energy
[r]evolution

A SUSTAINABLE NETHERLANDS ENERGY OUTLOOK

GWEC
GLOBAL WIND ENERGY COUNCIL

EREC
EUROPEAN RENEWABLE ENERGY COUNCIL

GREENPEACE

report 2013 Netherlands 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 THE BORSSELE POWER PLANT IN THE PROVINCE OF ZEALAND OF THE NETHERLANDS HAS BEEN OPERATING FOR 40 YEARS. IT IS THE SECOND OLDEST NUCLEAR POWER PLANT IN THE EUROPEAN UNION.

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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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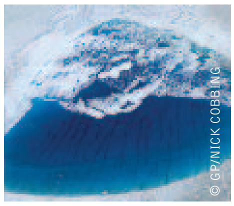

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image NORTH HOYLE WIND FARM, UK'S FIRST WIND FARM IN THE IRISH SEA WHICH WILL SUPPLY 50,000 HOMES WITH POWER.

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introduction

"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."

image THE 'AMERCENTRALE' IN GEERTRUIDENBERG IN THE SOUTH OF THE NETHERLANDS IS A POWER PLANT OF RWE/ESSENT. IT RUNS MAINLY ON COAL. THE CO_2-EMISSIONS OF THE PLANT COMPRISED 3.8 MILLION TONNES IN 2011.

This first Dutch edition of the energy revolution appears two years after the devastating earthquake and tsunami in Japan and the following Fukushima nuclear disaster. In some countries the devastating events in Japan led to a radical change in the energydebate, especially in Germany. Chancellor Angela Merkel announced an *Energiewende*: within ten years all nuclear power plants in Germany will be closed. Solar cells and wind farms are taking over traditional power generators at an impressive rate.

In the Netherlands the situation is -unfortunately- different. In 2012 the Dutch government started a life-extension procedure for the second oldest nuclear power plant in the European Union, the Borssele power plant. Furthermore, three coal-fired power stations are under construction. Internationally, the Netherlands have emerged on the lower rungs of many lists regarding climate and energy, be it the production of sustainable energy or the reduction of the economy's CO_2-intensity. Meanwhile, oil giant Royal Dutch Shell is searching for the last of our earth's oil in the Arctic and other vulnerable regions.

That said, even in the Netherlands there are glimpses of hope. The new government has announced that 16 percent of Dutch energy should originate from renewable sources by 2020. This offers great opportunities for the development of wind farms and solar cells. Additionally, it will create new jobs, much needed in times of economic crisis.

In 2009 European leaders agreed that emissions of greenhouse gasses in the EU need to be 80 to 95 percent lower in 2050, than they were in 1990. However, a concrete plan of how to achieve this has yet to be made. The European Commission predicts that if current legislation and trends continue in the same fashion, the reduction of harmful greenhouse gas emissions will only reach 40 percent. The current trends in the Netherlands are also bleak. Between 1990 and 2011 energy consumption grew by 20 percent, and CO_2 emissions grew by six percent.

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.

Greenpeace wants to see an energy revolution. The Netherlands need to move away from dangerous nuclear energy and the fossil fuels that are driving climate change. Renewable energy and more energy efficiency are cornerstones in the battle to reduce the Dutch contribution to climate change and secure greater energy security.

This publication lays out a blueprint for a sustainable energy supply in the Netherlands. The course can be changed. As well as its nuclear power plant, the country can survive without its coal-fired power plants. The Netherlands have enough capacity to meet electricity demands. Closing down all coal-fired power plants in 2020 would lower CO_2 emissions by 15 percent, compared to the 1990 level.

Renewable energy technologies are competing at an ever-increasing level with conventional power sources (which have been heavily subsidised for decades). The Netherlands is perfectly situated to develop large offshore wind farms; solar cells and onshore wind farms can also contribute a great deal. By 2030 solar and wind power can already account for 50 percent of Dutch electricity generation.

In the transport sector much higher energy efficiency can be achieved by making cars run more economically and introducing more electric cars. Freight transport can increase the use of the existing rail network and waterways. Gas consumption can be decreased by finally insulating houses properly. By 2050 The Netherlands can still use energy, while contributing very little to climate change.

However, it is important that the Dutch government and the EU lay out clear long-term plans. 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. Only then will the business community be persuaded to make vital investments. Only then the Netherlands will catch up and turn the energy revolution into a reality.

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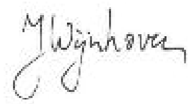

Joris Wijnhoven
CLIMATE & ENERGY UNIT
GREENPEACE NETHERLANDS

MAY 2013

executive summary

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

© BAS BEENTJES / GREENPEACE

image THE NEW RAINBOW WARRIOR SAILS PAST THE PRINCESS AMALIA WIND FARM, 12 MILES FROM THE COAST OF IJMUIDEN. THE PARK CONSISTS OF 60 WINDMILLS WHICH ARE ABLE TO SUPPLY 125,000 HOMES WITH CLEAN ENERGY.

The Energy [R]evolution Scenario has became a well known and well respected energy analysis since it was first published for Europe in 2005. Global Energy [R]evolution editions were published in 2007, 2008, 2010 and 2012. This is the first Dutch edition.

The Energy [R]evolution provides a consistent fundamental pathway for how to protect our climate: getting the world from where we are now to where we need to be by phasing out fossil fuels and cutting CO_2 emissions while ensuring energy security.

the fossil fuel dilemma

Raising energy demand is putting pressure on fossil fuel supply and now pushing oil exploration towards "unconventional" oil resources. Remote and sensitive environments such as the Arctic are under threat from increased drilling, while the environmentally destructive tar sands projects in Canada are being pursued to extract more marginal sources. However, scarcity of conventional oil is not the most pressing reason to phase-out fossil fuels: cutting back dramatically is essential to save the climate of our planet. Switching from fossil fuels to renewables also offers substantial benefits such as independence from world market fossil fuel prices and the creation of millions of new green jobs. It can also provide energy to the two billion people currently without access to energy services. The Energy [R]evolution 2012 took a closer look at the measures required to phase-out oil faster in order to save the Arctic from oil exploration, avoid dangerous deep sea drilling projects and to leave oil shale in the ground.

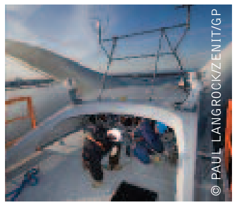

image TEST WINDMILL N90 2500, BUILT BY THE GERMAN COMPANY NORDEX, IN THE HARBOUR OF ROSTOCK. THIS WINDMILL PRODUCES 2.5 MEGA WATT AND IS TESTED UNDER OFFSHORE CONDITIONS. TWO TECHNICIANS WORKING INSIDE THE TURBINE.

climate change threats

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

In order to avoid the most catastrophic impacts of climate change, the global temperature increase must be kept as far below 2°C as possible. This is still possible, but time is running out. To stay within this limit, global greenhouse gas emissions will need to peak by 2015 and decline rapidly after that, reaching as close to zero as possible by the middle of the 21st century. The main greenhouse gas is carbon dioxide (CO_2) produced by using fossil fuels for energy and transport. Keeping the global temperature increase to 2°C is often referred to as a 'safe level' of warming, but this does not reflect the reality of the latest science. This shows that a warming of 2°C above pre-industrial levels would pose unacceptable risks to many of the world's key natural and human systems.[1] Even with a 1.5°C warming, increases in drought, heat waves and floods, along with other adverse impacts such as increased water stress for up to 1.7 billion people, wildfire frequency and flood risks, are projected in many regions. Neither does staying below 2°C rule out large-scale disasters such as melting ice sheets. Partial de-glaciation of the Greenland ice sheet, and possibly the West Antarctic ice sheet, could even occur from additional warming within a range of 0.8 – 3.8°C above current levels.[2] If rising temperatures are to be kept within acceptable limits then we need to significantly reduce our greenhouse gas emissions. This makes both environmental and economic sense.

global negotiation

Recognising the global threats of climate change, the signatories to the 1992 UN Framework Convention on Climate Change (UNFCCC) agreed to the Kyoto Protocol in 1997. The Protocol entered into force in early 2005 and its 193 members meet continuously to negotiate further refinement and development of the agreement. Only one major industrialised nation, the United States, has not ratified the protocol. In 2011, Canada announced its intention to withdraw from the protocol. In Copenhagen in 2009, the members of the UNFCCC were not able to deliver a new climate change agreement towards ambitious and fair emission reductions. At the 2012 Conference of the Parties in Durban, there was agreement to reach a new agreement by 2015 and to adopt a second commitment period at the end of 2012. However, the United Nations Environment Program's examination of the climate action pledges for 2020 shows a major gap between what the science demands to curb climate change and what the countries plan to do. The proposed mitigation pledges put forward by governments are likely to allow global warming to at least 2.5 to 5 degrees temperature increase above pre-industrial levels.[3]

the nuclear issue

The nuclear industry promises that nuclear energy can contribute to both climate protection and energy security, however their claims are not supported by data. The most recent Energy Technology Perspectives report published by the International Energy Agency includes a Blue Map scenario including a quadrupling of nuclear capacity between now and 2050. To achieve this, the report says that on average 32 large reactors (1,000 MWe each) would have to be built every year from now until 2050. According to the IEA's own scenario, such massive nuclear expansion would cut carbon emissions by less than 5%. More realistic analysis shows the past development history of nuclear power and the global production capacity make such expansion extremely unviable. Japan's major nuclear accident at Fukushima in March 2011 following a tsunami came 25 years after the disastrous explosion in the Chernobyl nuclear power plant in former Soviet Union, illustrating the inherent risks of nuclear energy. Nuclear energy is simply unsafe, expensive, has continuing waste disposal problems and can not reduce emissions by a large enough amount.

climate change and security of supply

Security of supply – both for access to supplies and financial stability – is now at the top of the energy policy agenda. Recent rapidly fluctuating oil prices are lined to a combination of many events, however one reason for these price fluctuations is that supplies of all proven resources of fossil fuels are becoming scarcer and more expensive to produce. Some 'non-conventional' resources such as shale oil have become economic, with devastating consequences for the local environment. The days of 'cheap oil and gas' are coming to an end. Uranium, the fuel for nuclear power, is also a finite resource. By contrast, the reserves of renewable energy that are technically accessible globally are large enough to provide more than 40 times more energy than the world currently consumes, forever, according to the latest IPCC Special report Renewables (SRREN). Renewable energy technologies are at different levels of technical and economic maturity, but a variety of sources offer increasingly attractive options. Cost reductions in just the past two years have changed the economic of renewables fundamentally, especially wind and solar photovoltaics. The common feature of all renewable energy sources, the wind, sun, earth's crust, and ocean is that they produce little or no greenhouse gases and are a virtually inexhaustible 'fuel'. Some technologies are already competitive; the solar and the wind industry have maintained double digit growth rates over 10 years now, leading to faster technology deployment world wide.

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

3 UNITED NATIONS ENVIRONMENT PROGRAMME (UNEP): 'BRIDGING THE EMISSIONS GAP'. A UNEP SYNTHESIS REPORT, NOV. 2011.

Energy efficiency is a sleeping giant – offering the most cost competitive way to reform the energy sector. There is enormous potential for reducing our consumption of energy, while providing the same level of energy services. New business models to implement energy efficiency must be developed and must get more political support. This study details a series of energy efficiency measures which can substantially reduce demand across industry, homes, business and services as well as transport.

the energy [r]evolution key principles

The expert consensus is that this 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. 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 concentrating solar power are essential. Building up clusters of renewable micro grids, especially for people living in remote areas, will be a central tool in providing sustainable electricity to the almost two billion people around who currently don't have access to electricity.

projections to reality

Projection of global installed wind power capacity at the end of 2010 in the first Global Energy [R]evolution, published in January 2007.

>> 156 GW

Actual global installed wind capacity at the end of 2010.

>> 197 GW

While at the end of 2011 already 237 GW have been installed. More needs to be done.

the energy [r]evolution – key results

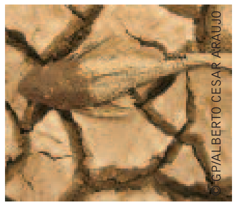
Renewable energy sources account for 3.9% of Netherland's primary energy demand in 2010. The main source is biomass, which is mostly used in the heat sector.

For electricity generation renewables contribute about 9.5% and for heat supply, around 2.4%, mostly from biomass. About 94.9% of the primary energy supply today still comes from fossil fuels and 1.2% from nuclear energy.

The Energy [R]evolution scenario describes development pathways to a sustainable energy supply, achieving the urgently needed CO_2 reduction target and a nuclear phase-out, without unconventional oil resources. The results of the Energy [R]evolution scenario which will be achieved through the following measures:

- **Curbing energy demand:** The Netherlands' energy demand is projected by combining population development, GDP growth and energy intensity. Under the Reference scenario, total final energy demand decreases by 6% from the current 2,064 PJ/a to 1,940 PJ/a in 2050. In the Energy [R]evolution scenario, final energy demand decreases by 37% compared to current consumption and it is expected to reach around 1,300 PJ/a by 2050.
- **Controlling power demand:** Under the Energy [R]evolution scenario, electricity demand is expected to increase in both the industry sector as well as in the residential and service sector, and to grow also in the transport sector. Total electricity demand will rise from 107 TWh/a to 131 TWh/a by the year 2050. Compared to the Reference scenario, efficiency measures in the industry, residential and service sectors avoid the final electricity consumption of about 18 TWh/a.
- **Reducing heating demand:** Under the Energy [R]evolution scenario, demand for heat supply is expected to decrease almost constantly. Compared to the Reference scenario, consumption equivalent to 330 PJ/a is avoided through efficiency gains 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.
- **Electricity generation:** A dynamically growing renewable energy market and an increasing share of renewable electricity. 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, 78% of the electricity produced in the Netherlands will come from renewable energy sources. Already by 2020, the share of renewable electricity production will be 44% and 58% by 2030. The installed capacity of renewables, mainly wind and PV, will reach 42 GW in 2030 and 70 GW by 2050.

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



- **Future costs of electricity generation:** Under the Energy [R]evolution scenario the costs of electricity generation do not significantly increase in the long term compared to the Reference scenario. The maximum difference will be about 0.2 €ct/kWh up to 2020. Because of rising prices for conventional fuels and the lower CO_2 intensity of electricity generation, electricity generation costs will become even more economically favourable under the Energy [R]evolution scenario and by 2050 costs will be 4.5 €ct/kWh below those in the Reference version.

- **The future electricity bill:** Under the Reference scenario unchecked growth in demand, an increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity generation costs rising from today's € 12 billion per year to more than € 19 billion in 2050. The Energy [R]evolution scenario not only complies with Netherland's CO_2 reduction targets, but also helps to stabilise energy costs and relieve the economic pressure on society. Increasing energy efficiency and shifting energy supply to renewables lead to long term costs for electricity supply that are even 5% lower than in the Reference scenario.

- **Fuel costs savings:** Because renewable energy, except biomass, has no fuel costs, the fuel cost savings in the Energy [R]evolution scenario reach a total of $ 136 billion up to 2050, or $ 3.5 billion per year. The total fuel cost savings therefore would cover more than one and a half times the total additional investments compared to the Reference scenario. These renewable energy sources would then go on to produce electricity without any further fuel costs beyond 2050, while the costs for coal and gas will continue to be a burden on national economies.

- **Heating supply:** Renewables currently meet 2.4% of Netherlands's primary heat demand, the main contribution coming from the use of biomass. The expansion and extended use of district heating networks are important for the large scale utilisation of geothermal and solar thermal energy. Dedicated support instruments are required to ensure a dynamic development. In the Energy [R]evolution scenario, renewables provide 24% of Netherlands's total heat demand in 2030 and 65% in 2050.

- **Future investments in the heat sector:** It would require a major revision of current investment strategies in heating technologies. Especially solar and geothermal and heat pump technologies need enormous increase in installations, if these potentials are to be tapped for the heat sector. Installed capacity needs to increase by the factor of 120 for solar thermal and by the factor of 750 for geothermal and heat pumps. Capacity of biomass technologies will decrease but remain a main pillar of heat supply. Renewable heating technologies are extremely variable, 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 in total requires around € 98 billion to be invested in renewable heating technologies until 2050 (including investments for replacement after the economic lifetime of the plants) - approximately € 2,5 billion per year.

- **Sustainable transport:** A key target in the Netherlands is to introduce incentives for people to drive smaller and more efficient cars. In addition, it is vital to shift transport use to efficient modes like rail, light rail and buses, especially in the urban areas. Together with rising prices for fossil fuels, these changes reduce the growth in car sales projected under the Reference scenario. Compared to the Reference scenario, energy demand from the transport sector will be reduced by 49% in 2050 under the Energy [R]evolution scenario. Energy demand under the Energy [R]evolution scenario will decrease from 483 PJ/a in 2010 to 235 PJ/a. Highly efficient propulsion technology with hybrid, plug-in hybrid and battery-electric power trains will bring large efficiency gains. By 2030, electricity will provide 9% of the transport sector's total energy demand in the Energy [R]evolution, while in 2050 the share will be 33%.

- **Primary energy consumption:** Under the Energy [R]evolution scenario, primary energy demand will decrease by 40% from today's 3,490 PJ/a to 2,100 PJ/a. Compared to the Reference scenario, overall primary energy demand will be reduced by 32% in 2050 under the Energy [R]evolution scenario (REF: 3,110 PJ in 2050). The Energy [R]evolution scenario aims to phase out coal and oil as fast as technically and economically possible. Coal power plants are phased out by 2020. This is made possible mainly by the present overcapacity to produce power in the Netherlands and the rise of renewable electricity production. Oil combustion engines are replaced fastly in the transport sector by very efficient electric vehicles. This leads to an overall renewable primary energy share of 24% in 2030 and 54% in 2050. Nuclear energy is phased out before 2015.

- **Development of CO_2 emissions:** The Netherlands' emissions of CO_2 will decrease by 26% between 2010 and 2050 under the Reference scenario, under the Energy [R]evolution scenario they will decrease from 172 million tonnes in 2010 to 21 million tonnes in 2050. Annual per capita emissions will drop from 10.4 tonnes to 1.2 tonnes. In spite of 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 renewables in vehicles will reduce emissions in the transport sector. By 2050, Netherlands's CO_2 emissions are 86% below 1990 levels.

1

climate and energy policy

THE UNFCCC AND THE KYOTO PROTOCOL

INTERNATIONAL ENERGY POLICY

RENEWABLE ENERGY TARGETS

POLICY CHANGES IN THE ENERGY SECTOR

POLITICAL RECOMMENDATIONS FOR THE NETHERLANDS

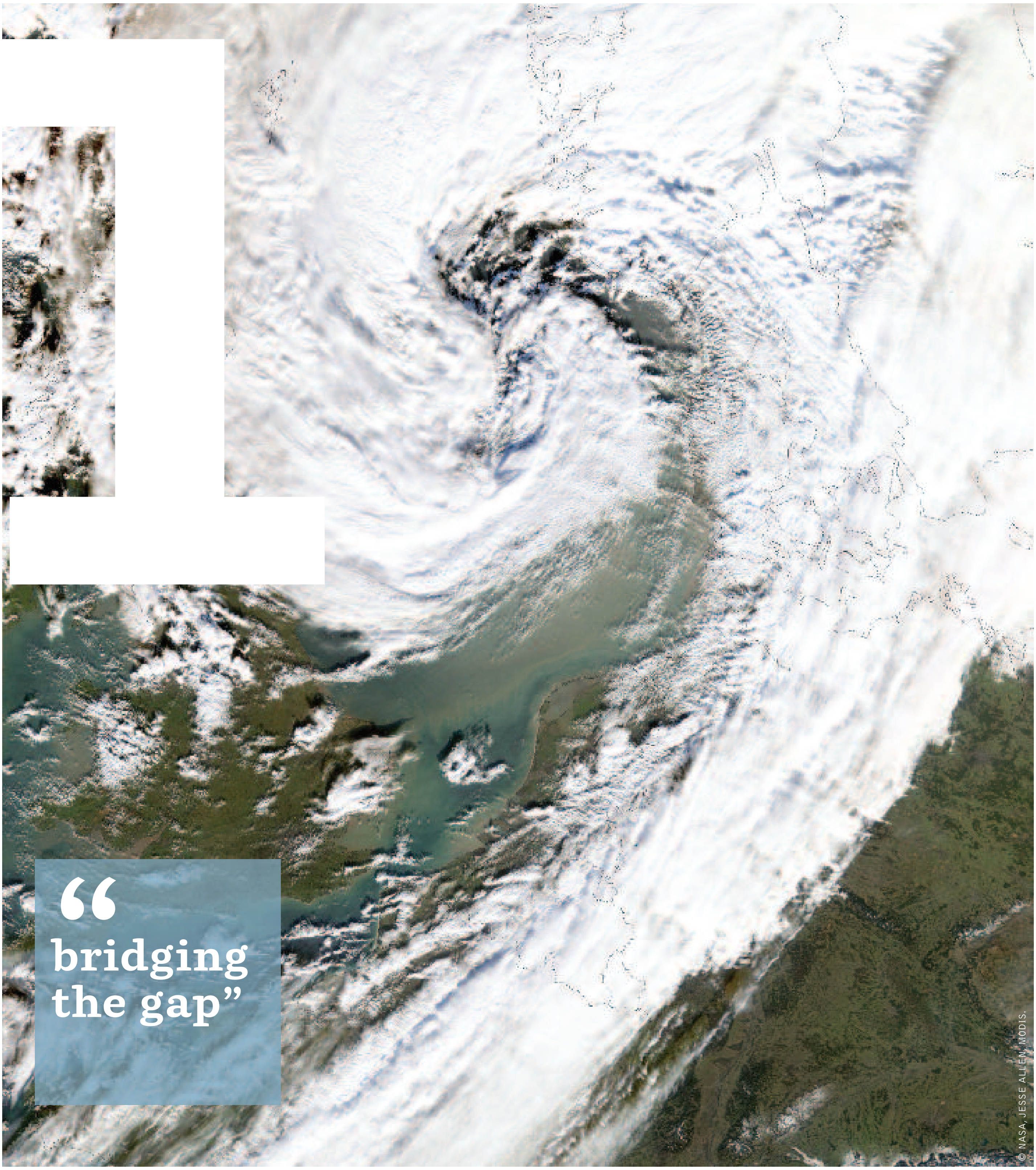


image THE CLOUDS OVER NORTHERN EUROPE HAVE THE MENACING CURL OF A LOW PRESSURE SYSTEM ASSOCIATED WITH SEVERE WINTER STORMS. THIS PARTICULAR STORM LASHED THE UNITED KINGDOM, SCANDINAVIA, NORTHERN GERMANY, AND RUSSIA WITH HURRICANE-FORCE WINDS AND INTENSE RAINS. ACCORDING TO NEWS REPORTS, 14 PEOPLE DIED 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.

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

If we do not take urgent and immediate action to protect the climate, the threats from climate change could become irreversible.

The goal of climate policy should be to keep the global mean temperature rise to less than 2°C above pre-industrial levels. We have very little time within which we can change our energy system to meet these targets. This means that global emissions will have to peak and start to decline by the end of the next decade at the latest.

The only way forwards is a rapid reduction in the emission of greenhouse gases into the atmosphere.

1.1 the UNFCCC and the kyoto protocol

Recognising the global threats of climate change, the signatories to the 1992 UN Framework Convention on Climate Change (UNFCCC) agreed the Kyoto Protocol in 1997. The Protocol entered into force in early 2005 and its 193 members meet continuously to negotiate further refinement and development of the agreement. Only one major industrialised nation, the United States, has not ratified the protocol. In 2011, Canada announced its intention to withdraw from the protocol.

box 1.1: what does the kyoto protocol do?

The Kyoto Protocol commits 193 countries (signatories) to reduce their greenhouse gas emissions by 5.2% from their 1990 level. The global target period to achieve cuts was 2008-2012. Under the protocol, many countries and regions have adopted regional and national reduction targets. The European Union commitment is for overall reduction of 8%, for example. In order to help reach this target, the EU also created a target to increase its proportion of renewable energy from 6% to 12% by 2010.

In Copenhagen in 2009, the 195 members of the UNFCCC were supposed to deliver a new climate change agreement towards ambitious and fair emission reductions. Unfortunately the ambition to reach such an agreement failed at this conference.

At the 2012 Conference of the Parties in Durban, there was agreement to reach a new agreement by 2015. At the Doha Climate Change Conference in November 2012, the European Union and a handful of countries outside the EU have committed themselves to a continuation of the Kyoto protocol beyond 2012. However, the United Nations Environment Program's examination of the climate action pledges for 2020 shows that there is still a major gap between what the science demands to curb climate change and what the countries plan to do. The proposed mitigation pledges put forward by governments are likely to allow global warming to at least 2.5 to 5 degrees temperature increase above pre-industrial levels.[4]

reference
4 UNEP EMISSIONS GAP REPORT.

This means that the new agreement in 2015, with the Fifth Assessment Report of the IPCC on its heels, should strive for climate action for 2020 that ensures that the world stay as far below an average temperature increase of 2°C as possible. Such an agreement will need to ensure:

- That industrialised countries reduce their emissions on average by at least 40% by 2020 compared to their 1990 level.
- That industrialised countries provide funding of at least $140 billion a year to developing countries under the newly established Green Climate Fund to enable them to adapt to climate change, protect their forests and be part of the energy revolution.
- That developing countries reduce their greenhouse gas emissions by 15 to 30% compared to their projected growth by 2020.

1.2 international energy policy

At present there is a distortion in many energy markets, where renewable energy generators have to compete with old nuclear and fossil fuel power stations but not on a level playing field. This is because consumers and taxpayers have already paid the interest and depreciation on the original investments so the generators are running at a marginal cost. Political action is needed to overcome market distortions so renewable energy technologies can compete on their own merits.

While governments around the world are liberalising their electricity markets, the increasing competitiveness of renewable energy should lead to higher demand. Without political support, however, renewable energy remains at a disadvantage, marginalised because there has been decades of massive financial, political and structural support to conventional technologies. Developing renewables will therefore require strong political and economic efforts for example, through laws that guarantee stable tariffs over a period of up to 20 years. Renewable energy will also contribute to sustainable economic growth, high quality jobs, technology development, global competitiveness and industrial and research leadership.

1.3 renewable energy targets

A growing number of countries have established targets for renewable energy in order to reduce greenhouse emissions and increase energy security. Targets are usually expressed as installed capacity or as a percentage of energy consumption and they are important catalysts for increasing the share of renewable energy worldwide.

However, in the electricity sector the investment horizon can be up to 40 years. Renewable energy targets therefore need to have short, medium and long term steps and must be legally binding in order to be effective. They should also be supported by incentive mechanisms such as feed-in tariffs for renewable electricity generation. To get significant increases in the proportion of renewable energy, targets must be set in accordance with the local potential for each technology (wind, solar, biomass etc) and be complemented by policies that develop the skills and manufacturing bases to deliver the agreed quantity.

Data from the wind and solar power industries show that it is possible to maintain a growth rate of 30 to 35% in the renewable energy sector. In conjunction with the European Photovoltaic Industry Association,[5] the European Solar Thermal Power Industry Association[6] and the Global Wind Energy Council,[7] the European Renewable Energy Council, Greenpeace has documented the development of these clean energy industries in a series of Global Outlook documents from 1990 onwards and predicted growth up to 2020 and 2040.

1.4 policy changes in the energy sector

Greenpeace and the renewable energy industry share a clear agenda for the policy changes which need to be made to encourage a shift to renewable sources.

The main demands are:

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

Conventional energy sources receive an estimated $409 billion[8] in subsidies in 2010, resulting in heavily distorted markets. Subsidies artificially reduce the price of power, keep renewable energy out of the market place and prop up non-competitive technologies and fuels. Eliminating direct and indirect subsidies to fossil fuels and nuclear power would help move us towards a level playing field across the energy sector. Renewable energy would not need special provisions if markets factored in the cost of climate damage from greenhouse gas pollution. Subsidies to polluting technologies are perverse in that they are economically as well as environmentally detrimental. Removing subsidies from conventional electricity supply would not only save taxpayers' money, it would also dramatically reduce the need for renewable energy support.

1.4.1 the most effective way to implement the energy [r]evolution: feed-in laws

To plan and invest in energy infrastructure whether for conventional or renewable energy requires secure policy frameworks over decades.

The key requirements are:

a. Long term security for the investment The investor needs to know if the energy policy will remain stable over the entire investment period (until the generator is paid off). Investors want a "good" return on investment and while there is no universal definition of a good return, it depends to a large extent on the inflation rate of the country. Germany, for example, has an average inflation rate of 2% per year and a minimum return of investment expected by the financial sector is 6% to 7%. Achieving 10 to 15% returns is seen as extremely good and everything above 20% is seen as suspicious.

b. Long-term security for market conditions The investor needs to know, if the electricity or heat from the power plant can be sold to the market for a price which guarantees a "good" return on investment (ROI). If the ROI is high, the financial sector will invest, it is low compared to other investments financial institutions will not invest.

c. Transparent Planning Process A transparent planning process is key for project developers, so they can sell the planned project to investors or utilities. The entire licensing process must be clear and transparent.

d. Access to the grid A fair access to the grid is essential for renewable power plants. If there is no grid connection available or if the costs to access the grid are too high the project will not be built. In order to operate a power plant it is essential for investors to know if the asset can reliably deliver and sell electricity to the grid. If a specific power plant (e.g. a wind farm) does not have priority access to the grid , the operator might have to switch the plant off when there is an over supply from other power plants or due to a bottleneck situation in the grid. This arrangement can add high risk to the project financing and it may not be financed or it will attract a "risk-premium" which will lower the ROI.

1.5 political recommendations for the netherlands

In order to phase out the use of gas, oil, coal and nuclear energy and to switch over to clean energy derived from wind, sun, geothermal heat and plant matter a mixture of measures is needed. There is not just one panacea or one technique that will enable the switch to clean energy to become a fact, it will, of course, come down to a combination of resources. Without assuming to have the perfect blueprint for the energy revolution, Greenpeace advocates for these directions to be followed for the implementation of a successful energy policy.

1.5.1 CO_2 emissions should have a fair price

The switch to clean energy supply can only be successful when there is a fair price tag on CO_2 emissions. Fortunately the principle of 'the polluter pays' is fairly uncontroversial, likewise the notion that government intervention is indispensible in order to correct the market at this point. Indeed, without government interference it would not be possible to calculate the price of the social cost of CO_2 emissions.

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


© LANGROCK/ZENIT/GP

Although it would seem that a consensus exists about the principles, in practice it is different: the polluter does not pay. Worse still the polluter actually benefits. The Emissions Trading System (ETS) is inadequate and indeed the large-scale consumers and producers of fossil fuels receive large tax concessions. This must change.

Repair the ETS The EU Emissions Trading System (ETS) is in principle a good system for connecting a fair price to CO_2 emissions. Although Greenpeace has criticised the emission ceilings as being too high, the system could work if less emission permits were issued. Due to the excessive issuing of permits and the economic recession, the ETC is threatening to become a face. In order for sustainable energy to have a reasonable chance opposed to fossil energy and to prevent the use of a large amount of tax revenue on subsidies, one ton of CO_2 emissions should cost between 40 and 50 euro. At the beginning of 2013 the price plummeted to 4 to 5 euro, with even a downward offshoot to as low as under the 3 euro. The system can not function with such prices; the stimulus for businesses to reduce their emissions is just too low.

The EC has proposed to temporarily subtract 900 million euros worth of rights from the ETS. This is a first step but still, according to Greenpeace, this is not enough. For the CO_2 price to be structurally at a level of 40 to 50 euro per ton, more rights will have to be withdrawn, i.e. for more than 2 billion. Furthermore, this must not be temporary (backloading) but structural (set aside).

Until then: national policy Regardless of the outcome, the discussion about the withdrawal of emission allowances from the ETS system will last for some years. Given the economic circumstances the price of CO_2 emissions will stay low for years to come. The energy revolution cannot be put on hold. In order to make investments in clean power possible, it is necessary, on a national level, to take measures to give CO_2 emissions an honest price, at the least in the electricity sector. This can be done in different ways, for instance by increasing the coal tax, setting a bottom line price for CO_2 for the energy sector or setting a maximum for emissions of CO_2 per kilowatt hour.

Greening fiscal policy According to figures from Ecofys and CE from 2011 the Dutch government gave in 2010 in total 5.8 billion euros in tax advantages to users and producers of fossil energy. The government support of sustainable energy was 1.3 billion. According to Greenpeace this is completely the wrong way around; apparently the government chooses to subsidise the polluter rather than make them pay. Step by step an end has to come to this phenomenon.

The main direction that should be taken is a shift from taxation on labour to taxation of raw materials and energy use. Less taxation on labour and more on raw materials and energy use cuts both ways: people are recruited and the work market is stimulated, while the incentive to be economical with scarce resources is enhanced.

1.5.2 energy sector

Stop with nuclear power Greenpeace advocates that the only Dutch nuclear power plant, in Borssele, which is at the end of its technical lifespan, should be shut down at the end of 2013. Nuclear energy is expensive and there is still no solution for the growing mountain of radioactive waste. That nuclear waste can be used in the making of nuclear weapons is a frightening scenario. Moreover, time and again it is apparent how unsafe nuclear power plants are. On top of this we do not need nuclear power: the Netherlands is already in the situation of having more than enough capacity for generating power.

Stop with coal Greenpeace wants to see the end of coal-fired power stations before 2020 because of their CO_2 emissions and their emissions of particulate matter (which is damaging to health). Coal is presently the energy source for 20 percent of Dutch electricity production. The installed coal power plant capacity comprised 4.1 GW in 2010. Three coal plants with a total capacity of 3.4 GW, are under construction and due to start operating in 2014. Coal power can easily be phased out by 2020, because of the present overcapacity to produce power in the Netherlands (gas power plants) and the rise of renewable electricity production.

Decentralised energy generation The decentralised generation of energy deserves strong support from the government. The facilitation and support of citizens individually and in groups in their initiatives to generate power from sun and wind energy would create a wonderful momentum. Already 100,000 homes have solar panels installed on their roofs and this number could increase rapidly. Fiscal stimulation can be enormously encouraging to private investments into sustainable energy.

Greenpeace appeals for the right to sustainable energy. At the moment that right exists only, in fact, on an individual level in your own home, to an acceptable limit of 5,000 kWh. However, Greenpeace wants the government to allow citizens (or groups of citizens) to generate untaxed energy at another location to a limit of 5,000 kWh. In this way cooperation formation is stimulated and people who do not have a suitable home for energy generation can still generate sustainable energy.

Cogeneration In numerous factories and through the production of electricity an enormous amount of heat is lost. This is a shame because other factories, households and agriculture all do their best to generate warmth. For this reason it is crucial that waste heat from such processes is captured and put to use elsewhere.

Cogeneration has to be strongly stimulated, also with subsidies, for as long as this promising technique is not viable everywhere. Eventually this technique must be made, wherever possible, compulsory. Power stations that do not make use of cogeneration should, at a certain point, be closed.

Wind at sea Offshore wind is a promising source of renewable energy. At sea the wind blows harder than on land, making better returns for windmills. Furthermore offshore windmills are less in the way than on land, they can be more easily placed. On the other hand offshore wind energy is more expensive than onshore wind energy. Greenpeace believes that we can no longer wait with the building of large-scale offshore wind farms. Additionally many Dutch companies want to jump at the opportunity, which will create a lot of work. Greenpeace wants there to be 6,000 MW of energy realised by offshore wind before 2020. In order to reach this goal the national government needs to commit to new projects in the coming two years. They must guarantee that the licences will be granted, cables built out to sea and that there is enough money in the so-called SDE for the financing of the unviable parts of the operation.

Wind on land According to Greenpeace wind on land is an unmissable ingredient in the sustainable energy mix. The Netherlands is very suitable for onshore wind simply because it is a very windy country. At the same time you can see that the Dutch are very lax in their handling of this promising option. There is not enough creativity in looking for locations for windmills and there is no investment in support, which is crucial in the carrying out of successful wind projects. Greenpeace wants the government to be much more active in helping to ensure that onshore wind energy get its chance, for instance by making it fiscally attractive for citizens to participate in wind energy. In this way the chances of support will grow. In 2020 Greenpeace would like to see the realisation of at least 6,000 to 8,000 MW of onshore wind power. Concentrated in places where this is possible and also in ''forgotten' locations like business zones and other places where corporations can create the necessary support. The government finances any unviable gaps.

Biomass On the subject of large-scale co-firing with biomass in coal-fired power stations Greenpeace is very reticent. There can be no question of subsidised co-firing: there is no indication that co-firing can ever be viable, furthermore subsiding gets in the way of real innovation, such as wind energy. Subsidizing would also lead to an improvement in the business case of unwanted coal-fired power stations.

From the environmental viewpoint a major obstacle is the availability of truly sustainable biomass and the fact that the CO_2 gain of large-scale co-firing with biomass compared with fossil fuels is highly questionable. For the use of biomass there should be good criteria for the securement of environmental gains. In the first place, it should be established that there really are less CO_2 emissions in comparison to fossil fuels. Secondly it should be established that there is no displacement of agricultural land. The rights of the local population should be respected. Furthermore the use of biomass should be based on the highest quality application: wood would be better put to use in the making of furniture or for building or as a raw material in the chemical industry and then as the last option to be burnt. This principle is called cascading: only when all these conditions are met may there be a possibility of (unsubsidised) co-firing. However, Greenpeace does see a role for the use of plant matter specifically in decentralised energy generation.

1.5.3 energy conservation

Built-up areas In the past decade the Netherlands has failed to utilise the promising potential of making buildings, both residential and other buildings, significantly more energy efficient. Even measures that earn their money back within less than five years are being left unused. Greenpeace finds that the approach used to tempt homeowners, housing associations, building administrators, businesses, schools and hospitals into large-scale insulation projects is insufficient. It is therefore high time to implement more compulsory measures, whereby the government defines the required level (energy labels) and owners, administrators and tenants are given time to meet the target. This would include financially attractive preconditions, like a low VAT-rate for building improvements, easy and affordable access to loans for insulation materials and help for businesses wanting to develop services that minimise hassle and bureaucracy for homeowners.

Energy conservation for businesses The business community is equally guilty of not tapping into the opportunities that lay before them, even when it comes to measures that earn their money back in a relatively short time frame. The rules that state that businesses who fall under the Environmental Protection Act (the majority of businesses in the Netherlands) are required to invest in energy saving measures that have a five year financial return are failing, due mainly to the poor enforcement by local governments. Greenpeace would like to see local governments given more freedom to involve businesses in the enforcement of such laws and make investments, of which the benefits are undisputed, compulsory.

The government has signed numerous agreements with large businesses, all of which fall under the ETS-System, in which they have promised to do more on energy efficiency. Greenpeace has observed that this approach is failing. A complex bureaucracy has been created in which businesses try to prove that their energy use has decreased slightly per unit of product, any serious climate legislation should focus on overall energy conservation. It is exactly this, the overall energy conservation, which has trailed behind expectations. This is why Greenpeace is advocating for the government to lay down compulsory targets for large businesses, possibly supplemented by a bonus-malus system, whereby businesses get tax credits for performing well and sanctions if their investments are lagging behind.

Appliances Technological improvements have made it possible to produce economically more energy efficient electrical goods. The Netherlands should push for the EU to implement stricter energy requirements for fridges, lamps, plasma televisions and the like, to insure that this potential is acted on.

1.5.4 transport

Road Traffic The social costs of the transportation of people and goods still outweigh the total contribution automobilists and the transport industry make to the treasury through taxes, levies and duties. Moreover, the current road tax system is in conflict with the idea that it is the polluter that should pay for their pollution. It is for this reason that a transition should be made to a system whereby road traffic participants pay for each kilometer driven, taking the vehicles environmental performance and the time and location of the journey into account. Sales tax should also lean more favourably towards green vehicles: energy efficient cars should be taxed less than high polluting cars.

In addition, the Netherlands should push within the EU for the strictest standards for CO_2 emissions from vehicles. By using lighter materials and techniques like electric propulsion, new cars can easily be produced to run 40% more efficiently than current models.

Greenpeace is against the further rise of blending requirements for biofuels, as long as sustainability criteria are not met and the CO_2 gains remains highly questionable.

Aviation and maritime The aviation and maritime sectors have been left out of this national scenario. Greenpeace advocates for the aviation sector (as has been agreed upon) and the maritime sector to fall under the ETS-System.

the energy [r]evolution concept

KEY PRINCIPLES THE "3 STEP IMPLEMENTATION" THE NEW ELECTRICITY GRID

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.[9] 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.[10]

   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.

references

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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.

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.[11]

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

61.5 units
LOST THROUGH INEFFICIENT GENERATION AND HEAT WASTAGE

3.5 units
LOST THROUGH TRANSMISSION AND DISTRIBUTION

13 units
WASTED THROUGH INEFFICIENT END USE

100 units >>
ENERGY WITHIN FOSSIL FUEL

38.5 units >>
OF ENERGY FED TO NATIONAL GRID

35 units >>
OF ENERGY SUPPLIED

22 units
OF ENERGY ACTUALLY UTILISED

reference
11 '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.

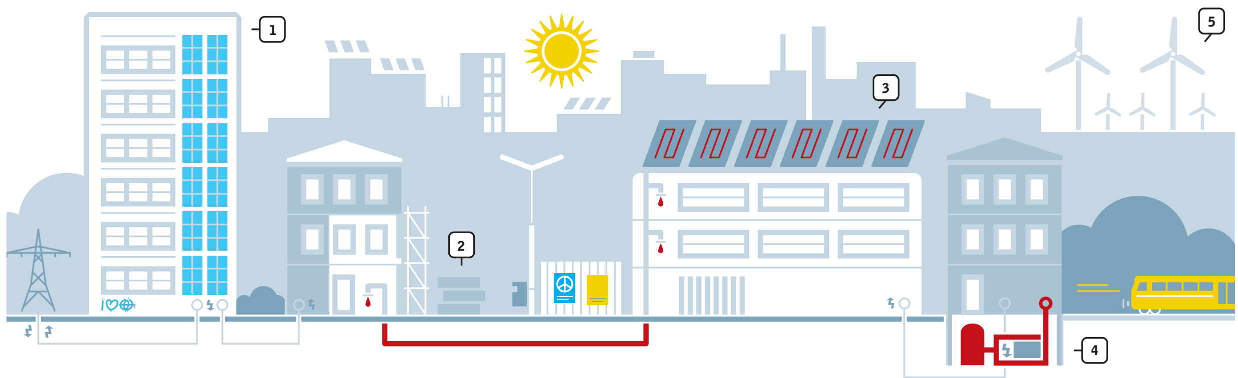
Cogeneration (CHP) The increased use of combined heat and power generation (CHP) will improve the supply system's energy conversion efficiency, whether using natural gas or biomass. In the longer term, a decreasing demand for heat and the large potential for producing heat directly from renewable energy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

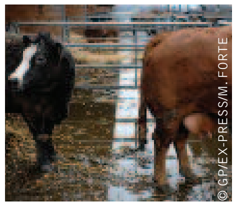
EXISTING TECHNOLOGIES, APPLIED IN A DECENTRALISED WAY AND COMBINED WITH EFFICIENCY MEASURES AND ZERO EMISSION DEVELOPMENTS, CAN DELIVER LOW CARBON COMMUNITIES AS ILLUSTRATED HERE. POWER IS GENERATED USING EFFICIENT COGENERATION TECHNOLOGIES PRODUCING BOTH HEAT (AND SOMETIMES COOLING) PLUS ELECTRICITY, 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 SOLAR, WIND, BIOMASS AND HYDRO RESOURCES. NATURAL GAS, WHERE NEEDED, CAN BE DEPLOYED IN A HIGHLY EFFICIENT MANNER.

city



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

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.



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. 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.			Mostly large power plants that are owned and 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 - except for 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							■

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.

Access to energy in 2012: The International Year of Sustainable Energy for All In December 2010, the United Nations General Assembly declared 2012 the International Year of Sustainable Energy for All, recognizing that "...access to modern affordable energy services in developing countries is essential for the achievement of the internationally agreed development goals, including the Millennium Development Goals, and sustainable development, which would help to reduce poverty and to improve the conditions and standard of living for the majority of the world's population."

The General Assembly's Resolution 65/151 called on UN Secretary-General Ban Ki-Moon to organize and coordinate activities during the Year in order to "increase awareness of the importance of addressing energy issues", including access to and sustainability of affordable energy and energy efficiency at local, national, regional and international levels.

box 2.1: about sustainable energy for all

From the IEA Report "Energy for All – financing access for the poor.[12]

The International Energy Agency's World Energy Outlook (WEO) has focused attention on modern energy access for a decade. In a special early excerpt of World Energy Outlook 2011, the IEA tackled the critical issue of financing the delivery of universal access to modern forms of energy. The report recognised that energy access can create a better life for individuals, alleviating poverty and improving health, literacy and equity.

Globally, over 1.3 billion people, more than a quarter of the world's population are without access to electricity and 2.7 billion people are without clean cooking facilities. More than 95% of these people are either in sub-Saharan Africa or developing Asia and 84% are in rural areas. In 2009, the IEA estimates that $9.1 billion was invested globally in extending access to modern energy services and will average $14 billion per year, projected between 2010 and 2030, mostly devoted to new on-grid electricity connections in urban areas. Even with this there will be one billion people without electricity and 2.7 billion people without clean cooking facilities in 2030. To provide universal modern energy access by 2030 the IEA forecasts that annual average investment needs would need to be $48 billion per year, more than five-times the level of 2009, and most in sub-Saharan Africa.

The IEA puts forwards five actions to achieve universal, modern energy access:

1. Adopt a clear and consistent statement that modern energy access is a political priority and that policies and funding will be reoriented accordingly. National governments need to adopt a specific energy access target, allocate funds and define their delivery strategy.
2. Mobilise additional investment in universal access, above the $14 billion per year assumed in our central scenario, of $34 billion per year - equivalent to around 3% of global investment in energy infrastructure over the period to 2030. All sources and forms of investment have their part to play, reflecting the varying risks and returns of particular solutions.
3. Overcome the significant banners to large growth in private sector investment. National governments need to adopt strong governance and regulatory frameworks and invest in internal capacity building. The public sector, including multilateral and bilateral institutions, needs to use its tools to leverage greater private sector investment where the business case is marginal and encourage the development of repeatable business models. When used, public subsidies must be well targeted to reach the poorest.
4. Concentrate a large part of multilateral and bilateral direct funding on those difficult areas of access which do not initially offer an adequate commercial return. Provision of end-user finance is required to overcome the barrier of the initial capitals. Local banks and microfinance arrangements can support the creation of local networks and the necessary capacity in energy sector activity.
5. Collection of robust, regular and comprehensive data to quantify the outstanding challenge and monitor progress towards its elimination. International concern about the issue of energy access is growing.

Discussions at the Energy for All Conference in Oslo, Norway (October 2011) and the COP17 in Durban, South Africa (December 2011) have established the link between energy access, climate change and development which can now be addressed at the United Nations Conference on Sustainable Development (Rio+20) in Rio de Janeiro, Brazil in June 2012. That conference will be the occasion for commitments to specific action to achieve sustainable development, including universal energy access, since as currently the United Nations Millennium Development Goals do not include specific targets in relation to access to electricity or to clean cooking facilities.

reference
12 SPECIAL EXCERPT OF THE WORLD ENERGY OUTLOOK 2011.

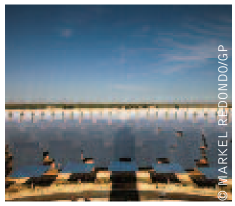


image GEMASOLAR IS A 15 MWE SOLAR-ONLY POWER TOWER PLANT, EMPLOYING MOLTEN SALT TECHNOLOGIES FOR RECEIVING AND STORING ENERGY. IT'S 16 HOUR MOLTEN SALT STORAGE SYSTEM CAN DELIVER POWER AROUND THE CLOCK. IT RUNS AN EQUIVALENT OF 6,570 FULL HOURS OUT OF 8,769 TOTAL. FUENTES DE ANDALUCÍA SEVILLE, SPAIN.

In response, the new global initiative, Sustainable Energy for All, launched at the General Assembly in September 2011, along with a High Level Group, is designed to mobilise action from governments, the private sector and civil society globally. The initiative has three inter-linked objectives: universal access to modern energy services, improved rates of energy efficiency, and expanded use of renewable energy sources.

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

Step 3: optimised integration – renewables 24/7 A complete transformation of the energy system will be necessary to accommodate the significantly higher shares of renewable energy expected under the 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'.[13] 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 28).

reference
13 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.

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.

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.

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.[14] 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.[15] 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.[16] Together, the combination ensures sufficient electricity supply to cover demand.

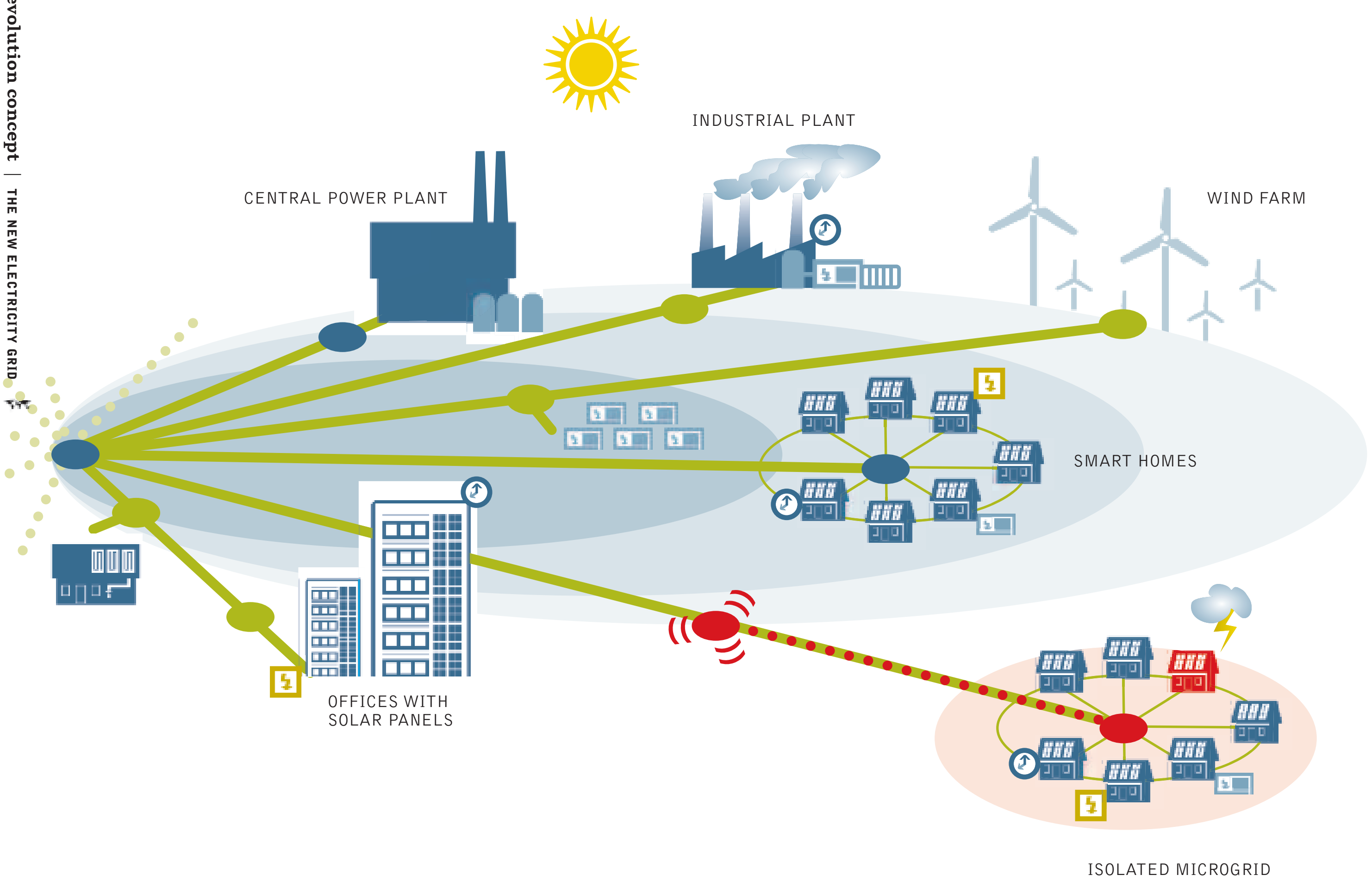
Electricity storage options. Pumped storage is the most established technology for storing energy from a type of hydroelectric power station. Water is pumped from a lower elevation reservoir to a higher elevation during times of low cost, off-peak electricity. During periods of high electrical demand, 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

14 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.
15 SEE ALSO HTTP://WWW.KOMBIKRAFTWERK.DE/INDEX.PHP?ID=27.
16 SEE ALSO HTTP://WWW.SOLARSERVER.DE/SOLARMAGAZIN/ANLAGEJANUAR2008_E.HTML.

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

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

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

SMART APPLIANCES
CAN SHUT OFF IN RESPONSE TO FREQUENCY FLUCTUATIONS

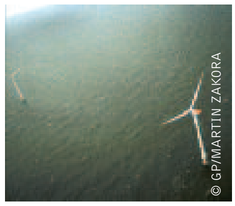
DEMAND MANAGEMENT
USE CAN BE SHIFTED TO OFF-PEAK TIMES TO SAVE MONEY

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

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

DISTURBANCE IN THE GRID

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



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.[17]

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?[18]

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.

references

17 GREENPEACE REPORT, 'NORTH SEA ELECTRICITY GRID [R]EVOLUTION', SEPTEMBER 2008.
18 BATTLE OF THE GRIDS, GREENPEACE INTERNATIONAL, FEBRUARY 2011.

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

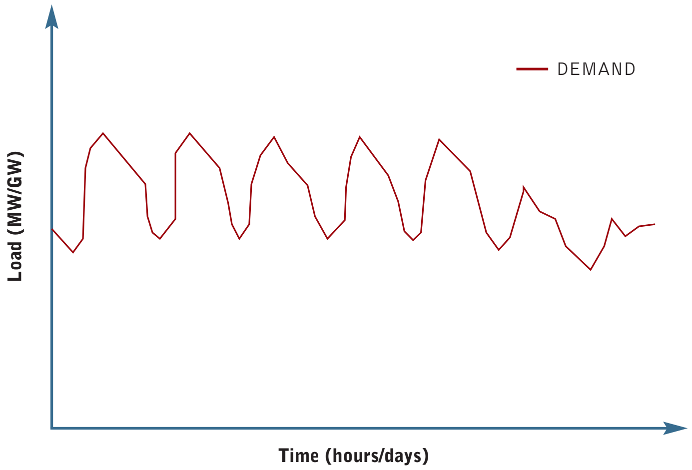
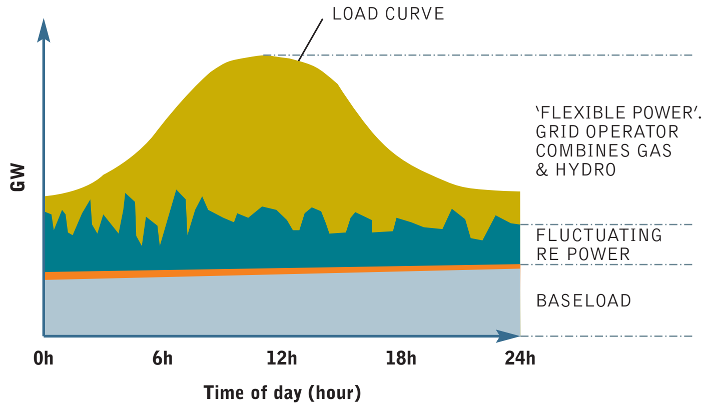


figure 2.5: the evolving approach to grids

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.

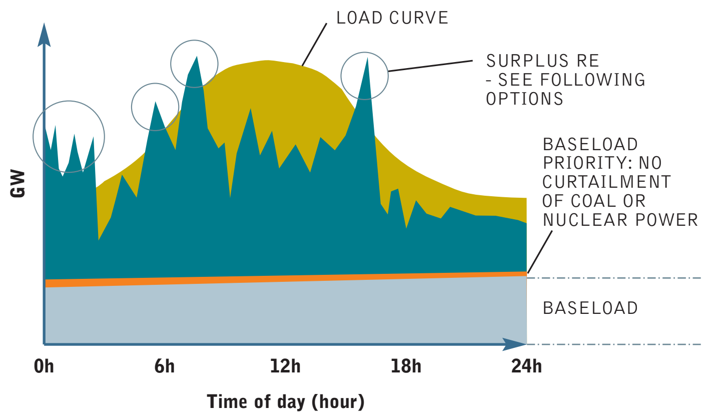


image GREENPEACE OPENS A SOLAR ENERGY WORKSHOP IN BOMA. A MOBILE PHONE GETS CHARGED BY A SOLAR ENERGY POWERED CHARGER.

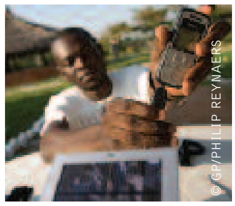
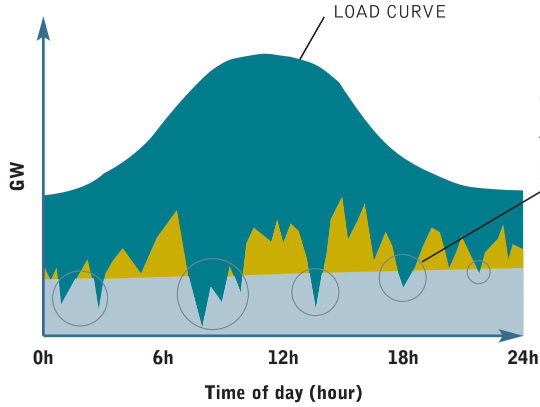


figure 2.5: the evolving approach to grids *continued*

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.

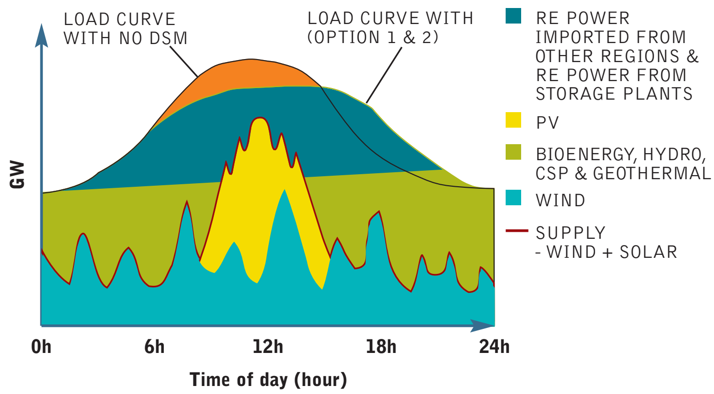
Technically difficult, not a solution.



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.

implementing the energy [r]evolution

RENEWABLE ENERGY PROJECT PLANNING BASICS

RENEWABLE ENERGY FINANCING BASICS

3

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.

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).

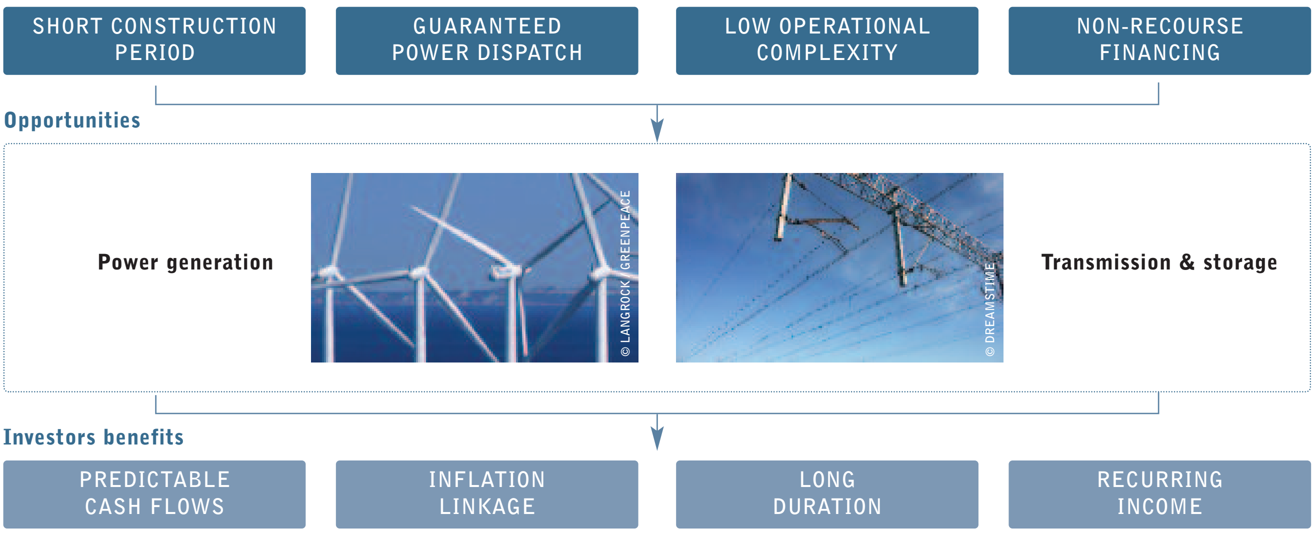
P = Project developer, **M** = Meteorological Experts, **I** = Investor, **U** = utility.

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 financing, 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.

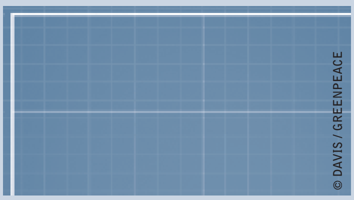
figure 3.3: investment stages of renewable energy projects

RISKS

Higher → Lower

Stage

DEVELOPMENT



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

CONSTRUCTION

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

OPERATIONS

- Operations
- Maintenance
- Refinancing
- Refurbishment/Repowering

Strategy

EARLY-STAGE GREENFIELD | LATE-STAGE GREENFIELD | BROWNFIELD

source
SWISS RE PRIVATE EQUITY PARTNERS.

3.2.1 overcoming barriers to finance and investment for renewable energy

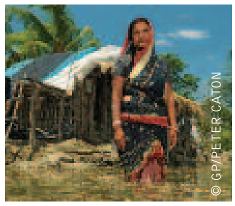
table 3.2: categorisation of barriers to renewable energy investment

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[19] 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[20] 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).

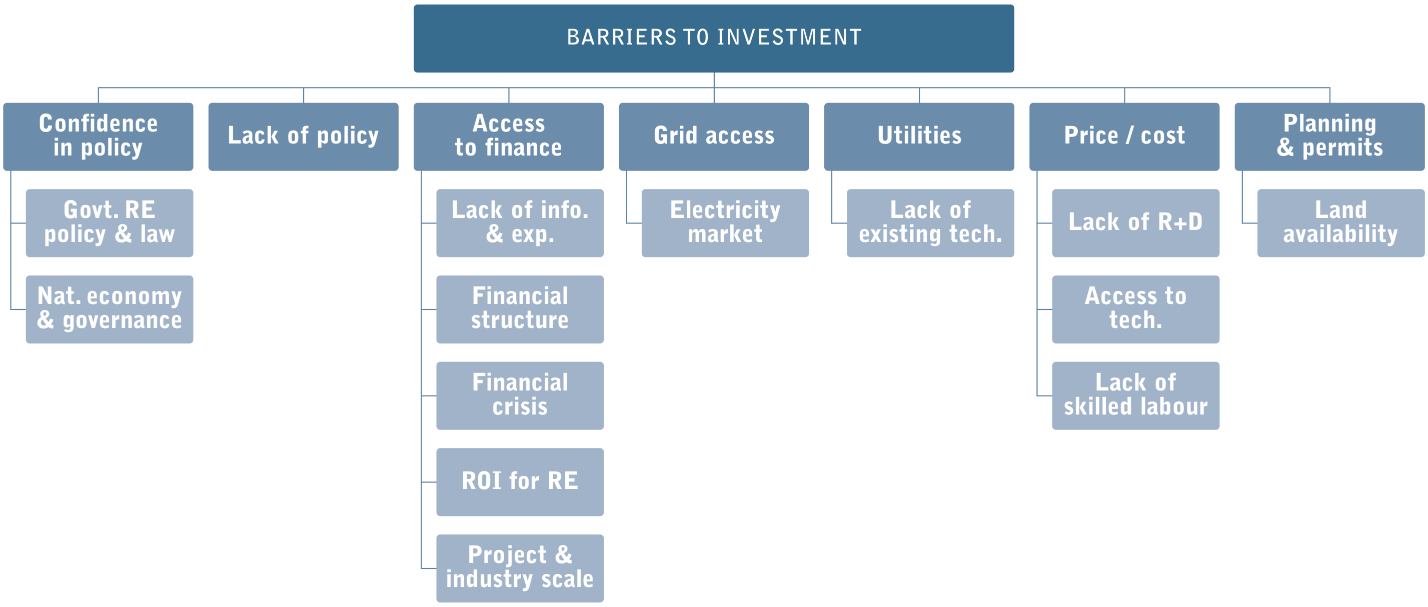
Concerns over planning and permit issues are significant, though vary significantly in their strength and nature depending on the jurisdiction.

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.[21]
- 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



references

19 SOURCES INCLUDE: INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC) (2011) SPECIAL REPORT ON RENEWABLE ENERGY SOURCES AND CLIMATE CHANGE MITIGATION (SRREN), 15TH JUNE 2011. UNITED NATIONS ENVIRONMENT PROGRAMME (UNEP), BLOOMBERG NEW ENERGY FINANCE (BNEF) (2011). GLOBAL TRENDS IN RENEWABLE ENERGY INVESTMENT 2011, JULY 2011. RENEWABLE ENERGY POLICY NETWORK FOR THE 21ST CENTURY (REN21) (2011). RENEWABLES 2011, GLOBAL STATUS REPORT, 12 JULY, 2011. ECOFYS, FRAUNHOFER ISI, TU VIENNA EEG, ERNST & YOUNG (2011). FINANCING RENEWABLE ENERGY IN THE EUROPEAN ENERGY MARKET BY ORDER OF EUROPEAN COMMISSION, DG ENERGY, 2ND OF JANUARY, 2011.

20 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.

21 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

4

"towards a sustainable energy supply system."

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.

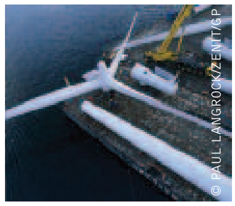


image CONSTRUCTION OF THE OFFSHORE WINDFARM AT MIDDELGRUNDEN NEAR COPENHAGEN, DENMARK.

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).[22] 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 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) and this into a carbon budget for The Netherlands: the basis of this Energy [R]evolution for the Netherlands. 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[23] 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 Energy [R]evolution scenario for The Netherlands shows that renewable energy would reach 30% of Netherlands's energy supply before 2030.

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

reference

22 INTERNATIONAL ENERGY AGENCY (IEA), 'WORLD ENERGY OUTLOOK 2011', OECD/IEA 2011.
23 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.[24] 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 energy efficiency study for industry, households and services

The demand study by Utrecht University aimed to develop a low energy demand scenario for the period 2009 to 2050 covering the world regions as defined in the IEA's World Energy Outlook report series. Calculations were made for each decade from 2009 onwards. Energy demand was split up into electricity and fuels and their consumption was considered in industry and for 'other' consumers, including households, agriculture and services.

Under the low energy demand scenario, worldwide final energy demand in industry and other sectors is 31% lower in 2050 compared to the Reference scenario, resulting in a final energy demand of 256 EJ (ExaJoules). The energy savings are fairly equally distributed over the two main sectors. The most important energy saving options would be efficient production and combustion processes and improved heat insulation and building design. Chapter 10 provides more details about this study. The demand projections for the Reference scenario have been updated on the basis of the Current Policies scenario from IEA's World Energy Outlook 2011.

4.1.2 the future for transport

The DLR Institute of Vehicle Concepts in Stuttgart, Germany has developed a global scenario for all transport modes covering ten world regions. The aim was to produce a demanding but feasible scenario to lower global CO_2 emissions from transport in keeping with the overall objectives of this report. The approach takes into account a vast range of technical measures to reduce the energy consumption of vehicles, but also considers the dramatic increase in vehicle ownership and annual mileage taking place in developing countries. The major parameters are vehicle technology, alternative fuels, changes in sales of different vehicle sizes of light duty vehicles (called the segment split) and changes in tonne-kilometres and vehicle-kilometres travelled (described as modal split). The Reference scenario for the transport sector is also based on the fuel consumption path of the Current Policies scenario from WEO 2011.

By combining ambitious efforts towards higher efficiency in vehicle technologies, a major switch to grid-connected electric vehicles (especially LDVs) and incentives for vehicle users to save carbon dioxide the global Energy [R]evolution study finds that it is possible to reduce CO_2 emissions from 'well-to-wheel' in the transport sector in 2050 by roughly 77%[25] compared to 1990 and 81% compared to 2009. By 2050, in this scenario, 25% of the final energy used in transport will still come from fossil sources, mainly gasoline, kerosene and diesel. Renewable electricity will cover 41%, biofuels 11% and hydrogen 20%. Total energy consumption will be reduced by 26% in 2050 compared to 2009 even though there are enormous increases in fuel use in some regions of the world. The peak in global CO_2 emissions from transport occurs between 2015 and 2020. From 2012 onwards, new legislation in the US and Europe will contribute to breaking the upwards trend. From 2020, the effect of introducing grid-connected electric cars can be clearly seen.

4.1.3 fossil fuel assessment report

As part of the Energy [R]evolution scenario, Greenpeace also commissioned the Ludwig-Bölkow-Systemtechnik Institute in Munich, Germany to research a new fossil fuel resources assessment taking into account planned and ongoing investments in coal, gas and oil on a global and regional basis (see fossil fuel pathway Chapter 7).

4.1.4 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.

references

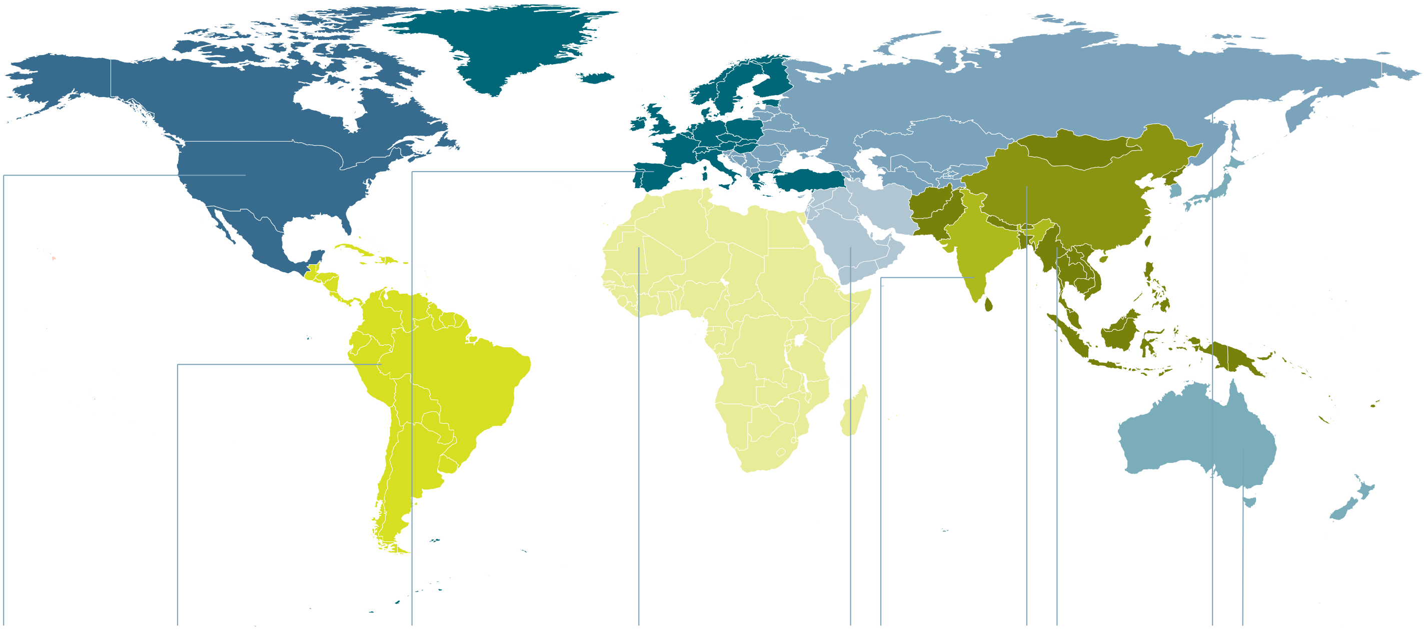
24 ENERGY [R]EVOLUTION: A SUSTAINABLE WORLD ENERGY OUTLOOK', GREENPEACE INTERNATIONAL, 2007, 2008 AND 2010.
25 TRANSPORT EMISSIONS IN 1990 BASED ON WEO 2011.

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.

4.2 main scenario assumptions

To develop a global energy scenario requires a model that reflects the significant structural differences between different countries' energy supply systems. The International Energy Agency breakdown of ten world regions, as used in the ongoing series of World Energy Outlook reports, has been chosen because the IEA also provides the most comprehensive global energy statistics.[26] In line with WEO 2011, this new edition maintains the ten region approach. The countries in each of the world regions are listed in Figure 4.1.

figure 4.1: world regions used in the scenarios



oecd north america[27]

Canada, Mexico, United States of America

latin america

Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Bermuda, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, French Guiana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, St. Kitts-Nevis-Anguila, Saint Lucia, St. Vincent and Grenadines, Suriname, Trinidad and Tobago, Uruguay, Venezuela

oecd europe

Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom

africa

Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Democratic Republic of Congo, Cote d'Ivoire, Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Reunion, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, United Republic of Tanzania, Togo, Tunisia, Uganda, Zambia, Zimbabwe

middle east

Bahrain, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, United Arab Emirates, Yemen

india

India

china

People's Republic of China including Hong Kong

other non oecd asia[52]

Afghanistan, Bangladesh, Bhutan, Brunei, Cambodia, Chinese Taipei, Fiji, French Polynesia, Indonesia, Kiribati, Democratic People's Republic of Korea, Laos, Macao, Malaysia, Maldives, Mongolia, Myanmar, Nepal, New Caledonia, Pakistan, Papua New Guinea, Philippines, Samoa, Singapore, Solomon Islands, Sri Lanka, Thailand, Vietnam, Vanuatu

eastern europe/eurasia

Albania, Armenia, Azerbaijan, Belarus, Bosnia-Herzegovina, Bulgaria, Croatia, Serbia and Montenegro, former Republic of Macedonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Romania, Russia, Slovenia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan, Cyprus[28], Malta[28]

oecd asia oceania

Australia, Japan, Korea (South), New Zealand

references

26 INTERNATIONAL ENERGY AGENCY (IEA), PARIS: 'ENERGY BALANCES OF NON-OECD COUNTRIES' AND 'ENERGY BALANCES OF OECD COUNTRIES', 2011 EDITION.

27 WEO 2011 DEFINES THE REGION „OECD AMERICAS" AS USA, CANADA, MEXICO, AND CHILE. CHILE THUS BELONGS TO BOTH, OECD AMERICAS AND LATIN AMERICA IN WEO 2011. TO AVOID DOUBLE COUNTING OF CHILE, THE REGION "OECD NORTH AMERICA" HERE IS DEFINED WITHOUT CHILE, IN CONTRAST TO WEO 2011.

28 CYPRUS AND MALTA ARE ALLOCATED TO THE REGION EASTERN EUROPE/EURASIA FOR STATISTICAL REASONS.

29 WEO 2011 DEFINES THE REGION "NON OECD ASIA" INCLUDING CHINA AND INDIA. AS CHINA AND INDIA ARE ANALYSED INDIVIDUALLY IN THIS STUDY, THE REGION "REMAINING NON OECD ASIA" HERE IS BASED ON WEO'S "NON OECD ASIA", BUT WITHOUT CHINA AND INDIA.

4.3 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 projection
(IN MILLIONS)

	2009	2015	2020	2025	2030	2040	**2050**
The Netherlands	16.6	16.8	17.0	17.3	17.3	17.3	**17.2**

source UNEP WORLD POPULATION PROSPECT 2010.

4.4 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.[30] 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 while Netherland`s economy is projected to grow 0.9% per year over the projection period.

reference
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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%
The Netherlands	1.3%	0.9%	0.8%	0.9%
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)

4.5 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).

4.6 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)[31], 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

4.7 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.[32]

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[33], while a 2007 US Department of Energy report found installing carbon capture systems to most modern plants resulted in a near doubling of costs.[34] These costs are estimated to increase the price of electricity in a range from 21-91%.[35]

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.[36] 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.[37]

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.[38] 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.[39]

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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33 ABANADES, J C ET AL., 2005, PG 10.
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35 RUBIN ET AL., 2005A, PG 40.
36 RAGDEN, P ET AL., 2006, PG 18.
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image SATELLITE IMAGE OF JAPAN'S DAI ICHI POWER PLANT SHOWING DAMAGE AFTER THE EARTHQUAKE AND TSUNAMI OF 2011.

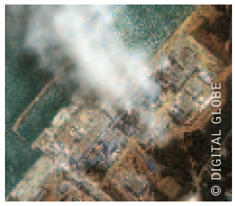

table 4.5: development of efficiency and investment costs for selected new power plant technologies

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.

4.8 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[40], from the analysis of recent technology foresight and road mapping studies, including the European Commission funded NEEDS project (New Energy Externalities Developments for Sustainability)[41] 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 NEIJ, L, 'COST DEVELOPMENT OF FUTURE TECHNOLOGIES FOR POWER GENERATION - A STUDY BASED ON EXPERIENCE CURVES AND COMPLEMENTARY BOTTOM-UP ASSESSMENTS', ENERGY POLICY 36 (2008), 2200-2211.
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4.8.1 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.

4.8.2 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.

4.8.3 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.

4.8.4 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.

4.8.5 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.

4.8.6 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 21-79 €cents/kWh[42], and for initial tidal stream farms in the range of 12-23 €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.[43]

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 G.J. DALTON, T. LEWIS (2011): PERFORMANCE AND ECONOMIC FEASIBILITY ANALYSIS OF 5 WAVE ENERGY DEVICES OFF THE WEST COAST OF IRELAND; EWTEC 2011.

43 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.

4.8.7 hydro power

Hydro power is a mature technology with a significant part of its global resource already exploited. There is still, however, some potential left both for new schemes (especially small scale run-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.

4.8.8 summary of renewable energy cost development

Figure 4.2 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 4.3. 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: future development of investment costs for renewable energy technologies (NORMALISED TO 2010 COST LEVELS)

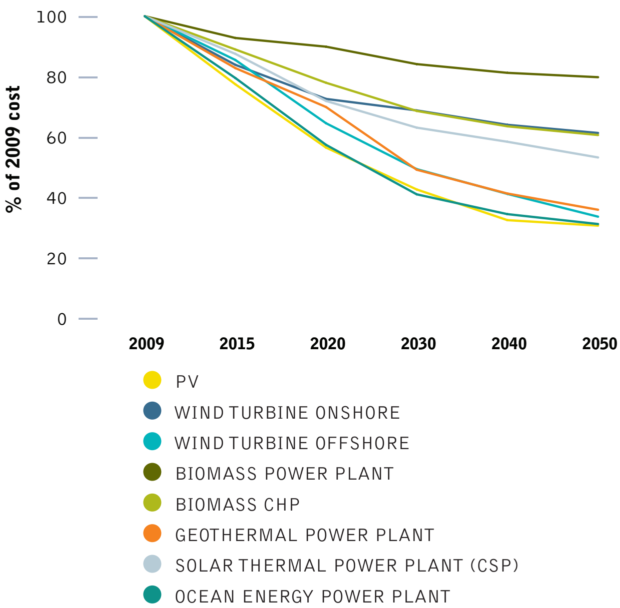
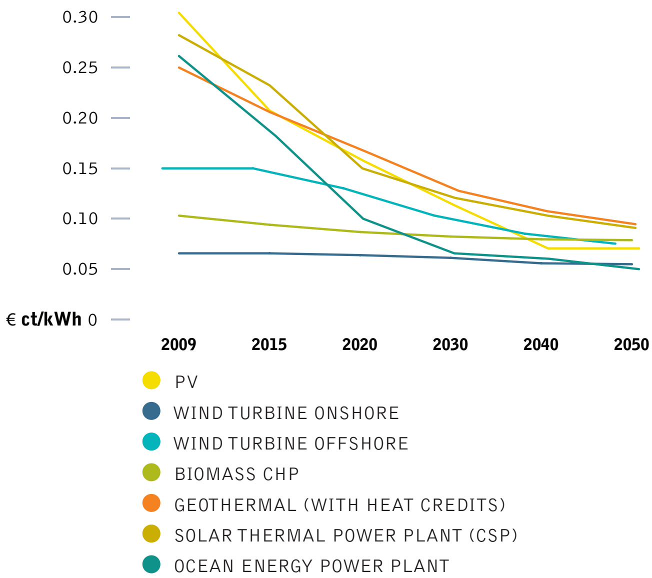


figure 4.3: expected development of electricity generation costs from renewable options
EXAMPLE FOR OECD EUROPE



4.9 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.

4.9.1 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 €/m² 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 €/m², depending on the share of solar energy in the whole heating system and the level of storage required.

4.9.2 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.

4.9.3 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.

4.9.4 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.[44]

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.

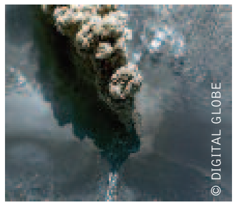
table 4.13: overview over expected investment costs pathways for heating technologies (IN €2010/KWTH

	2015	2020	2030	2040	2050
Geothermal district 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
44 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.



4.10 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.

4.10.1 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.

4.10.2 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 4.4: global oil production 1950 to 2011 and projection till 2050

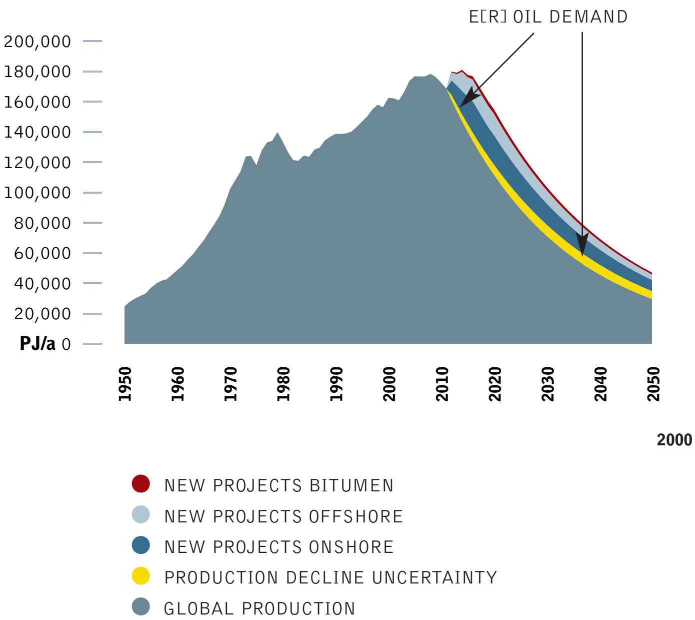
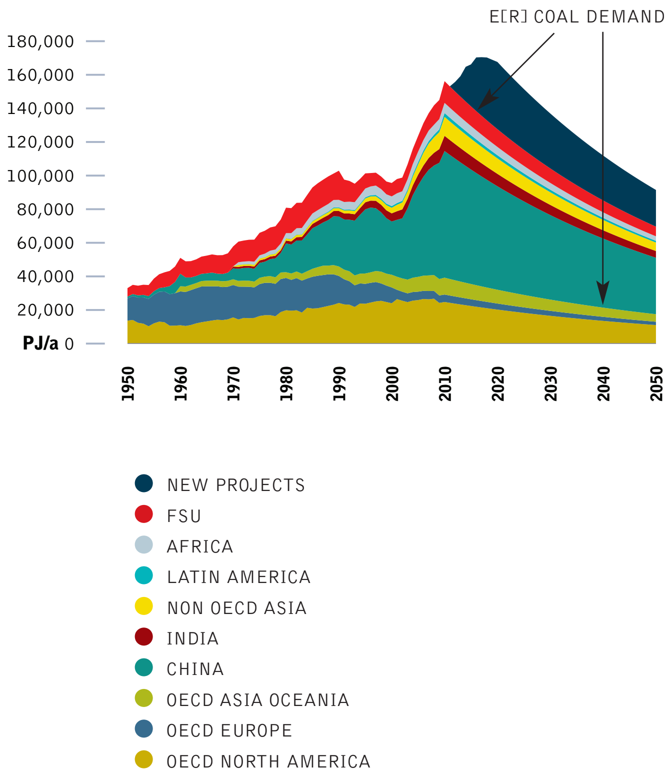


figure 4.5: coal scenario: base decline of 2% per year and new projects



4.11 review: greenpeace scenario projections of the past

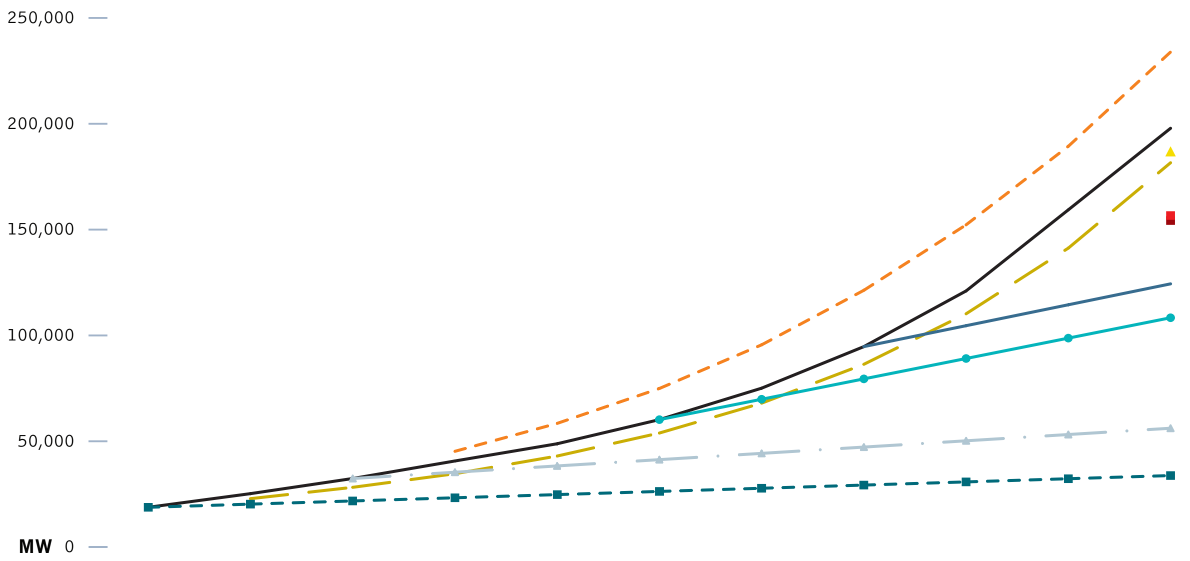
Greenpeace has published numerous projections in cooperation with renewable industry associations and scientific institutions in the past decade. This section provides an overview of the projections between 2000 and 2011 and compares them with real market developments and projections of the IEA World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

4.11.1 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 were 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 4.6: wind power: short term prognosis vs real market development - global cumulative capacity



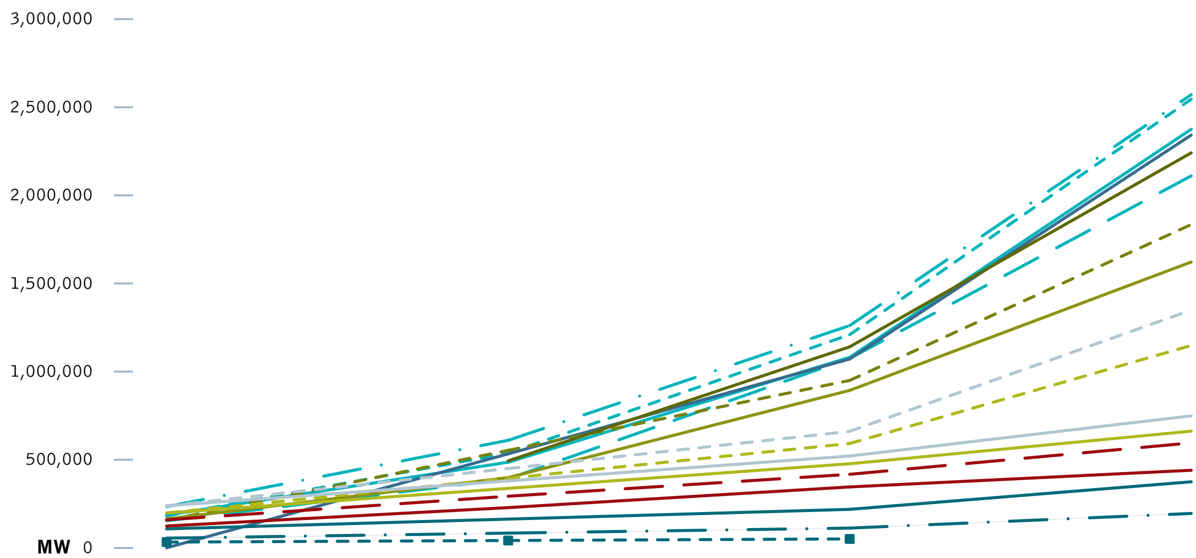
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
REAL	17,400	23,900	31,100	39,431	47,620	59,091	74,052	93,820	120,291	158,864	197,637
WF 10 (1999)		21,510	26,901	33,371	41,781	52,715	66,929	85,407	109,428	140,656	181,252
WF 12 (2002)				44,025	57,306	73,908	94,660	120,600	151,728	189,081	233,905
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.

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 4.7: wind power: long term market projections until 2030



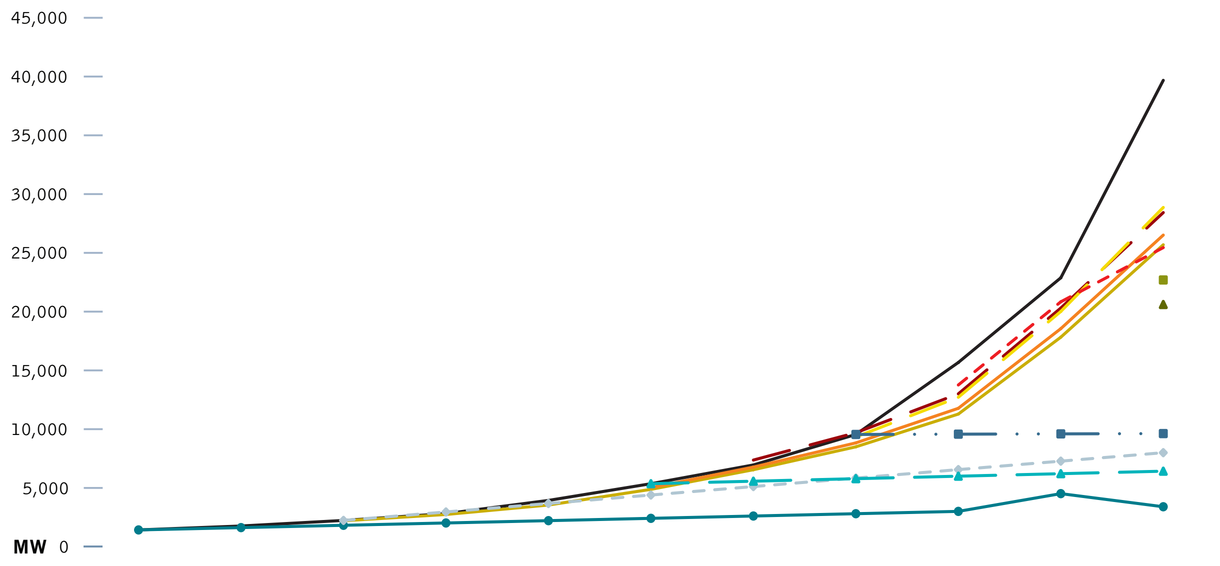
	2010	2015	2020	2030
WF 10 (1999)	181,252	537,059	1,209,466	2,545,232
WF 12 (2002)	233,905	610,000	1,261,157	2,571,000
GWEO 2006 (Advanced)	153,759	391,077	1,074,835	2,110,401
GWEO 2008 (Advanced)	186,309	485,834	1,080,886	2,375,000
GWEO 2008 (Advanced)	0	533,233	1,071,415	2,341,984
E[R] 2007	156,149	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

4.11.2 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 4.8: photovoltaics: short term prognosis vs real market development - global cumulative capacity



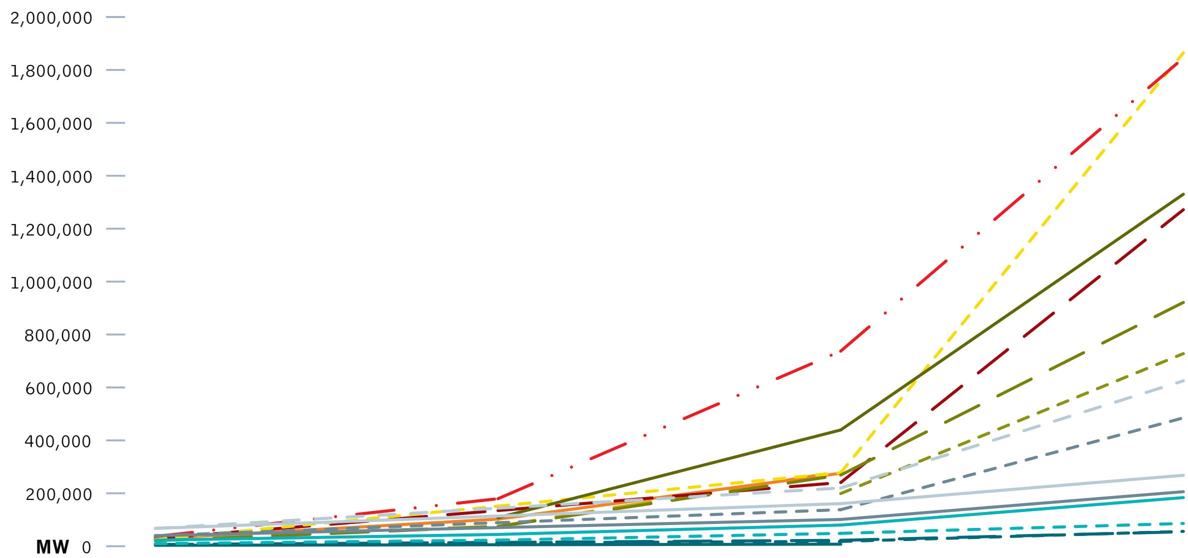
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
REAL	1,428	1,762	2,236	2,818	3,939	5,361	6,956	9,550	15,675	22,878	39,678
SG I 2001			2,205	2,742	3,546	4,879	6,549	8,498	11,285	17,825	25,688
SG II 2004						5,026	6,772	8,833	11,775	18,552	26,512
SG III 2006							7,372	9,698	13,005	20,305	28,428
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 4.9: photovoltaic: long term market projections 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

4.12 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 Center (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 netherlands 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

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

image A QUARTER OF THE LAND IN THE NETHERLANDS DUE TO IT’S LOW ELEVATION, LEAVES THE LAND VULNERABLE TO FLOODS. FOR THE PAST 2,000 YEARS, THE DUTCH HAVE EMPLOYED EVER-INCREASING INGENUITY TO NOT ONLY HOLD BACK THE SEA, BUT TO ANNEX LAND FROM THE NORTH SEA. THE LANDSAT 5 SATELLITE OBSERVED ROTTERDAM PORT’S LAND RECLAMATION EXPANSION IN 2010.

5.1 energy demand by sector

Combining the projections on population development, GDP growth and energy intensity results in future development pathways for Netherlands's final energy demand. These are shown in Figure 5.1 for the Reference and the Energy [R]evolution scenario. Under the Reference scenario, total final energy demand decreases by 6% from the current 2,064 PJ/a to 1,940 PJ/a in 2050. In the Energy [R]evolution scenario, final energy demand decreases by 37% compared to current consumption and it is expected to reach around 1,300 PJ/a by 2050.

Under the Energy [R]evolution scenario, electricity demand is expected to increase in both the industry sector as well as in the residential and service sector, and to grow also in the transport sector (see Figure 5.2). Total electricity demand will rise from 107 TWh/a to 131 TWh/a by the year 2050. Compared to the Reference scenario, efficiency measures in the industry, residential and service sectors avoid the final electricity consumption of about 18 TWh/a. This reduction can be achieved in particular by introducing highly efficient electronic devices using the best available technology in all demand sectors. However, total electricity demand rises also in the Energy [R]evolution scenario as renewable electricity is increasingly used for heat generation and electric mobility.

Efficiency gains in the heat supply sector are even larger. Under the Energy [R]evolution scenario, demand for heat supply is expected to decrease almost constantly (see Figure 5.4). Compared to the Reference scenario, consumption equivalent to 330 PJ/a is avoided through efficiency gains 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)

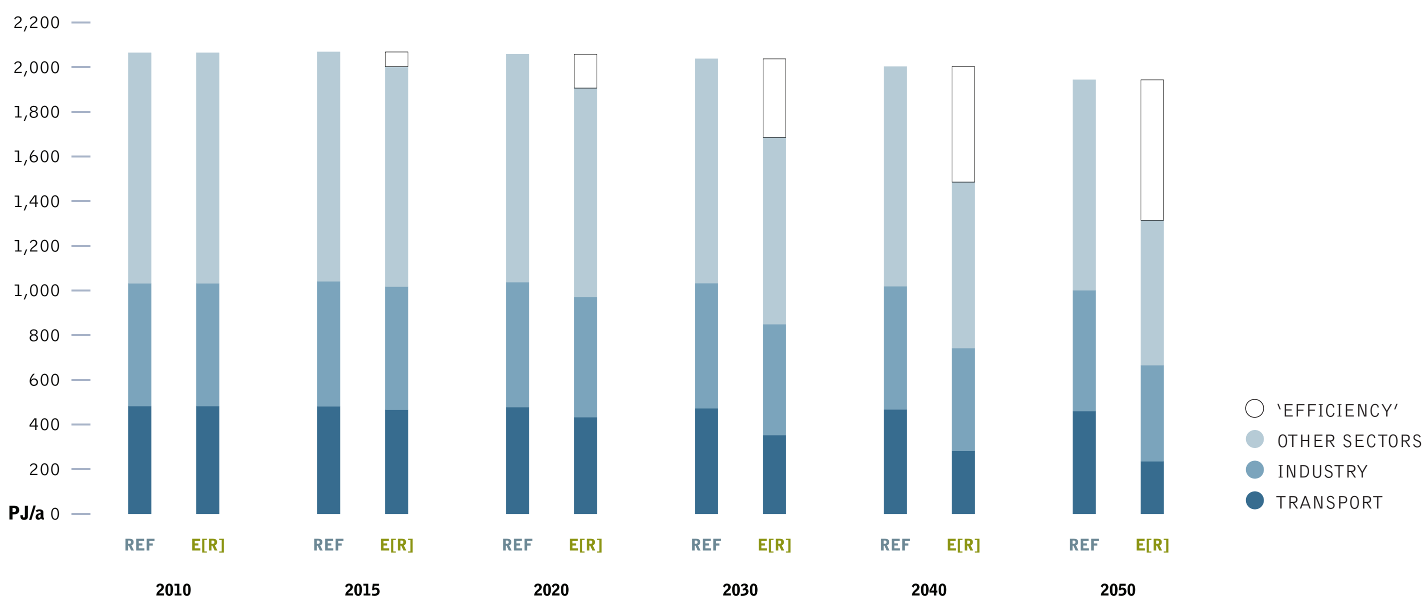


image A TRUCK DROPS ANOTHER LOAD OF WOOD CHIPS AT THE BIOMASS POWER PLANT IN LELYSTAD, THE NETHERLANDS.

image AERIAL VIEW OF A WIND TURBINE IN FRONT OF THE COAL-FIRED E.ON POWER PLANT AT MAASVLAKTE.

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

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

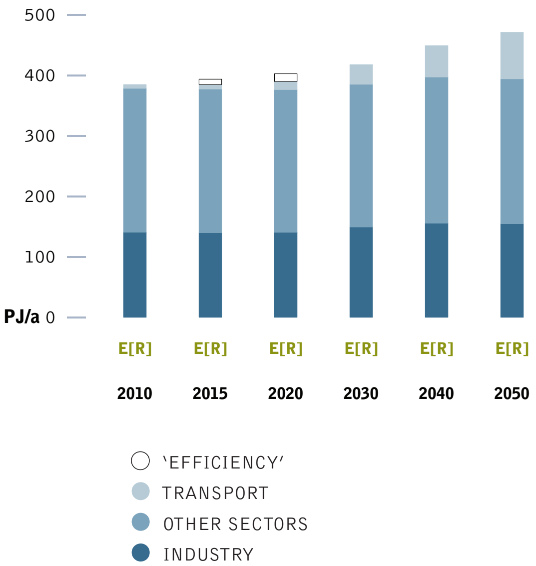


figure 5.4: development of heat demand by sector in the energy [r]evolution scenario

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

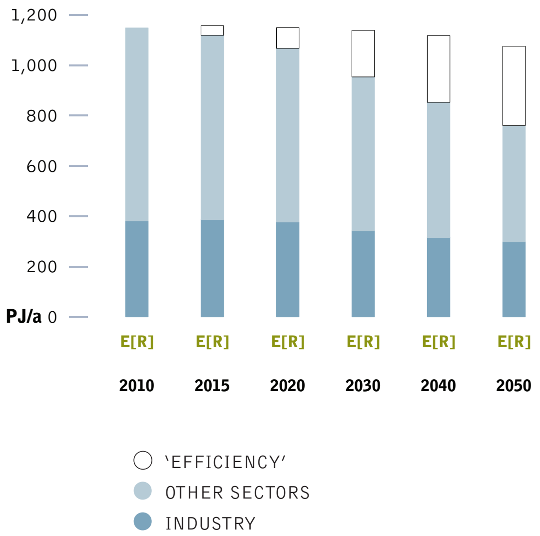
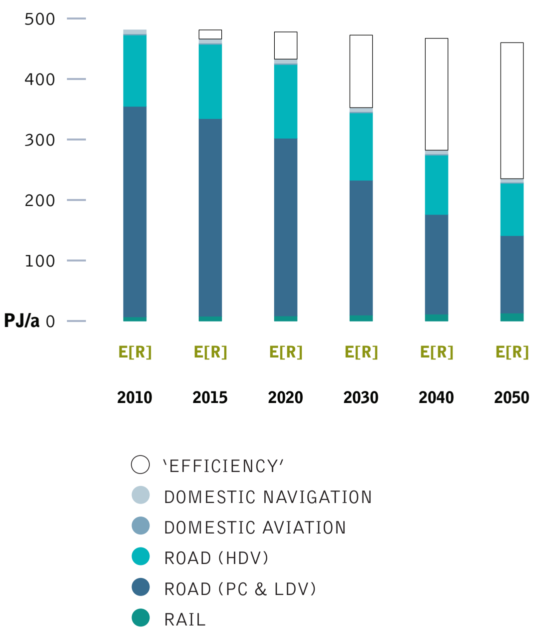


figure 5.3: development of the transport demand by sector in the energy [r]evolution scenario



5.2 electricity generation

The development of the electricity supply sector is characterised by a dynamically growing renewable energy market and an increasing share of renewable electricity. 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, 78% of the electricity produced in the Netherlands will come from renewable energy sources. Already by 2020, the share of renewable electricity production will be 44% and 58% by 2030. The installed capacity of renewables, mainly wind and PV, will reach 42 GW in 2030 and 70 GW by 2050.

Table 5.1 shows the comparative evolution of the different renewable technologies in the Netherlands over time. Already by 2020 wind and PV become the main contributors of the growing market share. After 2020, the continuing growth of wind and PV will continue to dominate the renewable technology mix. The Energy [R]evolution scenario will lead to a high share of fluctuating power generation sources (photovoltaic, wind and ocean) of 50% 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

		2010	2020	2030	2040	2050
Hydro	REF	0.1	0.1	0.1	0.1	0.1
	E[R]	0.1	0.1	0.1	0.1	0.1
Biomass	REF	1.2	2.3	2.7	2.9	3.1
	E[R]	1.2	2.0	2.3	3.0	4.0
Wind	REF	2.2	6.0	7.8	8.8	10
	E[R]	2.2	14	18	22	27
Geothermal	REF	0	0.1	0.1	0.2	0.2
	E[R]	0	0.1	0.2	0.6	1.0
PV	REF	0.1	1.6	2.2	2.6	3.0
	E[R]	0.1	8.3	21	34	37
CSP	REF	0	0	0	0	0
	E[R]	0	0	0	0	0
Ocean energy	REF	0	0	0	0	0
	E[R]	0	0	0.01	0.1	0.6
Total	**REF**	**3.6**	**10**	**13**	**15**	**16**
	E[R]	**3.6**	**24**	**42**	**60**	**70**

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)

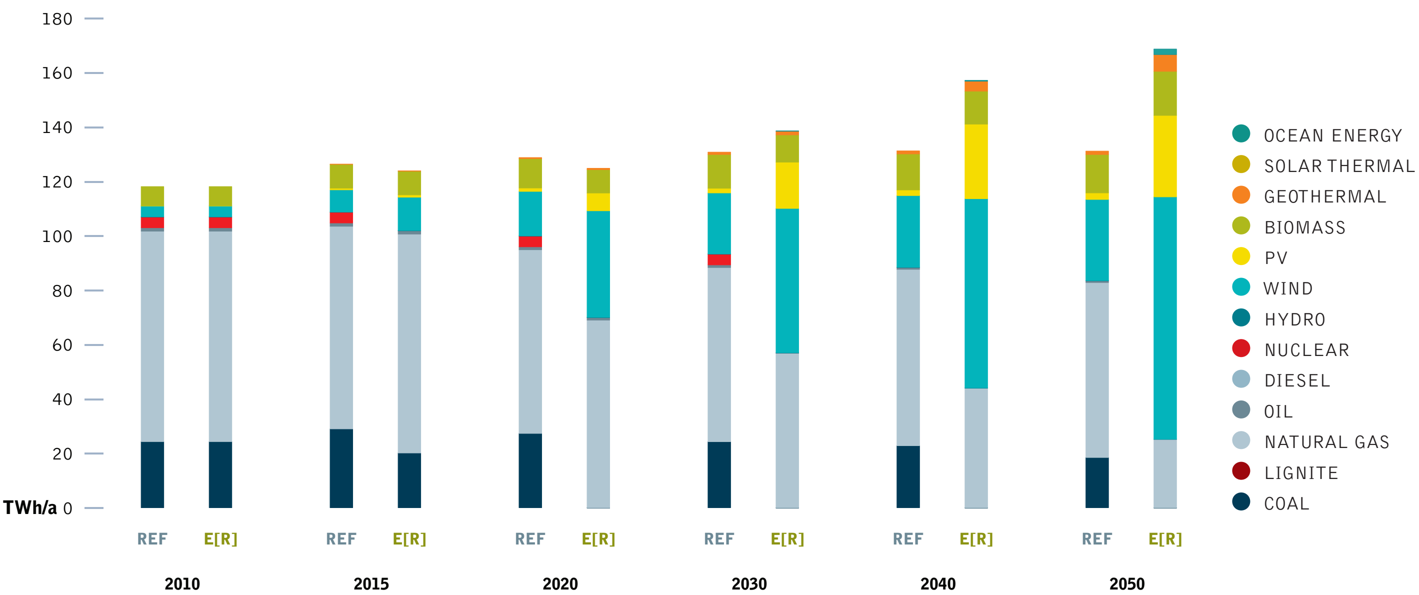
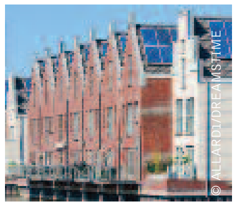


image SOLAR PLANT WITH A WIND TURBINE AT A FARM IN THE NETHERLANDS.

image DUTCH HOUSES WITH SOLAR PANELS IN HEERHUGOWAARD, THE NETHERLANDS.



5.3 future costs of electricity generation

Figure 5.6 shows that the introduction of renewable technologies under the Energy [R]evolution scenario does not significantly increase the future costs of electricity generation in the long term compared to the Reference scenario. The maximum difference will be about 0.2 €ct/kWh up to 2020. Because of rising prices for conventional fuels and the lower CO_2 intensity of electricity generation, electricity generation costs will become even more economically favourable under the Energy [R]evolution scenario and by 2050 costs will be 4.5 €ct/kWh below those in the Reference version.

Under the Reference scenario, on the other hand, unchecked growth in demand, an increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity generation costs rising from today's €12 billion per year to more than €19 billion in 2050. Figure 5.6 shows that the Energy [R]evolution scenario not only complies with Netherlands's CO_2 reduction targets, but also helps to stabilise energy costs and relieve the economic pressure on society. Increasing energy efficiency and shifting energy supply to renewables lead to long term costs for electricity supply that are even 5% lower than in the Reference scenario.

5.4 future investments in the power sector

It would require €171 billion in investment for the Energy [R]evolution scenario to become reality (including investments for replacement after the economic lifetime of the plants) - approximately €4.2 billion annual or €95 billion more than in the Reference scenario (€76 billion). Under the Reference version, the levels of investment in conventional power plants add up to almost 19% while approximately 81% would be invested in renewable energy and cogeneration (CHP) until 2050.

Under the Energy [R]evolution scenario, however, Netherlands 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.

Because renewable energy has no fuel costs, however, the fuel cost savings in the Energy [R]evolution scenario reach a total of €136 billion up to 2050, or €3.5 billion per year. The total fuel cost savings therefore would cover 143% of the total additional investments compared to the Reference scenario. These renewable energy sources would then go on to produce electricity without any further fuel costs beyond 2050, while the costs for coal and gas will continue to be a burden on national economies.

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

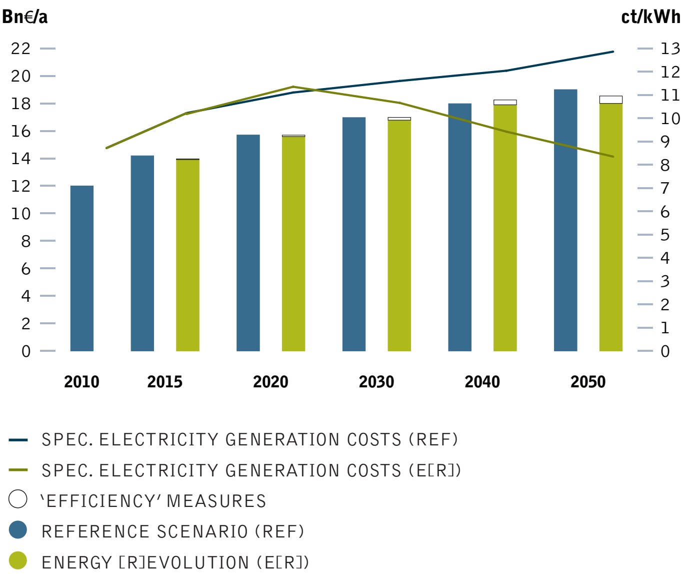
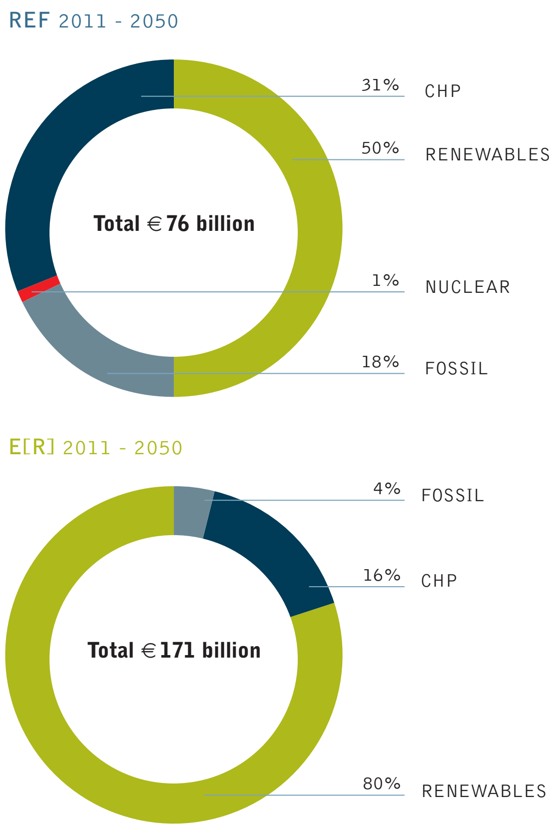


figure 5.7: investment shares - reference scenario versus energy [r]evolution scenario



5.5 heating supply

Today, renewables meet 2.4% of Netherlands's primary heat demand, the main contribution coming from the use of biomass. The expansion and extended use of district heating networks are important for the large scale utilisation of geothermal and solar thermal energy. Dedicated support instruments are required to ensure a dynamic development. In the Energy [R]evolution scenario, renewables provide 24% of Netherlands's total heat demand in 2030 and 65% in 2050.

- Energy efficiency measures help to reduce the currently growing energy demand for heating by 29% in 2050 (relative to the Reference scenario), in spite of improving living standards.
- In the industry sector solar collectors, geothermal energy (incl. heat pumps), and electricity from renewable sources are increasingly substituting for fossil fuel-fired systems.
- A shift from coal and oil to natural gas in the remaining conventional applications leads to a further reduction of CO_2 emissions.

Table 5.2 shows the development of the different renewable technologies for heating in Netherlands over time. Biomass will remain the main contributor of the growing renewable 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

		2010	2020	2030	2040	2050
Biomass	REF	25	42	97	105	113
	E[R]	25	58	100	121	133
Solar collectors	REF	1	2	2	2	3
	E[R]	1	18	55	97	107
Geothermal	REF	0	18	23	27	30
	E[R]	0	25	72	158	234
Electricity	REF	21	21	21	21	20
	E[R]	21	20	25	39	54
Hydrogen	REF	0	0	0	0	0
	E[R]	0	0	10	43	77
Total	**REF**	**47**	**82**	**143**	**156**	**166**
	E[R]	**47**	**121**	**262**	**458**	**604**

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

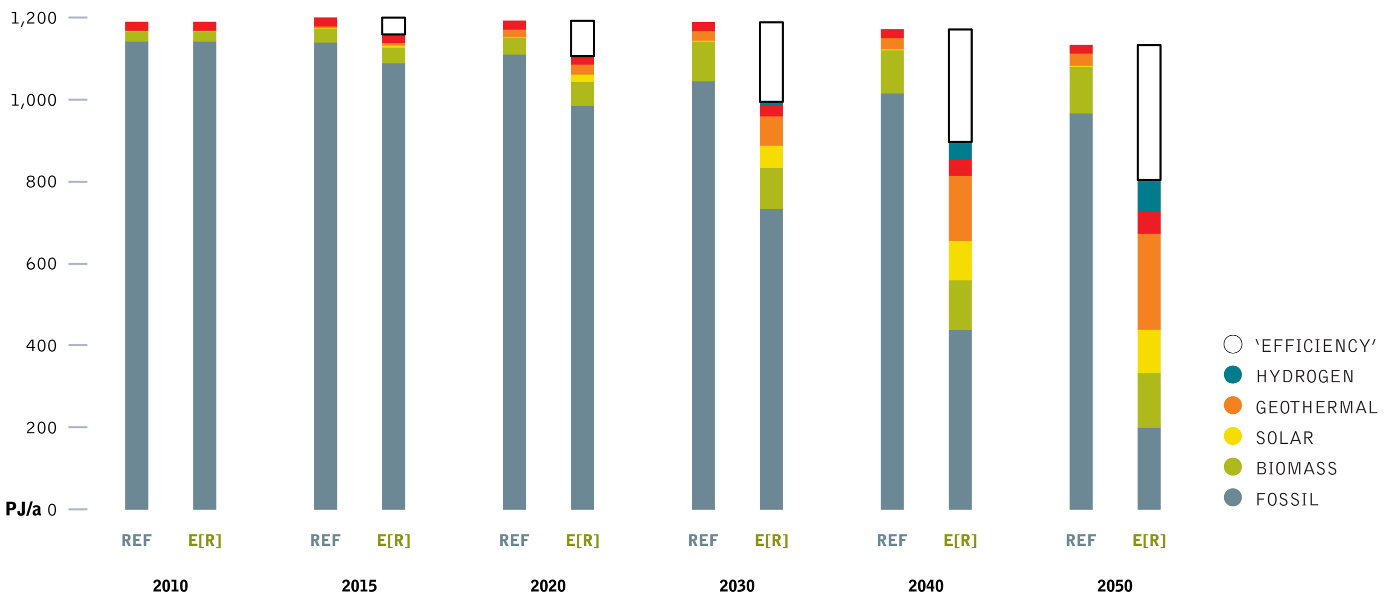


image THE 'FIRE TUBE' FROM A STEAM KETTLE THROUGH WHICH GAS WITH A TEMPERATURE OF 900-950 DEGREES CELCIUS TRAVELS. THIS TURNS THE SURROUNDING WATER INTO STEAM AT THE LELYSTAD POWER PLANT.

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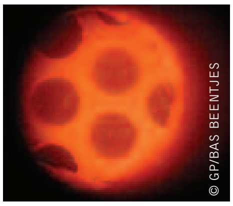


5.6 future investments in the heat sector

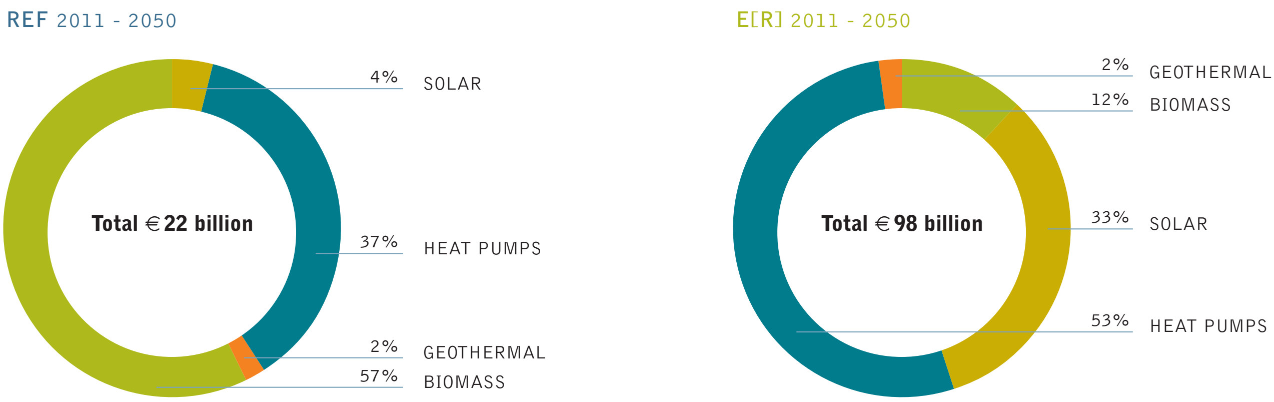
Also in the heat sector the Energy [R]evolution scenario would require a major revision of current investment strategies in heating technologies. Especially solar and geothermal and heat pump technologies need enormous increase in installations, if these potentials are to be tapped for the heat sector. Installed capacity needs to increase by the factor of 120 for solar thermal and by the factor of 750 for geothermal and heat pumps. Capacity of biomass technologies will decrease but remain a main pillar of heat supply

Renewable heating technologies are extremely variable, 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 in total requires around €98 billion to be invested in renewable heating technologies until 2050 (including investments for replacement after the economic lifetime of the plants) - approximately €2.5 billion per year.

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

		2010	2020	2030	2040	2050
Biomass	REF	4	5	12	13	13
	E[R]	4	8	12	12	12
Geothermal	REF	0	0	0	0	0
	E[R]	0	0	0	1	1
Solar thermal	REF	0	0	1	1	1
	E[R]	0	5	17	29	32
Heat pumps	REF	0	2	3	3	3
	E[R]	0	3	10	21	29
Total	**REF**	**4**	**8**	**16**	**17**	**18**
	E[R]	**4**	**17**	**39**	**64**	**76**

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



5.7 transport

A key target in the Netherlands is to introduce incentives for people to drive smaller and more efficient cars. In addition, it is vital to shift transport use to efficient modes like rail, light rail and buses, especially in the urban areas. Together with rising prices for fossil fuels, these changes reduce the growth in car sales projected under the Reference scenario. Compared to the Reference scenario, energy demand from the transport sector will be reduced by 49% in 2050 under the Energy [R]evolution scenario. Energy demand under the Energy [R]evolution scenario will decrease from 483 PJ/a in 2010 to 235 PJ/a.

Highly efficient propulsion technology with hybrid, plug-in hybrid and battery-electric power trains will bring large efficiency gains. By 2030, electricity will provide 9% of the transport sector's total energy demand in the Energy [R]evolution, while in 2050 the share will be 33%.

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

		2010	2020	2030	2040	2050
Rail	REF	8	8	8	8	9
	E[R]	8	8	10	11	13
Road	REF	466	461	455	449	441
	E[R]	466	416	334	263	215
Domestic aviation	REF	2	2	2	3	3
	E[R]	2	2	2	2	2
Domestic navigation	REF	7	7	7	8	8
	E[R]	7	7	6	6	6
Total	**REF**	**483**	**478**	**473**	**467**	**460**
	E[R]	**483**	**433**	**353**	**282**	**235**

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

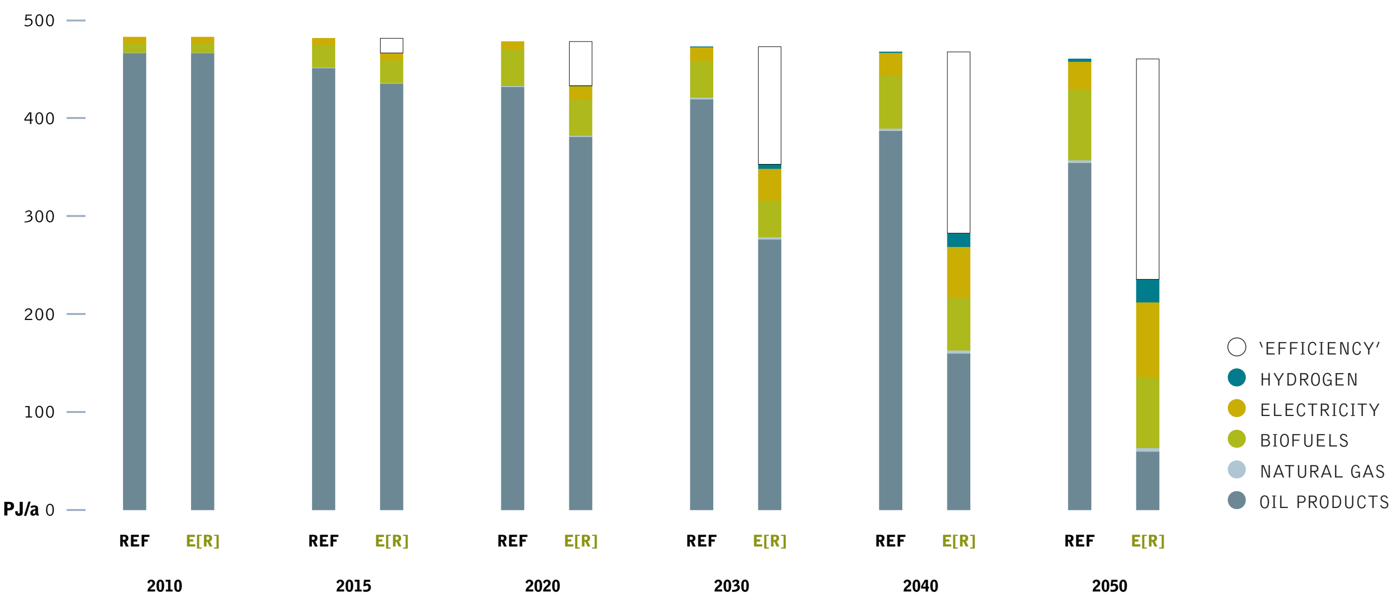


image NEW BUILDINGS WITH SOLAR PANELS IN THE NETHERLANDS.

image WIND TURBINES IN A CORN FIELD IN THE NETHERLANDS.

5.8 development of CO_2 emissions

The Netherlands' emissions of CO_2 will decrease by 26% between 2010 and 2050 under the Reference scenario, under the Energy [R]evolution scenario they will decrease from 172 million tonnes in 2010 to 21 million tonnes in 2050. Annual per capita emissions will drop from 10.4 tonnes to 1.2 tonnes. In spite of 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 renewables in vehicles will reduce emissions in the transport sector. By 2050, Netherlands's CO_2 emissions are 86% below 1990 levels.

5.9 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 5.11. Under the Energy [R]evolution scenario, primary energy demand will decrease by 40% from today's 3,490 PJ/a to 2,100 PJ/a. Compared to the Reference scenario, overall primary energy demand will be reduced by 32% in 2050 under the Energy [R]evolution scenario (REF: 3,110 PJ in 2050).

The Energy [R]evolution scenario aims to phase out coal and oil as fast as technically and economically possible. Coal power plants are phased out by 2020. This is made possible mainly by the present overcapacity to produce power in the Netherlands and the rise of renewable electricity production. Oil combustion engines are replaced fastly in the transport sector by very efficient electric vehicles. This leads to an overall renewable primary energy share of 24% in 2030 and 54% in 2050. Nuclear energy is phased out at the end of 2013.

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

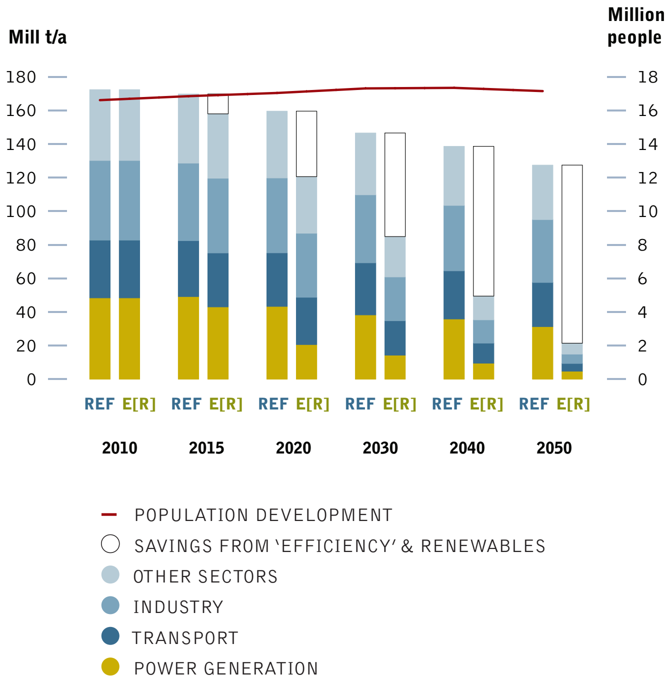


figure 5.11: primary energy consumption under the reference scenario and the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

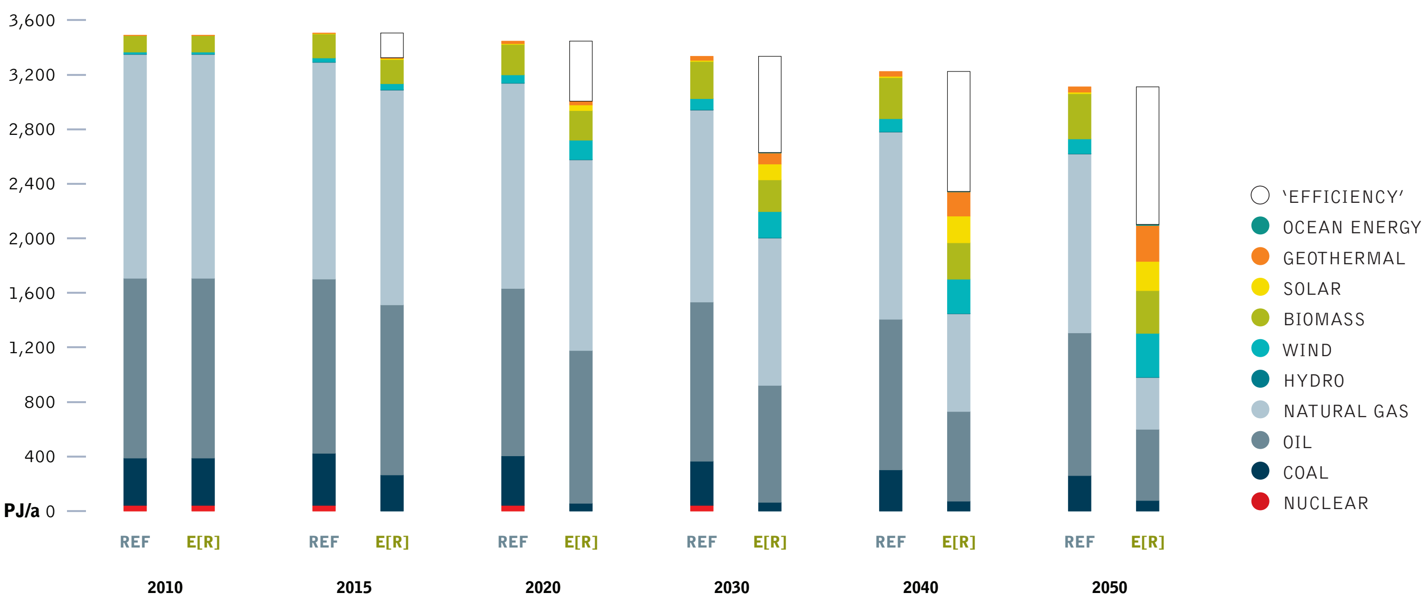


table 5.5: investment costs for electricity generation and fuel cost savings under the energy [r]evolution scenario compared to the reference scenario

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 €	3.9	0.9	0.5	3.8	9.1	0.3
Renewables	billion €	-25.8	-16.7	-36.1	-25.5	-104.1	-2.6
Total	billion €	**-21.9**	**-15.9**	**-35.6**	**-21.6**	**-95.0**	**-2.4**
CUMULATED FUEL COST SAVINGS							
SAVINGS CUMULATIVE E[R] VERSUS REF							
Fuel oil	billion €/a	0.1	1.5	2.0	1.7	5.4	0.1
Gas	billion €/a	0.0	10.7	28.6	54.9	94.2	2.4
Hard coal	billion €/a	4.2	10.7	10.8	10.0	35.7	0.9
Nuclear energy	billion €/a	0.3	0.4	0.1	0.0	0.7	0.0
Total	billion €/a	**4.6**	**23.3**	**41.5**	**66.7**	**136.0**	**3.4**

future employment

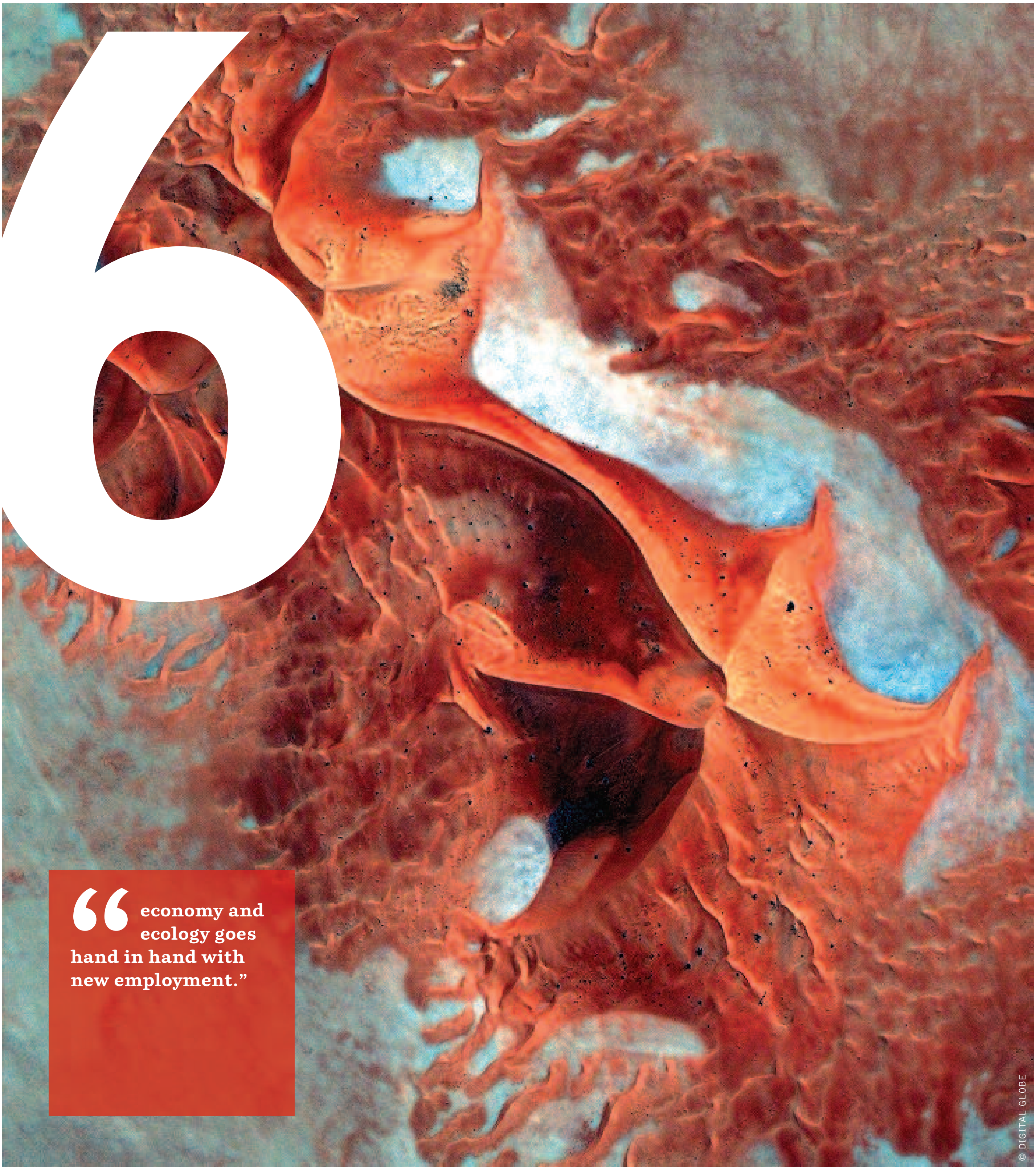


image SAND DUNES NEAR THE TOWN OF SAHMAH, OMAN.

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 World Energy Outlook 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 Netherlands's Energy [R]evolution and Reference scenario.

Employment is projected for The Netherlands 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 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 and induced jobs are not included in the calculations. Indirect jobs generally include jobs in secondary industries that supply the primary industry sector, for example, catering and accommodation. Induced jobs are those resulting from spending wages earned in the primary industries. Energy efficiency jobs are also excluded, despite the fact that the Energy [R]evolution includes significant development of efficiency, as the uncertainties in estimation are too great.

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

6.2 overview

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

image EMPLOYEE OF THE STAND-ALONE CHP BIOMASS PLANT IN LELYSTAD, NETHERLANDS. THROUGH BURNING OF WOOD CHIPS THE PLANT GENERATES ELECTRICITY (CAPACITY OF 1.5 MWE) AND/OR HEAT (CAPACITY 6.5 MWTH).

6.3 limitations

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 that are not included, including replacement of generating plant, and energy efficiency jobs.

Insufficient data means it was not possible to include a comprehensive assessment for the heat supply sector. 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.

6.4 employment factors

The employment factors used in the 2013 Netherlands analysis are shown in Table 6.2, with the main source given in the notes. Local factors have been used for gas production, biomass and hydro operations and maintenance (O&M), and for geothermal and heat. OECD factors from the 2012 global analysis (Rutovitz & Harris, 2012a) are used in all other cases, and more detail may be found there on derivation.

table 6.2: employment factors used in the 2013 analysis for the netherlands

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		Note 1
Gas	2	1.7	1.0	0.1	**4.4**	Note 2
Biomass	2	14.0	2.9	**2.5**	32.2	Note 3
Hydro-large	2	6.0	1.5	**2.7**		Note 4
Wind onshore	2	2.5	6.1	0.2		Note 5
Wind onshore	4	7.1	10.7	0.2		Note 6
PV	1	10.9	6.9	0.3		Note 7
Geothermal	2	6.8	3.9	0.4		Note 8
Solar thermal	2	8.9	4.0	0.5		Note 9
Ocean	2	9.0	1.0	0.3		Note 10
Geothermal - heat	15.2 jobs/ MW (construction and manufacturing)					Note 11
Solar - heat	17.7 jobs/ MW (construction and manufacturing)					Note 12
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					

notes on employment factors

1. Coal: Construction, manufacturing and operations and maintenance factors are from the JEDI model (National Renewable Energy Laboratory, 2011a).
2. Gas, oil and diesel: The factor for fuel (job years per PJ) is a local factor derived from production data from the IEA web portal (International Energy Agency, n.d.) and employment data from a Brattle Group report for the Ministry of Economic Affairs, Agriculture and Innovation (Harris, Bazelon, et al, 2010). Installation and manufacturing factors are from the JEDI model (National Renewable Energy Laboratory, 2011b). O&M factor is an average of the figures 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).
3. Bioenergy: O&M uses a local factor, and is the weighted average of factors for MSW and biogas, calculated from reported 2010 employment (Lako & Beurskens, 2011) and capacity (Centraal Bureau voor de Statistiek, 2013). There is no bioenergy fuel calculation for MSW or biogas, as all employment is included in the figure for O&M. Employment factors for construction and manufacturing use the average values of several European and US studies (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 European studies (Domac, Richards, & Risovic, 2005; EPRI, 2001; Hillring, 2002; Thornley, 2006; Upham & Speakman, 2007; Valente, Spinelli, & Hillring, 2011).
4. Hydro – large: A local factor for O&M was derived from current employment (Vuik, Zult, & Van Rossum, 2012). Construction and manufacturing factors are from a US study (Navigant Consulting, 2009).
5. Wind – onshore: The installation factor used is from the European Wind Energy Association (European Wind Energy Association, 2009). 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, reported in Rutovitz & Harris, 2012a.
6. Wind – offshore: All factors are from a German report (Price Waterhouse Coopers, 2012).
7. 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, 2010), 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).
8. Geothermal: The construction and installation factor is derived from a study conducted by Sinclair Knight Merz (SKM) (2005). The 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).
9. Solar thermal power: The calculated factor for OECD Europe is used, from a weighted average of power plants totalling 951 MW (Rutovitz & Harris, 2012a). Manufacturing is from the European Renewable Energy Council, 2008, page 16.
10. Ocean: These factors are taken from Rutovitz & Usher, 2010.
11. Geothermal and heat pumps: one overall factor has been used for jobs per MW installed, calculated for shallow geothermal and heat pumps for 2009. Employment for deep geothermal of 360 (Lako & Beurskens, 2011, p59) is subtracted from total sector employment of 2200 (Vuik et al., 2012, p44), and divided by the capacity installed in 2009 (Statistics Netherlands, 2010).
12. Solar thermal heating: One overall factor has been used for jobs per MW installed, using data for 2010 of 960 FTE employees (Lako & Beurskens, 2011) and newly installed capacity of 76,000 m^2 (Statistics Netherlands, 2010), equivalent to 54 MWth .

6.5 coal, gas and renewable technology trade

It is assumed that all manufacturing for energy technologies other than wind and PV occurs within the Netherlands, but that only 30% of manufacturing for these two technologies occurs domestically. This allows for such items as support frames and wind turbine towers, which are generally locally manufactured. There is no export calculated for the manufacturing sector.

On construction and installation, and operations and maintenance: It is assumed that for construction and installation (and operations and maintenance) the capacity in the Netherlands is filled with jobs in the Dutch business sectors. On the other hand, the export potential of the Dutch business sectors is not taken into account.

The Netherlands is self-sufficient in natural gas and is assumed to remain so for the study period. Exports are calculated using the projected gas production from the World Energy Outlook 2011 (International Energy Agency, 2011, Table 4.4). In the Reference scenario all gas production is used domestically by 2030. It is assumed that all coal is imported throughout the period.

The total woody biomass potential for the Netherlands is estimated at 32 PJ primary energy (Kuiper & Lint, 2008). Current domestic production of solid biomass other than MSW is estimated at 28 PJ, calculated from the 50% estimate for imported co-fired biomass in 2009 (Jonker & Junginger, 2011), and the data for primary energy from biomass (Statistics Netherlands, 2010). Domestic production of biomass fuel has therefore been capped at 28 PJ for 2010, rising to 32 PJ by 2020.

6.6 adjustment for learning rates – decline factors

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. These declines rates are calculated directly from the cost data used in the Energy [R]evolution modelling for the Netherlands.

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%
Biomass	1.6%	1.1%	0.7%
Hydro-large	-0.6%	-0.6%	-0.9%
Wind onshore	3.6%	2.8%	0.2%
Wind offshore	3.1%	7.2%	4.5%
PV	8.0%	4.4%	4.2%
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	0.4%	0.4%	0.4%
Gas CHP	0.5%	0.5%	1.0%
Oil CHP	0.4%	0.4%	0.8%
Biomass CHP	1.6%	1.1%	0.7%
Geothermal CHP	3.5%	5.4%	7.3%
Geothermal - heat	0%	0.7%	0.9%
Solar thermal heat	0%	0.7%	1.7%

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.

6.7 future employment in the energy sector

Energy sector jobs in The Netherlands are higher in the Energy [R]evolution scenario at every stage in the projection. Jobs increase by 68% in the Energy [R]evolution scenario by 2015, and are 54,000 by 2030, an increase of 63% compared to 2010. Jobs in the Reference scenario fall 14% by 2015, and are approximately half of the 2010 level by 2030.

- There are approximately 56,000 energy sector jobs in the Energy [R]evolution Reference scenario and 29,000 in the Reference scenario at 2015, compared to 33,000 in 2010.
- In 2020, there are nearly 49,000 jobs in the Energy [R]evolution scenario, and 28,000 in the Reference scenario.
- In 2030, there are approximately 54,000 jobs in the Energy [R]evolution scenarios, and 18,000 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 Reference scenario decrease by 48% between 2010 and 2030, with job losses in most technology sectors.

In the Energy [R]evolution Scenario, extremely strong growth in renewable energy leads to an increase of 63% in total energy sector jobs between 2010 and 2030. Renewable energy accounts for 87% of energy jobs by 2030, with renewable heating accounting for the greatest share (53%), followed by solar PV, biomass, and wind.

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

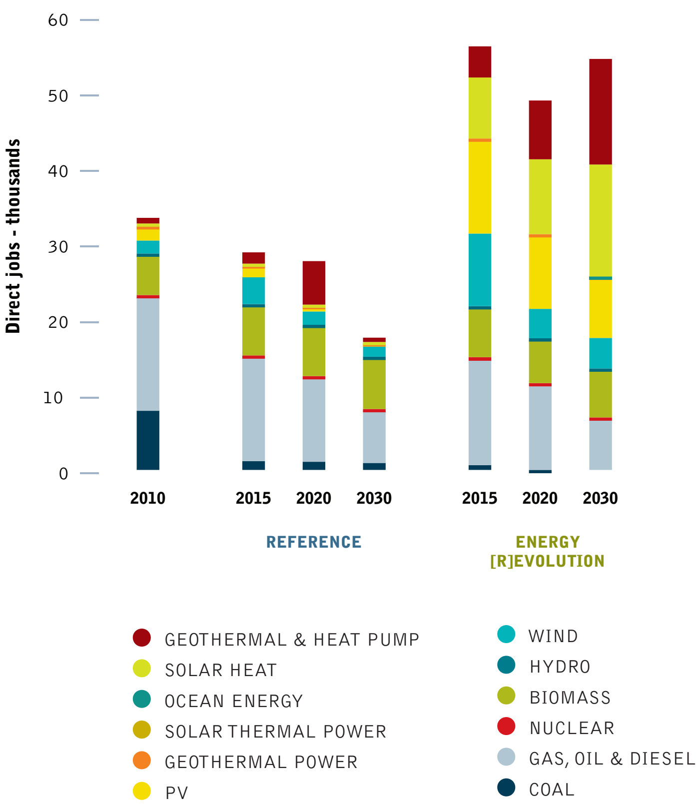


table 6.4: total employment in the energy sector

		REFERENCE			ENERGY [R]EVOLUTION		
	2010	2015	2020	2030	2015	2020	2030
Coal	8,000	1,000	1,000	1,000	1,000	-	-
Gas, oil & diesel	15,000	14,000	11,000	7,000	14,000	11,000	7,000
Nuclear	200	200	200	200	500	400	400
Renewable	10,000	14,000	15,000	9,000	41,000	37,000	47,000
Total Jobs	**33,000**	**29,000**	**28,000**	**18,000**	**56,000**	**49,000**	**54,000**
Construction and installation	10,000	6,000	5,000	1,000	27,000	21,000	26,000
Manufacturing	4,000	2,000	3,000	1,000	9,000	8,000	12,000
Operations and maintenance	6,000	8,000	9,000	10,000	8,000	10,000	11,000
Fuel supply (domestic)	8,000	8,000	7,000	6,000	8,000	7,000	5,000
Gas export	4,000	5,000	3,000	-	5,000	3,000	1,000
Total Jobs	**33,000**	**29,000**	**28,000**	**18,000**	**56,000**	**49,000**	**54,000**

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

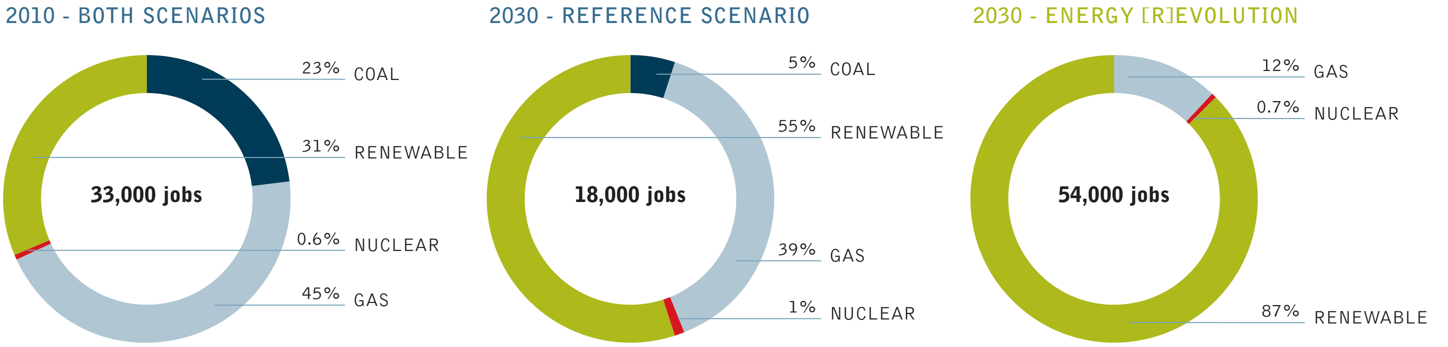


table 6.5: employment in the energy sector by technology, two scenarios

		REFERENCE			ENERGY [R]EVOLUTION		
By sector	2010	2015	2020	2030	2015	2020	2030
Construction and installation	9,400	4,600	1,500	700	18,100	9,200	7,200
Manufacturing	3,800	1,500	500	300	5,200	2,100	1,800
Operations and maintenance	6,500	8,200	9,400	9,600	7,800	9,800	10,600
Fuel supply (domestic)	8,100	7,700	7,200	6,200	7,600	6,700	4,900
Gas export	4,400	5,000	3,000	-	5,100	3,500	1,100
Solar and geothermal heat	1,100	1,700	5,900	700	12,200	17,700	28,800
Total jobs	**33,400**	**28,800**	**27,600**	**17,500**	**56,100**	**48,900**	**54,400**
By technology							
Coal	7,800	1,200	1,100	900	600	-	-
Gas, oil & diesel	15,100	13,800	11,100	6,900	13,800	11,100	6,600
Nuclear	200	200	200	200	500	400	400
Renewable	**10,200**	**13,600**	**15,400**	**9,600**	**41,100**	**37,400**	**47,400**
Biomass	5,300	6,600	6,600	6,700	6,500	5,700	6,200
Hydro	200	200	200	300	200	200	300
Wind	1,700	3,500	1,800	1,400	9,600	3,900	4,000
PV	1,900	1,500	700	400	12,500	9,800	8,000
Geothermal power	-	100	100	-	100	100	100
Solar thermal power	-	-	-	-	-	-	-
Ocean	-	-	-	-	-	-	10
Solar - heat	400	200	200	200	8,100	9,900	14,800
Geothermal & heat pump	700	1,500	5,800	600	4,100	7,800	14,000
Total jobs	**33,400**	**28,800**	**27,600**	**17,500**	**56,100**	**48,900**	**54,400**

note
numbers may not add up due to rounding

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.

6.8 employment in the renewable heating sector

In the Energy [R]evolution scenario, the renewable heating sector grows extremely strongly, creating an estimated 27,000 jobs by 2030. It should be stressed that there is a high degree of uncertainty in these estimates. This analysis includes jobs associated with fuel supply in the biomass sector, and jobs in installation and manucturing for direct heat from solar, geothermal and heat pumps.

6.8.1 employment in solar heating

In the Energy [R]evolution scenario, solar heating would provide 6% of total heat supply by 2030, and would employ approximately 14,800 people. In the Reference scenario, the sector remains very small, with solar heating providing only 0.2% of heat supply, and employing less than 160 people in 2030, down from 360 in 2010.

6.8.2 employment in geothermal and heat pump heating

In the Energy [R]evolution scenario, geothermal and heat pump heating would provide 7% of total heat supply by 2030, and employ approximately 14,000 people.

In the Reference scenario growth is also strong to 2020, with geothermal and heat pump heating expanding five fold, and providing 5,800 jobs. Growth slows from 2020 to 2030, with the sector increasing by only 25% and jobs falling to 600 people.

6.8.3 employment in biomass heat

Biomass heat provides between 8% and 10% of total heat supply by 2030 in both scenarios, and employs approximately 300 people.

table 6.6: solar heating: capacity, heat supplied and direct jobs

			REFERENCE			ENERGY [R]EVOLUTION	
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	MW	380	450	590	1,560	5,430	16,620
Heat supplied	PJ	1.3	1.5	2.0	5.2	18.1	55.0
Share of total supply	%	0.1%	0.1%	0.2%	0.5%	2%	6%
Annual increase in capacity	MW	17	14	14	609	773	1,372
Employment							
Direct jobs in installation and manufacture	jobs	220	180	160	8,100	9,900	14,800

table 6.7: geothermal and heat pump heating: capacity, heat supplied and direct jobs

			REFERENCE			ENERGY [R]EVOLUTION	
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	MW	580	2,540	2,970	920	3,570	10,440
Heat supplied	PJ	4	18	23	6	25	72
Share of total supply	%	0.3%	1.5%	2.0%	0.5%	2.3%	7.4%
Annual increase in capacity	MW	98	392	42	271	529	1,041
Employment							
Direct jobs in installation and manufacture	jobs	1,500	5,800	600	4,100	7,800	14,000

table 6.8: biomass heat: direct jobs in fuel supply

			REFERENCE			ENERGY [R]EVOLUTION	
Energy	UNIT	2015	2020	2030	2015	2020	2030
Heat supplied	PJ	34	42	97	38	58	100
Share of total supply	%	3%	4%	8%	3%	5%	10%
Employment							
Direct jobs in fuel supply	jobs	170	170	300	180	210	310

6.8.4 employment in biomass

Biomass provides significant energy sector employment in both scenarios. Job numbers remain relatively stable, with between 5,300 and 6,600 for the whole period.

Biomass provided 6% of generation in 2010, which rises by 2030 to 9% in the Reference scenario, and 7% in the Energy [R]evolution scenario. Employment does not increase in line with generation, because a high proportion of the biomass feedstock is imported, so jobs are created elsewhere.

Jobs in heating from biomass fuels are included here.

6.8.5 employment in wind energy

In the Energy [R]evolution scenario, wind energy provides 38% of total electricity generation by 2030, and employs approximately 4,000 people. Growth is much more modest in the Reference Scenario, with wind energy providing 17% of generation, and employing approximately 1,400 people.

6.8.6 employment in solar photovoltaics

Strong growth in PV in the Energy [R]evolution scenario results in 8,000 jobs by 2030, with PV supplying 12% of electricity. In the Reference scenario solar photovoltaics provides only 1.3% of generation and employs roughly 400 people in 2030, a sharp decline from 2015 figures.

table 6.9: biomass: capacity, generation and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	MW	1,660	2,320	2,700	1,640	2,040	2,280
Total generation	TWh	8.8	10.8	12.4	8.8	8.6	10.0
Share of total supply	%	6.9%	8.4%	9.5%	7.1%	6.9%	7.1%
Annual increase in capacity	MW	110	30	20	40	-30	60
Employment							
Direct jobs in construction, manufacture, O&M	jobs	5,700	5,700	5,800	5,700	4,900	5,500
Direct jobs in fuel supply (includes heat)	jobs	900	900	800	800	800	700
Total biomass jobs	jobs	6,600	6,600	6,600	6,500	5,700	6,200

table 6.10: wind energy: capacity, generation and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	MW	3,420	6,000	7,800	5,330	13,800	17,620
Total generation	TWh	8.1	16.3	22.4	12.2	39.2	53.0
Share of total supply	%	6%	13%	17%	10%	31%	38%
Annual increase in capacity	MW	350	190	120	840	360	550
Employment							
Direct jobs in construction, manufacture, operation and maintenance	jobs	3,500	1,800	1,400	9,600	3,900	4,000

table 6.11: solar photovoltaics: capacity, generation and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	MW	800	1,600	2,150	1,100	8,300	21,300
Total generation	TWh	0.6	1.3	1.7	0.9	6.5	17.0
Share of total supply	%	0.5%	1.0%	1.3%	0.7%	5.2%	12.1%
Annual increase in capacity	MW	160	60	40	1,440	1,250	1,310
Employment							
Direct jobs in construction, manufacture, operation and maintenance	jobs	1,500	700	400	12,500	9,800	8,000

image TESTING THE SCOT RENEWABLES TIDAL TURBINE OFF KIRWALL IN THE ORKNEY ISLANDS.

6.8.7 employment in coal

In 2010 there were approximately 8,000 jobs in the coal sector, mainly construction jobs for new coal power stations at Eemshaven and Maasvlakte. By 2015 the construction is complete, and coal jobs are reduced to 1,200 in the Reference scenario and 600 in the Energy [R]evolution scenario.

In the Reference Scenario, jobs in the coal sector fall by 25% from 2015 to 2030. This reflects the gradual reduction of coal generation, which drops by 16% between 2010 and 2030.

Coal sector employment in the Energy [R]evolution scenario falls below 100 by 2020, reflecting a complete phase out of coal generation between 2015 and 2030. Coal jobs in both scenarios include coal used for heat supply.

6.8.8 employment in gas, oil & diesel

Jobs in the gas sector contribute approximately half of current energy sector jobs in the Netherlands, with 15,100 in 2010. In both scenarios, gas employment is projected to fall by 54% by 2030, to approximately 6,900 in the Reference scenario and 6,600 in the Energy [R]evolution scenario. Gas production and distribution contribute the greatest share of gas employment in 2010, with approximately 11,600 jobs. These are significantly reduced by 2030, as The Netherlands gas production falls by approximately 49%.

In the same period electricity generation from gas falls by 17% in the Reference scenario and by 24% in the Energy [R]evolution scenario, which further compounds the job losses in this sector.

table 6.12: fossil fuels: capacity, generation 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	1,200	1,100	900	600	neg	neg
gas, oil & diesel	jobs	13,800	11,100	6,900	13,800	11,100	6,600
COAL							
Energy							
Installed capacity	MW	7,260	6,860	6,100	3,700	neg	neg
Total generation	TWh	29	27	24	20	neg	neg
Share of total supply	%	23%	21%	19%	16%	neg	neg
Annual increase in capacity	MW	867	-78	-114	-982	-6.5	-0.1
GAS, OIL & DIESEL							
Energy							
Installed capacity	MW	19,850	17,120	15,920	19,850	17,200	14,330
Total generation	TWh	76	69	65	82	70	59
Share of total supply	%	60%	53%	50%	66%	56%	42%
Annual increase in capacity	MW	551	-513	-104	521	-473	-204

note
"neg" = negligible

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abbreviations

CO_2	Carbon Dioxide
EIA	Energy Information Administration (USA)
EWEA	European Wind Energy Association
FTE	Full Time Equivalent
GWh	Gigawatt hour
IEA	International Energy Agency
ISF	Institute for Sustainable Futures
MSW	Municipal Solid Waste
MW	Megawatt
NREL	National Renewable Energy Laboratories (U.S)
O&M	Operations and Maintenance
OECD	Organisation for Economic Co-operation and Development
PV	Photovoltaic
REN21	Renewables Global Status Report
TWh	Terawatt hour

the silent revolution – past and current market developments

THE GLOBAL POWER PLANT MARKET IN 2011

THE GLOBAL RENEWABLES MARKET IN 2011

RENEWABLES GAINING GROUND IN THE PERIOD 2000-2010

DEVELOPMENT MAIN POWER PLANT MARKETS 1970-2010

7

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

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.

7.1 the global power plant market in 2011

The global power plant market continues to grow and reached a record high in 2011 with approximately 292 GW of new capacity added or under construction by beginning of 2012. While renewable energy power plant dominate close to 40% of the overall market, followed by gas power plants with 26%, coal power plants still represent a share of 34% or just over 100 GW or roughly 100 new coal power plants. These power plants will emit CO_2 over the coming decades and lock-in the world's power sector towards a dangerous climate change pathway.

7.2 the global renewables market in 2011

The renewable energy sector has been growing substantially over the last 10 years. In 2011, the increases in the installation rates of both wind and solar power were particularly impressive. The total amount of renewable energy installed worldwide is reliably tracked by the Renewable Energy Policy Network for the 21st Century (REN21). Its latest global status report (2012) shows how the technologies have grown. The following text has been taken from the Renewables 2012 – Global Status Report– published in June 2012 with the permit of REN 21 and is a shortened version of the executive summary:

Renewable Energy Growth in All End-Use Sectors

Renewable energy sources have grown to supply an estimated 16.7% of global final energy consumption in 2010. Of this total, modern renewable energy accounted for an estimated 8.2%, a share that has increased in recent years, while the share from traditional biomass has declined slightly to an estimated 8.5%. During 2011, modern renewables continued to grow strongly in all end-use sectors: power, heating and cooling, and transport.

In the power sector, renewables accounted for almost half of the estimated 208 gigawatts (GW) of electric capacity added globally during 2011. Wind and solar photovoltaics (PV) accounted for almost 40% and 30% of new renewable capacity, respectively, followed by hydropower (nearly 25%). By the end of 2011, total renewable power capacity worldwide exceeded 1,360 GW, up 8% over 2010; renewables comprised more than 25% of total global power-generating capacity (estimated at 5,360 GW in 2011) and supplied an estimated 20.3% of global electricity. Non-hydropower renewables exceeded 390 GW, a 24% capacity increase over 2010.

The heating and cooling sector offers an immense yet mostly untapped potential for renewable energy deployment. Heat from biomass, solar, and geothermal sources already represents a significant portion of the energy derived from renewables, and the sector is slowly evolving as countries (particularly in the European Union) are starting to enact supporting policies and to track the share of heat derived from renewable sources. Trends in the heating (and cooling) sector include an increase in system size, expanding use of combined heat and power (CHP), the feeding of renewable heating and cooling into district networks, and the use of renewable heat for industrial purposes.

Renewable energy is used in the transport sector in the form of gaseous and liquid biofuels; liquid biofuels provided about 3% of global road transport fuels in 2011, more than any other renewable energy source in the transport sector. Electricity powers trains, subways, and a small but growing number of passenger cars and motorised cycles, and there are limited but increasing initiatives to link electric transport with renewable energy.

figure 7.1: global power plant market 2011

NEW POWER PLANTS BY TECHNOLOGY INSTALLED & UNDER CONSTRUCTION IN 2011

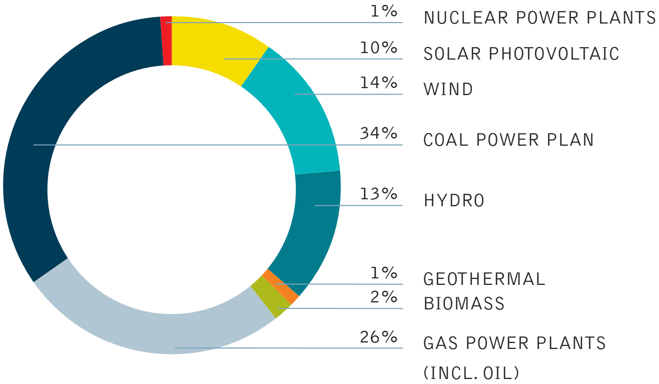


figure 7.2: global power plant by region

NEW INSTALLATIONS IN 2011

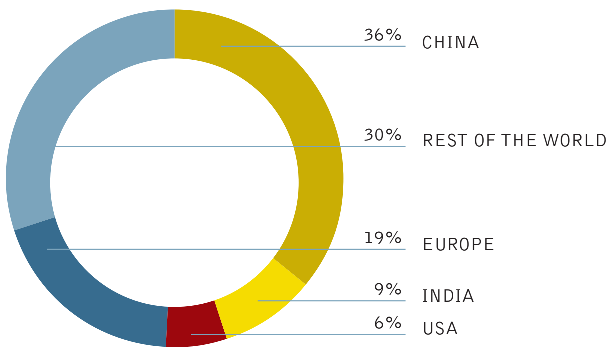


image NESJAVELLIR GEOTHERMAL PLANT GENERATES ELECTRICITY AND HOT WATER BY UTILIZING GEOTHERMAL WATER AND STEAM. IT IS THE SECOND LARGEST GEOTHERMAL POWER STATION IN ICELAND. THE STATION PRODUCES APPROXIMATELY 120MW OF ELECTRICAL POWER, AND DELIVERS AROUND 1,800 LITRES (480 US GAL) OF HOT WATER PER SECOND, 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.

table 7.1: overview global renewable energy market 2011

		2009	2010	2011
Investment in new renewable capacity (annual)	billion USD	161	220	257
Renewable power capacity (total, not including hydro)	GW	250	315	390
Renewable power capacity (total, including hydro)	GW	1,170	1,260	1,360
Hydropower capacity (total)	GW	915	945	970
Solar PV capacity (total)	GW	23	40	70
Concentrating solar thermal power (total)	GW	0.7	1.3	1.8
Wind power capacity (total)	GW	159	198	238
Solar hot water/heat capacity (total)	GW	153	182	232
Ethanol production (annual)	billion litres	73.1	86.5	86.1
Biodiesel production (annual)	billion litres	17.8	18.5	21.4
Countries with policy targets	#	89	109	118
States/provinces/countries with feed in policies	#	82	86	92
States/provinces/countries with RPS/quota policies	#	66	69	71
States/provinces/countries with biofuel mandates	#	57	71	72

Solar PV grew the fastest of all renewable technologies during the period from end-2006 through 2011, with operating capacity increasing by an average of 58% annually, followed by concentrating solar thermal power (CSP), which increased almost 37% annually over this period from a small base, and wind power (26%). Demand is also growing rapidly for solar thermal heat systems, geothermal ground-source heat pumps, and some solid biomass fuels, such as wood pellets. The development of liquid biofuels has been mixed in recent years, with biodiesel production expanding in 2011 and ethanol production stable or down slightly compared with 2010. Hydropower and geothermal power are growing globally at rates averaging 2–3% per year. In several countries, however, the growth in these and other renewable technologies far exceeds the global average.

A Dynamic Policy Landscape

At least 118 countries, more than half of which are developing countries, had renewable energy targets in place by early 2012, up from 109 as of early 2010. Renewable energy targets and support policies continued to be a driving force behind increasing markets for renewable energy, despite some setbacks resulting from a lack of long-term policy certainty and stability in many countries.

The number of official renewable energy targets and policies in place to support investments in renewable energy continued to increase in 2011 and early 2012, but at a slower adoption rate relative to previous years. Several countries undertook significant policy overhauls that have resulted in reduced support; some changes were intended to improve existing instruments and achieve more targeted results as renewable energy technologies mature, while others were part of the trend towards austerity measures.

Renewable power generation policies remain the most common type of support policy; at least 109 countries had some type of renewable power policy by early 2012, up from the 96 countries reported in the GSR 2011. Feed-in-tariffs (FITs) and renewable portfolio standards (RPS) are the most commonly used policies in this sector. FIT policies were in place in at least 65 countries and 27 states by early 2012. While a number of new FITs were enacted, most related policy activities involved revisions to existing laws, at times under controversy and involving legal disputes. Quotas or Renewable Portfolio Standards (RPS) were in use in 18 countries and at least 53 other jurisdictions, with two new countries having enacted such policies in 2011 and early 2012.

Policies to promote renewable heating and cooling continue to be enacted less aggressively than those in other sectors, but their use has expanded in recent years. By early 2012, at least 19 countries had specific renewable heating/cooling targets in place and at least 17 countries and states had obligations/mandates to promote renewable heat. Numerous local governments also support renewable heating systems through building codes and other measures. The focus of this sector is still primarily in Europe, but interest is expanding to other regions.

Investment Trends

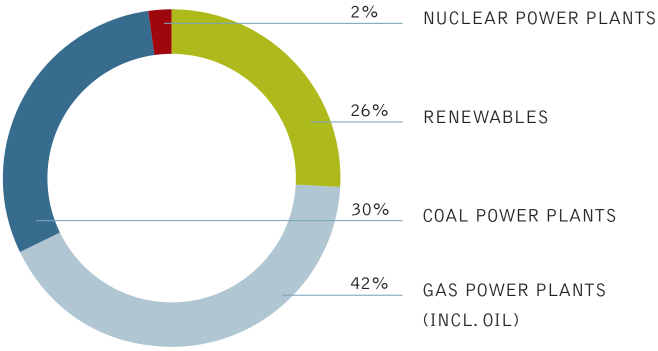
Global new investment in renewables rose 17% to a record $ 257 billion in 2011. This was more than six times the figure for 2004 and almost twice the total investment in 2007, the last year before the acute phase of the recent global financial crisis. This increase took place at a time when the cost of renewable power equipment was falling rapidly and when there was uncertainty over economic growth and policy priorities in developed countries. Including large hydropower, net investment in renewable power capacity was some $ 40 billion higher than net investment in fossil fuel capacity.

7.3 renewables gaining ground in the period 2000-2010

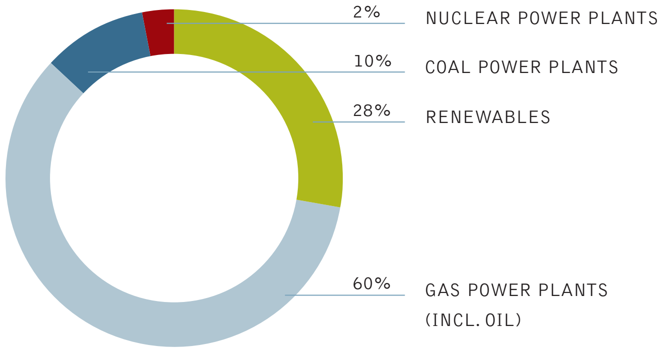
Since the year 2000, the wind power market gained a growing market share within the global power plant market. Initially only a handful of countries, namely Germany, Denmark and Spain, dominated the wind market, but the wind industry now has projects in over 70 countries around the world. Following the 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 7.3: power plant market shares

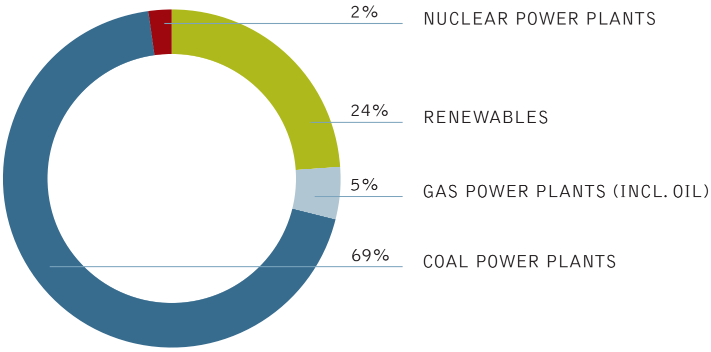
global power plant market shares 2000-2010



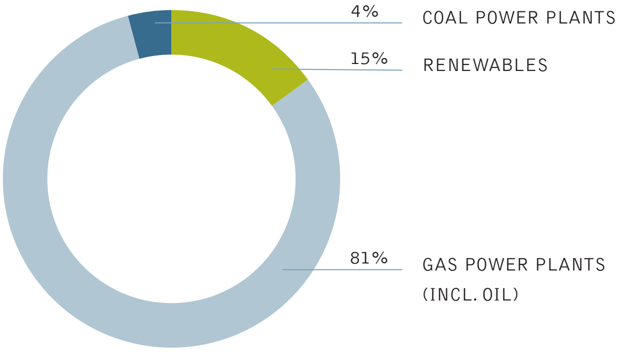
global power plant market shares 2000-2010 - excluding china



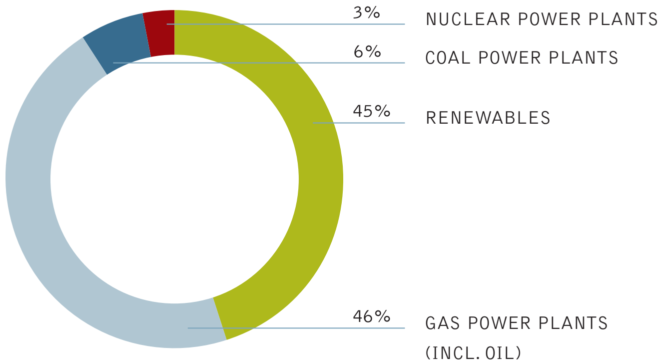
china: power plant market shares 2000-2010



usa: power plant market shares 2000-2010



EU 27: power plant market shares 2000-2010



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

image WORKERS OUTSIDE GEOTHERMAL POWER PLANT IN KAWERAU, NEW ZEALAND.

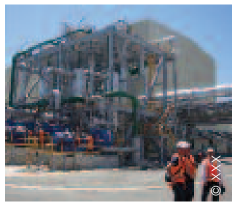
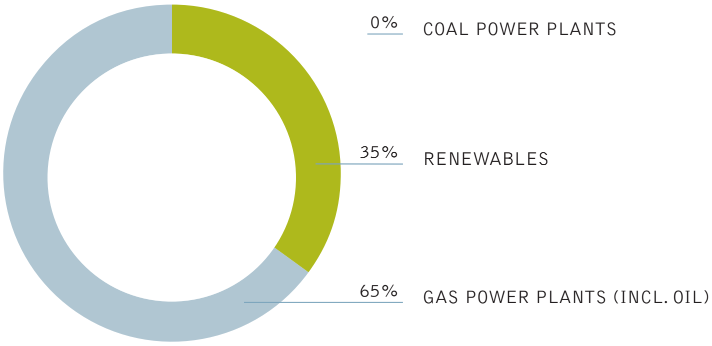


figure 7.4: netherlands: new build power plant market shares 2000-2010



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.

7.4 development main power plant markets 1970-2010

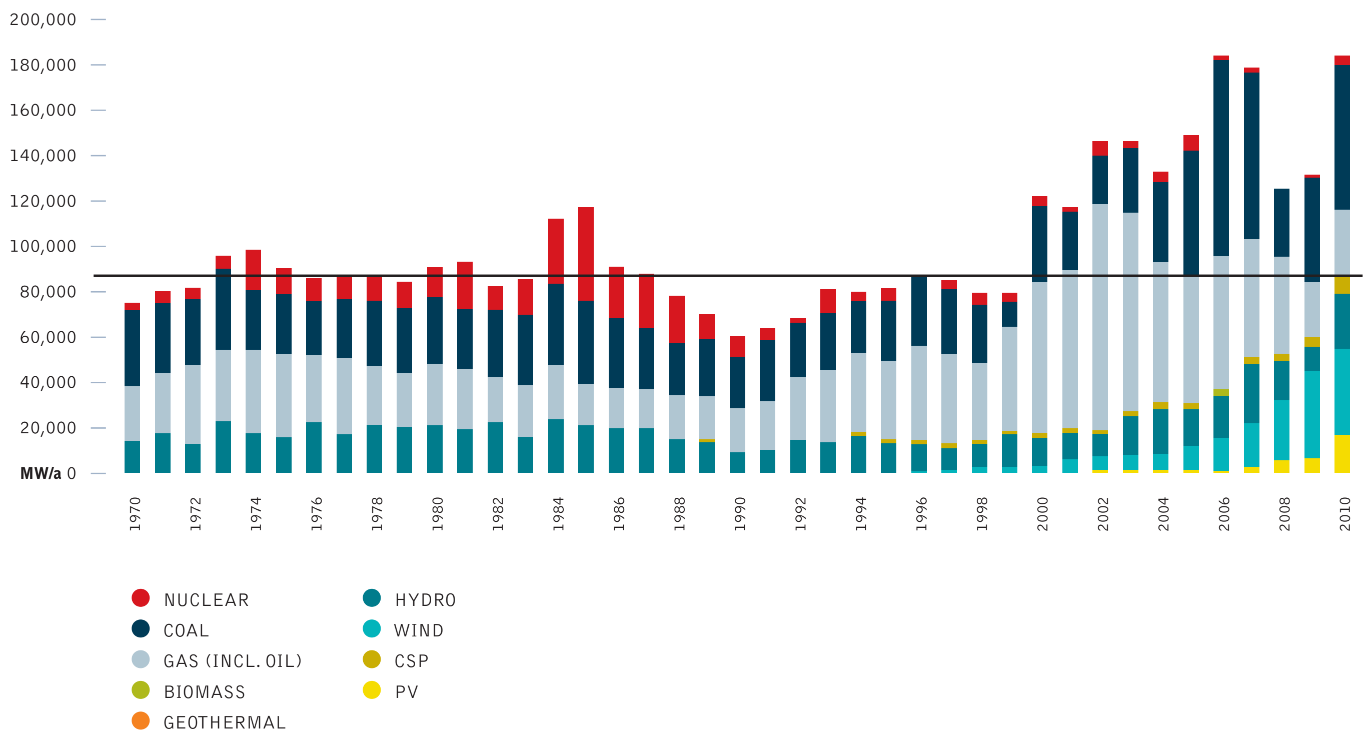
A new analysis of the global power plant market shows that since the late 1990s, wind and solar installations grew faster than any other power plant technology across the world - about 430,000 MW total installed capacities between 2000 and 2010. However, it is too early to claim the end of the fossil 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[45] 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.

figure 7.5: global power plant market 1970-2010



source
Platts, IEA, Breyer, Teske.

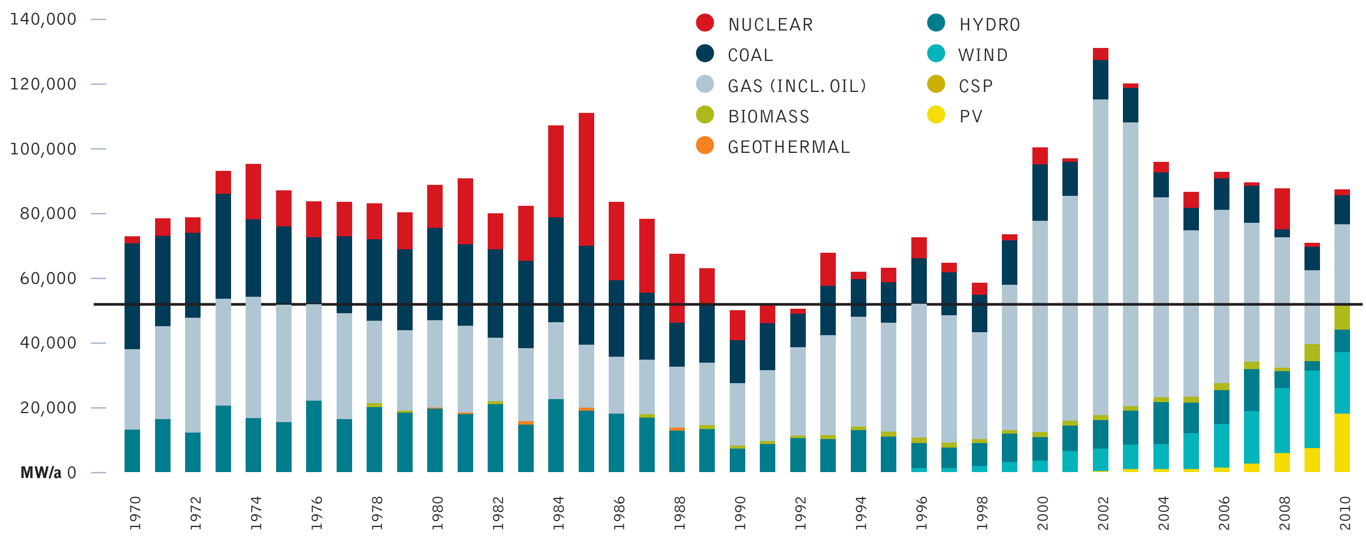
reference
45 ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT.

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

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.

The graphs show how much electricity market liberalisation influences the choice of power plant technology. While the US and European power sectors moved towards deregulated markets, which favour mainly gas power plants, China added a large amount of coal until 2009, with the first signs for a change in favour of renewable energy in 2009 and 2010.

figure 7.6: global power plant market 1970-2010, excluding china

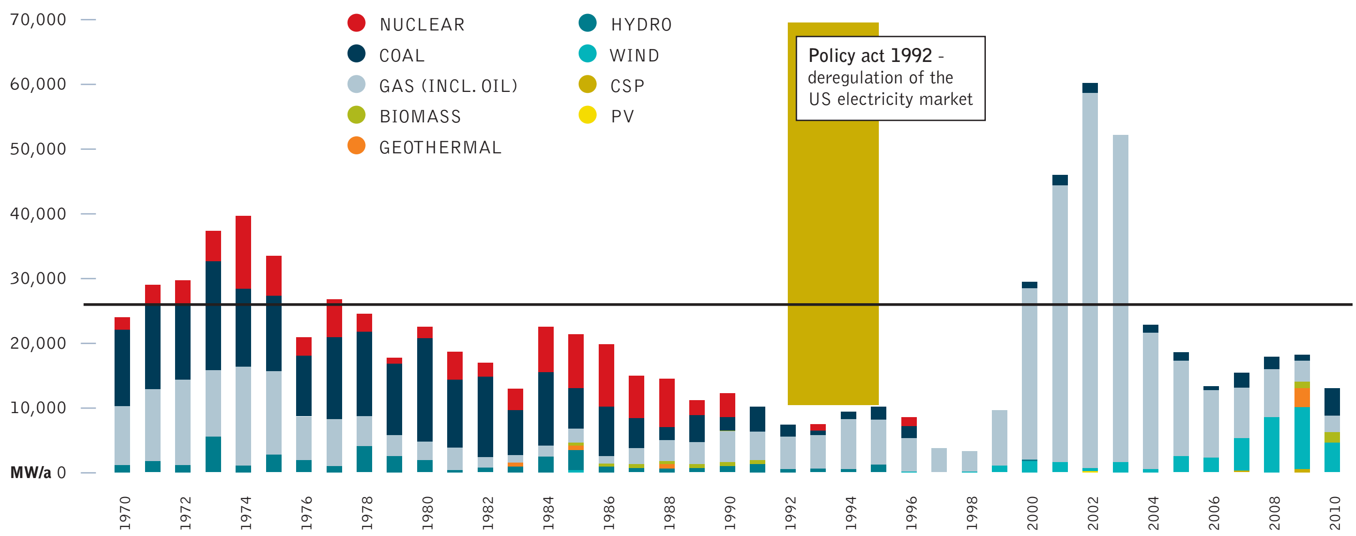


source
Platts, IEA, Breyer, Teske.

USA: Liberalisation of the US power sector started with the Energy Policy Act 1992, and became a game changer for the whole sector. While the US in 2010 is still far away from a fully liberalised electricity market, the effect has been a shift from coal and nuclear towards gas and wind. Since 2005 wind power plants have made up an increasing share of the new installed capacities as a result of mainly state-based renewable eneggy support programmes. Over the past year, solar photovoltaic plays a growing role with a project pipeline of 22,000 MW (Photon 4-2011, page 12).

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 7.7: usa: power plant market 1970-2010



source
Platts, IEA, Breyer, Teske.

figure 7.8: europe (eu 27): power plant market 1970-2010

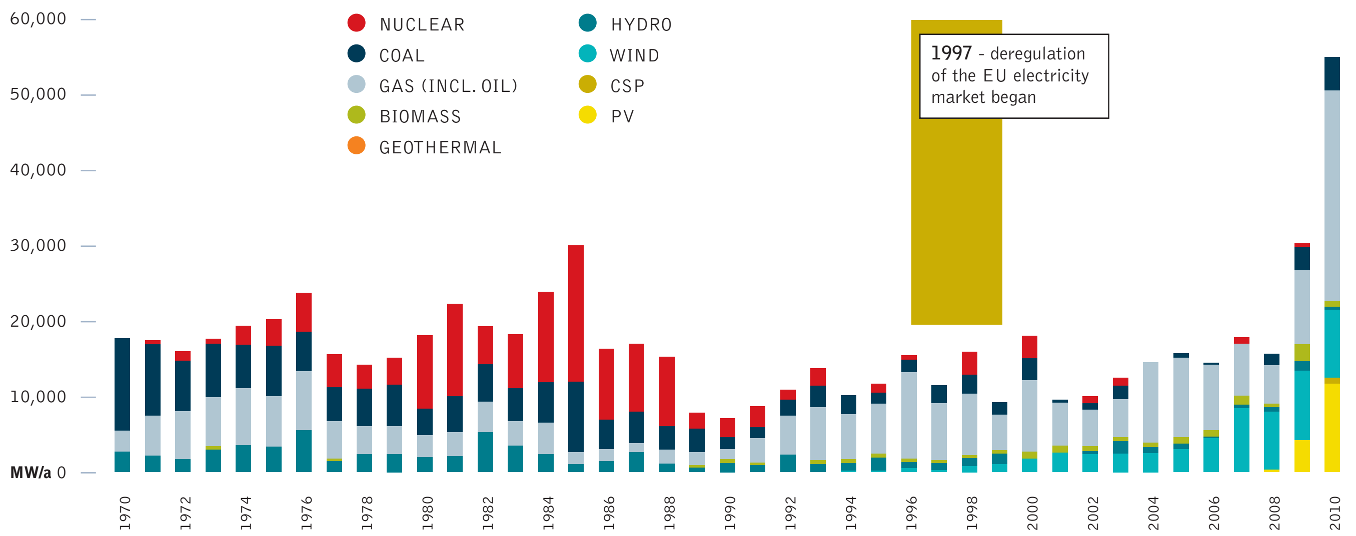
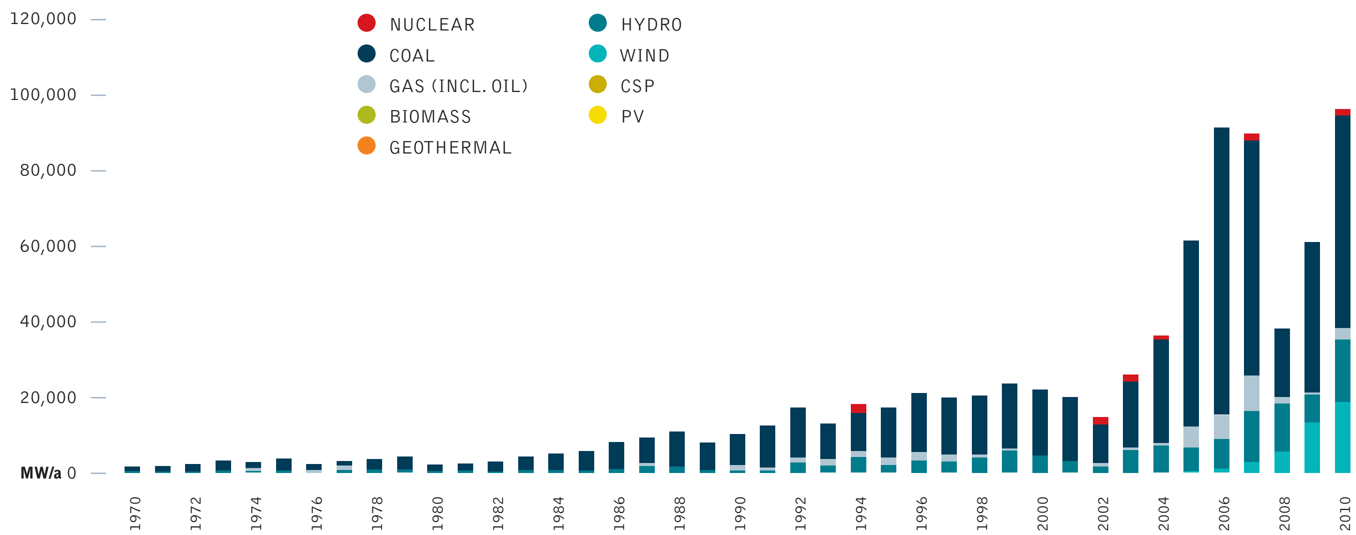


image THE MARANCHON WIND FARM IS ONE OF THE LARGEST IN EUROPE WITH 104 GENERATORS, AND IS OPERATED BY IBERDROLA.

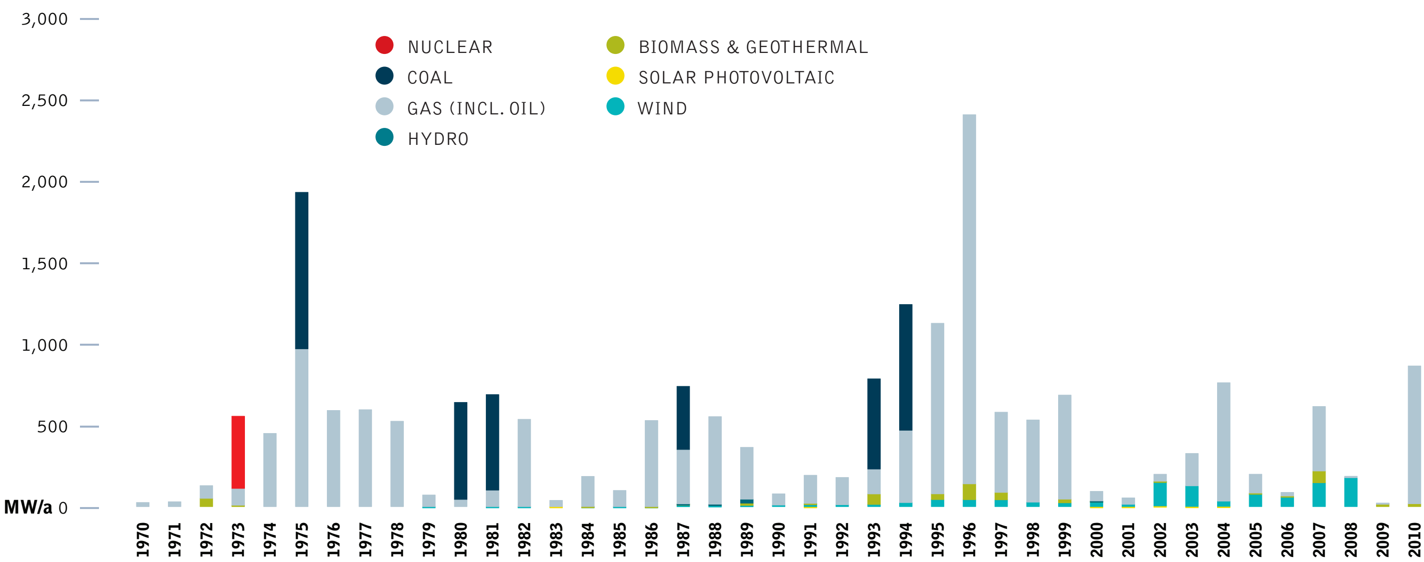
China: The steady economic growth in China since the late 1990s, and the growing power demand, led to an explosion of the coal power plant market, especially after 2002. In 2006 the market hit the peak year for new coal power plants: 88% of the newly installed coal power plants worldwide were built in China. At the same time, China is trying to take its dirtiest plants offline, between 2006 and 2010, a total of 76,825MW of small coal power plants were phased out under the "11th Five Year" programme. While coal still dominates the new added capacity, wind power is rapidly growing as well. Since 2003 the wind market doubled each year and was over 18,000 MW[46] by 2010, 49% of the global wind market. However, coal still dominates the power plant market with over 55 GW of new installed capacities in 2010 alone. The Chinese government aims to increase investments into renewable energy capacity, and during 2009, about €20.7 billion (RMB162.7 billion) went to wind and hydro power plants which represents 44% of the overall investment in new power plants, for the first time larger than that of coal (RMB 149.2billion), and in 2010 the figure was €21.5 billion (RMB168 billion) – 4.8% more in the total investment mix compared with the previous year 2009.

figure 7.9: china: power plant market 1970-2010



source
Platts, IEA, Breyer, Teske.

figure 7.10: netherlands: power plant market 1970-2010



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

energy resources and security of supply

GLOBAL

OIL

GAS

COAL

NUCLEAR

RENEWABLE ENERGY

BIOMASS IN THE 2012 ENERGY [R]EVOLUTION

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.

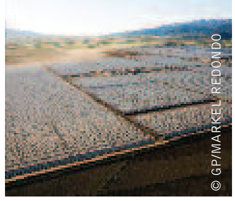


image AERIAL PHOTO OF THE ANDASOL 1 SOLAR POWER STATION, EUROPE'S FIRST COMMERCIAL PARABOLIC TROUGH SOLAR POWER PLANT. ANDASOL 1 WILL SUPPLY UP TO 200,000 PEOPLE WITH CLIMATE-FRIENDLY ELECTRICITY AND SAVE ABOUT 149,000 TONNES OF CARBON DIOXIDE PER YEAR COMPARED WITH A MODERN COAL POWER PLANT.

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.

7.1.1 the reserves chaos

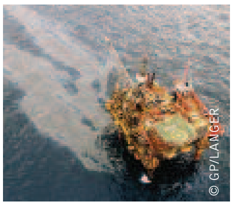
Public information about oil and gas reserves is strikingly inconsistent, and potentially unreliable for legal, commercial, historical and sometimes political reasons. The most widely available and quoted figures, those from the industry journals Oil and Gas Journal and World Oil, have limited value 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.



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[47] 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[48]

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.

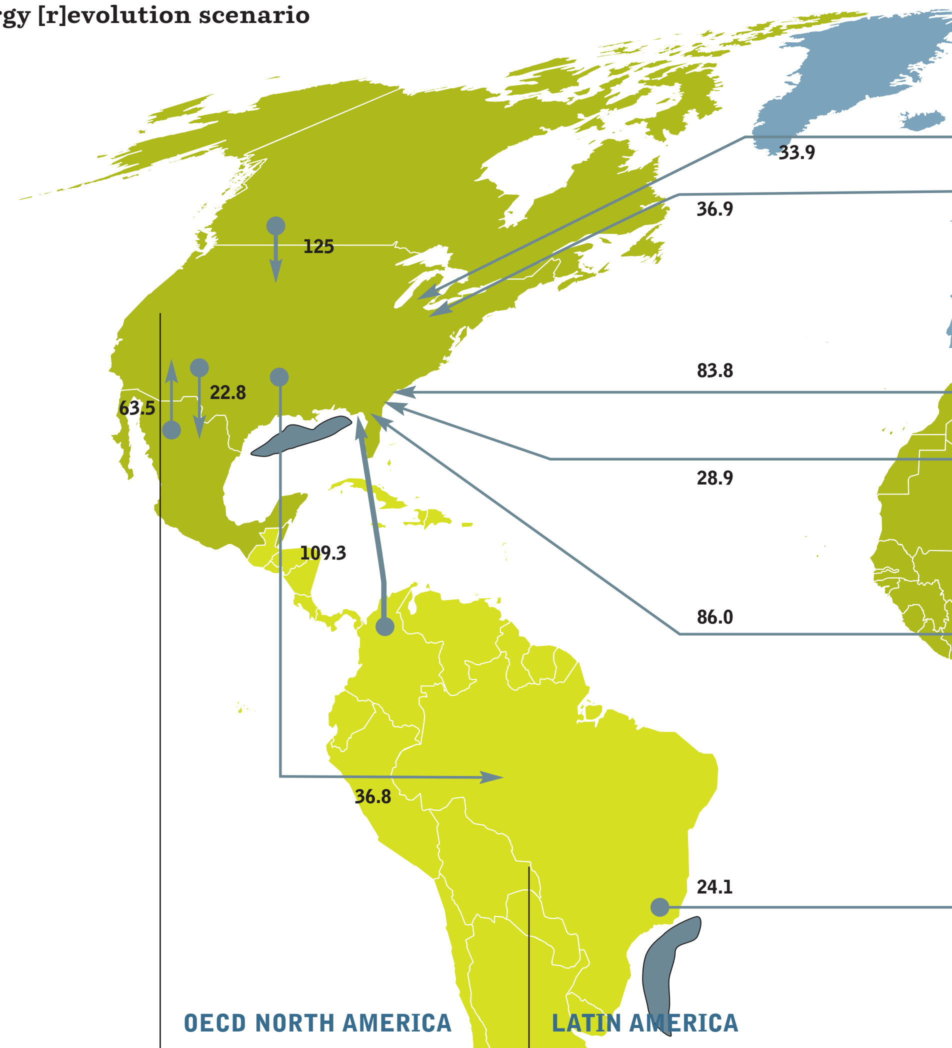
Coal is abundant and more equally distributed throughout the world than oil and gas. Global recoverable reserves are the largest of all fossil fuels, and most countries have at least some. Moreover, existing and prospective big energy consumers like the US, China and India are self-sufficient in coal 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.

references

47 THE INDEPENDENT, 10 DECEMBER 2007.
48 INTERSTATE NATURAL GAS ASSOCIATION OF AMERICA (INGAA), "AVAILABILITY, ECONOMICS AND PRODUCTION POTENTIAL OF NORTH AMERICAN UNCONVENTIONAL NATURAL GAS SUPPLIES", NOVEMBER 2008.

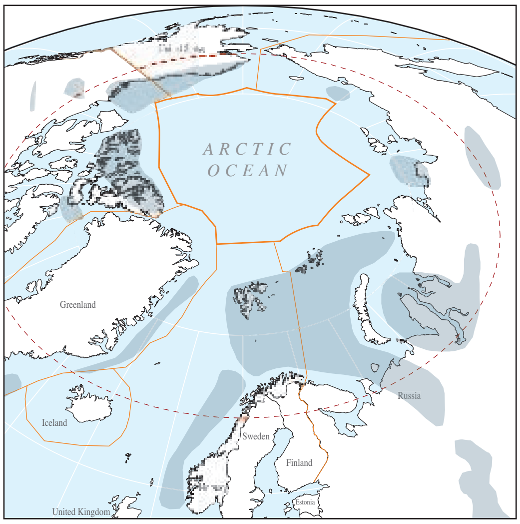
map 8.1: oil reference scenario and the energy [r]evolution scenario

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)

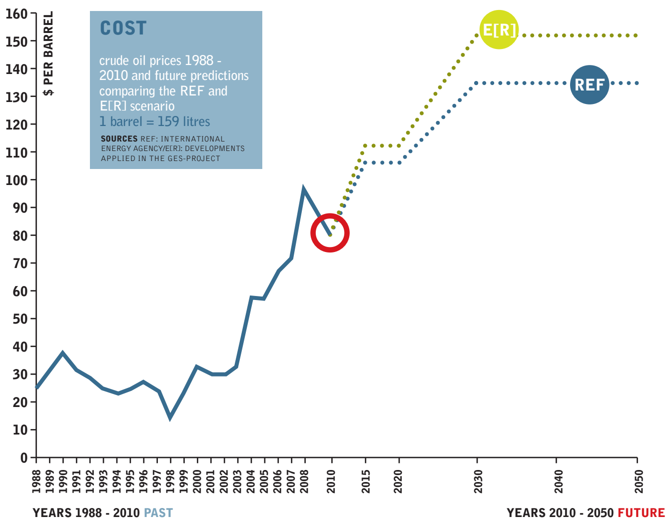
RESERVES TOTAL THOUSAND MILLION BARRELS [TMB] | SHARE IN % OF GLOBAL TOTAL [END OF 2011]

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

CONSUMPTION PER PERSON LITERS [L]

H HIGHEST | M MIDDLE | L LOWEST

0 1000 KM



8 energy resources & security of supply | OIL

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

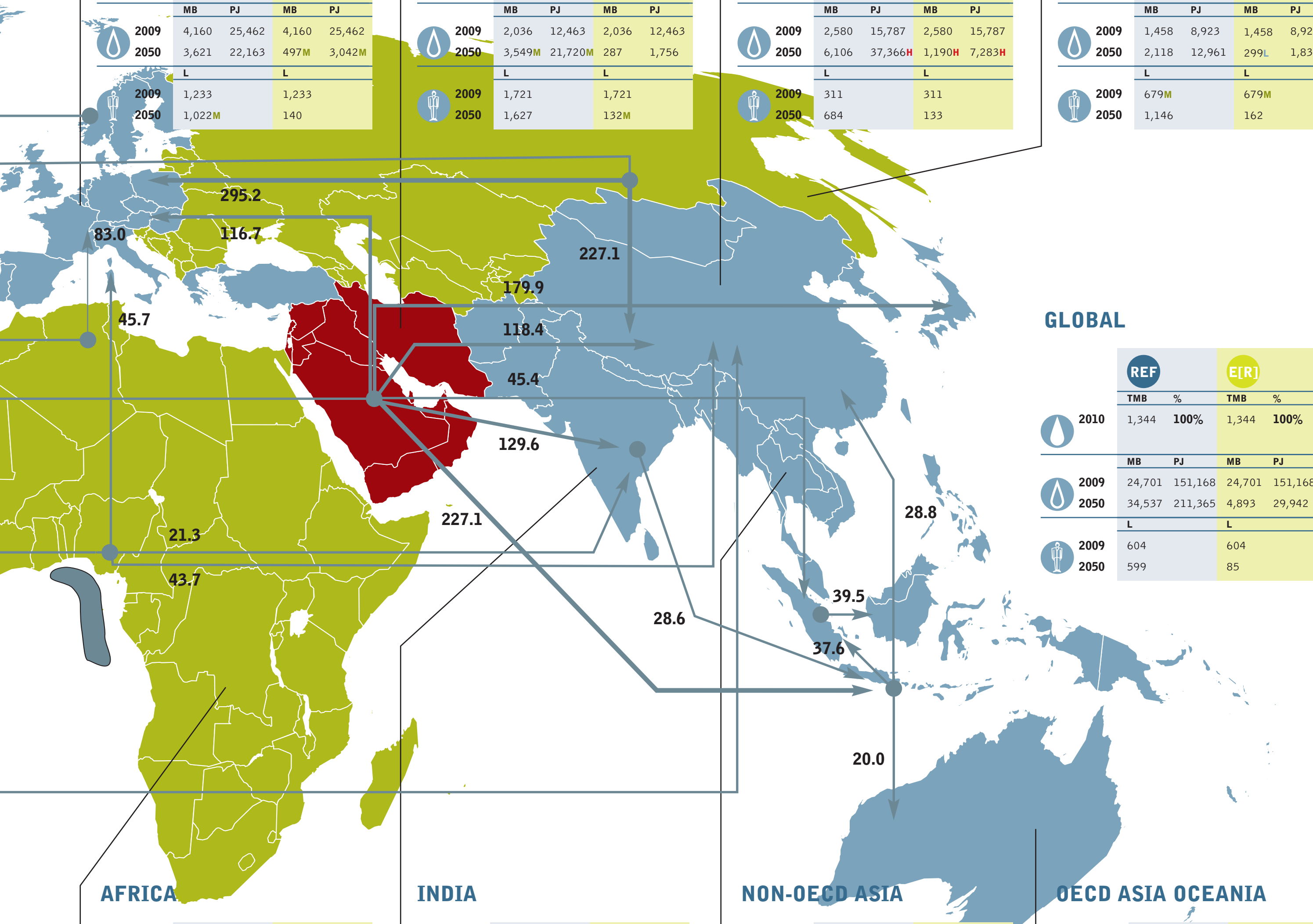
		REF		E[R]	
		TMB	%	TMB	%
	2010	752.5H	56.0%H	752.5H	56.0%H
		MB	PJ	MB	PJ
	2009	2,036	12,463	2,036	12,463
	2050	3,549M	21,720M	287	1,756
		L		L	
	2009	1,721		1,721	
	2050	1,627		132M	

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	

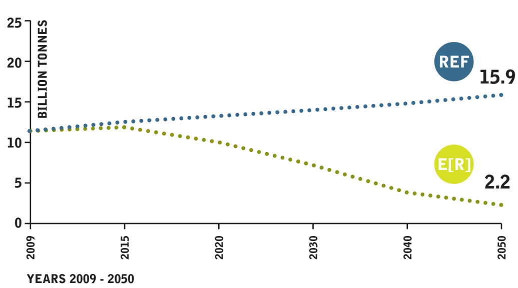
OECD ASIA OCEANIA

		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



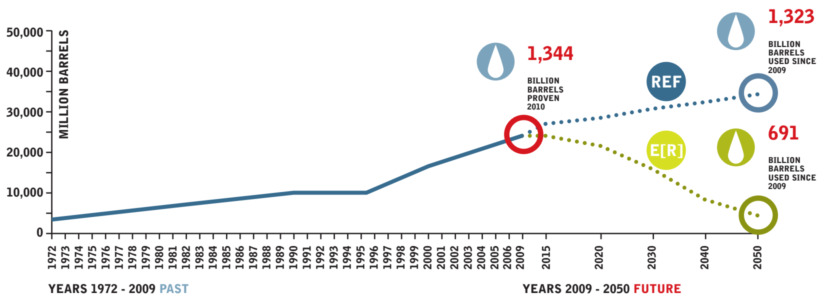
RESERVES AND CONSUMPTION

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



GREENPEACE

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 m³	%	tn m³	%
Reserves	2010	9.9	5.2%	9.9	5.2%
		bn m³	PJ	bn m³	PJ
Consumption per region	2009	731H	27,790H	731H	27,790H
	2050	890H	33,814H	67	2,559
		m³		m³	
Consumption per person	2009	1,598		1,598	
	2050	1,496		113	

LATIN AMERICA

		REF		E[R]	
		tn m³	%	tn m³	%
Reserves	2010	7.4	3.9%	7.4	3.9%
		bn m³	PJ	bn m³	PJ
Consumption per region	2009	119	4,539	119	4,539
	2050	301	11,441	62	2,373
		m³		m³	
Consumption per person	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)

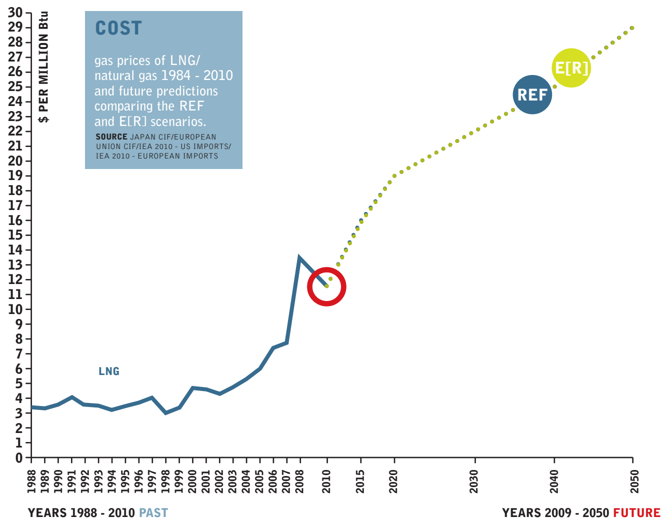
RESERVES TOTAL TRILLION CUBIC METRES [tn m³] | SHARE IN % OF GLOBAL TOTAL [END OF 2011]

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

CONSUMPTION PER PERSON CUBIC METRES [m³]

H HIGHEST | M MIDDLE | L LOWEST

0 1000 KM



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

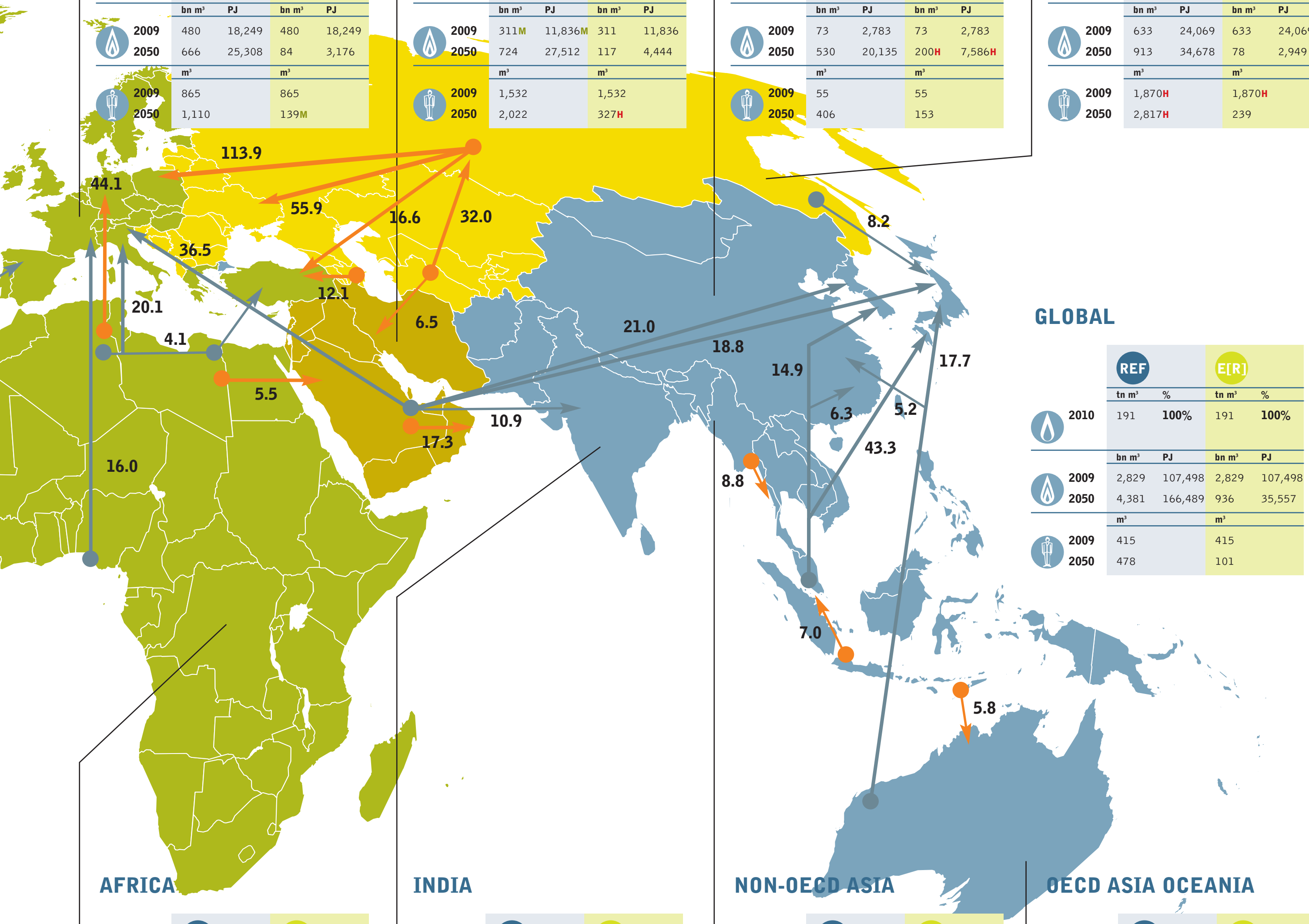
	REF		E[R]	
	tn m^3	%	tn m^3	%
2010	75.8H	39.7%H	75.8H	39.7%H
	bn m^3	PJ	bn m^3	PJ
2009	311M	11,836M	311	11,836
2050	724	27,512	117	4,444
	m^3		m^3	
2009	1,532		1,532	
2050	2,022		327H	

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

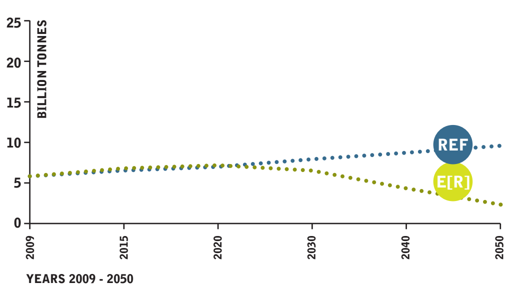
	REF		E[R]	
	tn m^3	%	tn m^3	%
2010	3.3	1.7%	3.3	1.7%
	bn m^3	PJ	bn m^3	PJ
2009	158	6,019	158	6,019
2050	211L	8,020L	61L	2,302L
	m^3		m^3	
2009	789M		789M	
2050	1,095M		314	

CO_2 EMISSIONS FROM GAS

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

billion tonnes

SOURCE GPI/EREC

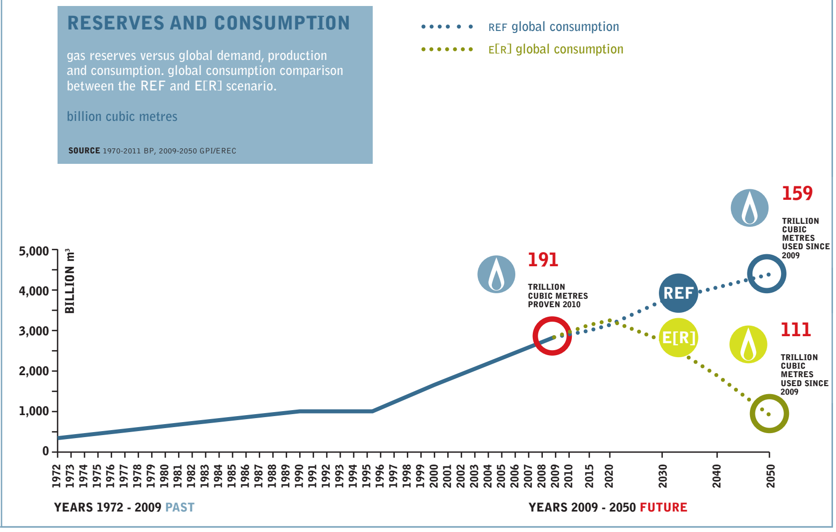


RESERVES AND CONSUMPTION

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

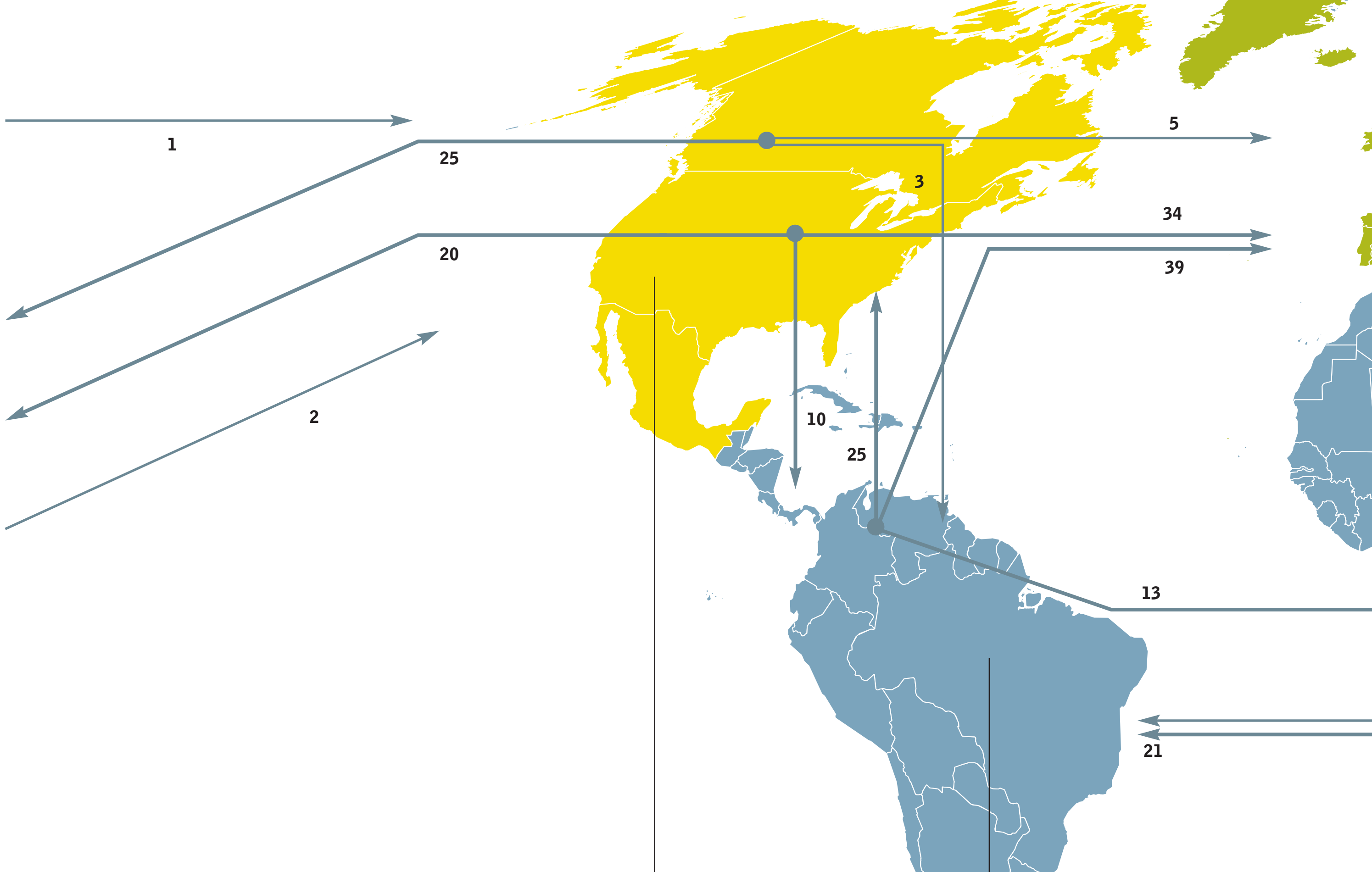
billion cubic metres

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



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

WORLDWIDE SCENARIO



NON RENEWABLE RESOURCE

COAL

OECD NORTH AMERICA

	REF mn t	REF %	E[R] mn t	E[R] %
2009	245,088	28.6% H	245,088	28.6% H

	REF mn t	REF PJ	E[R] mn t	E[R] PJ
2009	1,701	21,335	1,701	21,335
2050	1,145M	21,963	148	3,405

	REF t	E[R] t
2009	2.0	2.0
2050	1.6	0.2

LATIN AMERICA

	REF mn t	REF %	E[R] mn t	E[R] %
2009	12,508	1.5%	12,508	1.5%

	REF mn t	REF PJ	E[R] mn t	E[R] PJ
2009	37	737	37	737
2050	80	1,741	38	873

	REF t	E[R] t
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

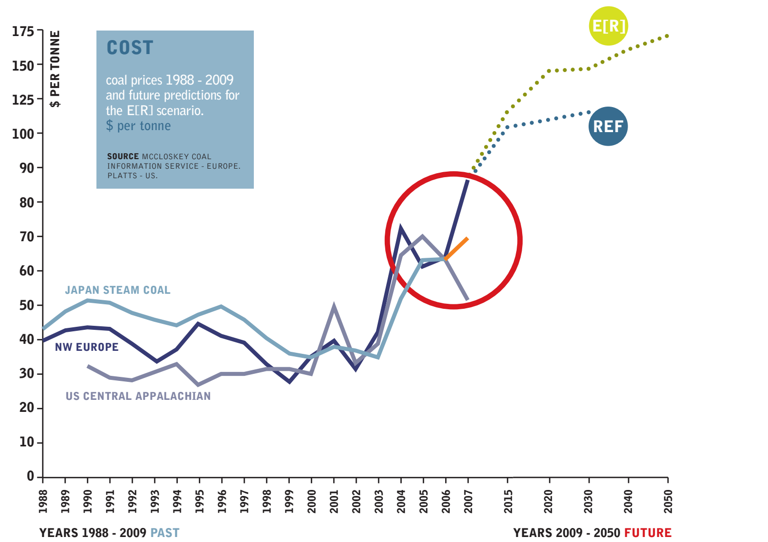
TRADE FLOWS (MILLION TONNES)

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



OECD EUROPE

	REF mn t	REF %	E[R] mn t	E[R] %
2011	80,121 M	9.4%M	80,121	9.4%M

	REF mn t	REF PJ	E[R] mn t	E[R] PJ
2009	980	13,134M	980	13,134M
2050	630	9,417	38	874

	REF t	E[R] t
2009	1.0	1.0
2050	0.7	0.1M

MIDDLE EAST

	REF mn t	REF %	E[R] mn t	E[R] %
2009	1,203L	0.1%L	1,203L	0.1%L

	REF mn t	REF PJ	E[R] mn t	E[R] PJ
2009	6L	134L	6	134
2050	5L	116L	28	637

	REF t	E[R] t
2009	0.0L	0.0
2050	0.0L	0.0L

CHINA

	REF mn t	REF %	E[R] mn t	E[R] %
2009	114,500	13.4%	114,500	13.4%

	REF mn t	REF PJ	E[R] mn t	E[R] PJ
2009	2,840H	65,408H	2,840H	65,408H
2050	4,178H	96,223H	188H	4,334H

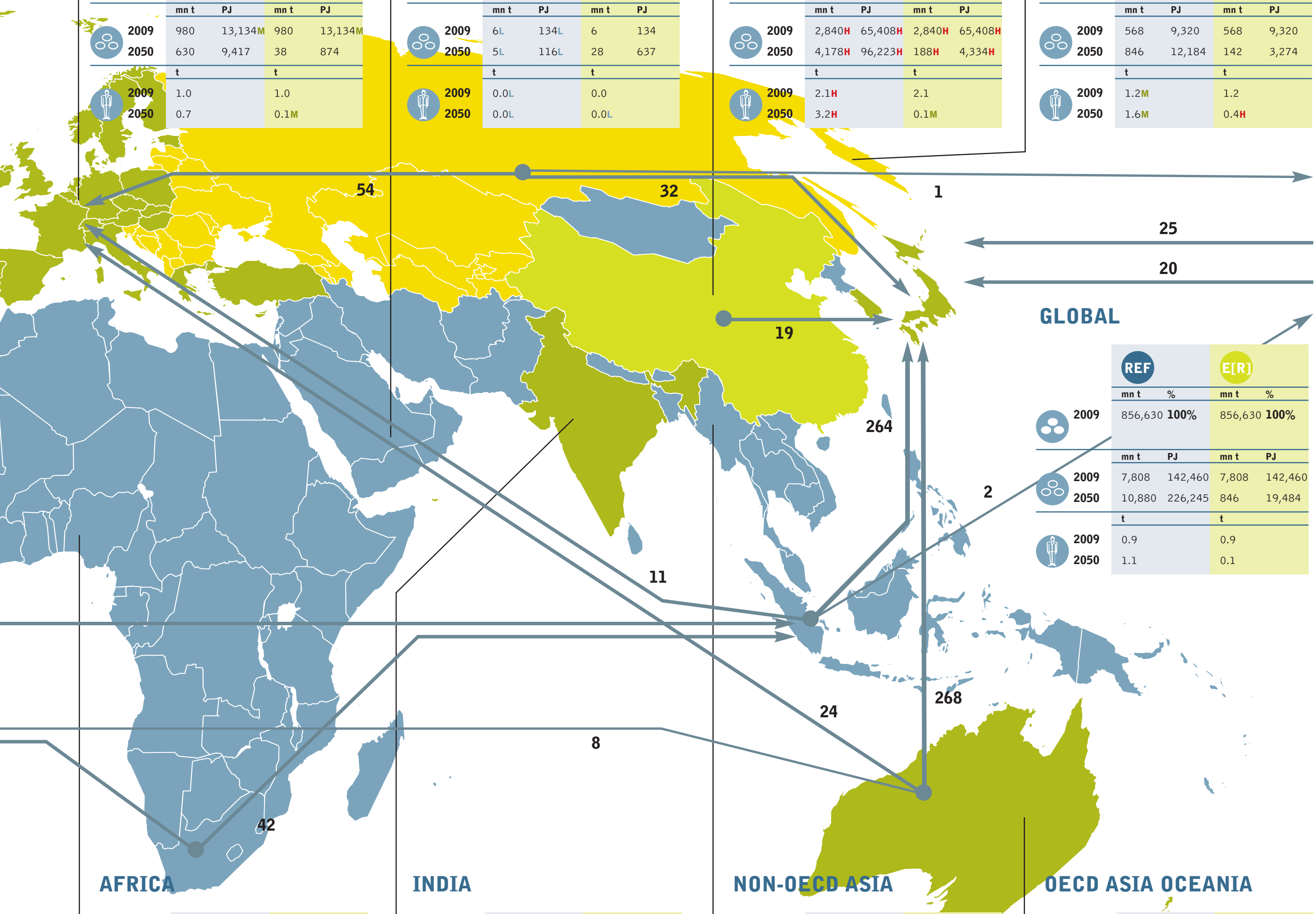
	REF t	E[R] t
2009	2.1H	2.1
2050	3.2H	0.1M

EAST EUROPE/EURASIA

	REF mn t	REF %	E[R] mn t	E[R] %
2009	224,483	26.2%	224,483	26.2%

	REF mn t	REF PJ	E[R] mn t	E[R] PJ
2009	568	9,320	568	9,320
2050	846	12,184	142	3,274

	REF t	E[R] t
2009	1.2M	1.2
2050	1.6M	0.4H



GLOBAL

	REF mn t	REF %	E[R] mn t	E[R] %
2009	856,630	100%	856,630	100%

	REF mn t	REF PJ	E[R] mn t	E[R] PJ
2009	7,808	142,460	7,808	142,460
2050	10,880	226,245	846	19,484

	REF t	E[R] t
2009	0.9	0.9
2050	1.1	0.1

AFRICA

	REF mn t	REF %	E[R] mn t	E[R] %
2009	31,692	3.7%	31,692	3.7%

	REF mn t	REF PJ	E[R] mn t	E[R] PJ
2009	192	4,414	192	4,414
2050	586	13,493	40	921

	REF t	E[R] t
2009	0.2	0.2
2050	0.3	0.0L

INDIA

	REF mn t	REF %	E[R] mn t	E[R] %
2009	60,600	7.1%M	60,600	7.1%M

	REF mn t	REF PJ	E[R] mn t	E[R] PJ
2009	593M	13,084	593M	13,084
2050	1,819	39,343	122M	2,803

	REF t	E[R] t
2009	0.5	0.5
2050	1.0M	0.1M

NON-OECD ASIA

	REF mn t	REF %	E[R] mn t	E[R] %
2009	8,988	1.0%	8,988	1.0%

	REF mn t	REF PJ	E[R] mn t	E[R] PJ
2009	374	5,658	374	5,658
2050	1,199	23,445M	76	1,754M

	REF t	E[R] t
2009	0.2	0.2
2050	0.7	0.1M

OECD ASIA OCEANIA

	REF mn t	REF %	E[R] mn t	E[R] %
2009	77,447	9%	77,447	9%

	REF mn t	REF PJ	E[R] mn t	E[R] PJ
2009	517	9,236	517	9,236
2050	392	8,319	26L	607L

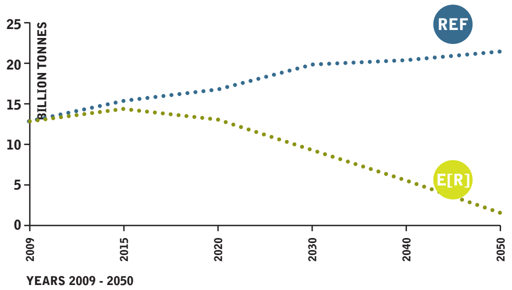
	REF t	E[R] t
2009	2.0	2.0
2050	1.9	0.1M

CO_2 EMISSIONS FROM COAL

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

billion tonnes

SOURCE GPI/EREC

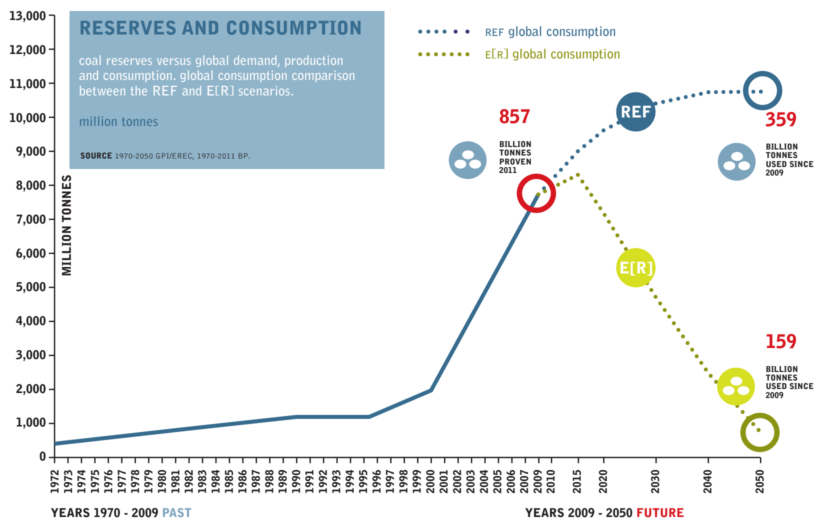


RESERVES AND CONSUMPTION

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.



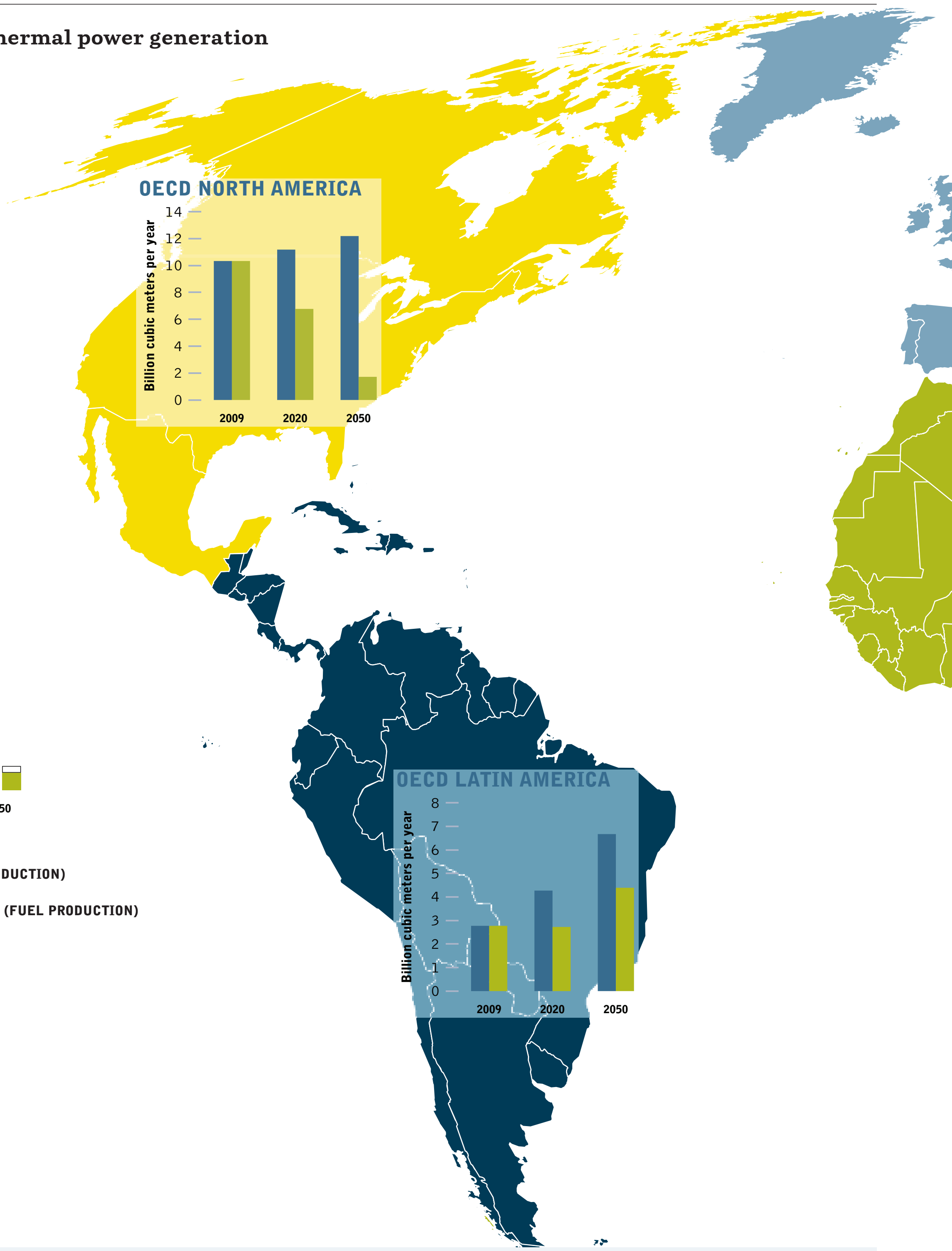
map 8.4: water demand for thermal power generation

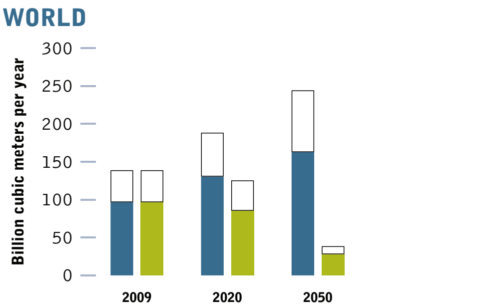
WORLDWIDE SCENARIO

LEGEND

REF REFERENCE SCENARIO

E[R] ENERGY [R]EVOLUTION SCENARIO





THERMAL POWER

REF REFERENCE SCENARIO (FUEL PRODUCTION)

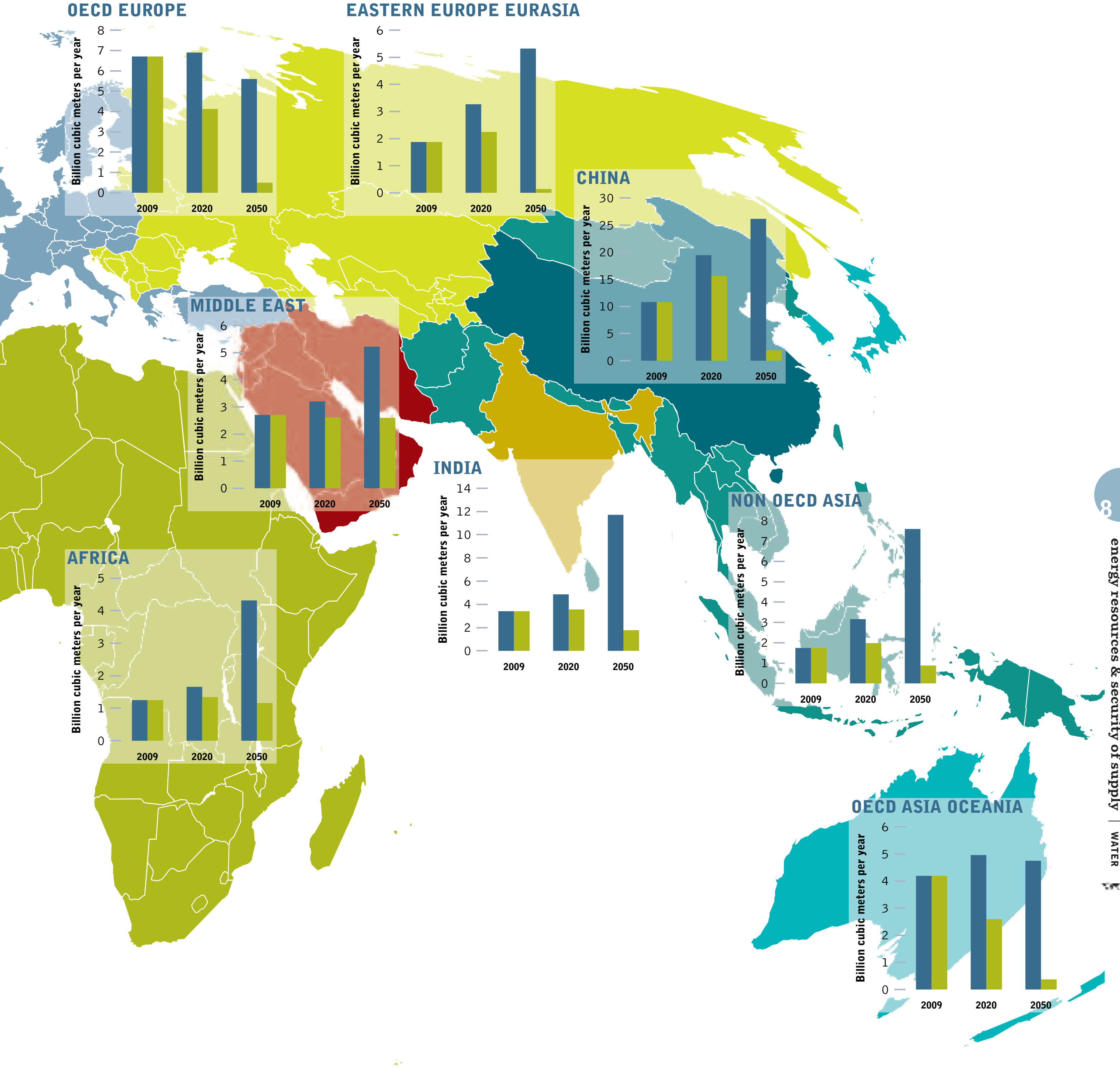
E[R] ENERGY [R]EVOLUTION SCENARIO (FUEL PRODUCTION)

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

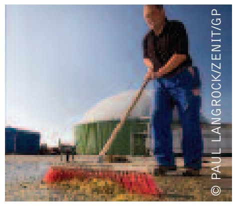
Uranium, the fuel used in nuclear power plants, is a finite resource whose economically available reserves are limited. Its distribution is almost as concentrated as oil and does not match global consumption. Five countries - Canada, Australia, Kazakhstan, Russia and Niger - control three quarters of 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[49] 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
49 '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.



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[50]

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)[51] 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	-

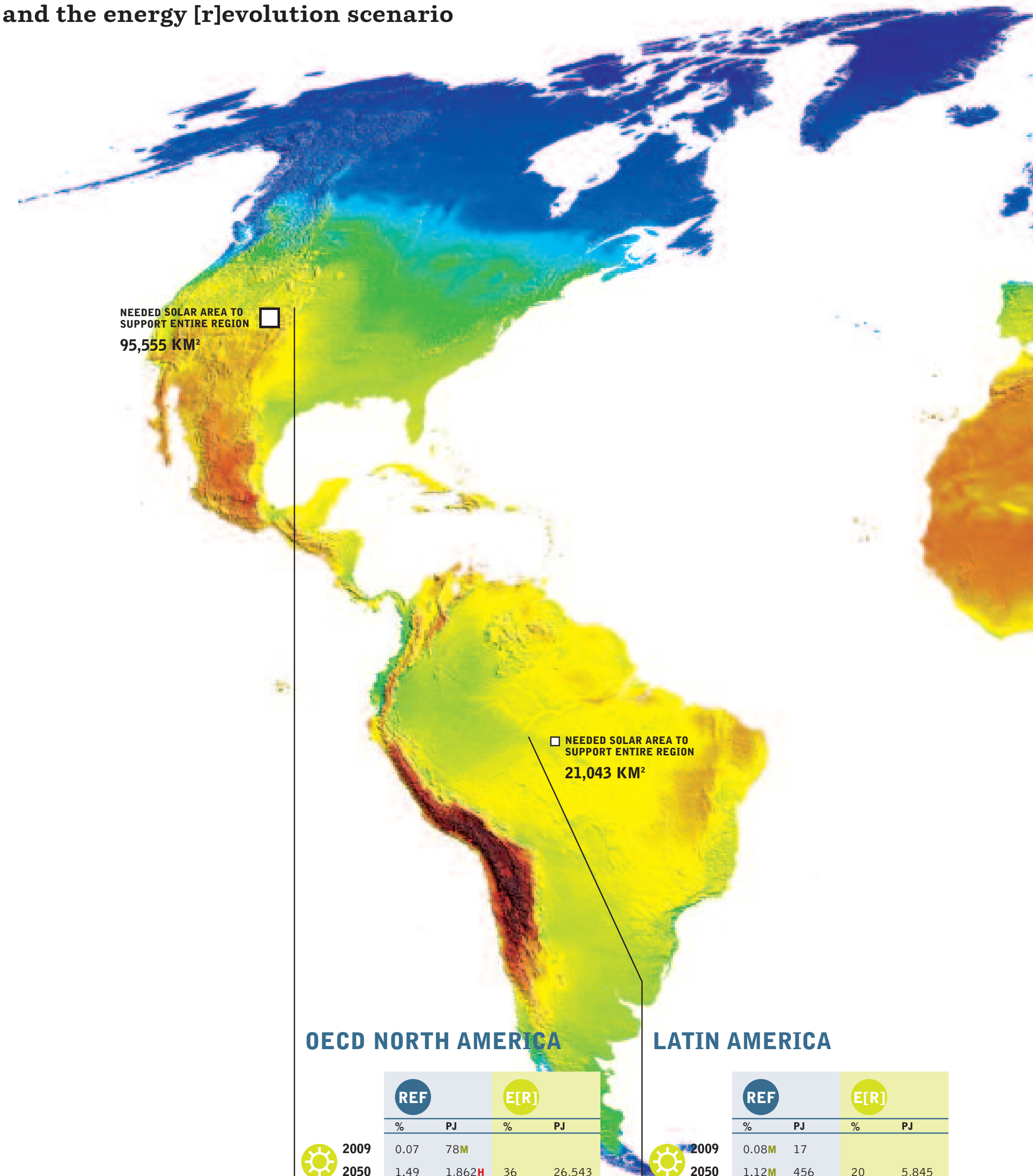
references

50 WBGU (GERMAN ADVISORY COUNCIL ON GLOBAL CHANGE).

51 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



OECD NORTH AMERICA

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

LATIN AMERICA

		REF %	REF PJ	E[R] %	E[R] PJ
Production per region	2009	0.08M	17		
	2050	1.12M	456	20	5,845
			kWh		kWh
Production per person	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 %	REF PJ	E[R] %	E[R] PJ
2009	0.15M	115		
2050	1.84H	1,495	25	11,649
		kWh		kWh
2009		59M		
2050		722		5,395M

MIDDLE EAST

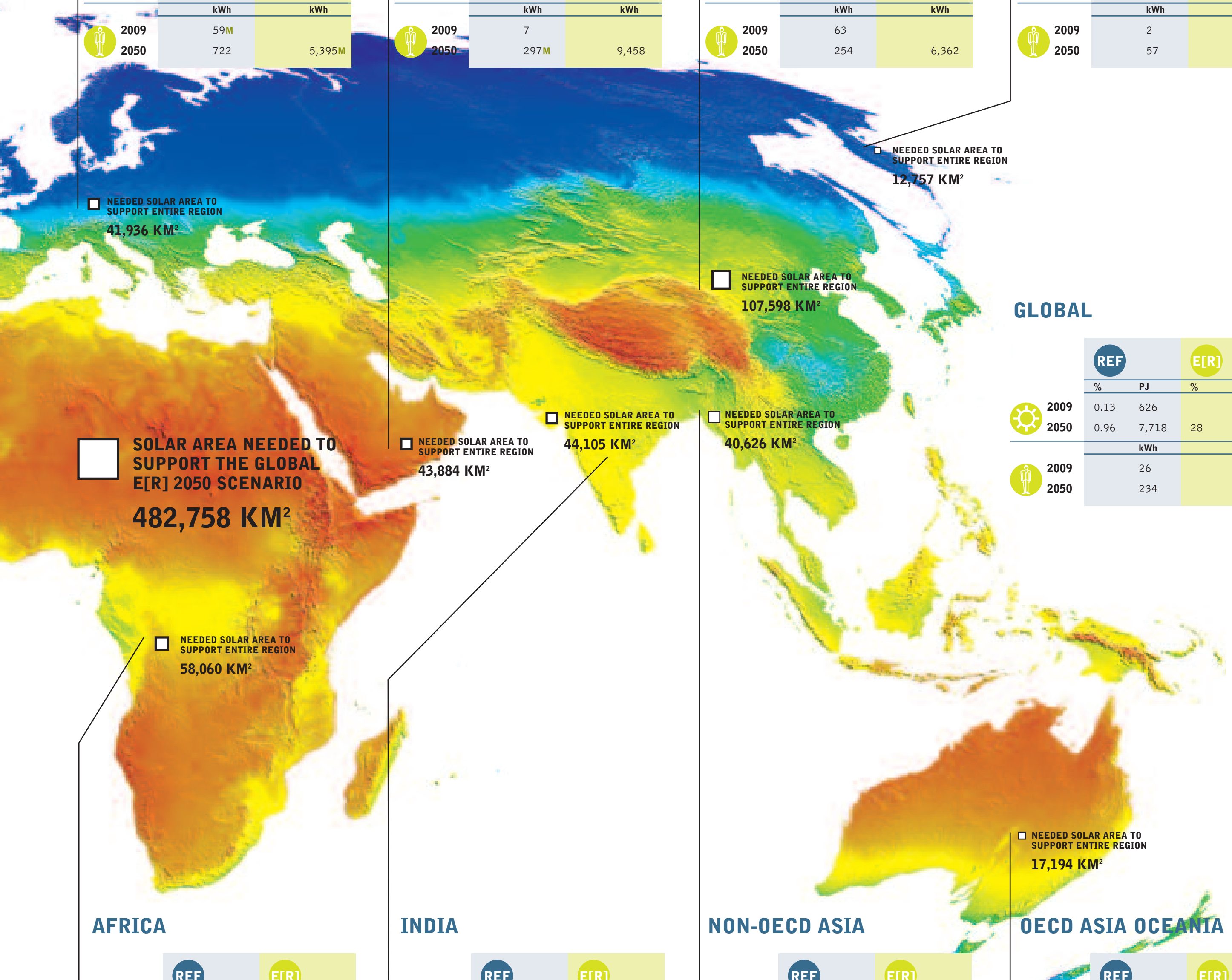
	REF %	REF PJ	E[R] %	E[R] PJ
2009	0.02	5		
2050	0.75	378	44H	12,190
		kWh		kWh
2009		7		
2050		297M		9,458

CHINA

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



GLOBAL

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

AFRICA

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

INDIA

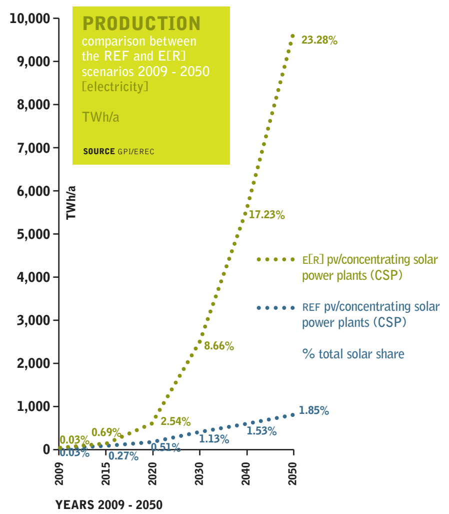
	REF %	REF PJ	E[R] %	E[R] PJ
2009	0.02	6		
2050	0.23	182	25	12,252M
		kWh		kWh
2009		1L		
2050		31L		2,011L

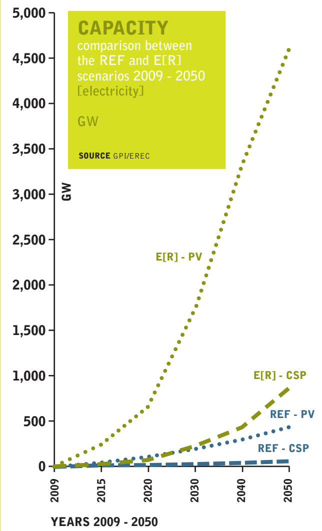
NON-OECD ASIA

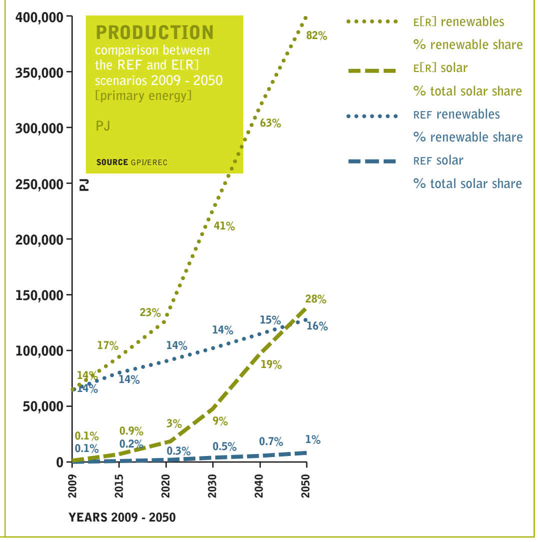
	REF %	REF PJ	E[R] %	E[R] PJ
2009	0.02	5		
2050	0.42	309	24	11,285
		kWh		kWh
2009		1L		
2050		57		2,169

OECD ASIA OCEANIA

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







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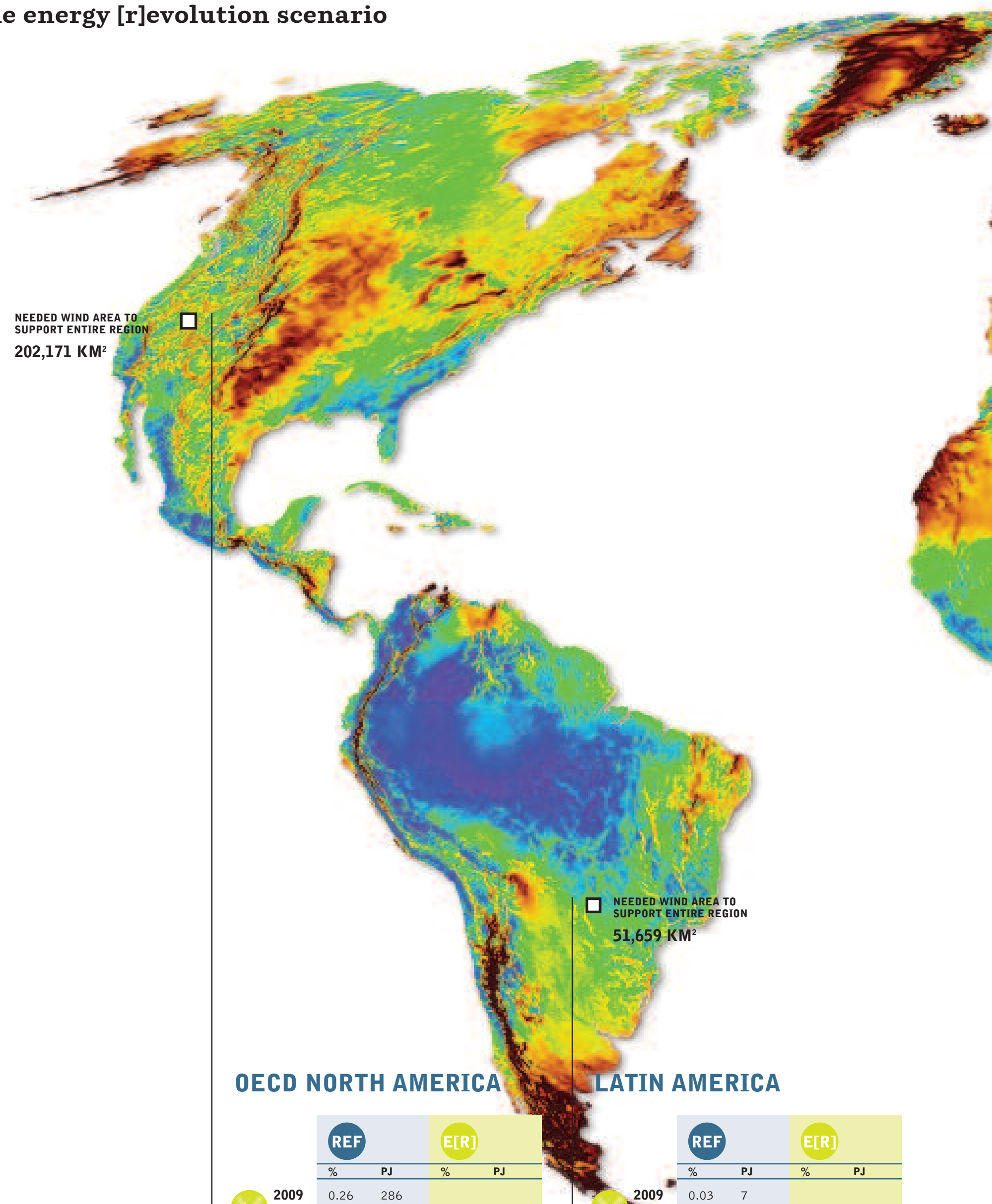
3TIER

map 8.6: wind reference scenario and the energy [r]evolution scenario

WORLDWIDE SCENARIO



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
			REF kWh		E[R] kWh
Production per person	2009		177		
	2050		1,038		4,203

LATIN AMERICA

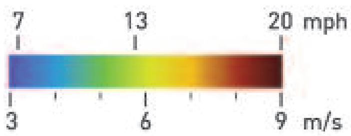
		REF %	REF PJ	E[R] %	E[R] PJ
Production per region	2009	0.03	7		
	2050	0.65	266	9	2,683
			REF kWh		E[R] kWh
Production per person	2009		4		
	2050		123		1,235

RENEWABLE RESOURCE

WIND

LEGEND

5km wind map - Mean wind speed at 80m



REF REFERENCE SCENARIO

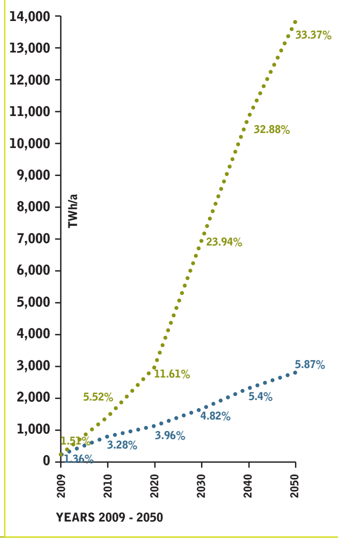
E[R] ENERGY [R]EVOLUTION SCENARIO

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

E[R] wind
REF wind
% REF total wind share

OECD EUROPE

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

MIDDLE EAST

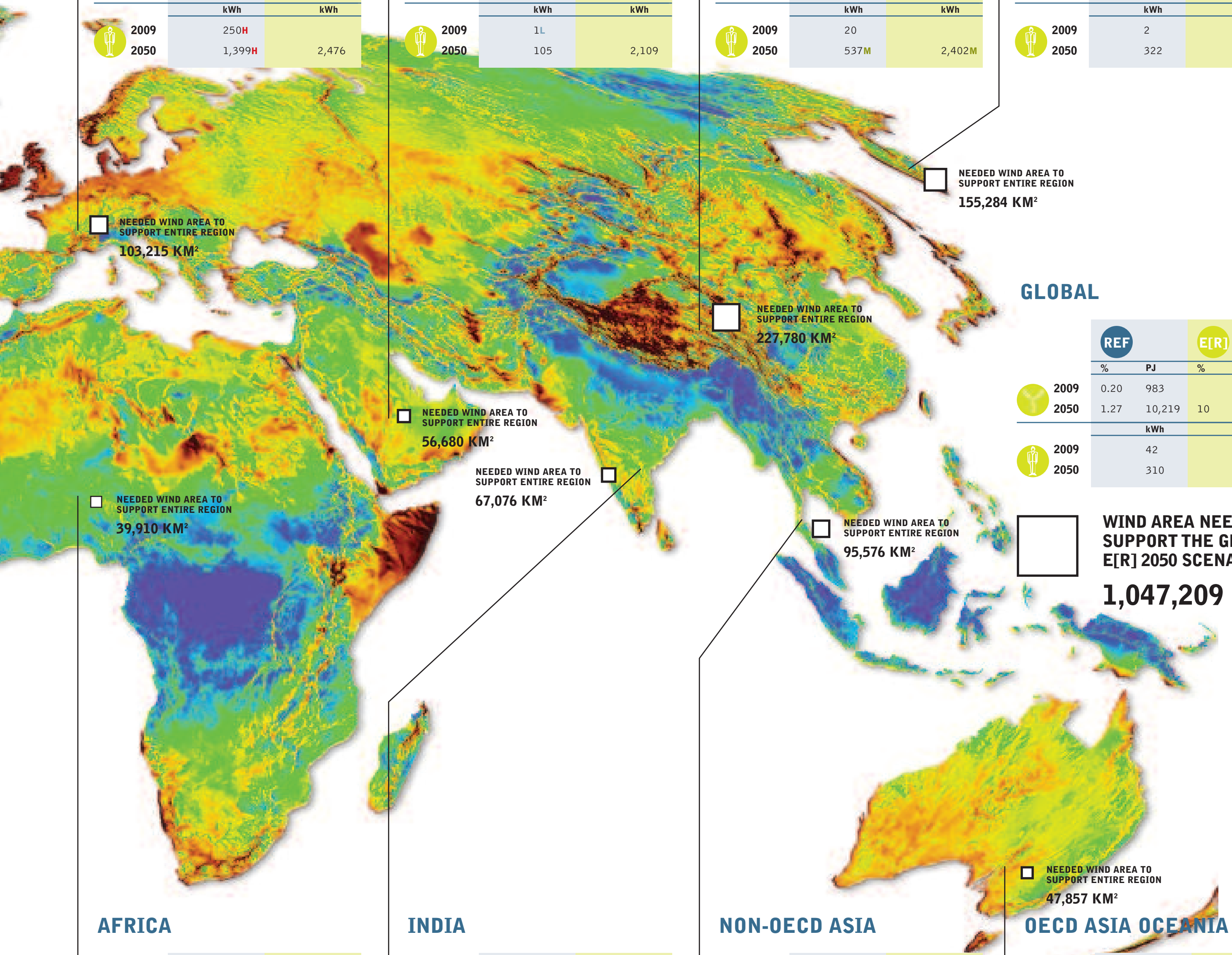
	REF %	REF PJ	E[R] %	E[R] PJ
2009	0.00L	1L		
2050	0.26L	133L	10M	2,718
		REF kWh		E[R] kWh
2009		1L		
2050		105		2,109

CHINA

	REF %	REF PJ	E[R] %	E[R] PJ
2009	0.10M	97M		
2050	1.52	2,756	11	11,284H
		REF kWh		E[R] 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
		REF kWh		E[R] kWh
2009		2		
2050		322		5,044H



GLOBAL

	REF %	REF PJ	E[R] %	E[R] PJ
2009	0.20	983		
2050	1.27	10,219	10	49,571
		REF kWh		E[R] 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
		REF kWh		E[R] kWh
2009		2		
2050		25L		280L

INDIA

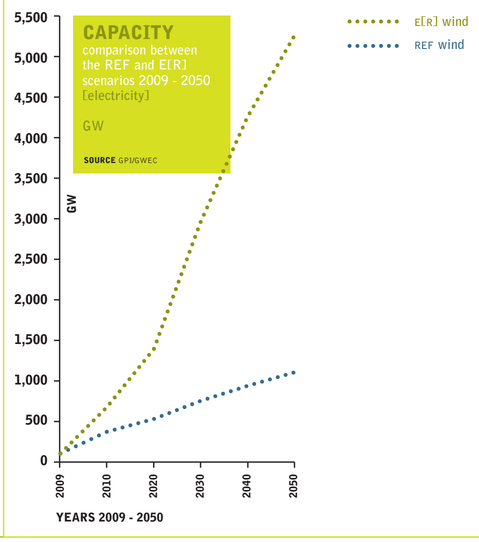
	REF %	REF PJ	E[R] %	E[R] PJ
2009	0.22	65		
2050	0.55	493	7	3,300
		REF kWh		E[R] kWh
2009		15		
2050		85		542

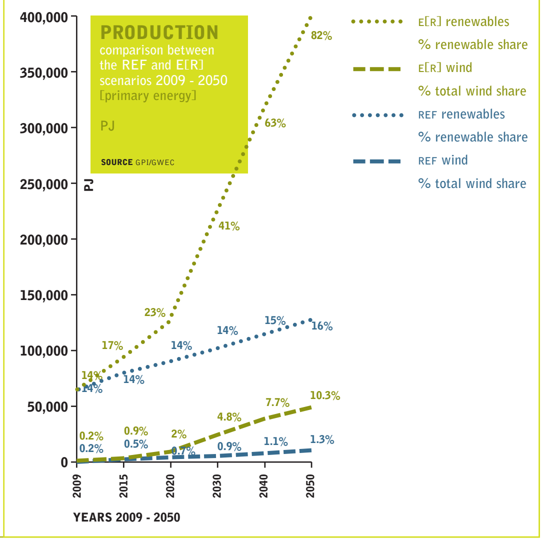
NON-OECD ASIA

	REF %	REF PJ	E[R] %	E[R] PJ
2009	0.01	3		
2050	0.79	583M	10M	4,590M
		REF kWh		E[R] 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
		REF kWh		E[R] kWh
2009		45M		
2050		612		3,686





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.

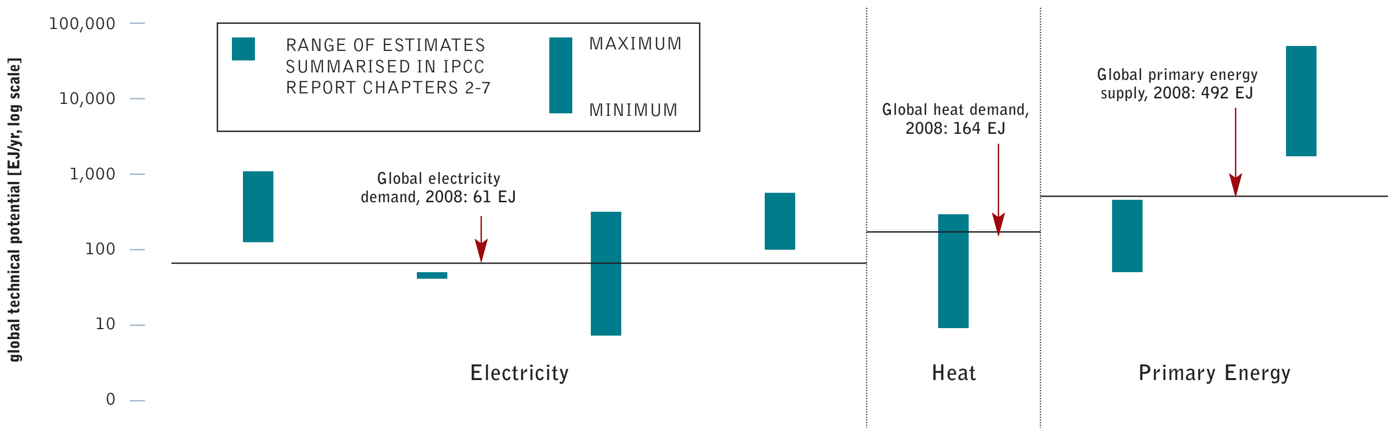
The various types of energy cannot necessarily be added together to estimate a total, because each type was estimated independently of the others (for example, the assessment did not take into account land use allocation; e.g. PV and concentrating solar power cannot occupy the same space even though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

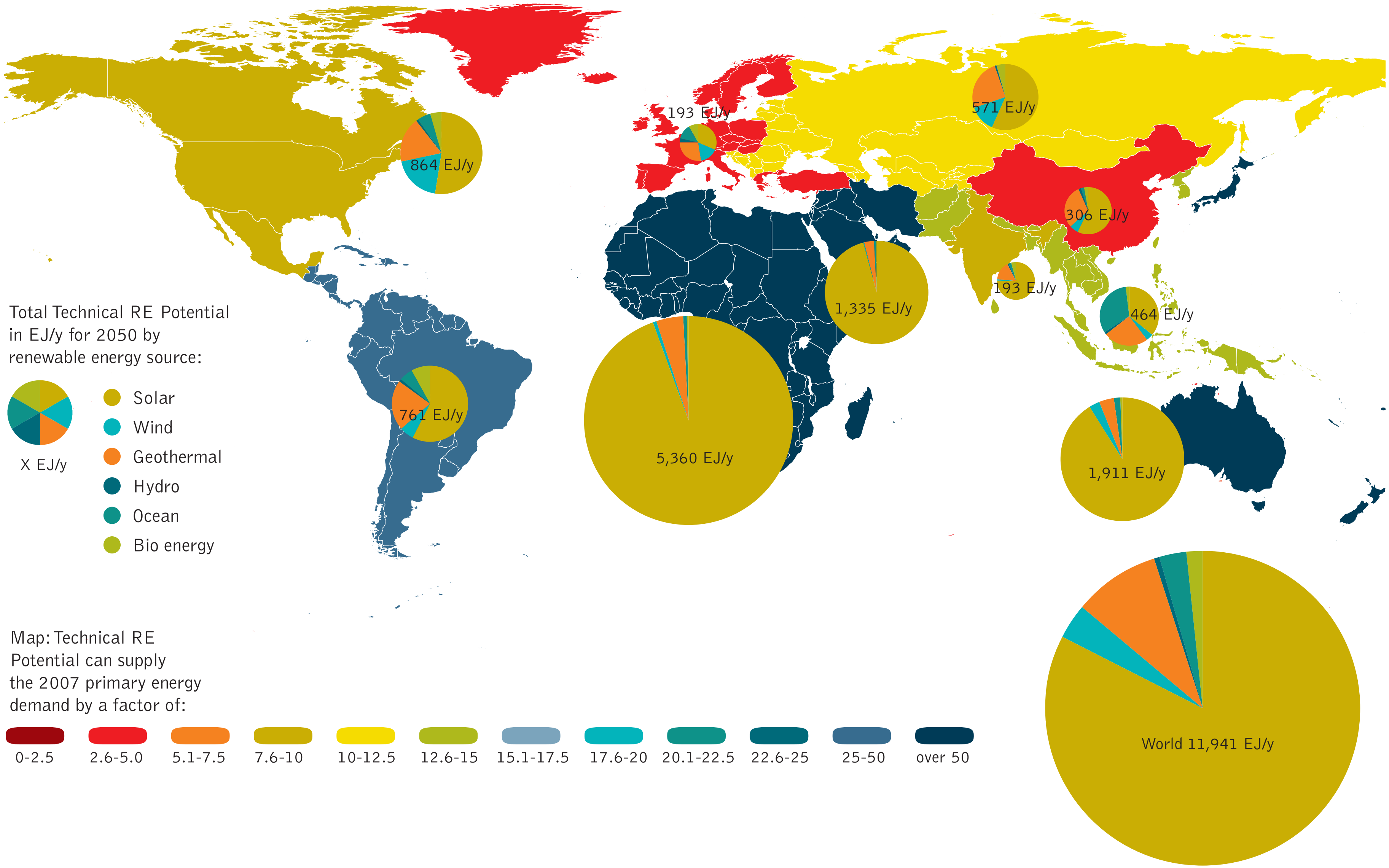
figure 8.1: ranges of global technical potentials of renewable energy sources



	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 and the energy [r]evolution

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.[52] 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).

reference

52 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.

8.6.1 how much biomass

Roughly 55 EJ/a of bioenergy was used globally in 2011[53] (approximately 10% of the world's energy[54]). 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.[55] 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[56], 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 tonnes of coal. It takes 60 million tonnes of dry biomass to generate one exajoule.
- Global energy use in 2009 was approximately 500 EJ

references

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

54 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.

55 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.

56 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).[57] 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.[58]
- 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.[59]
- 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.

references
57 WWF 2011. WWF ENERGY REPORT 2011. PRODUCED IN COLLABORATION WITH ECOFYS AND OMA. HTTP://WWF.PANDA.ORG/WHAT_WE_DO/FOOTPRINT/CLIMATE_CARBON_ENERGY/ENERGY_SOLUTIONS/RENEWABLE_ENERGY/SUSTAINABLE_ENERGY_REPORT/. SOURCES FOR BIOENERGY ARE ON PGS. 183-18.
58 BERINGER, T. ET AL. 2011. BIOENERGY PRODUCTION POTENTIAL OF GLOBAL BIOMASS PLANTATIONS UNDER ENVIRONMENTAL AND AGRICULTURAL CONSTRAINTS. GCB BIOENERGY, 3:299–312. DOI:10.1111/J.1757-1707.2010.01088.X
59 WBGU 2009. FUTURE BIOENERGY AND SUSTAINABLE LAND USE. EARTHSCAN, LONDON AND STERLING, VA

glossary & appendix

GLOSSARY OF COMMONLY USED TERMS AND ABBREVIATIONS

DEFINITION OF SECTORS

EU 27: SCENARIO RESULTS DATA

"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.

9.1 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 8.1: 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 9.2: 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

9.2 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.

the netherlands: scenario results data

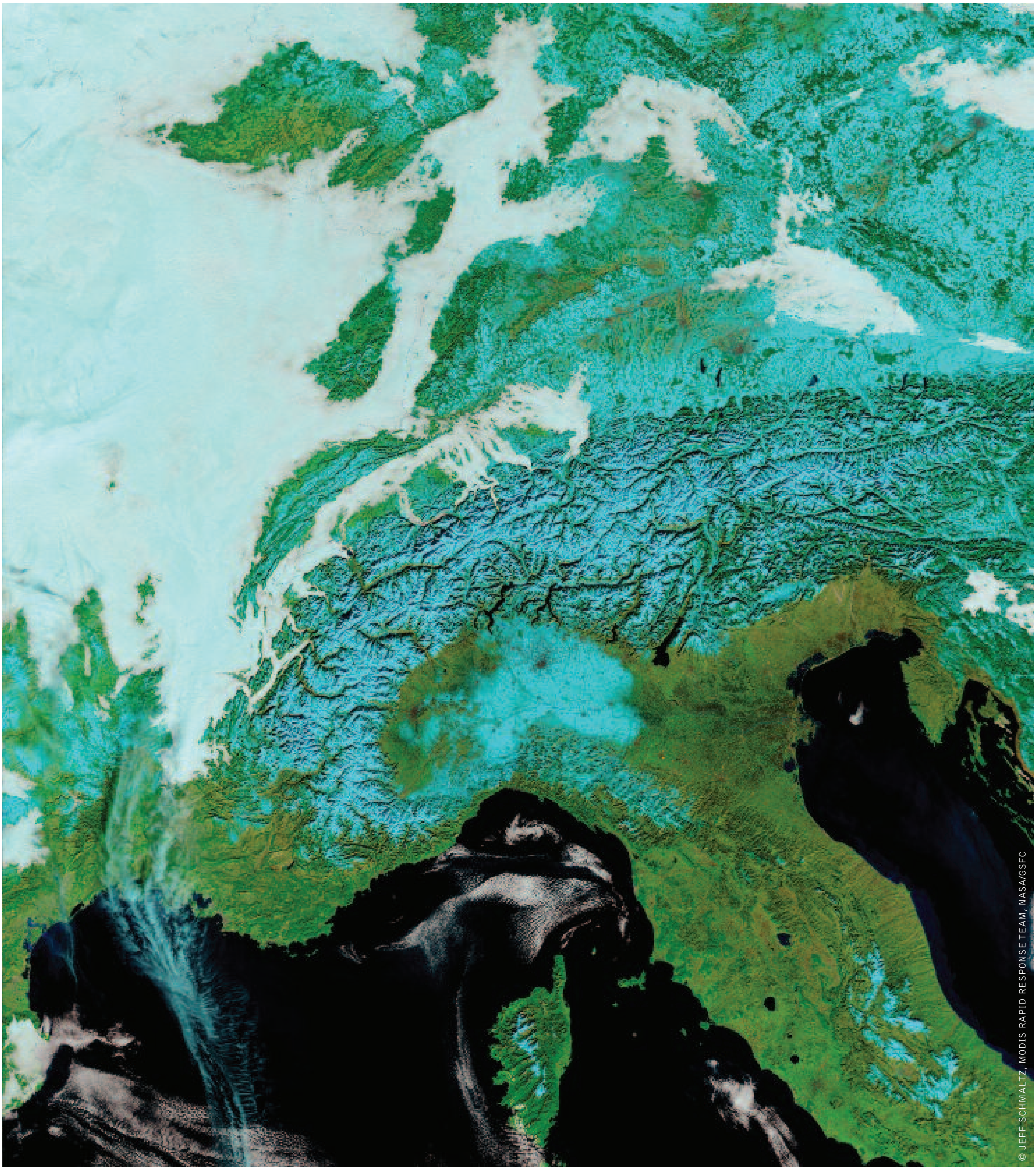


image CAPPED WITH SILVERY WHITE SNOW, THE ALPS ARC GRACEFULLY ACROSS NORTHERN ITALY, SWITZERLAND, AUSTRIA, AND SOUTHERN GERMANY AND FRANCE, 2006.

netherlands: reference scenario

table 9.3: netherlands: electricity generation

TWh/a	2010	2015	2020	2030	2040	2050
Power plants	**54**	**64**	**67**	**67**	**65**	**62**
Coal & non-renewable waste	14	19	18	16	15	11
Lignite	0	0	0	0	0	0
Gas	29	30	25	19	18	16
of which from H_2	0	0	0	0	0	0
Oil	0	0	0	0	0	0
Diesel	0	0	0	0	0	0
Nuclear	4.0	4.0	4.0	4.0	0	0
Biomass & renewable waste	3.0	3.0	3.0	3.0	3.0	3.0
Hydro	0.1	0.1	0.1	0.1	0.1	0.1
Wind	4.0	8.1	16	22	26	30
of which wind offshore	0.8	1.9	7.5	11	13	15
PV	0.1	0.6	1.3	1.7	2.1	2.4
Geothermal	0	0	0	0	0	0
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Combined heat & power plants	**64**	**62**	**62**	**64**	**67**	**69**
Coal & non-renewable waste	11	10	9.4	8.2	7.9	7.7
Lignite	0	0	0	0	0	0
Gas	49	45	43	45	47	49
of which from H_2	0	0	0	0	0	0
Oil	1.3	1.2	1.0	0.8	0.7	0.6
Biomass	4.1	5.8	7.8	9.4	10	11
Geothermal	0	0.1	0.4	0.8	1.0	1.1
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	44	41	40	41	42	44
Autoproducers	21	21	22	23	24	26
Total generation	**118**	**126**	**129**	**131**	**131**	**131**
Fossil	103	105	96	89	88	83
Coal & non-renewable waste	24	29	27	24	23	18
Lignite	0	0	0	0	0	0
Gas	77	75	68	64	65	64
Oil	1.3	1.2	1.1	1.0	0.7	0.6
Diesel	0	0	0	0	0	0
Nuclear	4.0	4.0	4.0	4.0	0	0
Hydrogen	0	0	0	0	0	0
Renewables	**11**	**18**	**29**	**38**	**43**	**48**
Hydro	0	0	0	0	0	0
Wind	4.0	8.1	16	22	26	30
PV	0.1	0.6	1.3	1.7	2.1	2.4
Biomass & renewable waste	7.0	8.8	11	12	13	14
Geothermal	0	0.1	0.4	0.9	1.1	1.3
Solar thermal	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Distribution losses	4	4	4	4	4	4
Own consumption electricity	10	10	10	10	10	10
Electricity for hydrogen production	0	0	0	0	0	1
Final energy consumption (electricity)	**107**	**109**	**112**	**114**	**115**	**115**
Fluctuating RES (PV, Wind, Ocean)	4	9	18	24	28	32
Share of fluctuating RES	3.4%	6.9%	13.6%	18.4%	21.6%	24.6%
RES share (domestic generation)	**9.5%**	**14.0%**	**22.4%**	**28.7%**	**32.7%**	**36.4%**

table 9.4: netherlands: heat supply

PJ/a	2010	2015	2020	2030	2040	2050
District heating	**1**	**2**	**2**	**3**	**3**	**3**
Fossil fuels	1	1	1	1	1	1
Biomass	0	0	0	1	1	1
Solar collectors	0	0	0	0	0	0
Geothermal	0	0	0	1	1	1
Heat from CHP	**134**	**135**	**136**	**158**	**170**	**184**
Fossil fuels	126	124	118	123	129	137
Biomass	7	11	15	28	32	37
Geothermal	0	1	3	7	9	10
Hydrogen	0	0	0	0	0	0
Direct heating	**1,056**	**1,064**	**1,056**	**1,029**	**999**	**947**
Fossil fuels	1,016	1,016	992	922	886	830
Biomass	18	23	27	68	72	75
Solar collectors	1	1	2	2	2	3
Geothermal[1]	0	3	14	15	17	19
Electricity[2]	21	21	21	21	21	20
Hydrogen	0	0	0	0	0	0
Total heat supply	**1,190**	**1,201**	**1,193**	**1,190**	**1,172**	**1,134**
Fossil fuels	1,143	1,141	1,111	1,046	1,017	968
Biomass	25	34	42	97	105	113
Solar collectors	1	1	2	2	2	3
Geothermal[1]	0	4	18	23	27	30
Electricity[2]	21	21	21	21	21	20
Hydrogen	0	0	0	0	0	0
RES share (including RES electricity)	**2.4%**	**3.5%**	**5.5%**	**10.8%**	**12.1%**	**13.5%**

1) including heat pumps; 2) direct electric heating

table 9.5: netherlands: CO_2 emissions

MILL t/a	2010	2015	2020	2030	2040	2050
Condensation power plants	**23**	**27**	**23**	**19**	**17**	**13**
Coal	11	15	14	13	11	8
Lignite	0	0	0	0	0	0
Gas	12	12	9	7	6	5
Oil	0	0	0	0	0	0
Diesel	0	0	0	0	0	0
Combined heat & power production	**32**	**29**	**27**	**25**	**25**	**25**
Coal	10	9	8	7	7	6
Lignite	0	0	0	0	0	0
Gas	21	19	18	18	18	18
Oil	1	1	1	1	1	1
CO_2 emissions power generation (incl. CHP public)	**55**	**56**	**50**	**45**	**43**	**38**
Coal	21	24	22	19	18	14
Lignite	0	0	0	0	0	0
Gas	33	31	27	24	24	23
Oil & diesel	1	1	1	1	1	1
CO_2 emissions by sector	**172**	**170**	**160**	**147**	**139**	**127**
% of 1990 emissions	115%	113%	106%	98%	92%	85%
Industry[1]	29	29	28	26	25	25
Other sectors[1]	42	41	40	37	35	32
Transport	34	33	32	31	29	26
Power generation[2]	48	49	43	38	36	31
Other conversion[3]	18	17	16	15	14	13
Population (Mill.)	16.6	16.8	17.0	17.3	17.3	17.2
CO_2 emissions per capita (t/capita)	**10.4**	**10.1**	**9.4**	**8.5**	**8.0**	**7.4**

1) including CHP autoproducers. 2) including CHP public. 3) district heating, refineries, coal transformation, gas transport.

table 9.6: netherlands: installed capacity

GW	2010	2015	2020	2030	2040	2050
Power plants	**13**	**21**	**23**	**23**	**23**	**22**
Coal & non-renewable waste	2.3	5.5	5.1	4.4	4.2	3.1
Lignite	0	0	0	0	0	0
Gas (incl. H_2)	7.3	10.6	8.9	7.2	6.8	5.8
Oil	0	0	0	0	0	0
Diesel	0	0	0	0	0	0
Nuclear	0.5	0.5	0.5	0.5	0	0
Biomass	0.5	0.5	0.5	0.5	0.5	0.5
Hydro	0	0	0	0	0	0
Wind	2.2	3.4	6.0	7.8	8.8	9.6
of which wind offshore	0.2	0.5	2.0	2.9	3.4	3.8
PV	0.1	0.8	1.6	2.2	2.6	3.0
Geothermal	0	0	0	0	0	0
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Combined heat & power production	**12.8**	**12.2**	**11.9**	**12.7**	**13.4**	**14.2**
Coal & non-renewable waste	1.8	1.8	1.8	1.7	1.7	1.7
Lignite	0	0	0	0	0	0
Gas (incl. H_2)	10.1	9.0	8.0	8.5	9.1	9.6
Oil	0.3	0.2	0.2	0.2	0.1	0.1
Biomass	0.7	1.2	1.8	2.2	2.4	2.6
Geothermal	0	0	0	0	0	0
Hydrogen (fuel cells)	0	0	0	0	0	0
CHP by producer						
Main activity producers	8.7	8.0	7.7	8.2	8.6	9.0
Autoproducers	4.2	4.2	4.2	4.5	4.9	5.2
Total generation	**26**	**34**	**35**	**35**	**36**	**36**
Fossil	22	27	24	22	22	20
Coal & non-renewable waste	4.1	7.3	6.9	6.1	5.9	4.8
Lignite	0	0	0	0	0	0
Gas (w/o H_2)	17	20	17	16	16	15
Oil	0.3	0.3	0.2	0.2	0.1	0.1
Diesel	0	0	0	0	0	0
Nuclear	0.5	0.5	0.5	0.5	0	0
Hydrogen (fuel cells, gas power plants, gas CHP)	0	0	0	0	0	0
Renewables	**3.6**	**6.0**	**10**	**13**	**15**	**16**
Hydro	0	0	0	0	0	0
Wind	2.2	3.4	6.0	7.8	8.8	9.6
PV	0.1	0.8	1.6	2.2	2.6	3.0
Biomass & renewable waste	1.2	1.7	2.3	2.7	2.9	3.1
Geothermal	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Fluctuating RES (PV, Wind, Ocean)	2.3	4.2	7.6	10	11	13
Share of fluctuating RES	8.9%	12.6%	22.0%	28.1%	31.2%	34.5%
RES share (domestic generation)	**13.8%**	**17.8%**	**29.1%**	**36.3%**	**39.8%**	**43.8%**

table 9.7: netherlands: primary energy demand

PJ/a	2010	2015	2020	2030	2040	2050
Total	**3,490**	**3,506**	**3,446**	**3,335**	**3,224**	**3,111**
Fossil	**3,309**	**3,251**	**3,097**	**2,901**	**2,782**	**2,621**
Hard coal	346	381	363	324	302	260
Lignite	0.6	0.4	0.2	0	0	0
Natural gas	1,644	1,592	1,507	1,410	1,375	1,314
Crude oil	1,318	1,277	1,227	1,167	1,104	1,046
Nuclear	**42**	**42**	**42**	**42**	**0**	**0**
Renewables	**138**	**213**	**307**	**391**	**442**	**490**
Hydro	0.4	0.4	0.4	0.4	0.4	0.4
Wind	14	29	59	81	95	107
Solar	1.2	3.6	6.1	8.2	10	12
Biomass	122	176	223	273	301	331
Geothermal/ambient heat	0.3	3.9	18	30	36	39
Ocean energy	0	0	0	0	0	0
RES share	**3.9%**	**5.9%**	**8.6%**	**11.5%**	**13.5%**	**15.5%**

table 9.8: netherlands: final energy demand

PJ/a	2010	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**2,712**	**2,716**	**2,706**	**2,685**	**2,650**	**2,591**
Total (energy use)	**2,064**	**2,068**	**2,058**	**2,037**	**2,002**	**1,943**
Transport	**483**	**481**	**478**	**473**	**467**	**460**
Oil products	466	451	432	419	387	354
Natural gas	0.5	1	1	2	2	3
Biofuels	10	23	37	37	54	72
Electricity	6	6	8	14	23	28
RES electricity	1	1	2	4	8	10
Hydrogen	0	0	0	0	1	3
RES share Transport	**2.1%**	**5.0%**	**8.1%**	**8.8%**	**13.2%**	**18.1%**
Industry	**549**	**560**	**560**	**560**	**552**	**541**
Electricity	141	145	147	151	150	147
RES electricity	13	20	33	43	49	54
District heat	51	51	51	59	60	63
RES district heat	2	3	6	13	15	17
Coal	3	2	1	0	0	0
Oil products	116	110	99	79	70	63
Gas	235	245	253	238	236	232
Solar	0	0	0	0	0	0
Biomass and waste	4.3	7	8	33	34	35
Geothermal/ambient heat	0	0	1	1	1	1
Hydrogen	0	0	0	0	0	0
RES share Industry	**3.5%**	**6.2%**	**9.4%**	**17.2%**	**19.1%**	**21.0%**
Other Sectors	**1,031**	**1,026**	**1,020**	**1,004**	**983**	**941**
Electricity	238	242	248	247	242	237
RES electricity	23	34	56	71	79	86
District heat	42	42	43	51	58	66
RES district heat	1	3	5	12	15	18
Coal	0	0	0	0	0	0
Oil products	36	28	22	14	10	7
Gas	697	689	672	631	608	563
Solar	1	1	1	2	2	3
Biomass and waste	17	22	24	48	51	53
Geothermal	0.3	2	9	10	12	13
Hydrogen	0	0	0	0	0	0
RES share Other Sectors	**4.1%**	**6.0%**	**9.4%**	**14.3%**	**16.2%**	**18.4%**
Total RES	**72**	**120**	**187**	**281**	**326**	**370**
RES share	**3.5%**	**5.8%**	**9.1%**	**13.8%**	**16.3%**	**19.0%**
Non energy use	**648**	**648**	**648**	**648**	**648**	**648**
Oil	541	541	541	541	541	541
Gas	96	96	96	96	96	96
Coal	11	11	11	11	11	11

netherlands: energy [r]evolution scenario

table 9.9: netherlands: electricity generation

TWh/a	2010	2015	2020	2030	2040	2050
Power plants	**54**	**63**	**66**	**82**	**107**	**126**
Coal & non-renewable waste	14	14	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	29	32	19	11	7.9	3.6
of which from H_2	0	0	0	0.6	1.2	1.1
Oil	0	0	0	0	0	0
Diesel	0	0	0	0	0	0
Nuclear	4.0	0	0	0	0	0
Biomass & renewable waste	3.0	3.1	0.9	0.3	0.2	0.2
Hydro	0.1	0	0	0	0	0
Wind	4.0	12	39	53	70	89
of which wind offshore	0.8	1.9	21	31	42	54
PV	0.1	0.9	6.5	17	27	30
Geothermal	0	0	0.2	0.7	1.3	1.4
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	0	0	0	0.1	0.3	2.0
Combined heat & power plants	**64**	**61**	**59**	**59**	**60**	**57**
Coal & non-renewable waste	11	6.0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	49	48	50	49	45	36
of which from H_2	0	0	0	1.9	7.5	13
Oil	1.3	1.1	0.8	0.1	0	0
Biomass	4.1	5.7	7.7	9.7	12	16
Geothermal	0	0.1	0.4	0.7	2.3	4.7
Hydrogen	0	0	0	0.1	0.5	0.7
CHP by producer						
Main activity producers	44	40	37	36	35	33
Autoproducers	21	21	22	23	25	24
Total generation	**118**	**124**	**125**	**141**	**166**	**184**
Fossil	103	102	70	57	44	25
Coal & non-renewable waste	24	20	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	77	81	69	57	44	25
Oil	1.3	1.2	0.9	0.1	0	0
Diesel	0	0	0	0	0	0
Nuclear	4.0	0	0	0	0	0
Hydrogen	0	0	0	2.7	9.2	15
Renewables	**11**	**22**	**55**	**82**	**113**	**144**
Hydro	0	0	0	0	0	0
Wind	4.0	12	39	53	70	89
PV	0.1	0.9	6.5	17	27	30
Biomass & renewable waste	7.0	8.8	8.6	10	12	16
Geothermal	0	0.1	0.5	1.4	3.6	6.2
Solar thermal	0	0	0	0	0	0
Ocean energy	0	0	0	0.1	0.3	2.0
Distribution losses	4	4	4	4	4	4
Own consumption electricity	10	10	9	8	8	7
Electricity for hydrogen production	0	0	0	10	35	53
Final energy consumption (electricity)	**107**	**107**	**108**	**116**	**125**	**131**
Fluctuating RES (PV, Wind, Ocean)	4	13	46	70	97	121
Share of fluctuating RES	3.4%	10.6%	36.6%	49.6%	58.5%	66.0%
RES share (domestic generation)	**9.5%**	**17.8%**	**44.0%**	**57.8%**	**68.1%**	**78.3%**
Difference compared to Ref.	**0**	**3**	**5**	**3**	**-1**	**-3**

table 9.10: netherlands: heat supply

PJ/a	2010	2015	2020	2030	2040	2050
District heating	**1**	**2**	**3**	**5**	**5**	**5**
Fossil fuels	1	1	2	2	1	0
Biomass	0	1	1	1	1	1
Solar collectors	0	0	0	1	2	2
Geothermal	0	0	0	1	1	1
Heat from CHP	**134**	**138**	**138**	**154**	**180**	**199**
Fossil fuels	126	126	121	114	93	59
Biomass	7	10	15	31	49	61
Geothermal	0	1	3	7	21	43
Hydrogen	0	0	0	2	17	37
Direct heating	**1,056**	**1021**	**966**	**837**	**713**	**600**
Fossil fuels	1,016	963	864	618	346	141
Biomass	18	27	43	68	71	71
Solar collectors	1	5	18	54	95	104
Geothermal[1]	0	5	21	64	136	190
Electricity[2]	21	20	20	25	39	54
Hydrogen	0	0	0	7	27	40
Total heat supply	**1,190**	**1160**	**1107**	**996**	**898**	**805**
Fossil fuels	1,143	1090	986	734	439	200
Biomass	25	38	58	100	121	133
Solar collectors	1	5	18	55	97	107
Geothermal[1]	0	6	25	72	158	234
Electricity[2]	21	20	20	25	39	54
Hydrogen	0	0	0	10	43	77
RES share (including RES electricity)	**2.4%**	**4.5%**	**9.5%**	**23.8%**	**44.9%**	**64.8%**
'Efficiency' savings (compared to Ref.)	**0**	**41**	**86**	**194**	**275**	**329**

1) incuding heat pumps; 2) direct electric heating

table 9.11: netherlands: CO_2 emissions

MILL t/a	2010	2015	2020	2030	2040	2050
Condensation power plants	**23**	**24**	**7**	**4**	**2**	**1**
Coal	11	11	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	12	13	7	4	2	1
Oil	0	0	0	0	0	0
Diesel	0	0	0	0	0	0
Combined heat & power production	**32**	**25**	**19**	**16**	**11**	**6**
Coal	10	6	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	21	19	18	15	11	6
Oil	1	1	1	0	0	0
CO_2 emissions power generation (incl. CHP public)	**55**	**50**	**26**	**19**	**13**	**7**
Coal	21	17	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	33	32	25	19	13	7
Oil & diesel	1	1	1	0	0	0
CO_2 emissions by sector	**172**	**158**	**121**	**85**	**49**	**21**
% of 1990 emissions	115%	105%	80%	57%	33%	14%
Industry[1]	29	28	25	18	10	4
Other sectors[1]	42	38	34	24	14	6
Transport	34	32	28	20	12	5
Power generation[2]	48	43	21	14	10	5
District heating & other conversion	18	16	13	8	4	1
Population (Mill.)	16.6	16.8	17.0	17.3	17.3	17.2
CO_2 emissions per capita (t/capita)	**10.4**	**9.4**	**7.1**	**4.9**	**2.9**	**1.2**
Reduction compared to Ref.	**0**	**12**	**39**	**62**	**89**	**106**

1) including CHP autoproducers. 2) including CHP public

table 9.12: netherlands: installed capacity

GW	2010	2015	2020	2030	2040	2050
Power plants	**13**	**20**	**31**	**45**	**61**	**70**
Coal & non-renewable waste	2.3	2.1	0	0	0	0
Lignite	0	0	0	0	0	0
Gas (incl. H_2)	7.3	10.6	8.0	5.5	5.0	5.0
Oil	0	0	0	0	0	0
Diesel	0	0	0	0	0	0
Nuclear	0.5	0	0	0	0	0
Biomass	0.5	0.6	0.3	0.1	0.1	0.1
Hydro	0	0.1	0.1	0.1	0.1	0.1
Wind	2.2	5.3	14	18	22	27
of which wind offshore	0.2	0.5	5.8	8.3	11	14
PV	0.1	1.1	8.3	21	34	37
Geothermal	0	0	0.03	0.1	0.2	0.2
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	0	0	0	0.01	0.1	0.6
Combined heat & power production	**12.8**	**12**	**11**	**11**	**11**	**11**
Coal & non-renewable waste	1.8	1.6	0	0	0	0
Lignite	0	0	0	0	0	0
Gas (incl. H_2)	10.1	9.0	9.0	8.8	8.1	6.4
Oil	0.3	0.2	0.2	0.02	0	0
Biomass	0.7	1.0	1.7	2.2	2.9	3.9
Geothermal	0	0	0	0.1	0.4	0.7
Hydrogen (fuel cells)	0	0	0	0	0	0
CHP by producer						
Main activity producers	8.7	8	7	7	7	6
Autoproducers	4.2	4	4	4	5	5
Total generation	**26**	**32**	**42**	**56**	**73**	**81**
Fossil	22	24	17	14	11	7.6
Coal & non-renewable waste	4.1	3.7	0	0	0	0
Lignite	0	0	0	0	0	0
Gas (w/o H_2)	17	20	17	14	11	7.6
Oil	0.3	0.3	0.2	0.02	0	0
Diesel	0	0	0	0	0	0
Nuclear	0.5	0	0	0	0	0
Hydrogen (fuel cells, gas power plants, gas CHP)	0	0	0	0.7	2.2	4.0
Renewables	**3.6**	**8.2**	**24**	**42**	**60**	**70**
Hydro	0	0.1	0.1	0.1	0.1	0.1
Wind	2.2	5.3	14	18	22	27
PV	0.1	1.1	8.3	21	34	37
Biomass & renewable waste	1.2	1.6	2.0	2.3	3.0	4.0
Geothermal	0	0	0.09	0.2	0.6	1.0
Solar thermal	0	0	0	0	0	0
Ocean energy	0	0	0	0.01	0.10	0.59
Fluctuating RES (PV, Wind, Ocean)	2.3	6	22	39	56	65
Share of fluctuating RES	8.9%	20.3%	53.2%	69.7%	76.9%	79.5%
RES share (domestic generation)	**13.8%**	**25.7%**	**58.6%**	**74.3%**	**81.9%**	**85.7%**

table 9.13: netherlands: primary energy demand

PJ/a	2010	2015	2020	2030	2040	2050
Total	**3,490**	**3,324**	**3,006**	**2,629**	**2,344**	**2,102**
Fossil	**3,309**	**3,089**	**2,578**	**2,004**	**1,449**	**982**
Hard coal	346	265	57	64	73	78
Lignite	0.6	0	0	0	0	0
Natural gas	1,644	1,577	1,401	1,083	719	382
Crude oil	1,318	1,247	1,120	857	657	522
Nuclear	**42**	**0**	**0**	**0**	**0**	**0**
Renewables	**138**	**235**	**427**	**625**	**894**	**1,120**
Hydro	0.4	0	0	0	0	0
Wind	14	44	141	191	251	321
Solar	1.2	8	42	116	196	214
Biomass	122	177	217	233	267	313
Geothermal/ambient heat	0.3	5	28	84	179	264
Ocean energy	0	0	0	0	1	7
RES share	**3.9%**	**7.1%**	**14.0%**	**23.5%**	**38.6%**	**54.1%**
'Efficiency' savings (compared to Ref.)	**0**	**181**	**440**	**705**	**880**	**1,009**

table 9.14: netherlands: final energy demand

PJ/a	2010	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**2,712**	**2,650**	**2,553**	**2,327**	**2,120**	**1,936**
Total (energy use)	**2,064**	**2,002**	**1,906**	**1,685**	**1,485**	**1,314**
Transport	**483**	**466**	**433**	**353**	**282**	**235**
Oil products	466	435	381	276	160	60
Natural gas	0.5	1	1	2	3	4
Biofuels	10	23	37	37	54	72
Electricity	6	7	13	32	52	77
RES electricity	1	1	6	19	35	60
Hydrogen	0	0	0	4	14	23
RES share Transport	**2.1%**	**5.2%**	**10.0%**	**16.6%**	**34.9%**	**63.8%**
Industry	**549**	**551**	**538**	**497**	**460**	**431**
Electricity	141	140	140	149	156	155
RES electricity	13	25	62	86	106	121
District heat	51	51	51	59	68	78
RES district heat	2	3	6	15	31	52
Coal	3	0	0	0	0	0
Oil products	116	107	81	35	0	0
Gas	235	241	239	183	110	34
Solar	0	0	3	16	34	39
Biomass and waste	4.3	11	21	33	33	33
Geothermal/ambient heat	0	1	3	13	32	50
Hydrogen	0	0	0	8	27	41
RES share Industry	**3.5%**	**7.4%**	**17.6%**	**33.8%**	**55.5%**	**76.0%**
Other Sectors	**1,031**	**984**	**935**	**836**	**743**	**648**
Electricity	238	238	236	236	242	240
RES electricity	23	42	104	136	164	188
District heat	42	48	50	58	72	82
RES district heat	1	3	6	15	33	54
Coal	0	0	0	0	0	0
Oil products	36	22	12	0	0	0
Gas	697	647	579	423	247	112
Solar	1	5	15	38	61	65
Biomass and waste	17	22	31	48	50	50
Geothermal	0.3	3	11	32	71	100
Hydrogen	0	0	0	0	0	0
RES share Other Sectors	**4.1%**	**7.6%**	**17.9%**	**32.3%**	**51.1%**	**70.4%**
Total RES	**72**	**140**	**305**	**496**	**734**	**934**
RES share	**3.5%**	**7.0%**	**16.0%**	**29.5%**	**49.4%**	**71.1%**
Non energy use	**648**	**648**	**647**	**642**	**635**	**622**
Oil	541	541	532	483	468	452
Gas	96	96	96	95	94	92
Coal	11	11	19	64	73	78

netherlands: investment

table 9.15: netherlands: 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)	**9,610**	**5,020**	**4,460**	**3,830**	**22,920**	**573**
Renewables	**17,860**	**10,360**	**14,430**	**9,990**	**52,640**	**1,316**
Biomass	5,500	3,530	4,270	2,510	15,810	395
Hydro	0	0	0	0	0	0
Wind	9,350	5,740	7,920	6,290	29,310	733
PV	2,400	600	1,680	760	5,440	136
Geothermal	600	500	560	430	2,090	52
Ocean energy	0	0	0	0	0	0
Energy [R]evolution						
Conventional (fossil & nuclear)	**5,680**	**4,150**	**3,940**	**20**	**13,800**	**345**
Renewables	**43,690**	**27,100**	**50,540**	**35,440**	**156,780**	**3,919**
Biomass	5,080	2,640	4,770	3,640	16,140	403
Hydro	0	0	0	0	0	0
Wind	26,660	10,210	25,690	16,310	78,860	1,971
PV	11,390	13,700	17,790	12,430	55,310	1,383
Geothermal	560	560	2,300	2,400	5,810	145
Ocean energy	0	0	0	660	660	17

table 9.16: netherlands: 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						
Heat pumps	3,590	470	3,580	660	8,300	208
Deep geothermal	90	40	130	240	500	13
Solar thermal	250	220	210	180	860	21
Biomass	2,250	5,110	1,290	3,900	12,540	313
Renewables	**6,170**	**5,830**	**5,210**	**4,980**	**22,200**	**555**
Energy [R]evolution scenario						
Heat pumps	5,060	9,300	19,340	18,250	51,960	1,299
Deep geothermal	160	40	970	920	2,090	52
Solar thermal	4,420	8,030	11,700	7,910	32,050	801
Biomass	3,730	3,710	2,410	2,100	11,950	299
Renewables	**13,370**	**21,080**	**34,420**	**29,180**	**98,050**	**2,451**

table 9.17: netherlands: total employment

		REFERENCE			ENERGY [R]EVOLUTION		
By sector	2010	2015	2020	2030	2015	2020	2030
Construction and installation	9,400	4,600	1,500	700	18,100	9,200	7,200
Manufacturing	3,800	1,500	500	300	5,200	2,100	1,800
Operations and maintenance	6,500	8,200	9,400	9,600	7,800	9,800	10,600
Fuel supply (domestic)	8,100	7,700	7,200	6,200	7,600	6,700	4,900
Gas export	4,400	5,000	3,000	-	5,100	3,500	1,100
Solar and geothermal heat	1,100	1,700	5,900	700	12,200	17,700	28,800
Total jobs	**33,400**	**28,800**	**27,600**	**17,500**	**56,100**	**48,900**	**54,400**
By technology							
Coal	7,800	1,200	1,100	900	600	-	-
Gas, oil & diesel	15,100	13,800	11,100	6,900	13,800	11,100	6,600
Nuclear	200	200	200	200	500	400	400
Renewable	**10,200**	**13,600**	**15,400**	**9,600**	**41,100**	**37,400**	**47,400**
Biomass	5,300	6,600	6,600	6,700	6,500	5,700	6,200
Hydro	200	200	200	300	200	200	300
Wind	1,700	3,500	1,800	1,400	9,600	3,900	4,000
PV	1,900	1,500	700	400	12,500	9,800	8,000
Geothermal power	-	100	100	-	100	100	100
Solar thermal power	-	-	-	-	-	-	-
Ocean	-	-	-	-	-	-	10
Solar - heat	400	200	200	200	8,100	9,900	14,800
Geothermal & heat pump	700	1,500	5,800	600	4,100	7,800	14,000
Total jobs	**33,400**	**28,800**	**27,600**	**17,500**	**56,100**	**48,900**	**54,400**

note
numbers may not add up due to rounding

energy
[r]evolution

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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The Global Wind Energy Council (GWEC) is the voice of the global wind energy sector. GWEC works at highest international political level to create better policy environment for wind power. GWEC's mission is to ensure that wind power established itself as the answer to today's energy challenges, producing substantial environmental and economic benefits. GWEC is a member based organisation that represents the entire wind energy sector. The members of GWEC represent over 1,500 companies, organisations and institutions in more than 70 countries, including manufacturers, developers, component suppliers, research institutes, national wind and renewables associations, electricity providers, finance and insurance companies.

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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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image THE PRINSES AMALIA WINDPARK THAT LIES 12 MILES OFF THE COAST OF THE NETHERLANDS. **front cover images** THIS IMAGE WAS ACQUIRED ON SEPTEMBER 24, 2002, BY THE ADVANCED SPACEBORNE THERMAL EMISSION AND REFLECTION RADIOMETER (ASTER) ON NASA'S TERRA SATELLITE AND SHOWS THE RESULTS OF THE DELTA WORKS PROJECT ON THE ISLANDS OF THE NETHERLANDS SOUTHERNMOST COASTAL PROVINCE, KNOWN AS ZEALAND. © NASA/GSFC/METI/ERSDAC/JAROS, AND U.S./JAPAN ASTER SCIENCE TEAM © GP/BEN DEIMAN, © GP/GERARD TIL.