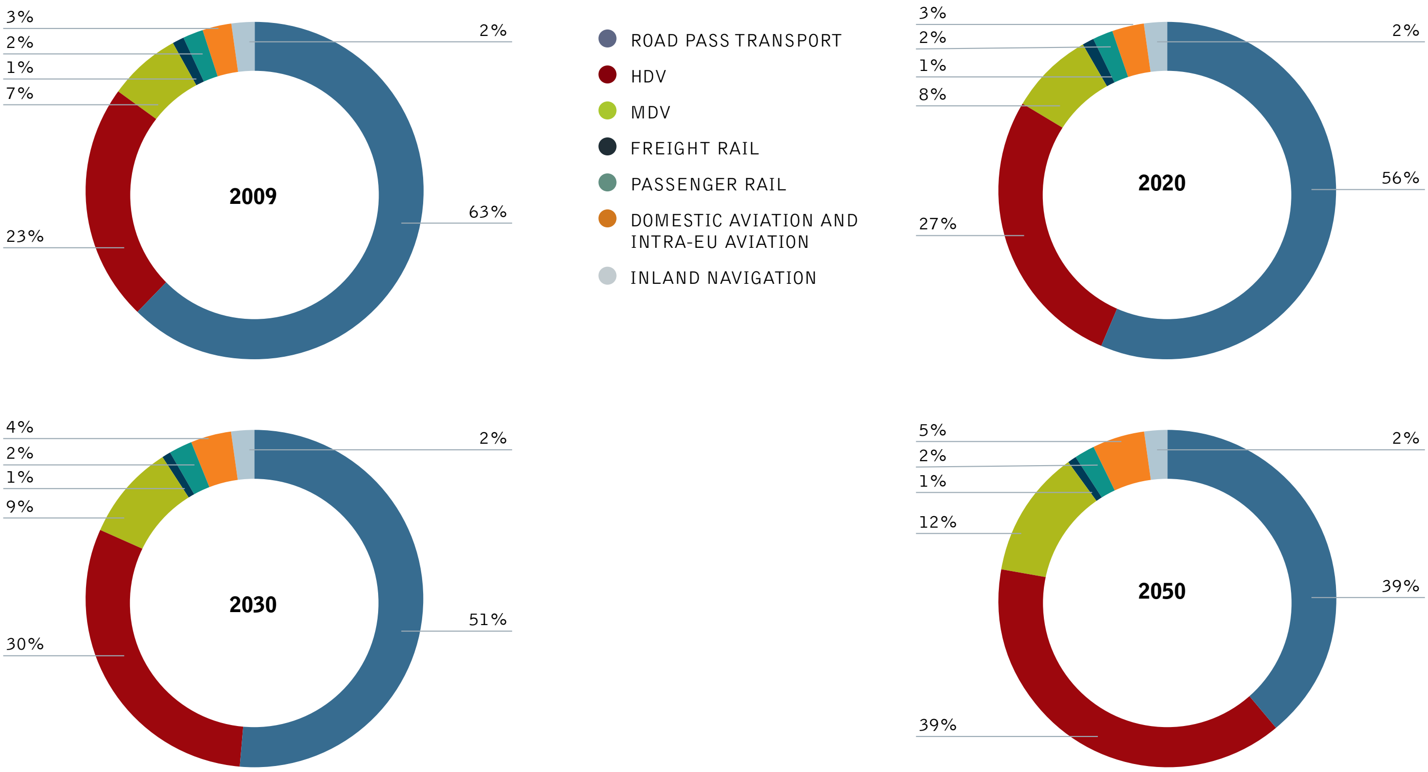
image TRAIN SIGNALS.

- Medium-duty vehicles (MDV) include medium-haul trucks, light-duty trucks and delivery vehicles.
- Heavy-duty vehicles (HDV) are long-haul trucks operating almost exclusively on diesel fuel. These trucks carry large loads with lower energy intensity (energy use per tonne-kilometre of haulage) than medium-duty trucks.
- Aviation denotes domestic and intra-European 27 air travel.
- Inland navigation denotes freight shipping with vessels operating on rivers and canals or in coastal areas for domestic transport purposes.

Figure 9.3 shows the breakdown of final energy demand for the transport modes in 2009 and 2050 in the Reference scenario.

As can be seen from the below figures, the largest share of energy demand comes from passenger road transport (mainly transport by car), although it decreases from 63% in 2009 to 39% in 2050. Of particular note is the high share of road transport in total transport energy demand: 93% in 2009 and 90% in 2050. As of 2009, overall energy demand in the transport sector of the EU 27 added up to about 13.5 EJ. This level is projected to remain nearly constant up to 2050 in the Reference scenario. In the ambitious Energy [R]evolution scenario, implying the implementation of all efficiency and behavioral measures described in Chapter 9.2, we calculated in fact a decrease of energy demand to 6.2 EJ, which is less than half of the total transport energy consumption in 2009.

figure 9.1: development of final energy use per transport mode from 2009 to 2050 in the reference scenario



9.2 technical and behavioural measures to reduce transport energy consumption

The following section describes how the transport modes contribute to total and relative energy demand. Then, a selection of measures for reducing total and specific energy transport consumption are put forward for each mode.

The three ways to decrease energy demand in the transport sector examined are:

- reduction of transport demand of high-energy intensity modes
- modal shift from high-energy intensive transport to low-energy intensity modes
- energy efficiency improvements.

Table 9.1 summarises these options and the indicators used to quantify them.

9.2.1 step 1: reduction of transport demand

To use less transport overall means reducing the amount of passenger-kilometres (p-km or passenger-km) travelled per capita and reducing freight transport demand. The amount of freight transport is to a large extent linked to GDP development and therefore difficult to influence. However, by improved logistics, for example optimal load profiles for trucks, using multimodal transport chains or a shift to regionally-produced and shipped goods demand can be limited.

Passenger transport The study focussed on the change in passenger-km per capita of high-energy intensity air transport and personal vehicles modes. Passenger transport by light-duty vehicles (LDV), for example, is energy demanding both in absolute and relative terms. Policy measures that enforce a reduction of passenger-km travelled by individual transport modes are an effective means to reduce transport energy demand.

Policy measures for reducing passenger transport demand in general could include:

- charge and tax policies that increase transport costs for individual transport
- price incentives for using public transport modes
- installation or upgrading of public transport systems
- incentives for working from home
- stimulating the use of video conferencing in business
- improved cycle paths in cities.

table 9.2: **LDV passenger-km per capita**

	2009	2020 REF	2050 REF	2020 E[R]	2050 E[R]
EU 27	9,818	11,455	13,769	10,799	9,015

table 9.1: **selection of measures and indicators**

MEASURE	REDUCTION OPTION	INDICATOR
Reduction of transport demand	Reduction in volume of passenger transport in comparison to the Reference scenario	Passenger-km/capita
	Reduction in volume of freight transport in comparison to the Reference scenario	Tonne-km/unit of GDP
Modal shift	Modal shift from trucks to rail	MJ/tonne-km
	Modal shift from cars to public transport	MJ/Passenger-km
Energy efficiency improvements	Shift to energy efficient passenger car drive trains (battery electric vehicles, hybrid and fuel cell hydrogen cars) and trucks (fuel cell hydrogen, hybrid, battery electric, catenary or inductive supplied)	MJ/Passenger-km, MJ/tonne-km
	Shift to powertrain modes that can be fuelled by renewable energy (electric, fuel cell hydrogen)	MJ/Passenger-km, MJ/tonne-km
	Autonomous efficiency improvements of transport modes over time	MJ/Passenger-km, MJ/tonne-km

image ITALIAN EUROSTAR TRAIN.

image TRUCK.

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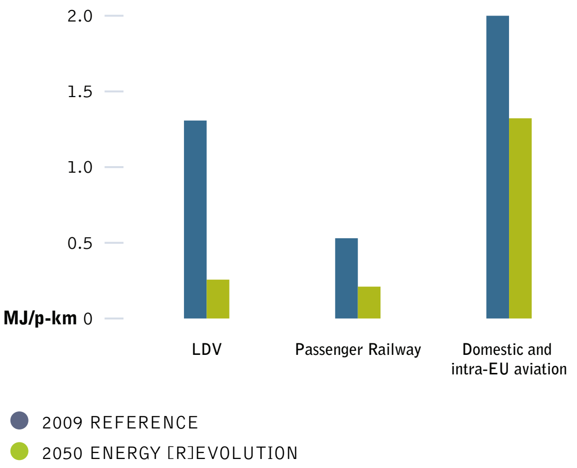
The reduction in passenger-km per capita in the Energy [R]evolution scenario compared to the Reference scenario comes with a general reduction in car use due to behavioral and traffic policy changes and partly with a shift of transport to public modes. A shift from energy-intensive individual transport to low-energy intensive demand public transport of course aligns with an increase in low-energy intensive public transport passenger-km.

9.2.2 step 2: changes in transport mode

In order to figure out which vehicles or transport modes are the most efficient for each purpose requires an analysis of the current state of transport modes' technologies. Then, the energy use and intensity for each type of transport is used to calculate energy savings resulting from a transport mode shift. The following information is required:

- Passenger transport: Energy demand per passenger-kilometre, measured in MJ/p-km.
- Freight transport: Energy demand per kilometre of transported tonne of goods, measured in MJ/tonne-km.

figure 9.2: stock-weighted passenger transport energy intensity for 2009 and 2050



For the purpose of this study, passenger transport includes light-duty vehicles, passenger rail and air transport. Freight transport includes medium-duty vehicles, heavy-duty vehicles, inland navigation, marine transport and freight rail. WBCSD 2004 data was used as baseline data and updated where more recent information was available.

Passenger transport Travelling by rail is the most efficient – but car transport improves strongly. Figure 9.2 shows the average specific energy consumption (energy intensity) by transport mode in 2009 and in the Energy [R]evolution scenario in 2050. Passenger transport by rail will consume on a per passenger-km basis 18% less energy in 2050 than car transport and 84% less than aviation.

Figure 9.2 shows that in order to reduce transport energy demand, passengers will need to shift from cars and especially air transport to the lower energy intensive passenger rail transport.

In the [E]nergy [R]evolution scenario it is assumed that a certain portion of passenger-kilometer of domestic air traffic and intraregional air traffic (i. e., traffic among two countries within the EU 27) is suitable to be substituted by high speed rail (HSR). For international aviation there is obviously no substitution potential to other modes whatsoever.

We assumed for the Energy [R]evolution scenario that by 2050 a maximum of 40% of passenger-km in domestic air traffic and 20% in intra-EU 27 air traffic can be substituted by high speed rail services. This requires massive infrastructure investments as suggested in the EU White Paper on Transport where the European high-speed rail network is intended to be tripled by 2030 compared to today's corridor length.

Figures 9.3 and 9.4 shows how passenger-km of both domestic aviation and rail passenger traffic would change due to modal shift in the Energy [R]evolution scenario against the Reference scenario (the rail passenger-km includes, besides the modal shift, a general increase in rail passenger-km as people use rail over individual transport).

figure 9.3: aviation passenger-km in the reference and energy [r]evolution scenario

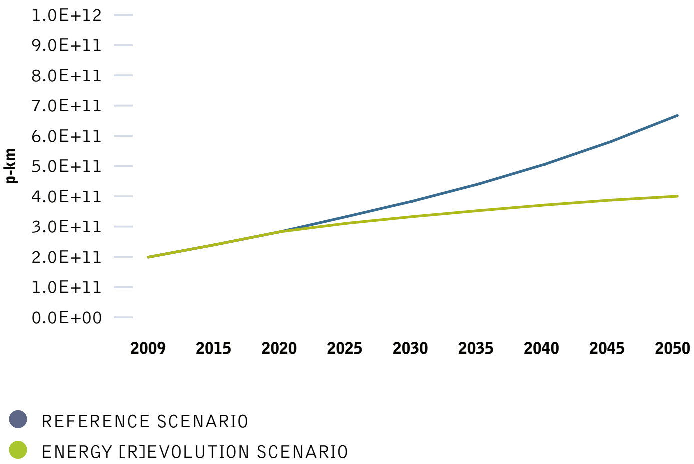


figure 9.4: rail passenger-km in the reference and energy [r]evolution scenario

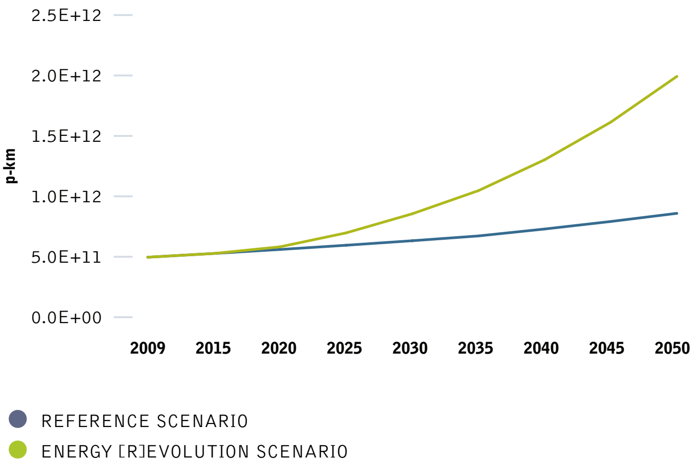


Figure 9.5 and 9.6 show the resulting passenger-km of all modes in the Reference and Energy [R]evolution scenario; the Energy [R]evolution scenario includes the decreasing LDV passenger-km compared to the Reference scenario.

figure 9.5: passenger-km over time in the reference scenario

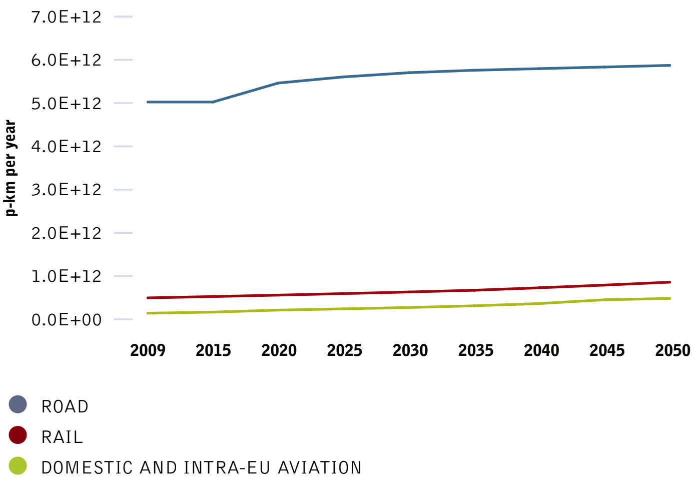


figure 9.6: passenger-km over time in the energy [r]evolution scenario

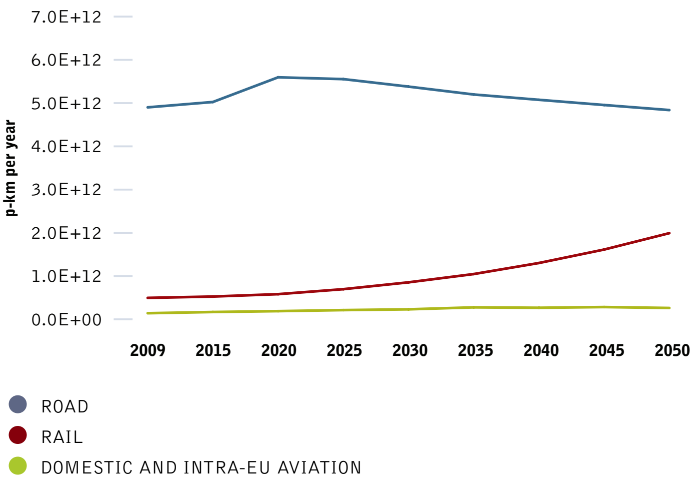
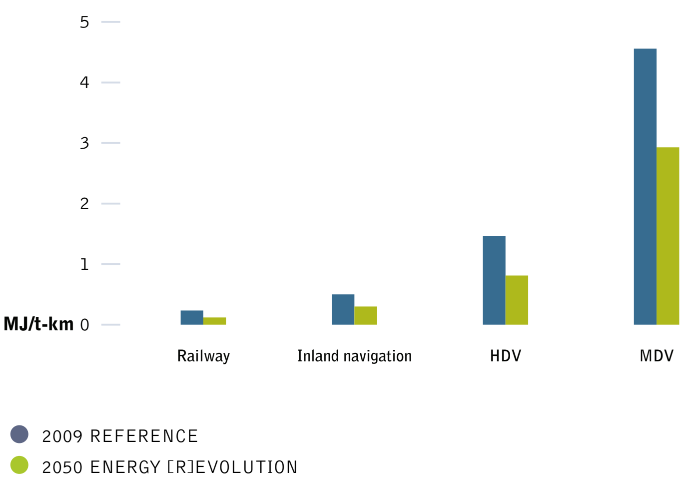


image TRANSPORT POLLUTION.

Freight transport Similar to Figure 9.2 which showed average specific energy consumption for passenger transport modes, Figure 9.7 shows the respective energy consumption for various freight transport modes in 2009 and in the Energy [R]evolution scenario 2050. The values are weighted according to stock-and-traffic performance. The energy intensity of all modes of transport is expected to decrease by 2050. In absolute terms, road transport shows the largest efficiency gains whereas transport on rail and water remain the modes with the lowest relative energy demand per tonne-km. Rail freight transport will consume 85% less energy per tonne-km in 2050 than long haul HDV. This shows the large energy savings achievable by a modal shift from road to rail.

figure 9.7: average (stock-weighted) freight transport energy intensity in the energy [r]evolution scenario



Modal shifts for transporting goods in the Energy [R]evolution scenario The figures above indicate that as much road freight as possible should be shifted from road-bound freight transport to less energy intensive freight rail, in order to achieve maximum energy savings from modal shifts. Since the use of ships largely depends on the geography of a country, no modal shift is proposed for inland navigation but instead a shift towards freight rail. As the goods transported by medium-duty vehicles are mainly going to regional destinations (and are therefore unsuitable for the long distance nature of freight rail transport), no modal shift to rail is assumed for this type of transport. For long-haul heavy-duty vehicle transport, however, especially low value density, heavy goods that are transported on a long range are suitable for a modal shift to railways.[60] We assumed an increasing share over time of tonne-km being shifted from HDV to rail up to 2050 in the Energy [R]evolution scenario. That is, up to 30% of total HDV-tonne-km in 2050.

Figure 9.8 and Figure 9.9 show the resulting tonne-km of the modes in the Reference scenario and Energy [R]evolution scenario. In the Energy [R]evolution scenario freight transported by rail is larger in absolute numbers than freight transported by heavy-duty vehicles.

A modal shift in this range needs to be accompanied by massive investments into the railroad network. Infrastructure enhancements comprise new tracks, intermodal freight terminals, a more rigoruous introduction of a common train control and management systems, just to mention a few. Not least, seamless multi-country rail transport will need harmonisation across borders for development and operation.

figure 9.8: tonne-km over time in the reference scenario

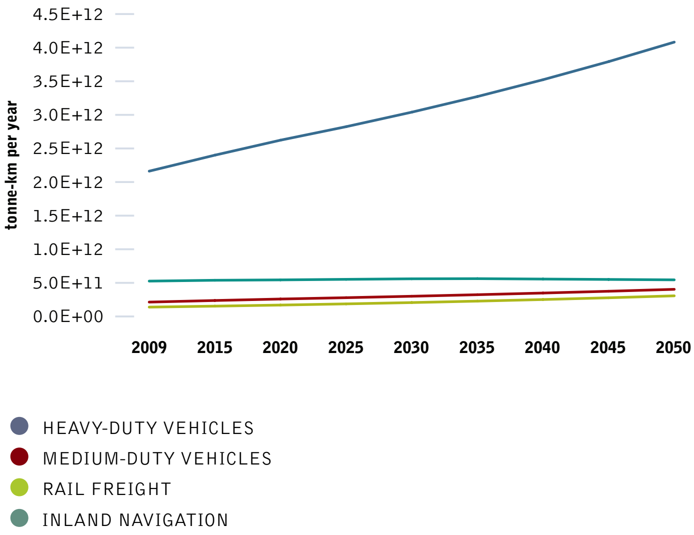
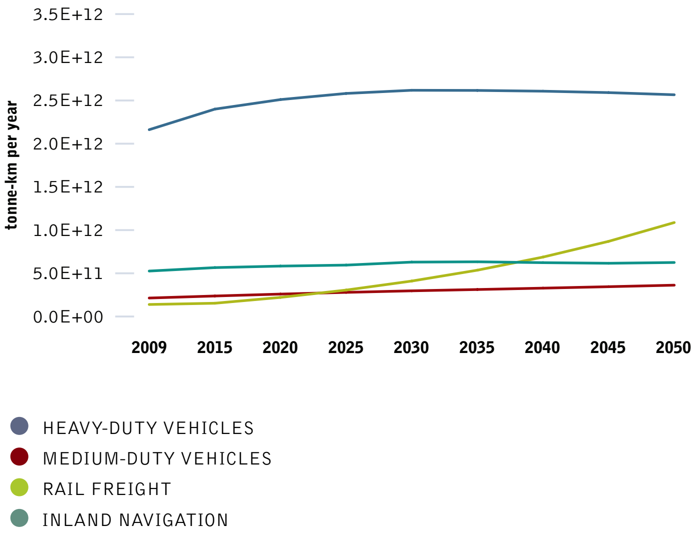


figure 9.9: tonne-km over time in the energy [r]evolution scenario



reference

60 TAVASSZY AND VAN MEIJEREN 2011.

9.2.3 step 3: efficiency improvements

Energy efficiency improvements are the third important way of reducing transport energy demand. This section explains ways of improving energy efficiency up to 2050 for each type of transport, namely:

- air transport
- passenger and freight trains
- trucks
- inland navigation and marine transport
- cars.

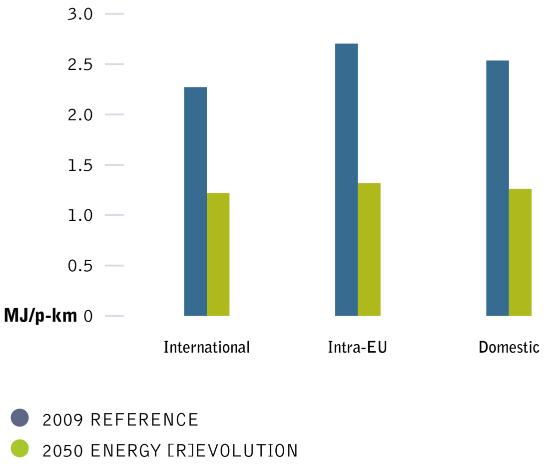
In general, an integral part of any energy reduction scheme is an increase in the load factor – this applies both for freight and passenger transport. As the load factor increases, fewer transport vehicles are needed and thus the energy intensity decreases when measured on a passenger-km or tonne-km base. There are already sophisticated efforts in aviation to optimise the load factor, however for other modes such as road and rail freight transport there is still room for improvement. Increasing the load factor may be achieved through improved logistics and supply chain planning for freight transport and in enhanced capacity utilisation in passenger transport.

Air transport A study conducted by NASA in 2011 shows that energy use of new subsonic aicrafts can be reduced by up to 58% up to 2035. Akerman (2005) reports that a more than 50% reduction in fuel use is technically feasible by 2050. Technologies to reduce fuel consumption of aircrafts mainly comprise:

- Aerodynamic adaptations to reduce the drag of the aircraft, for example by improved control of laminar flow, the use of riblets and multi-functional structures, the reduction in fasteners, flap fairings and the tail size as well as by advanced supercritical airfoil technologies.
- Structural technologies to reduce the weight of the aircraft while at the same time increasing the stiffness. Examples include the use of new lightweight materials like advanced metals, composites and ceramics, the use of improved coatings as well as the optimised design of multi-functional, integrated structures.
- Subsystem technologies including, for example, advanced power management and generation as well as optimised flight avionics and wiring.
- Propulsion technologies like advanced gas turbines for powering the aircraft more efficiently; this could also include:
  - improved combustion emission measures, improvements in cold and hot section materials, and the use of turbine blade/vane technology;
  - investigation of all-electric, fuel-cell gas turbine and electric gas turbine hybrid propulsion devices;
  - the usage of electric propulsion technologies comprise advanced lightweight motors, motor controllers and power conditioning equipment.

The scenario projects a halving in specific energy consumption on a per passenger-km basis for future aircrafts in 2050 based on 2009 energy intensities. Figure 9.10 shows the energy intensities in the Energy [R]evolution scenario for international, intra-EU and domestic aviation.

figure 9.10: energy intensity (MJ/p-km) for air transport in the energy [r]evolution scenario



Passenger and freight trains Transport of passengers and freight by rail is currently one of the most energy efficient means of transport. However, there is still potential to reduce the specific energy consumption of trains. Apart from operational and policy measures to reduce energy consumption like raising the load factor of trains, technological measures to reduce energy consumption of future trains are also necessary. Key technologies are:

- reducing the total weight of a train; this is seen as the most significant measure to reduce traction energy consumption. By using lightweight structures and lightweight materials, the energy needed to overcome inertial and grade resistances as well as friction from tractive resistances can be reduced.
- aerodynamic improvements to reduce aerodynamic drag, especially important when running at high velocity. A reduction of aerodynamic drag is typically achieved by streamlining the profile of the train.
- switch from diesel-fuelled to more energy efficient electrically powered trains.
- improvements in the traction system to further reduce frictional losses. Technical options include improvements of the major components as well as improvements in the energy management software of the system.
- regenerative braking to recover waste energy. The energy can either be transferred back into the grid or stored on-board in an energy storage device. Regenerative braking is especially effective in regional traffic with frequent stops.

image CHARGING AN ELECTRIC CAR.

- improved space utilisation to achieve a more efficient energy consumption per passenger-kilometre. The simplest way to achieve this is to transport more passengers per train. This can either be achieved by a higher average load factor, more flexible and shorter trainsets or by the use of double-deck trains on highly frequented routes.
- improved accessory functions, e.g. for passenger comfort. A substantial amount of energy in a train needed is to ensure the comfort of the train's passengers by heating and cooling. Strategies to enhance efficiency include adjustments to the cabin design, changes to air intakes and using waste heat from the propulsion system.

By research on developing an advanced high-speed train, DLR's 'Next Generation Train' project aims to reduce the specific energy consumption per passenger-kilometre by 50% relative to today's state-of-the-art high speed trains.[61]

The Energy [R]evolution scenario uses energy intensity data of the EU-project TOSCA, 2011 for electric and diesel fuelled trains in Europe as input for our calculations. These data were available for 2009 and as forecasts for 2025 and 2050.

Figure 9.11 and 9.12 shows the weighted average share of electric and diesel traction today and as of 2030 and 2050 in the Energy [R]evolution scenario.

Electric trains as of today are about 2 to 3.5 times less energy intensive (on a tank-to-wheel-perspective) than diesel trains depending on the specific type of rail transport. As an increasing share of electric energy is to come from renewable sources in the future, the projections to 2050 include a massive shift away from diesel to electric traction in the Energy [R]evolution scenario.

figure 9.11: fuel share of electric and diesel rail traction for passenger transport in p-km

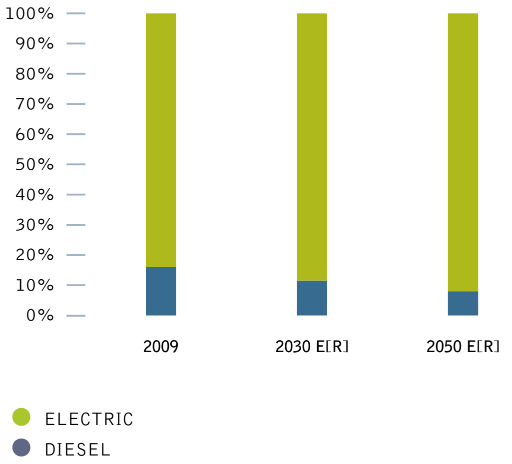
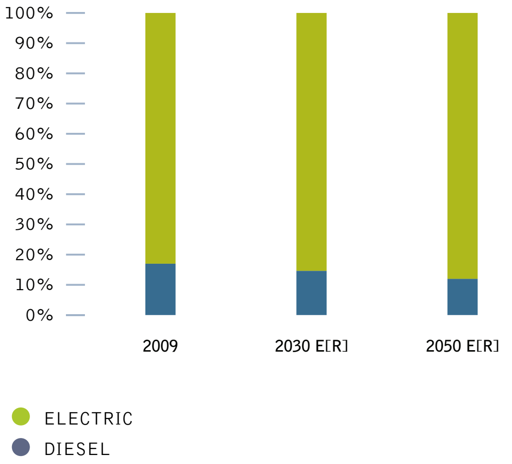


figure 9.12: fuel share of electric and diesel rail traction for freight transport in tonne-km



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references

[61] WWW.DLR.DE/NGT.

Figure 9.13 shows the energy intensity per region in the Energy [R]evolution scenario for passenger rail and Figure 9.14 shows the energy intensity per region in the Energy [R]evolution scenario for freight rail, both in comparison to the other IEA world regions.

figure 9.13: energy intensities for passenger rail transport in the energy [r]evolution scenario

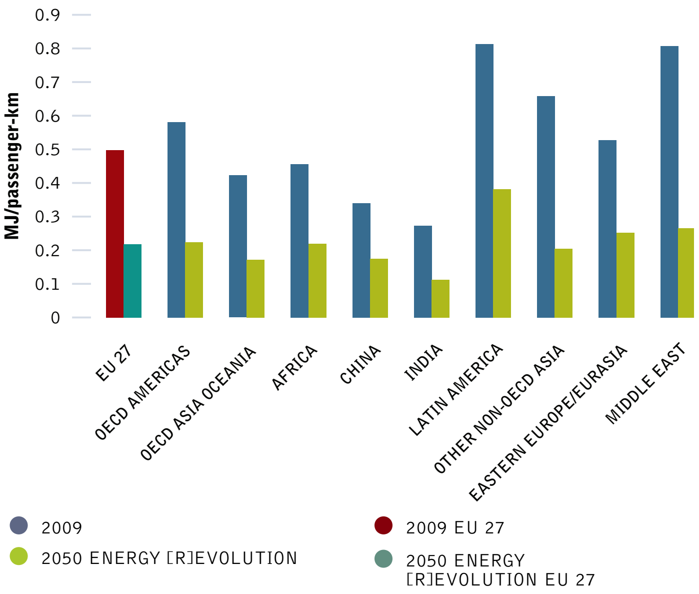
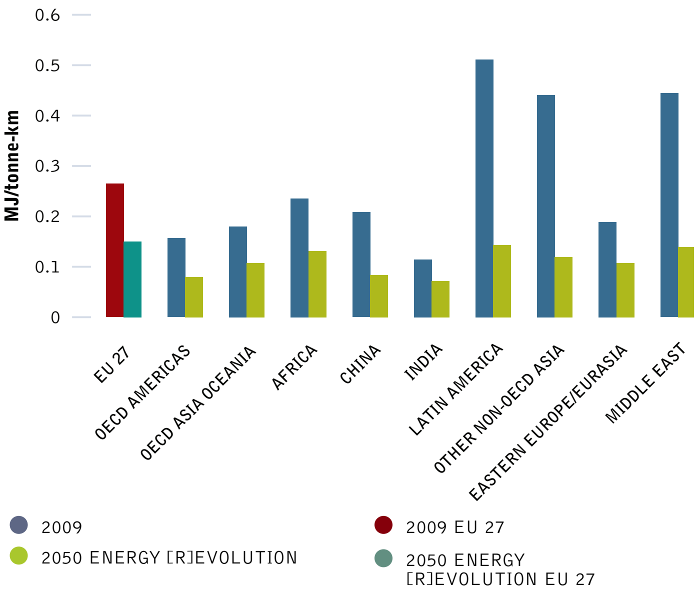


figure 9.14: energy intensities for freight rail transport in the energy [r]evolution scenario



Heavy and medium-duty vehicles (freight by road) Freight transport on the road forms the backbone of logistics in the EU 27 today. But it is, apart from air freight transport, the most energy intensive way of moving goods around. However, gradual progress is being made in the fields of drivetrain efficiency, lightweight construction, alternative power trains and fuels.

This study models a major shift in drivetrain market share of medium- and heavy-duty vehicles in our Energy R]evolution scenario in the future. Today, the great majority of MDV and HDV is powered by internal combustion engines, fuelled mainly by diesel and in MDV as well by a small share of gasoline and gas (CNG and LPG). The Energy [R]evolution scenario to 2050 includes a considerable shift to electric and fuel cell hydrogen powered vehicles (FCV), as well as autonomous diesel hybrids.

The electric MDV stock in the model will be mainly composed of battery electric vehicles (BEV), and a relevant share of hybrid electric vehicles (HEV). Hybrid drivetrains will replace conventional internal combustion engines also in heavy-duty vehicles. In addition to this, both hybrid electric vehicles supplied with current via overhead catenary lines and BEV are modeled in the Energy [R]evolution scenario for HDV applications. In recent years, several field test have been conducted by truck manufacturers and research bodies on powering heavy-duty trucks with electric energy via an overhead catenary. Siemens has proved the technical feasibility of the catenary technology for trucks with experimental vehicles in its eHighway project (Figure 9.15).

figure 9.15: HDV operating fully electrically under a catenary (picture by Siemens)[62]

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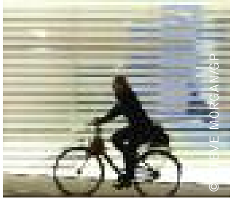
reference

[62] SACHVERSTÄNDIGENRAT FÜR UMWELTFRAGEN (2012).

image DEUTSCHE BAHN AG IN GERMANY, USING RENEWABLE ENERGY. WIND PARK MAERKISCH LINDEN (BRANDENBURG) RUN BY THE DEUTSCHE BAHN AG.

image CYCLING THROUGH FRANKFURT.



The trucks are equipped with a hybrid diesel powertrain to be able to operate when not connected to the overhead line. When under a catenary the trucks can operate fully electric at speeds of up to 90 km/h. Similar tests with pantograph-equipped hybrid trucks are underway in Sweden run by a consortium of research and industry stakeholders. While this technology is seen often as a niche application, the 'Umweltrat', an expert advisory board to the German federal government, has suggested to electrify the right lanes of all major German highways.

In addition to the electrified power trains in the Energy [R]evolution scenario, FCV were integrated into the vehicle stock, too. FCV are beneficial especially for long haul transports where no overhead catenary lines are available and the driving range of BEV would not be sufficient.

Figure 9.16 and Figure 9.17 show the market shares of the power train technologies discussed here for MDV and HDV in 2009, in the 2030 Energy [R]evolution and in the 2050 Energy [R]evolution scenario. These figures form the basis of the energy consumption calculation in the Energy [R]evolution scenario.

Energy [R]evolution fleet-average transport energy intensities for MDV and HDV were derived using region-specific IEA energy intensity data of MDV and HDV transport until 2050[63], with the specific energy consumption factors of Figure 9.18 applied to the IEA data and weighted with the market shares of the power train technologies.

table 9.3: EU 27 average energy intensities for MDV and HDV in 2009 and 2050 over time in the energy [r]evolution

	2009	2020 E[R]	2030 E[R]	2050 E[R]
MDV	4.56 MJ/t-km	4.19 MJ/t-km	3.87 MJ/t-km	2.36 MJ/t-km
HDV	1.46 MJ/t-km	1.32 MJ/t-km	1.12MJ/t-km	0.47 MJ/t-km

figure 9.16: fuel share of medium duty vehicles by transport performance (tonne-km)

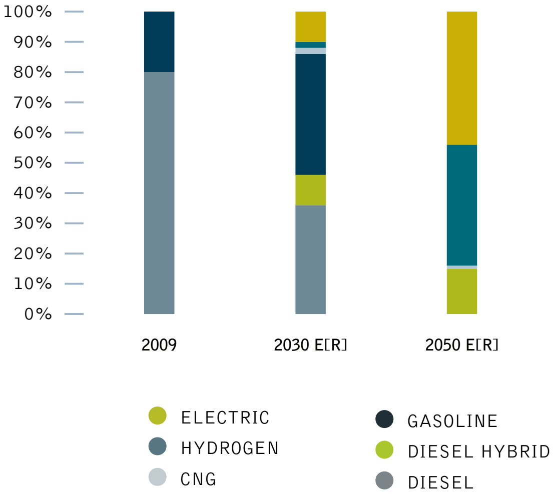
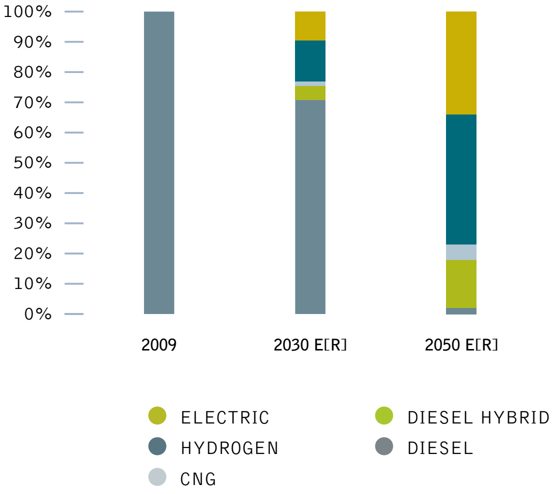


figure 9.17: fuel share of heavy duty vehicles by transport performance (tonne-km)



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reference
63 FULTON & EADS (2004).

The reduction in energy intensity on a per tonne-km basis between 2009 and 2050 Energy [R]evolution is then 48% for MDV and 68% for HDV.

Inland Navigation Technical measures to reduce energy consumption of inland vessels include:[64]

- aerodynamic improvements to the hull to reduce friction resistance
- improving the propeller design to increase efficiency
- enhancing engine efficiency.

For **inland navigation** we assumed a reduction of 40% of average energy intensity in relation to a 2009 value of 0.5 MJ/t-km. This means a reduction to 0.3 MJ/t-km.

Marine Transport Several technological measures can be applied to new vessels in order to reduce overall fuel consumption in national and international marine transport. These technologies comprise for example:

- weather routing to optimise the vessel's route
- autopilot adjustments to minimise steering
- improved hull coatings to reduce friction losses
- improved hull openings to optimise water flow
- air lubrication systems to reduce water resistances
- improvements in the design and shape of the hull and rudder
- waste heat recovery systems to increase overall efficiency
- improvement of the diesel engine (e.g. common-rail technology)
- installing towing kites and wind engines to use wind energy for propulsion
- using solar energy for onboard power demand.

Adding up each technology's effectiveness as stated by ICCT (2011), these technologies have an overall potential to improve energy efficiency of new vessels between 18.4% and about 57%. Another option to reduce energy demand of ships is simply to reduce operating speeds. Up to 36% of fuel consumption can be saved by reducing the vessel's speed by 20%.[65] Eyring et al. (2005) report that a 25% reduction of fuel consumption for an international marine diesel fleet is achievable by using more efficient alternative propulsion devices only.[66] Up to 30% reduction in energy demand is reported by Marintek (2000) only by optimising the hull shape and propulsion devices of new vessels.[67]

9.3 Light-duty vehicles

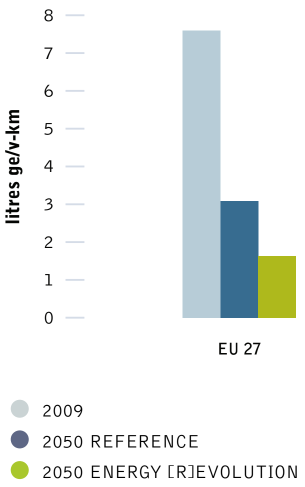
9.3.1 projection of the CO_2 emission development

This section draws on a study on future vehicle technologies conducted by the DLR's Institute of Vehicle Concepts. The approach shows the potential of different technologies to increase the energy efficiency of future cars (light-duty vehicles) and gives a detailed analysis of possible cost developments.[68]

Many technologies can be used to improve the fuel efficiency of conventional passenger cars. Examples include improvements in engines, weight reduction as well as friction and drag reduction. The impact of the various measures on fuel efficiency can be substantial. The introduction of hybrid vehicles, combining a conventional internal combustion engine with an electric motor and a battery, can further reduce fuel consumption. Applying advanced lightweight materials, in combination with new propulsion technologies, can bring fuel consumption levels down to 1 litre ge/100 km.

The figure below shows the energy intensities of light-duty vehicles in the Reference scenario and in the Energy [R]evolution scenario.

figure 9.18: energy intensities (litres ge/v-km) of light-duty vehicles (stock-weighted fleet average) in the reference and energy [r]evolution scenario



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references

[64] BASED ON VAN ROMPUY, 2010.
[65] ICCT, 2011.
[66] EYRING ET AL., 2005.
[67] MARINTEK, 2000.
[68] DLR, 2011.

image 4 WHEEL DRIVE.

Although the average fuel consumption of the passenger car fleet is projected to decrease significantly until 2050 compared to the 2009 value in the Reference scenario, we project an even bigger reduction potential in the Energy [R]evolution scenario.

With a combination of continuous, rigorous drivetrain efficiency improvements, a shift of large to medium and medium to small vehicles and a rapid introduction of conventional hybrids, PHEVs and BEV fleet average tailpipe CO_2 emissions in new cars can be reduced to 80 g/km in 2020 and 60 g/km in 2025 in the Energy [R]evolution scenario. Figure 9.19 and 9.20 shows the projected CO_2 emission development in both scenarios for the EU 27 vehicle stock and sales alike.

The Reference scenario shows a continous decrease in average car energy intensity over time. The more ambitious changes described in the Energy [R]evolution scenario translate into even lower tailpipe emissions than in the Reference scenario.

Table 9.4 summarises the energy efficiency improvement for passenger transport in the Energy [R]evolution scenario and Table 9.5 shows the energy efficiency improvement for freight transport in the Energy [R]evolution scenario.

figure 9.19: tailpipe CO_2 emissions for light-duty vehicles (stock weighted fleet average) in the reference and energy [r]evolution scenario

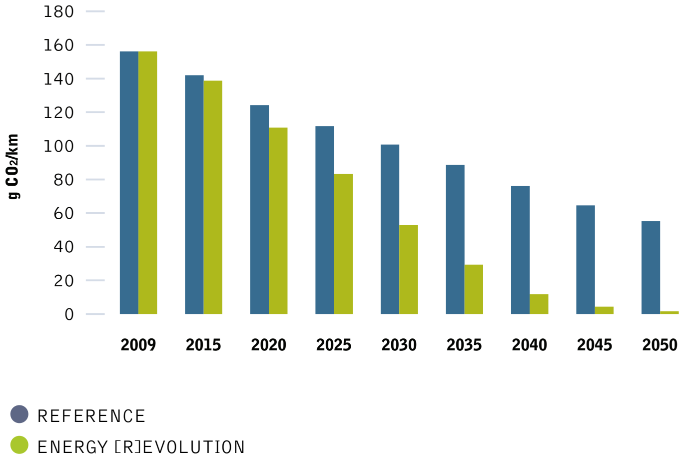

table 9.4: technical efficiency potential for passenger transport

MJ/P-KM	2009	2020E[R]	2030 E[R]	2050 E[R]
LDV	1.3	0.9	0.5	0.3
Air (Domestic)	2.5	2.1	1.8	1.2
Buses	0.5	0.4	0.4	0.3
Mini-buses	0.5	0.4	0.4	0.3
Two wheels	0.5	0.4	0.4	0.3
Three wheels	0.7	0.6	0.6	0.5
Passenger rail	0.5	0.4	0.3	0.2

figure 9.20: tailpipe CO_2 emissions for light-duty vehicles (stock weighted sales average) in the reference and energy [r]evolution scenario

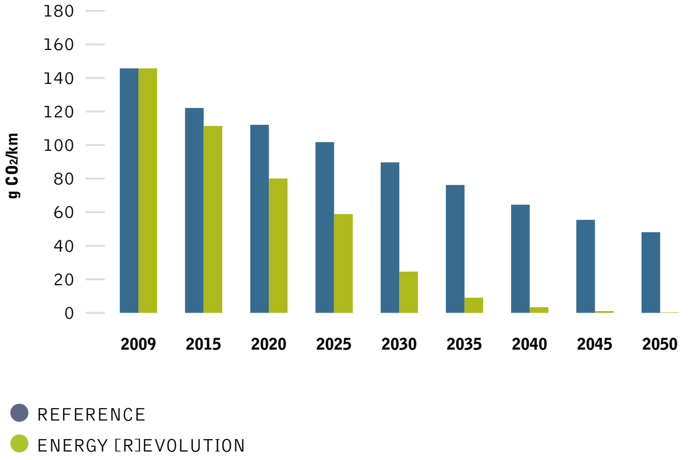

table 9.5: technical efficiency potential for freight transport

MJ/T-KM	2009	2020 E[R]	2030 E[R]	2050 E[R]
MDV	4.6	4.2	3.9	2.9
HDV	1.5	1.3	1.2	0.8
Freight rail	0.2	0.2	0.2	0.1
Inland navigation	0.5	0.4	0.4	0.3

9.3.2 projection of the future technology mix

For the future vehicle segment split the scenario deals with the light-duty vehicle sales in three segments: small, medium and large vehicles. For our purposes we divide up the numerous car types as follows:

- The very small and small sized car bracket includes city, supermini, minicompact cars as well as one and two seaters, compact and subcompact cars, micro and subcompact vans and small SUVs.
- The medium sized bracket includes car derived vans and small station wagons, upper medium class, midsize cars and station wagons, executive class, compact passenger vans, car derived pickups, medium SUVs, 2WD and 4WD.
- The large car bracket includes all kinds of luxury class, luxury multi-purpose vehicles, medium and heavy vans, compact and full-size pickup trucks (2WD, 4WD), standard and luxury SUVs.

The segment split is shown in Figure 9.21. In the Energy [R]evolution scenario we projected a shift of sales from large to medium and medium to small up to 2050 compared to 2009, which supports in delivering significant energy demand reductions.

9.3.3 projection of the future technology mix

Further to incremental efficiency improvements, greater occupancy rates and a shift toward smaller vehicle segments, a radical shift is needed in the fuels used in cars to achieve the CO_2 reduction targets in the Energy [R]evolution scenario. This means that conventional fossil fuelled cars are no longer sold in 2050 and that the petrol and diesel fuelled autonomous hybrids and plug-in hybrids (PHEV) that we have today are also phased out by 2050. That is, two generations of hybrid technologies will pave the way for the complete transformation toward light-duty vehicles with full battery electric or hydrogen fuel cell powertrains. Since it may not be possible to power LDVs for all purposes by rechargeable batteries only, hydrogen is introduced as a renewable fuel especially for larger long-range LDVs. Biofuels and remaining oil would be used in other sectors where a substitution is even harder to achieve than for LDVs. Figures 9.22 to 9.24 show the development of powertrain sales shares over time for small, medium and large LDVs up to 2050 in the Energy [R]evolution scenario.

figure 9.21: LDV vehicle sales by segment in 2009 and 2050 in the energy [r]evolution scenario

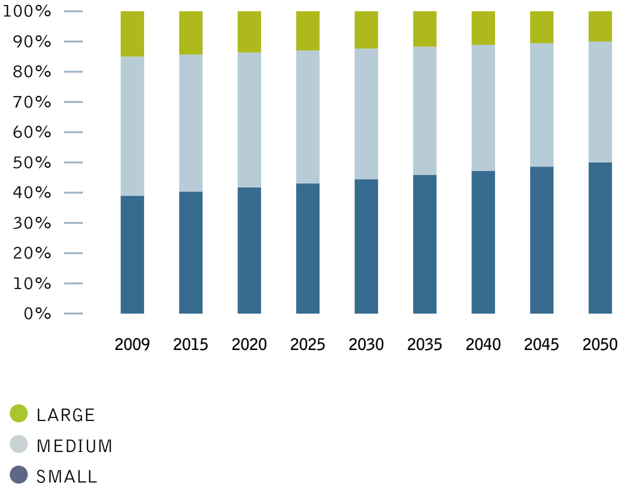

figure 9.22: sales share of vehicle technologies in small LDVs up to 2050 in the energy [r]evolution scenario

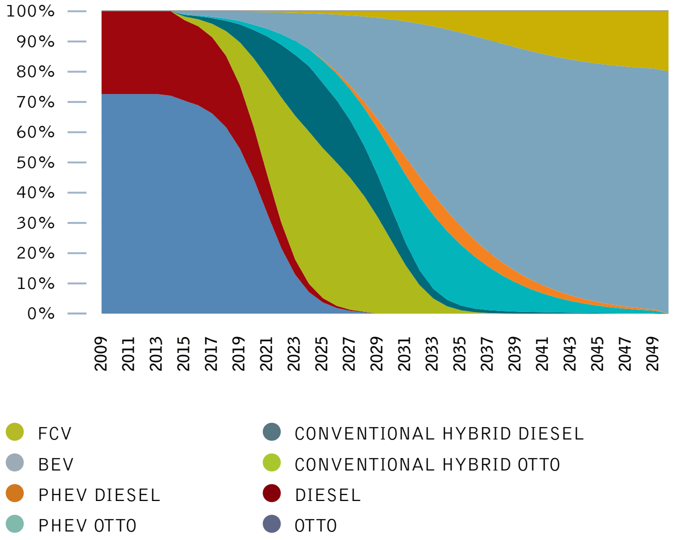

image A SIGN PROMOTES A HYDROGEN REFUELING STATION IN REYKJAVIK. THESE STATIONS ARE PART OF A PLAN TO TRY AND MAKE ICELAND A 'HYDROGEN ECONOMY.'

image PARKING SPACE FOR HYBRIDS ONLY.

© STEVE MORGAN/GP

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figure 9.23: sales share of vehicle technologies in medium LDVs up to 2050 in the energy [r]evolution scenario

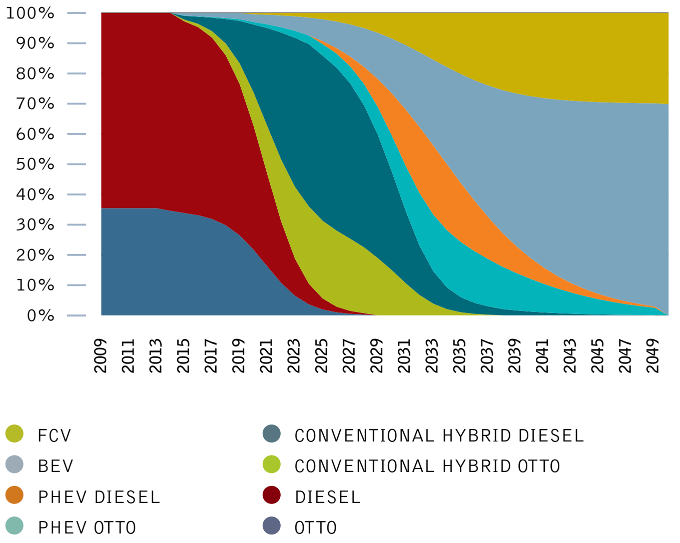
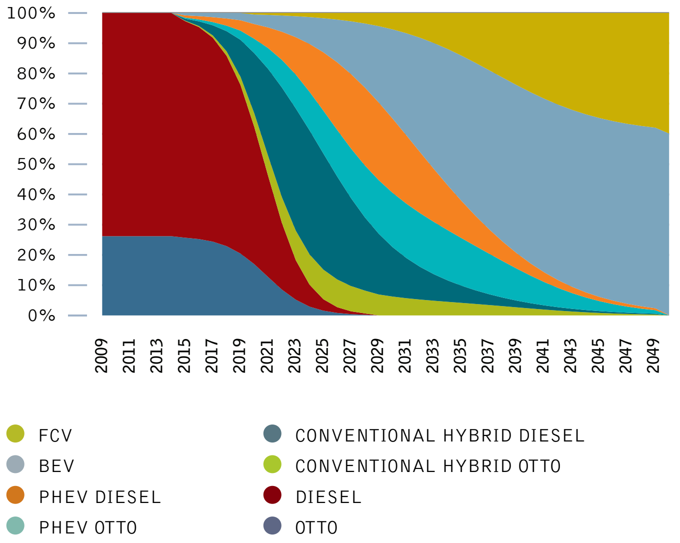


figure 9.24: sales share of vehicle technologies in large LDVs up to 2050 in the energy [r]evolution scenario



9.3.4 projection of the EU 27 vehicle stock development

There is a well-established correlation between GDP and passenger car sales. As GDP rises, car sales grow and thus vehicle stock and ownership increase as well. However, this scenario analysis found that technology shift in LDVs alone – although linked to enormous efficiency gains and fuel switch – is not sufficient to achieve the ambitious Energy [R]evolution CO_2-reduction targets. A slow-down of vehicle sales growth and a limitation or even reduction in vehicle ownership per capita compared to the Reference scenario was therefore required. Trends such as urbanisation processes as well as decreasing vehicle ownership rate in developed cities, support a different scenario compared to the Reference case. To break the global pattern of a century, this development needs to be supported by policy interventions to promote modal shift and alternative forms of car usage. The development of the EU 27 car stock in the Energy [R]evolution scenario is shown in Figure 9.25.

9.3.5 projection of future kilometres driven per year

Until a full shift from fossil to renewable fuels has taken place, driving on the road will create CO_2 emissions. A reduction in driving therefore contributes to our target for emissions reduction. However, this shift does not have to lead to reduced mobility because there are many opportunities for shifts from individual passenger road transport towards less CO_2 intensive public or non-motorised transport. The scenario is based on from the state-of-the-art knowledge on how LDVs are driven in the EU and then projects a decline in car usage. This is a further major building block of the Energy [R]evolution scenario, which goes hand in hand with new mobility concepts like co-modality and car-sharing concepts. Our projections of annual kilometres driven (AKD) by LDVs in the EU 27 is shown in Figure 9.26. We project a decrease in AKD in the EU 27 by about 0.25% per year until 2050 compared to 2009 in the Energy [R]evolution scenario.

figure 9.25: development of the LDV stock over time in the energy [r]evolution scenario

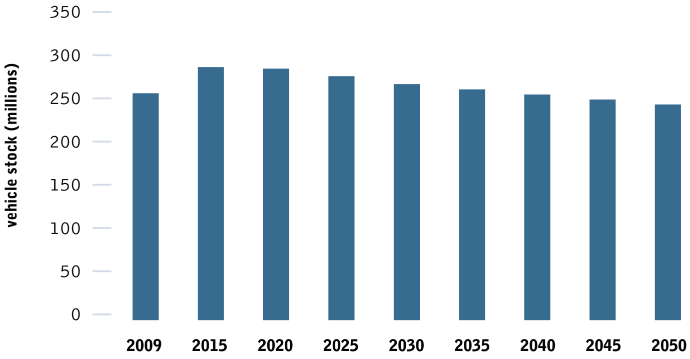
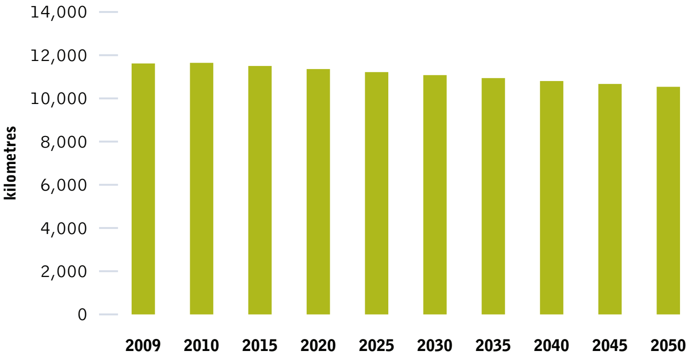


figure 9.26: average annual LDV kilometres driven in the energy [r]evolution scenario



9.3.6 renewable energy in the transport sector

In the Energy [R]evolution scenario, over half of the CO_2 reduction in the transport sector is achieved through a reduction in transport energy demand by 2050, through both behavioural measures and vehicle efficiency improvements. The remaining energy demand needs to be covered largely by renewable sources, to achieve the required CO_2 reductions in a sustainable manner. As petrol and diesel fuelled vehicles are phased out, alternative vehicle technologies are brought to market which can tap into electricity and hydrogen from renewable energy sources. By 2050, 85% of transport energy comes from renewable sources, compared to 4% in 2009.

box 9.2: eu renewable energy targets in transport

The EU's Renewable Energy Directive sets a target of 10% final energy consumption from renewable sources by 2020. Under the Energy [R]evolution a level of 6.2% is achieved, based on energy demand reductions, electrification of road and rail transport and the use of sustainable biofuels. This is in line with the requirements of the Directive since biofuels produced from waste and residues are counted twice, whereas renewable electricity in road vehicles is counted 2.5 times.

The Energy [R]evolution assumes that the potential for sustainable biomass is limited. For the EU 27 transport sector, there are no more than around 600 PJ available by 2050, given that other sectors such as power and heat production will also partly rely on biomass energy.

It is also assumed that battery electric vehicles will not be able to fully meet road transport demand. This is why our alternative scenario envisages hydrogen as a third renewable energy option for the transport sector.

Hydrogen can be produced through the electrolysis of water using power from renewable sources. If this is done at decentralised units, there is no need to transport the hydrogen along expensive pipeline networks. However, some level of central production will also be needed, in combination with distribution e.g. by trucks during on-peak times. This is because storage capacity at filling stations will likely remain limited for reasons of public acceptance.

Electrolysers that produce hydrogen with limited full load hours can also help to stabilise the power grid, by using excess electricity and avoiding additional peak loads in the system.

However, the future development of both electrolyser and fuel cell technologies is highly uncertain. This is why hydrogen used in fuel cell vehicles should be considered as a placeholder in our scenario for "chemical storage of renewable power". Alternatively, the renewable hydrogen could be converted into synthetic methane or liquid fuels depending on the economic benefits (storage costs vs. additional losses) as well as technology and market development in the transport sector (combustion engines vs. fuel cells). These different pathways are currently all explored in parallel. While all of them involve significant energy conversion losses, they are considered a valid alternative to the non-use of excess renewable power, and may finally be required to phase out crude oil and run 85% of transport operations on renewable energy in 2050.

9.4 conclusion

In a business as usual world we project only a very slight decrease in transport energy demand until 2050 in the EU 27. The aim of this Transport Chapter was therefore to show ways to dramatically reduce transport energy demand in general, and the dependency on climate-damaging fossil fuels in particular, also in view of the ever rising transport energy demand in other world regions.

The findings of our scenario calculations show that in order to reach the ambitious energy reduction goals of the Energy [R]evolution scenario a combination of behavioral changes and tremendous technical efforts is needed:

- a decrease of passenger- and freight-kilometres on a per capita base,
- a massive shift to electrically and hydrogen powered vehicles whose energy sources are produced from renewable sources,
- a gradual decrease of all modes' energy intensities,
- a modal shift from aviation to high speed rail and from road freight to rail freight.

These measures should be accompanied by major efforts on the installation and extension of the necessary infrastructures, e. g. railway networks, charging and fueling infrastructure for electric vehicles, just to mention a few.

The EU should support these efforts by tightening existing vehicle efficiency and fuel regulations and introducing new standards for trucks and other vehicle categories. In parallel, it should adopt regulations to control both fossil and renewable fuel production such that the energy demand in transport is met by truly sustainable, low-carbon energy. The EU should also support relevant research and innovation efforts and promote the standardisation and roll-out of refuelling infrastructure for alternative fuels across all member states.

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glossary & appendix

GLOSSARY OF COMMONLY USED TERMS AND ABBREVIATIONS

DEFINITION OF SECTORS

EU 27: SCENARIO RESULTS DATA

10

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

© NASA/JESSE ALLEN, ROBERT SIMMON

image ICEBERGS FLOATING IN MACKENZIE BAY ON THE THE NORTHEASTERN EDGE OF ANTARCTICA’S AMERY ICE SHELF, EARLY FEBRUARY 2012.

10.1 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 (Kilojoule) = 1,000 Joules
MJ (Megajoule) = 1 million Joules
GJ (Gigajoule) = 1 billion Joules
PJ (Petajoule) = 10^{15} Joules
EJ (Exajoule) = 10^{18} Joules

W Watt, measure of electrical capacity:
kW (Kilowatt) = 1,000 watts
MW (Megawatt) = 1 million watts
GW (Gigawatt) = 1 billion watts
TW (Terawatt) = 1^{12} watts

kWh Kilowatt-hour, measure of electrical output:
kWh (Kilowatt-hour) = 1,000 watt-hours
TWh (Terawatt-hour) = 10^{12} watt-hours

t Tonnes, measure of weight:
t = 1 tonne
Gt = 1 billion tonnes

table 10.1: conversion factors - fossil fuels

FUEL					
Coal	23.03	MJ/kg	1 cubic	0.0283	m^3
Lignite	8.45	MJ/kg	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 10.2: 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

10.2 definition of sectors

The definition of different sectors follows the sectorial break down of 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, aviation, domestic navigation. Fuel used for ocean, coastal 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.

EU 27: scenario results data

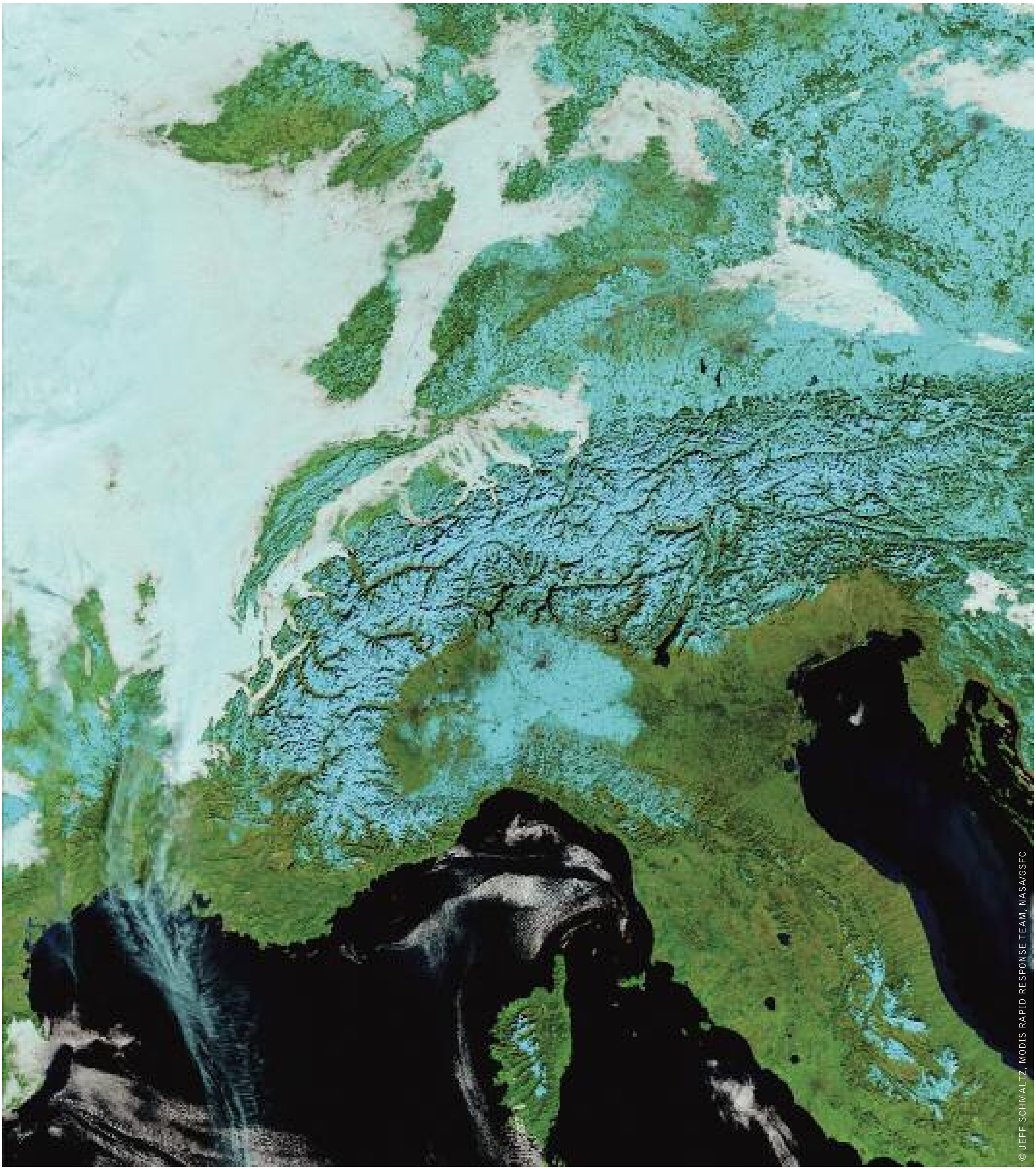

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image CAPPED WITH SILVERY WHITE SNOW, THE ALPS ARC GRACEFULLY ACROSS NORTHERN ITALY, SWITZERLAND, AUSTRIA, AND SOUTHERN GERMANY AND FRANCE, 2006.

EU 27: reference scenario

table 10.3: EU 27: electricity generation

TWh/a	2009	2015	2020	2030	2040	2050
Power plants	**2,530**	**2,731**	**2,870**	**3,147**	**3,330**	**3,484**
Coal	348	317	360	401	340	320
Lignite	248	214	191	182	152	114
Gas	436	451	494	605	705	757
Oil	50	26	18	13	12	11
Diesel	9	7	6	5	4	3
Nuclear	894	883	840	757	699	662
Biomass	65	90	93	100	123	142
Hydro	328	353	362	375	383	391
Wind	133	306	400	541	660	769
of which wind offshore	0	12	32	85	145	210
PV	14	71	86	132	175	209
Geothermal	6	9	10	15	19	23
Solar thermal power plants	0	2	8	14	20	27
Ocean energy	0	1	2	9	38	56
Combined heat & power plants	**646**	**706**	**741**	**812**	**883**	**954**
Coal	141	159	168	168	168	169
Lignite	93	91	89	88	88	86
Gas	315	350	369	411	464	516
Oil	37	30	22	12	11	8
Biomass	59	77	94	133	152	175
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	458	505	530	580	630	688
Autoproducers	188	201	211	232	253	266
Total generation	**3,175**	**3,437**	**3,611**	**3,959**	**4,213**	**4,438**
Fossil	1,677	1,644	1,716	1,885	1,944	1,984
Coal	488	476	528	569	508	489
Lignite	341	305	280	270	240	200
Gas	751	800	862	1,016	1,169	1,273
Oil	87	56	39	25	23	19
Diesel	9	7	6	5	4	3
Nuclear	894	883	840	757	699	662
Hydrogen	0	0	0	0	0	0
Renewables	**605**	**909**	**1,055**	**1,318**	**1,570**	**1,792**
Hydro	328	353	362	375	383	391
Wind	133	306	400	541	660	769
of which wind offshore	0	12	32	85	145	210
PV	14	71	86	132	175	209
Biomass	124	167	187	233	275	316
Geothermal	6	9	10	15	19	23
Solar thermal	0	2	8	14	20	27
Ocean energy	0	1	2	9	38	56
Distribution losses	188	182	175	175	172	176
Own consumption electricity	284	284	286	297	306	327
Electricity for hydrogen production	0	0	0	0	0	0
Final energy consumption (electricity)	**2,719**	**2,964**	**3,144**	**3,485**	**3,734**	**3,934**
Fluctuating RES (PV, Wind, Ocean)	147	378	488	682	873	1,034
Share of fluctuating RES	4.6%	11.0%	13.5%	17.2%	20.7%	23.3%
RES share (domestic generation)	**19.0%**	**26.4%**	**29.2%**	**33.3%**	**37.3%**	**40.4%**

table 10.4: EU 27: heat supply

PJ/a	2009	2015	2020	2030	2040	2050
District heating	**615**	**723**	**798**	**764**	**579**	**426**
Fossil fuels	473	558	616	590	447	329
Biomass	139	162	179	172	130	96
Solar collectors	0	0	0	0	0	0
Geothermal	2	2	3	3	2	1
Heat from CHP	**1,793**	**1,955**	**2,059**	**2,426**	**2,868**	**3,221**
Fossil fuels	1,517	1,666	1,736	2,018	2,402	2,709
Biomass	276	289	323	408	465	512
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
Direct heating 1)	**17,126**	**18,516**	**19,322**	**20,158**	**20,742**	**20,972**
Fossil fuels	14,801	15,745	16,316	16,455	16,352	15,977
Biomass	2,214	2,601	2,786	3,336	3,873	4,323
Solar collectors	52	80	101	189	323	448
Geothermal 2)	59	91	120	178	195	223
Total heat supply 1)	**19,535**	**21,194**	**22,179**	**23,348**	**24,189**	**24,619**
Fossil fuels	16,791	17,968	18,668	19,063	19,201	19,015
Biomass	2,630	3,053	3,288	3,917	4,468	4,931
Solar collectors	52	80	101	189	323	448
Geothermal 2)	61	93	122	180	197	225
Hydrogen	0	0	0	0	0	0
RES share (including RES electricity)	**14.0%**	**15.2%**	**15.8%**	**18.4%**	**20.6%**	**22.8%**

1) heat from electricity (direct) not included; 2) including heat pumps.

table 10.5: EU 27: co$_2$ emissions

MILL t/a	2009	2015	2020	2030	2040	2050
Condensation power plants	**793**	**714**	**733**	**762**	**685**	**636**
Coal	299	274	313	344	267	241
Lignite	277	239	213	177	142	101
Gas	172	175	188	226	263	283
Oil	39	21	15	12	11	9
Diesel	7	5	4	3	3	2
Combined heat & power production	**451**	**416**	**377**	**383**	**415**	**427**
Coal	148	158	137	129	140	137
Lignite	118	83	68	73	76	75
Gas	152	155	158	172	192	209
Oil	34	20	14	8	7	5
CO_2 emissions power generation (incl. CHP public)	**1,244**	**1,129**	**1,110**	**1,145**	**1,101**	**1,062**
Coal	446	432	450	474	408	378
Lignite	395	322	281	251	217	176
Gas	323	330	346	398	455	492
Oil & diesel	79	46	33	23	20	17
CO_2 emissions by sector	**3,529**	**3,497**	**3,514**	**3,469**	**3,340**	**3,191**
% of 1990 emissions	87%	87%	87%	86%	83%	79%
Industry 1)	452	487	486	452	418	371
Other sectors 1)	696	715	736	751	758	759
Transport	913	911	904	871	854	829
Power generation 2)	1,160	1,056	1,044	1,084	1,036	998
District heating & other conversion	308	328	343	310	274	233
Population (Mill.)	499	506	511	516	515	512
CO_2 emissions per capita (t/capita)	**7.1**	**6.9**	**6.9**	**6.7**	**6.5**	**6.2**

1) including CHP autoproducers. 2) including CHP public

table 10.6: EU 27: installed capacity

GW	2009	2015	2020	2030	2040	2050
Power plants	**689**	**804**	**859**	**968**	**1,047**	**1,106**
Coal	99	91	103	108	97	91
Lignite	34	29	25	23	19	14
Gas	121	125	141	173	204	219
Oil	41	27	22	14	14	12
Diesel	4	3	3	2	2	1
Nuclear	143	135	124	110	98	93
Biomass	11	14	14	15	18	20
Hydro	146	154	155	161	164	168
Wind	75	157	189	243	275	298
of which wind offshore	0	4	10	26	40	55
PV	14	67	77	110	137	163
Geothermal	1	1	2	2	3	4
Solar thermal power plants	0	1	2	4	5	6
Ocean energy	0	0	0	2	11	16
Combined heat & power production	**165**	**187**	**192**	**195**	**205**	**209**
Coal	39	43	41	40	39	38
Lignite	13	13	12	12	12	11
Gas	78	93	104	114	122	126
Oil	26	27	20	10	9	7
Biomass	10	12	14	20	23	27
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	112	125	130	135	142	147
Autoproducers	53	62	61	60	63	61
Total generation	**854**	**991**	**1,051**	**1,163**	**1,251**	**1,315**
Fossil	456	451	472	496	517	520
Coal	138	133	144	148	136	129
Lignite	48	42	37	35	30	25
Gas	199	218	245	287	327	346
Oil	66	54	43	24	22	19
Diesel	4	3	3	2	2	1
Nuclear	143	135	124	110	98	93
Hydrogen	0	0	0	0	0	0
Renewables	**256**	**406**	**455**	**558**	**636**	**702**
Hydro	146	154	155	161	164	168
Wind	75	157	189	243	275	298
of which wind offshore	0	4	10	26	40	55
PV	14	67	77	110	137	163
Biomass	20	26	29	36	42	47
Geothermal	1	1	2	2	3	4
Solar thermal	0	1	2	4	5	6
Ocean energy	0	0	0	2	11	16
Fluctuating RES (PV, Wind, Ocean)	89	224	267	355	422	478
Share of fluctuating RES	10.4%	22.6%	25.4%	30.5%	33.7%	36.3%
RES share (domestic generation)	**30.0%**	**40.9%**	**43.3%**	**48.0%**	**50.8%**	**53.3%**

table 10.7: EU 27: primary energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total	**69,247**	**71,275**	**72,282**	**73,537**	**73,593**	**72,949**
Fossil	**52,657**	**52,546**	**52,941**	**53,063**	**52,054**	**50,732**
Hard coal	7,418	7,385	7,586	7,470	6,421	5,658
Lignite	3,759	3,088	2,714	2,421	2,104	1,715
Natural gas	17,430	18,758	19,748	21,464	22,909	23,877
Crude oil	24,050	23,315	22,894	21,708	20,620	19,482
Nuclear	**9,761**	**9,646**	**9,173**	**8,261**	**7,632**	**7,228**
Renewables	**6,829**	**9,082**	**10,168**	**12,213**	**13,907**	**14,989**
Hydro	1,179	1,271	1,305	1,349	1,378	1,408
Wind	478	1,102	1,439	1,949	2,378	2,770
Solar	103	353	484	789	1,132	1,443
Biomass	4,823	5,977	6,490	7,481	8,284	8,584
Geothermal/ambient heat	244	374	445	615	597	581
Ocean energy	2	4	5	31	138	203
RES share	**9.6%**	**12.4%**	**13.7%**	**16.2%**	**18.5%**	**20.1%**

table 10.8: EU 27: final energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**48,349**	**51,337**	**52,990**	**54,963**	**56,339**	**57,019**
Total (energy use)	**44,116**	**47,133**	**48,733**	**50,687**	**52,126**	**52,868**
Transport	**13,493**	**13,877**	**13,952**	**13,665**	**13,572**	**13,288**
Oil products	12,647	12,610	12,494	11,998	11,708	11,312
Natural gas	91	122	139	185	262	328
Biofuels	502	854	993	1,093	1,145	1,121
Electricity	252	292	325	389	457	525
RES electricity	48	77	95	129	170	212
Hydrogen	0	0	0	0	0	1
RES share Transport	**4.1%**	**6.7%**	**7.8%**	**8.9%**	**9.7%**	**10.0%**
Industry	**10,675**	**12,203**	**12,516**	**12,580**	**12,547**	**12,435**
Electricity	3,538	4,095	4,248	4,443	4,543	4,588
RES electricity	674	1,083	1,241	1,479	1,693	1,853
District heat	624	680	689	689	714	760
RES district heat	54	116	122	126	123	126
Coal	733	1,005	1,090	923	715	378
Oil products	1,525	1,430	1,341	1,153	935	758
Gas	3,334	3,827	3,931	3,944	3,911	3,877
Solar	0	0	0	0	0	0
Biomass and waste	920	1,166	1,217	1,427	1,729	2,073
Geothermal/ambient heat	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
RES share Industry	**15.4%**	**19.4%**	**20.6%**	**24.1%**	**28.3%**	**32.6%**
Other Sectors	**19,948**	**21,053**	**22,265**	**24,443**	**26,007**	**27,145**
Electricity	5,998	6,283	6,744	7,716	8,443	9,051
RES electricity	1,142	1,661	1,970	2,569	3,146	3,654
District heat	1,418	1,590	1,733	2,016	2,207	2,331
RES district heat	122	260	281	322	319	301
Coal	521	436	421	324	313	301
Oil products	3,275	3,194	3,139	2,979	2,771	2,568
Gas	7,104	7,683	8,165	8,813	9,232	9,547
Solar	52	80	100	188	322	448
Biomass and waste	1,541	1,725	1,879	2,281	2,575	2,731
Geothermal/ambient heat	40	62	83	127	143	167
RES share Other Sectors	**14.5%**	**18.0%**	**19.4%**	**22.4%**	**25.0%**	**26.9%**
Total RES	**5,095**	**7,084**	**7,982**	**9,741**	**11,365**	**12,686**
RES share	**11.5%**	**15.0%**	**16.4%**	**19.2%**	**21.8%**	**24.0%**
Non energy use	**4,233**	**4,204**	**4,257**	**4,276**	**4,213**	**4,151**
Oil	3,684	3,687	3,735	3,751	3,696	3,641
Gas	503	473	479	481	474	467
Coal	47	43	44	44	44	43

EU 27: energy [r]evolution scenario

table 10.9: EU 27: electricity generation

TWh/a	2009	2015	2020	2030	2040	2050
Power plants	**2,530**	**2,599**	**2,584**	**2,709**	**3,207**	**3,310**
Coal	348	272	226	117	49	0
Lignite	248	211	163	22	0	0
Gas	436	439	429	408	280	30
Oil	50	21	11	4	0	0
Diesel	9	7	5	3	1	0
Nuclear	894	756	461	78	0	0
Biomass	65	69	74	78	77	59
Hydro	328	343	352	362	375	386
Wind	133	348	549	939	1,255	1,411
of which wind offshore	0	49	122	459	637	707
PV	14	115	238	414	637	729
Geothermal	6	8	22	80	110	136
Solar thermal power plants	0	7	45	141	297	406
Ocean energy	0	1	10	63	125	153
Combined heat & power plants	**646**	**709**	**760**	**815**	**800**	**730**
Coal	141	150	146	97	26	0
Lignite	93	61	21	3	0	0
Gas	315	358	411	413	310	106
Oil	37	29	15	0	0	0
Biomass	59	106	151	228	297	394
Geothermal	0	5	16	73	162	204
Hydrogen	0	0	0	0	6	26
CHP by producer						
Main activity producers	458	505	530	560	525	480
Autoproducers	188	204	230	255	275	250
Total generation	**3,175**	**3,308**	**3,344**	**3,524**	**4,007**	**4,040**
Fossil	1,677	1,548	1,427	1,068	667	136
Coal	488	422	372	215	76	0
Lignite	341	272	184	25	0	0
Gas	751	797	840	821	590	136
Oil	87	50	26	4	0	0
Diesel	9	7	5	3	1	0
Nuclear	894	756	461	78	0	0
Hydrogen	0	0	0	0	6	26
Renewables	**605**	**1,003**	**1,457**	**2,378**	**3,335**	**3,878**
Hydro	328	343	352	362	375	386
Wind	133	348	549	939	1,255	1,411
of which wind offshore	0	49	122	459	637	707
PV	14	115	238	414	637	729
Biomass	124	176	225	306	374	453
Geothermal	6	13	38	153	272	340
Solar thermal	0	7	45	141	297	406
Ocean energy	0	1	10	63	125	153
Distribution losses	188	204	205	208	203	201
Own consumption electricity	284	259	250	217	173	139
Electricity for hydrogen production	0	0	14	154	613	897
Final energy consumption (electricity)	**2,719**	**2,891**	**2,930**	**3,076**	**3,314**	**3,296**
Fluctuating RES (PV, Wind, Ocean)	147	465	797	1,416	2,017	2,293
Share of fluctuating RES	4.6%	14.0%	23.8%	40.2%	50.3%	56.8%
RES share (domestic generation)	**19.0%**	**30.3%**	**43.6%**	**67.5%**	**83.2%**	**96.0%**
'Efficiency' savings (compared to Ref.)	**0**	**81**	**235**	**617**	**1,002**	**1,374**

table 10.10: EU 27: heat supply

PJ/a	2009	2015	2020	2030	2040	2050
District heating	**615**	**659**	**1,235**	**1,822**	**2,242**	**2,624**
Fossil fuels	473	467	692	592	282	105
Biomass	139	158	321	465	471	446
Solar collectors	0	20	148	483	1,054	1,522
Geothermal	2	13	74	282	435	551
Heat from CHP	**1,793**	**2,061**	**2,322**	**2,856**	**3,382**	**3,353**
Fossil fuels	1,517	1,598	1,622	1,476	985	296
Biomass	276	422	557	721	925	1,149
Geothermal	0	41	143	658	1,454	1,829
Hydrogen	0	0	0	2	18	79
Direct heating[1]	**17,126**	**17,689**	**16,945**	**14,826**	**12,474**	**9,933**
Fossil fuels	14,801	14,830	13,075	8,978	4,984	1,063
Biomass	2,214	2,417	2,423	2,012	1,639	1,303
Solar collectors	52	176	685	2,122	3,193	3,867
Geothermal[2]	59	266	762	1,714	2,596	3,289
Hydrogen	0	0	0	0	62	411
Total heat supply[1]	**19,535**	**20,408**	**20,502**	**19,504**	**18,097**	**15,910**
Fossil fuels	16,791	16,895	15,389	11,046	6,251	1,465
Biomass	2,630	2,996	3,301	3,197	3,034	2,898
Solar collectors	52	196	833	2,605	4,246	5,389
Geothermal[1]	61	320	979	2,654	4,486	5,669
Hydrogen	0	0	0	2	80	490
RES share (including RES electricity)	**14.0%**	**17.2%**	**24.9%**	**43.4%**	**65.4%**	**90.7%**
'Efficiency' savings (compared to Ref.)	**0**	**786**	**1,678**	**3,844**	**6,091**	**8,709**

1) heat from electricity (direct) not included; geothermal includes heat pumps

table 10.11: EU 27: co$_2$ emissions

MILL t/a	2009	2015	2020	2030	2040	2050
Condensation power plants	**793**	**662**	**553**	**280**	**144**	**11**
Coal	299	235	196	101	39	0
Lignite	277	236	182	22	0	0
Gas	172	170	163	152	105	11
Oil	39	16	9	3	0	0
Diesel	7	5	3	2	1	0
Combined heat & power production	**451**	**366**	**307**	**239**	**137**	**37**
Coal	148	150	119	75	22	0
Lignite	118	55	16	2	0	0
Gas	152	142	162	161	115	37
Oil	34	20	10	0	0	0
CO_2 emissions power generation (incl. CHP public)	**1,244**	**1,029**	**861**	**519**	**281**	**48**
Coal	446	384	315	176	61	0
Lignite	395	292	198	24	0	0
Gas	323	312	326	314	220	48
Oil & diesel	79	41	22	5	1	0
CO_2 emissions by sector	**3,529**	**3,316**	**2,826**	**1,807**	**879**	**197**
% of 1990 emissions	87%	82%	70%	45%	22%	5%
Industry[1]	452	437	374	255	147	27
Other sectors[1]	696	674	579	377	210	64
Transport	913	918	793	517	187	51
Power generation[2]	1,160	977	810	475	245	33
District heating & other conversion	308	309	270	183	90	21
Population (Mill.)	499	506	511	516	515	512
CO_2 emissions per capita (t/capita)	**7.1**	**6.5**	**5.5**	**3.5**	**1.7**	**0.4**
'Efficiency' savings (compared to Ref.)	**0**	**181**	**688**	**1,662**	**2,461**	**2,994**

1) including CHP autoproducers. 2) including CHP public

table 10.12: EU 27: installed capacity

GW	2009	2015	2020	2030	2040	2050
Power plants	**689**	**817**	**926**	**1,119**	**1,343**	**1,418**
Coal	99	78	65	34	14	0
Lignite	34	29	22	3	0	0
Gas	121	122	116	124	85	33
Oil	41	26	13	5	0	0
Diesel	4	3	2	1	0	0
Nuclear	143	115	68	11	0	0
Biomass	11	11	11	12	12	12
Hydro	146	150	151	155	161	165
Wind	75	171	246	368	458	492
of which wind offshore	0	15	38	139	177	186
PV	14	109	213	345	498	570
Geothermal	1	1	4	13	17	21
Solar thermal power plants	0	2	11	31	62	81
Ocean energy	0	0	3	18	36	44
Combined heat & power production	**165**	**187**	**193**	**185**	**157**	**131**
Coal	39	41	36	23	6	0
Lignite	13	8	3	0	0	0
Gas	78	94	114	114	77	31
Oil	26	27	15	0	0	0
Biomass	10	17	23	35	46	60
Geothermal	0	1	3	12	27	34
Hydrogen	0	0	0	0	1	5
CHP by producer						
Main activity producers	112	125	129	125	105	86
Autoproducers	53	62	65	60	51	45
Total generation	**854**	**1,004**	**1,119**	**1,304**	**1,499**	**1,549**
Fossil	456	428	385	303	182	64
Coal	138	118	100	57	20	0
Lignite	48	37	25	3	0	0
Gas	199	216	230	237	162	64
Oil	66	53	28	5	0	0
Diesel	4	3	2	1	0	0
Nuclear	143	115	68	11	0	0
Hydrogen	0	0	0	0	1	5
Renewables	**256**	**461**	**666**	**989**	**1,316**	**1,480**
Hydro	146	150	151	155	161	165
Wind	75	171	246	368	458	492
of which wind offshore	0	15	38	139	177	186
PV	14	109	213	345	498	570
Biomass	20	28	35	47	57	72
Geothermal	1	2	6	25	45	56
Solar thermal	0	2	11	31	62	81
Ocean energy	0	0	3	18	36	44
Fluctuating RES (PV, Wind, Ocean)	89	280	463	731	991	1105
Share of fluctuating RES	10.4%	27.8%	41.3%	56.0%	66.1%	71.4%
RES share (domestic generation)	**30.0%**	**45.9%**	**59.5%**	**75.9%**	**87.8%**	**95.5%**

table 10.13: EU 27: primary energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total	**69,247**	**67,881**	**63,042**	**55,803**	**49,975**	**43,664**
Fossil	**52,657**	**50,377**	**44,645**	**31,358**	**17,693**	**6,754**
Hard coal	7,418	6,649	5,588	3,030	1,554	760
Lignite	3,759	2,772	1,872	226	0	0
Natural gas	17,430	17,791	18,154	15,694	10,381	3,063
Crude oil	24,050	23,164	19,032	12,407	5,759	2,931
Nuclear	**9,761**	**8,254**	**5,033**	**852**	**0**	**0**
Renewables	**6,829**	**9,250**	**13,364**	**23,593**	**32,282**	**36,911**
Hydro	1,179	1,235	1,269	1,304	1,349	1,389
Wind	478	1,253	1,977	3,381	4,519	5,081
Solar	103	675	2,095	5,364	9,212	11,667
Biomass	4,823	5,411	5,952	6,446	6,272	6,013
Geothermal/ambient heat	244	671	2,036	6,871	10,479	12,210
Ocean energy	2	4	36	227	450	551
RES share	**9.6%**	**13.2%**	**21.4%**	**42.6%**	**65.1%**	**84.9%**
'Efficiency' savings (compared to Ref.)	**0**	**2,863**	**9,313**	**17,571**	**22,871**	**27,856**

table 10.14: EU 27: final energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**48,349**	**50,122**	**48,002**	**42,885**	**38,041**	**33,504**
Total (energy use)	**44,116**	**45,824**	**43,773**	**38,966**	**34,331**	**30,053**
Transport	**13,493**	**13,707**	**12,084**	**9,316**	**7,237**	**6,189**
Oil products	12,647	12,708	10,961	7,109	2,503	620
Natural gas	91	117	123	131	158	131
Biofuels	502	561	565	550	532	472
Electricity	252	320	401	1,134	2,522	3,074
RES electricity	48	97	175	765	2,099	2,951
Hydrogen	0	0	33	392	1,522	1,893
RES share Transport	**4.1%**	**4.8%**	**6.2%**	**17.0%**	**53.9%**	**84.7%**
Industry	**10,675**	**11,765**	**11,637**	**10,847**	**10,005**	**8,824**
Electricity	3,538	3,953	3,957	3,849	3,653	3,415
RES electricity	674	1,199	1,724	2,597	3,040	3,279
District heat	624	771	1,134	1,517	1,975	2,235
RES district heat	54	185	396	847	1,532	2,088
Coal	733	763	602	108	40	14
Oil products	1,525	1,463	863	389	130	22
Gas	3,334	3,713	3,703	3,172	1,823	218
Solar	0	34	169	525	950	1,128
Biomass and waste	920	1,044	1,082	911	774	570
Geothermal/ambient heat	0	23	128	376	595	794
Hydrogen	0	0	0	0	65	428
RES share Industry	**15.4%**	**21.1%**	**30.1%**	**48.5%**	**69.4%**	**93.7%**
Other Sectors	**19,948**	**20,353**	**20,052**	**18,803**	**17,089**	**15,040**
Electricity	5,998	6,133	6,189	6,087	5,726	5,277
RES electricity	1,142	1,860	2,696	4,107	4,766	5,066
District heat	1,418	1,639	2,024	2,694	3,188	3,318
RES district heat	122	394	715	1,524	2,507	3,121
Coal	521	409	343	72	0	0
Oil products	3,275	3,061	2,103	1,123	377	39
Gas	7,104	7,168	6,853	5,025	3,159	1,047
Solar	52	142	516	1,597	2,242	2,738
Biomass and waste	1,541	1,642	1,611	1,324	1,048	878
Geothermal/ambient heat	40	160	413	880	1,349	1,743
RES share Other Sectors	**14.5%**	**20.6%**	**29.7%**	**50.2%**	**69.7%**	**90.1%**
Total RES	**5,095**	**7,342**	**10,203**	**16,269**	**22,755**	**27,055**
RES share	**11.5%**	**16.0%**	**23.3%**	**41.8%**	**66.3%**	**90.0%**
Non energy use	**4,233**	**4,298**	**4,229**	**3,919**	**3,710**	**3,451**
Oil	3,684	3,659	3,453	2,957	2,513	2,206
Gas	503	574	582	590	603	623
Coal	47	64	194	372	594	621

EU 27: investment & employment

table 10.15: EU 27: total investment in power sector

MILLION €	2011-2020	2021-2030	2031-2040	2041-2050	2011-2050	2011-2050 AVERAGE PER YEAR
Reference scenario						
Conventional (fossil & nuclear)	**324,744**	**323,794**	**247,380**	**151,266**	**1,047,184**	**26,180**
Renewables	**411,962**	**336,260**	**360,557**	**281,106**	**1,389,885**	**34,747**
Biomass	46,245	49,480	32,987	30,137	158,848	3,971
Hydro	80,874	75,516	73,706	74,924	305,020	7,626
Wind	167,479	132,319	158,424	104,502	562,724	14,068
PV	95,301	60,586	68,724	46,672	271,283	6,782
Geothermal	8,708	6,601	4,670	4,119	24,097	602
Solar thermal power plants	12,274	7,483	8,215	12,269	40,240	1,006
Ocean energy	1,082	4,276	13,832	8,482	27,673	692
Energy [R]evolution						
Conventional (fossil & nuclear)	**108,793**	**89,192**	**74,284**	**8,580**	**280,849**	**7,021**
Renewables	**883,275**	**886,617**	**1,062,129**	**862,578**	**3,694,599**	**92,365**
Biomass	71,411	64,186	65,876	69,854	271,328	6,783
Hydro	70,003	72,576	79,166	78,507	300,252	7,506
Wind	305,523	330,176	331,528	253,067	1,220,293	30,507
PV	312,348	169,106	293,423	161,382	936,260	23,406
Geothermal	50,502	125,771	129,379	126,998	432,650	10,816
Solar thermal power plants	65,335	93,257	134,741	148,291	441,624	11,041
Ocean energy	8,153	31,545	28,015	24,480	92,192	2,305

table 10,16: EU 27: total investment in renewable heating only

(EXCLUDING INVESTMENTS IN FOSSIL FUELS)

MILLION €	2011-2020	2021-2030	2031-2040	2041-2050	2011-2050	2011-2050 AVERAGE PER YEAR
Reference scenario						
Renewables	**222,662**	**217,599**	**151,110**	**144,294**	**735,665**	**18,392**
Biomass	178,385	164,836	92,560	81,375	517,156	12,929
Geothermal	1,003	0	0	0	1,003	25
Solar	20,626	28,738	41,461	42,919	133,744	3,344
Heat pumps	22,648	24,025	17,089	20,001	83,762	2,094
Energy [R]evolution scenario						
Renewables	**512,409**	**629,679**	**881,122**	**920,617**	**2,943,826**	**73,596**
Biomass	101,971	12,012	2,789	0	116,772	2,919
Geothermal	45,777	19,101	112,413	141,335	318,625	7,966
Solar	193,641	390,814	444,792	495,406	1,524,653	38,116
Heat pumps	171,021	207,752	321,128	283,876	983,777	24,594

table 10.17: EU 27: total employment

THOUSAND JOBS		REFERENCE			ENERGY [R]EVOLUTION		
	2010	2015	2020	2030	2015	2020	2030
By sector							
Construction and installation	165	86	84	83	307	238	216
Manufacturing	183	82	64	44	366	269	197
Operations and maintenance	210	232	237	253	240	251	253
Fuel supply (domestic)	550	520	478	642	498	447	340
Coal and gas export	-	-	-	-	-	-	-
Solar and geothermal heat	10	12	10	11	69	212	205
Total jobs	**1,118**	**932**	**873**	**1,022**	**1,479**	**1,418**	**1,210**
By technology							
Coal	261	251	208	211	210	156	80
Gas, oil & diesel	193	179	154	286	185	169	121
Nuclear	57	60	63	62	70	88	95
Total renewables	**607**	**443**	**448**	**463**	**1,014**	**1,005**	**914**
Biomass	*215*	*235*	*247*	*271*	*232*	*245*	*252*
Hydro	*53*	*48*	*52*	*78*	*47*	*51*	*56*
Wind	*164*	*94*	*83*	*60*	*254*	*216*	*180*
PV	*160*	*47*	*49*	*30*	*355*	*209*	*156*
Geothermal power	*1.8*	*1.0*	*0.9*	*0.9*	*11*	*17*	*14*
Solar thermal power	*2.6*	*5.9*	*4.4*	*3.1*	*40*	*45*	*45*
Ocean	*0.3*	*0.3*	*1.1*	*3.7*	*4.7*	*10*	*6*
Solar - heat	*6*	*9*	*7*	*12*	*47*	*157*	*153*
Geothermal & heat pump	*4.0*	*2.6*	*3.0*	*3.7*	*22*	*55*	*52*
Total jobs	**1,118**	**932**	**873**	**1,022**	**1,479**	**1,418**	**1,210**

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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.

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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.

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