energy

[r]evolution

A SUSTAINABLE POLAND ENERGY OUTLOOK

GWEC
GLOBAL WIND ENERGY COUNCIL

EREC
EUROPEAN RENEWABLE ENERGY COUNCIL

GREENPEACE

report 2013 Poland 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)

date October 2013

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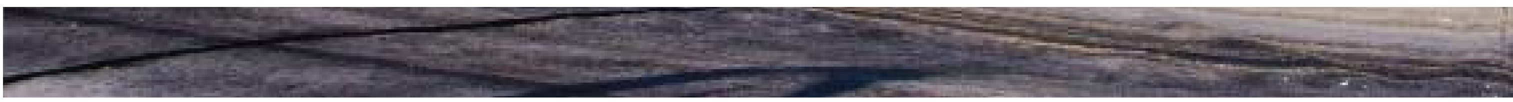

image LA DEHESA, 50 MW PARABOLIC THROUGH SOLAR THERMAL POWER PLANT WITH MOLTEN SALTS STORAGE IN SPAIN. COMPLETED IN FEBRUARY 2011, IT IS LOCATED IN LA GAROVILLA AND IT IS OWNED BY RENOVABLES SAMCA. WITH AN ANNUAL PRODUCTION OF 160 MILLION KWH, LA DEHESA WILL BE ABLE TO COVER THE ELECTRICITY NEEDS OF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

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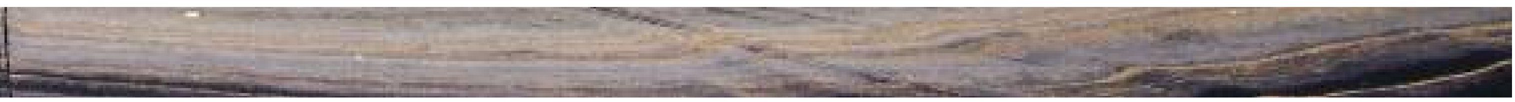

for further information about the global, regional and national scenarios please visit the Energy [R]evolution website: **www.energyblueprint.info/**
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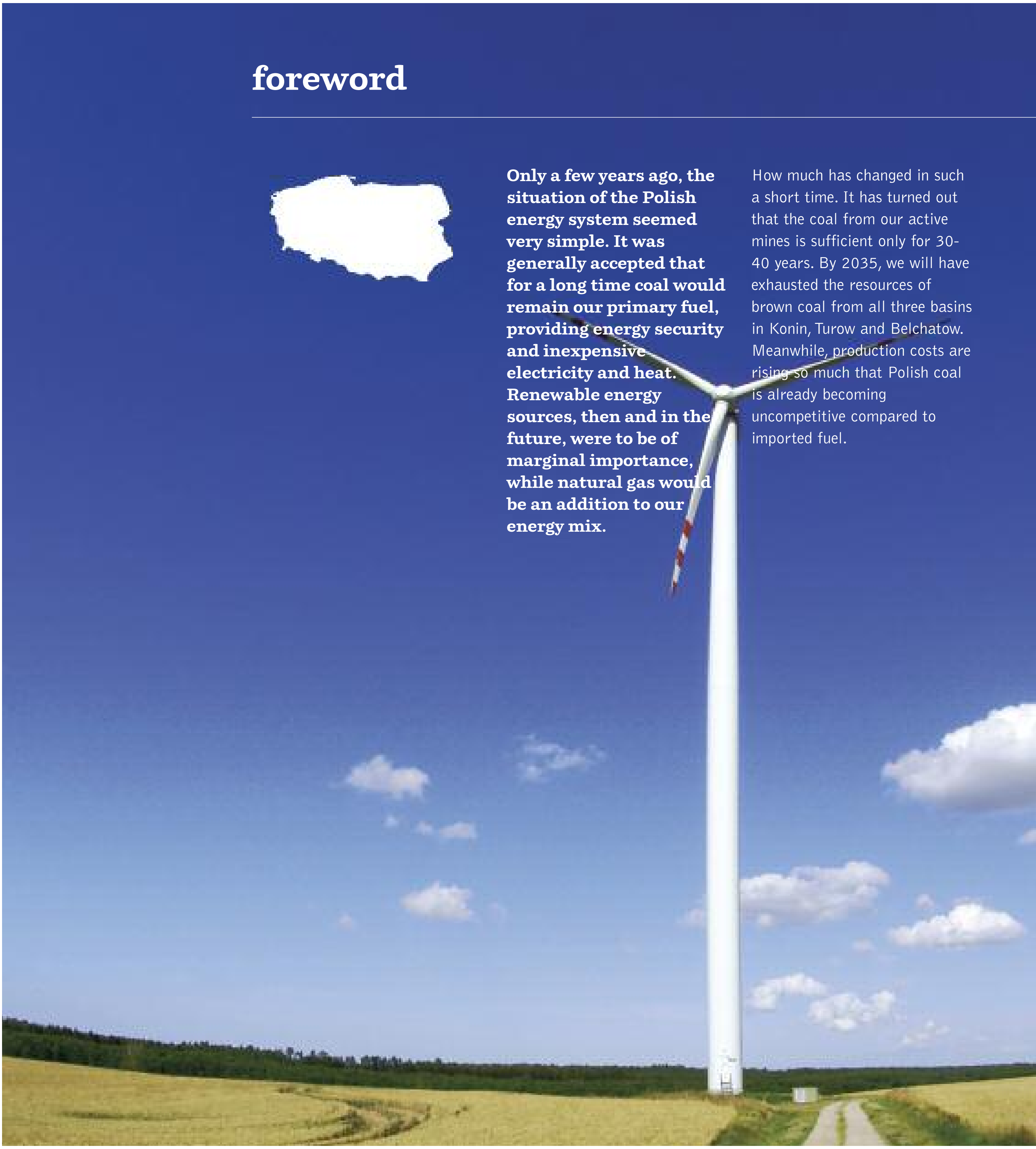
foreword

Only a few years ago, the situation of the Polish energy system seemed very simple. It was generally accepted that for a long time coal would remain our primary fuel, providing energy security and inexpensive electricity and heat. Renewable energy sources, then and in the future, were to be of marginal importance, while natural gas would be an addition to our energy mix.

How much has changed in such a short time. It has turned out that the coal from our active mines is sufficient only for 30-40 years. By 2035, we will have exhausted the resources of brown coal from all three basins in Konin, Turow and Belchatow. Meanwhile, production costs are rising so much that Polish coal is already becoming uncompetitive compared to imported fuel.



contents at a glance

image TURBINES ON A WIND FARM, POLAND.

Additionally, there is a problem of the rising costs of energy that is being produced in coal-fired power plants. Huge financial resources are needed to build new units in place of the old retiring ones and to purchase the rights to emit carbon dioxide. By 2020 the emission price or the costs of removing CO_2 from the flue gases will be in imposed on all CO_2 emissions from power plants.

The idea of building nuclear power plants which has been promoted by the Polish government for several years, does not save the day: the first such power plant with the capacity of 3000 MW would be built by 2025 at a horrendously high cost of 50-60 billion Polish złoty (€12-14 billion), and would contribute less than 10% to annual production.

It is clear that the era of highly centralized energy – a relic of the twentieth century – is coming to an end in Poland. This report present this system as a reference, which does not ensure energy security any more, is inefficient and harmful to the environment. The authors contrast it with a decentralized system, mainly based on the use of renewable energy sources, and named the alternative scenario.

It turns out that the potential of renewable energy in our country exceeds manifold our energy needs both at present and in the far-away future. The creation of the system built on renewable energy sources is made easier by the fact that proper policies will trigger the needed financing, as well as citizen and municipality initiatives. It also provides energy security in the local and national scale, creates tens of thousands of jobs especially on the local markets and is environmentally friendly.

Furthermore, such a system has much higher energy efficiency and does not require major investments in power lines. In the long run, it has many advantages, so while the Polish report calls the renewable energy system an alternative scenario, it will in fact become a dominant and viable solution. Over the next decades, both energy models will coexist side by side in changing proportions. While I am confident that this trend cannot be stopped, it can be slowed down by legal and economic barriers that exist today and which are being imposed by the coal lobby.

Today, the future of Polish energy will be decided for decades to come. It depends on the political will of the country's leaders which way we will go – whether we will be pushed into a dead-end street of more and more expensive and largely imported fossil fuels, or whether renewable energy sources are already today allowed opportunities to develop that they deserve. I hope that this study, presenting a feasible, realistic scenario for the Polish Energy [R]evolution, will be helpful in starting in-depth discussions, leading to the development of a 21st century energy strategy.

Maciej Nowicki
PROFESSOR . ASSOC. ENG. MINISTER OF THE ENVIRONMENT IN 1989-1991 AND 2007-2009.[1]
OCTOBER 2013

reference

1 DEVELOPER EKOFUNDUSZ FOUNDATION , DEALING WITH EKOKONWERSJĄ POLISH DEBT. IN 1994-1995 HE WAS VICE COMMENT [A01]: THIS IS A FOREWORD PREPARED FOR US BY MACIEJ NOWICKI , FORMER MINISTER OF ENVIRONMENT. HIS POSITIONS ARE WRITTEN BLOW THE CHAPTER P 5 UN COMMISSION ON SUSTAINABLE DEVELOPMENT, AND IN 2008-2009 CHAIRMAN OF THE UN FRAMEWORK CONVENTION ON CLIMATE CHANGE . WINNER OF " DER DEUTSCHE UMWELTPREIS "(SO-CALLED "GREENING NOBEL".

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

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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 A VIEW ACROSS THE WORKINGS OF PART OF THE KONIN COAL MINES OF WESTERN POLAND, PHOTOGRAPHED FROM THE WINDMILL OF MAREK MATUSZAK.

In autumn 2008, Greenpeace published the first Energy [R]evolution for Poland. This new Energy [R]evolution scenario for Poland is much more than just an update – it took all international trends in energy efficiency and renewable energy into account. A new and detailed analysis of the outlook and opportunities in Poland's transport sector, as well as a socio-economic analysis of job implications, has been added. Like the previous version, the Warsaw based Institute for Renewable Energy (IEO) and the DLR (German Space Agency) developed the scenarios.

This analysis concludes that Poland can implement the current EU climate and energy package known as 3x20 (which assumes a 20% reduction of carbon dioxide emissions, a 20% share of renewable energy sources (RES), and a 20% reduction in energy consumption by 2020), achieving the national target of 15% renewable energy by 2020, with a mix of different renewable energy sources.

The Polish government has a long and consistent history of opposing moves towards an energy system based on renewables. Under the EU Renewable Energy Directive, Poland must have a 15% renewable energy share by 2020. The government's main energy strategy, the *Energy Policy of Poland until 2030 (EPP 2030)*, adopted by the Polish government on 10 November 2009, aims to meet this target. However, instead of promoting investments in new clean power generation (solar, wind and small-scale biomass use), the government aims to deliver the target primarily by using biomass mixed with coal in existing coal plants. The International Energy Agency[1] warns that this approach is unbalanced and that additional policies and support are required to boost other renewable sources, for instance electricity from onshore and offshore wind.

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.

Over the past five years, the European Union has made great progress in the development of renewable energy, both in terms of the technology and in terms of increasing the share of renewable energy in the energy mix. At the end of 2011, the share of renewable energy in the EU's energy consumption exceeded 12.5%. Since 2008, investments in electricity generation from renewable sources accounted for more than half of all investment in new capacity in power, and in 2012 exceeded the threshold of 70%. In the Energy Roadmap 2050 published in December 2010, European Commission suggests that the share of renewable energy in 2050 will increase to a minimum of 55% of gross final energy consumption in all scenarios, and that the share of RES in electricity consumption will reach 64% to 97%. Currently the new draft of the Renewable Energy Directive calls for 30% renewables by 2030, while Greenpeace strongly recommends to establish a legally binding target of 45% renewable energy by 2030.

Unfortunately, in Poland the discussion about the future of renewable energy in the national energy mix is too often one-sided and based on stereotypes. Invariably, it seems to be the opinion of the government and of corporate power that Poland is bound to coal – despite the fact that national economic resources of coal are already significantly depleted.

Currently, Poland does not have a sustainable or long-term energy policy. The reference scenario presented in the report is based on the current Energy Policy of Poland until 2030 (EPP 2030) and takes into account subsequent adjustments of energy demand and supply by 2050. However, Poland needs to implement the EU Renewable Energy Directive but has failed to even fully transpose it into national law, something the Polish society is generally not aware of.

Due to a lack of reform and investment, Poland's power plants are aging. About 70% of them are over 30 years, 40% over 40, and 15% over 50 years old. A significant number of them is expected to be decommissioned soon. The type of plants chosen to replace them will determine Poland's power mix for the next decades – either locking the country into a high-carbon infrastructure, or creating a safe and sustainable energy future powered by renewables. Although a rare investment window of opportunity is open, the Polish government is currently planning a dozen new, large coal-fired power plants with the potential to contribute over 100 million tons of CO_2 emissions per year – one third of the country's current CO_2 emissions.[2] Without policies and laws that enable rapid growth of renewable energy and energy efficiency, the country risks ending up with an obsolete energy system, with rising costs and stranded assets, as the world moves beyond fossil fuels.

The authors believe that the Energy [R]evolution for Poland represents a valuable contribution to the Polish energy debate. Poland could have a secure and renewable energy supply with stable energy prices and secure jobs. The renewable industry can grow to the same size of the current coal industry over the next 15 years. Long-term policies for energy efficiency and renewable energy will help paving the way for a Polish Energy [R]evolution.

Rainer Hinrich-Rahlwes
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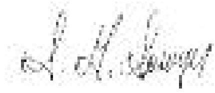
ENERGY COUNCIL (EREC)



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OCTOBER 2013

reference

2 IEA (2011), ENERGY POLICIES OF IEA COUNTRIES - POLAND, 2011 REVIEW.
3 WORLD RESOURCES INSTITUTE. 2012. GLOBAL COAL RISK ASSESSMENT. HTTP://WWW.WRI.ORG/PUBLICATION/GLOBAL-COAL-RISK-ASSESSMENT.

executive summary

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

image POWER GENERATING WIND TURBINES ON CULTIVATED WHEAT FIELD, POLAND. ALTERNATIVE ENERGY SOURCE.

The expert consensus is that a fundamental shift in the way we consume and generate energy must begin immediately and be well underway within the next ten years in order to avert the worst impacts of climate change.[4] The scale of the challenge requires a complete transformation of the way we produce, consume and distribute energy, while maintaining economic growth. The five key principles behind this Energy [R]evolution will be to:

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

Decentralised energy systems, where power and heat are produced close to the point of final use, reduce grid loads and energy losses in distribution. Investments in 'climate infrastructure' such as smart interactive grids and transmission grids to transport large quantities of offshore wind and concentrated solar power are essential. Building up clusters of renewable micro grids, especially for people living in remote areas, will be a central tool in providing sustainable electricity to the almost two billion people around the world who currently do not have access to electricity.

the energy [r]evolution for poland – key results

Renewable energy sources account for 7.8% of Poland'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 6.6% and for heat supply, around 10.6%, above all biomass but increasingly from geothermal heat pumps and solar thermal collectors. About 92% of the primary energy supply today still comes from fossil fuels.

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

reference
4 IPCC – SPECIAL REPORT RENEWABLES, CHAPTER 1, MAY 2011.

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

- **Curbing energy demand:** The Polish energy demand is projected by combining population development, GDP growth and energy intensity. Under the Reference scenario, total final energy demand increases by 11% from the current 2,718 PJ/a to 3,017 PJ/a in 2050. In the Energy [R]evolution scenario, final energy demand decreases by 32% compared to current consumption and it is expected to reach 1,855 PJ/a by 2050.

- **Controlling power demand:** Controlling power demand: Under the Energy [R]evolution scenario, due to economic growth, increasing living standards and electrification of the transport sector, electricity demand is expected to increase in the industry sector, as well as in the residential, service and transport sectors. Total electricity demand will rise from 119 TWh/a to 214 TWh/a by the year 2050. Compared to the Reference scenario, efficiency measures in the industry, residential and service sectors avoid the generation of about 46 TWh/a. This reduction can be achieved in particular by introducing highly efficient electronic appliances using the best available technology in all demand sectors.

- **Reducing heating demand:** Efficiency gains in the heating and cooling sector are even larger. Under the Energy [R]evolution scenario, demand for heating and cooling is expected to increase until 2015 and drop significantly afterwards. Compared to the Reference scenario, consumption equivalent to 395 PJ/a is avoided through efficiency gains by 2050. As a result of energy-related renovation of the existing stock of residential buildings, the introduction of low energy standards and 'passive climatisation' for new buildings, as well as highly efficient air conditioning systems, enjoyment of the same comfort and energy services will be accompanied by a much lower future energy demand.

- **Electricity generation:** The development of the electricity supply sector is charaterised by a dynamically growing renewable energy market and an increasing share of renewable electricity. This will compensate for the decision not to rely on nuclear reactors in the Energy [R]evolution scenario and reduce the number of fossil fuel-fired power plants required for grid stabilisation. By 2050, 88% of the electricity produced in the Poland region will come from renewable energy sources. 'New' renewables – mainly wind and PV – will contribute 54% to the total electricity generation. Already by 2020 the share of renewable electricity production will be 23% and 52% by 2030. The installed capacity of renewables will reach 48 GW in 2030 and 119 GW by 2050. Up to 2020 wind and PV will become the main contributors of the growing market share. After 2020, the continuing growth of wind and PV will be complemented by electricity from biomass. The Energy [R]evolution scenario will lead to a high share of fluctuating power generation sources (photovoltaic, wind and ocean) of 41% by 2030 and 75% by 2050, therefore the expansion of smart grids, demand side management (DSM) and storage capacity from the increased share of electric vehicles will be used for a better grid integration and power generation management.

- **Future costs of electricity generation:** The introduction of renewable technologies under the Energy [R]evolution scenario is possible while keeping costs per kWh of electricity generation similar to the reference scenario until 2030. The difference between the two scenarios will be less than 0.2 €ct/kWh up to 2020. Because of high prices for conventional fuels and the lower CO_2 intensity of electricity generation, from 2040 on electricity generation costs will become economically favourable under the Energy [R]evolution scenario and by 2050 costs will be 3.6 €ct/kWh below those in the Reference version.

- **The future electricity bill:** 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 supply costs rising from today's €10 billion per year to more than €36 billion in 2050, compared to €34 billion in the Energy [R]evolution scenario. The Energy [R]evolution scenario not only complies with Poland'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 approximately 7% lower than in the Reference scenario.

- **Future investment in power generation:** It would require €264 billion in investment for the Energy [R]evolution scenario to become reality (including investments for replacement after the economic lifetime of the plants) - approximately €6.4 billion per year or €132 billion more than in the Reference scenario (€132 billion). Under the Reference version, the levels of investment in conventional power plants add up to almost 57% while approximately 43% would be invested in renewable energy and CHP plants until 2050. Under the Energy [R]evolution scenario; however, Poland would shift almost 90% of the entire investment towards renewables and CHP. Until 2030, the fossil fuel share of power sector investment would be focused mainly on gas power plants.

- **Fuel costs savings:** Because renewable energy has no fuel costs, the fuel cost savings in the Energy [R]evolution scenario reach a total of €98 billion up to 2050, or €2.5 billion per year. The total fuel cost savings therefore would cover 74% 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 the national economy.

- **Heating supply:** Today, renewables meet 11% of Poland's energy demand for heating and cooling, the main contribution coming from the use of biomass. Dedicated support instruments are required to ensure a dynamic development in particular for environmental heat (from heat pumps) and solar thermal heat for space heating and hot water as well as for renewable process heat production. In the Energy [R]evolution scenario, renewables provide 31% of Poland's total heat demand in 2030 and 76% in 2050. Energy efficiency measures help to reduce the currently growing energy demand for heating and cooling by 28% in 2050 (relative to the reference scenario), in spite of improving living standards and economic growth.

In the industry sector solar collectors, geothermal energy (incl. heat pumps) as well as electricity and hydrogen 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.

- **Future investments in the heat sector:** The heating and cooling sector the Energy [R]evolution scenario would require a major revision of current investment strategies in heating technologies. Especially solar thermal, solar cooling and geothermal and heat pump technologies need enormous increase in installations, if these potentials are to be tapped for the heat sector. These technologies are practically non-existent in the Poland today. The use of biomass for heating purposes will be substantially reduced in the Energy [R]evolution scenario and be replaced by more efficient and sustainable renewable heating technologies. Renewable heating technologies are extremely variable, from low tech biomass stoves and unglazed solar collectors to very sophisticated enhanced geothermal systems and solar cooling systems. Thus it can only roughly be calculated, that the Energy [R]evolution scenario in total requires around €100 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.
- **Future employment in the energy sector:** Energy sector jobs in Poland are higher in the Energy [R]evolution scenario at every stage in the projection. The coal sector continues the decline of the last decades in both scenarios. In the Energy [R]evolution scenario, strong growth in renewable energy compensates for the loss of coal jobs, and overall energy sector jobs increase. In 2015 jobs are 17% higher than in 2010. Jobs then drop to 2030, but remain 4% above 2010 levels, at 174,400. Jobs in the Reference scenario drop gradually until 2020, and then reduce more steeply to 2030, when jobs are 23% below 2010 levels, at 130,100. Renewable energy accounts for 62% of energy jobs by 2030, with biomass having the greatest share (21%), followed by solar heating and geothermal heating.
- **Transport:** A key target in Poland is to introduce incentives for people to drive smaller cars. In addition, it is vital to shift transport use to efficient modes like rail, light rail and buses, especially in the expanding large metropolitan areas. Together with rising prices for fossil fuels, these changes reduce the huge growth in car sales projected under the Reference scenario. Due to population increase, GDP growth and higher living standards, energy demand from the transport sector is expected to increase in the reference scenario by 24% to 879 PJ/a in 2050, 170 PJ/a higher than today's levels (709 PJ/a). However, in 2050 efficiency measures and mode shifts will save 48% compared to the Reference scenario (879 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 12% of the transport sector's total energy demand in the Energy [R]evolution, while in 2050 the share will be 32%.
- **Primary energy consumption:** Under the Energy [R]evolution scenario, primary energy demand will decrease by 27% from today's 4,224 PJ/a to 3,085 PJ/a. Compared to the Reference scenario, overall primary energy demand will be reduced by 40% in 2050 under the Energy [R]evolution scenario (Reference scenario: 5,133 PJ in 2050). The Energy [R]evolution version aims to phase out coal and oil as fast as technically and economically possible. This is made possible mainly by replacement of coal power plants with renewables and a fast introduction of very efficient electric vehicles in the transport sector to replace oil combustion engines. This leads to an overall renewable primary energy share of 27% in 2030 and 66% in 2050. In contrast to the Reference scenario, no nuclear power plants will be built in Poland in the Energy [R]evolution scenario.
- **Development of CO_2 emissions:** Development of CO_2 emissions: While Poland's emissions of CO_2 will decrease by 16% between 2010 and 2050 under the Reference scenario, under the Energy [R]evolution scenario they will decrease from 309 million tonnes in 2010 to 36 million tonnes in 2050. Annual per capita emissions will drop from 8 tonne to 1 tonne. In spite of not relying on nuclear power and increasing power 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 also in the transport sector. With a share of 38% of CO_2, the industry sector will be the largest sources of emissions in 2050. By 2050, Poland's CO_2 emissions are 90% below 1990 levels.

policy changes

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

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

climate and energy policy

THE UNFCC AND THE KYOTO PROTOCOL

INTERNATIONAL ENERGY POLICY

POLISH ENERGY POLICY

RENEWABLE ENERGY TARGETS

POLICY CHANGES IN THE ENERGY SECTOR

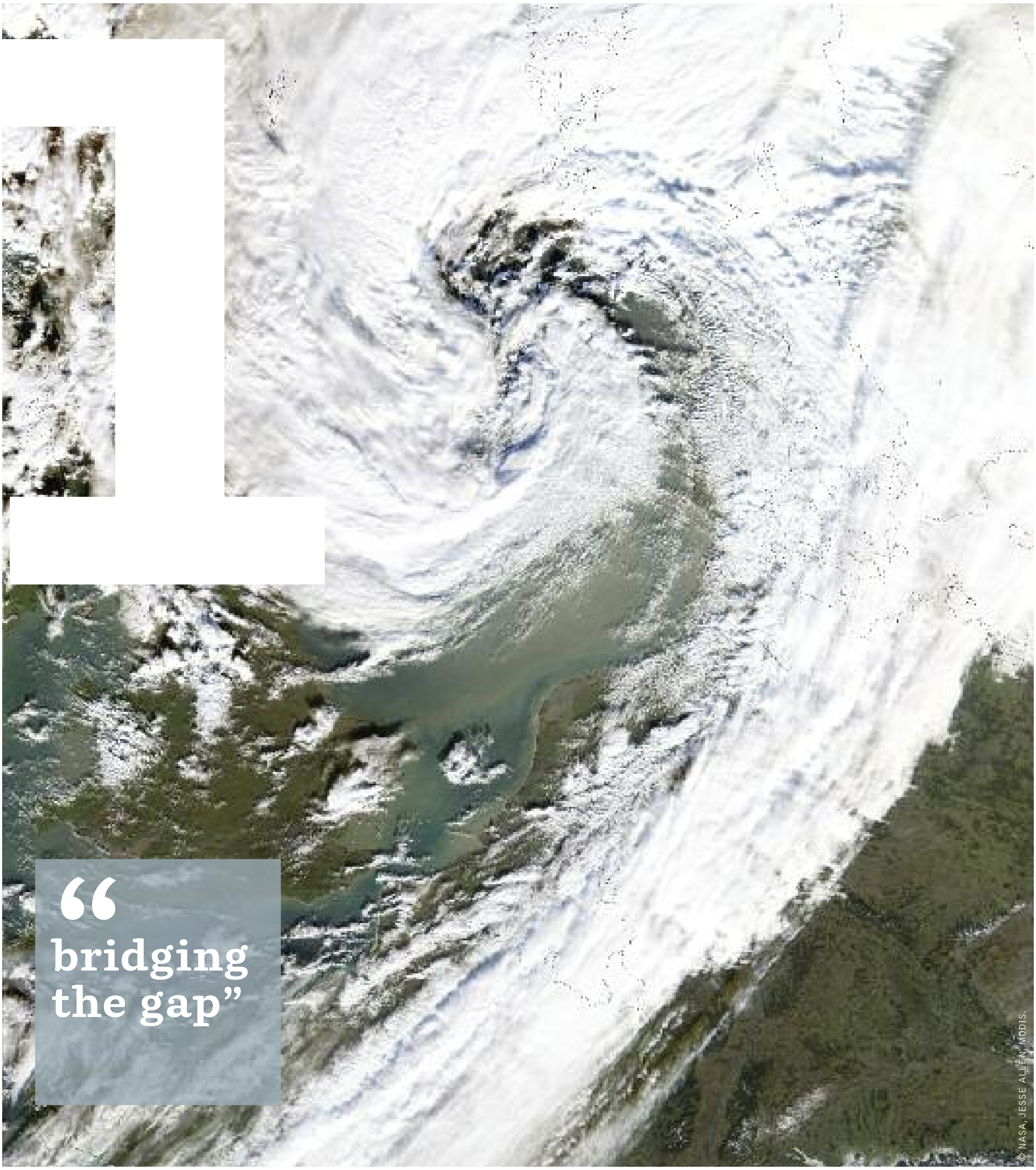


image THE CLOUDS OVER NORTHERN EUROPE HAVE THE MENACING CURL OF A LOW PRESSURE SYSTEM ASSOCIATED WITH SEVERE WINTER STORMS. THIS PARTICULAR STORM LASHED THE UNITED KINGDOM, SCANDINAVIA, NORTHERN GERMANY, AND RUSSIA WITH HURRICANE-FORCE WINDS AND INTENSE RAINS. ACCORDING TO NEWS REPORTS, 14 PEOPLE DIED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

Without urgent action to decarbonise our economies, climate change threats could become irreversible.

Governments have agreed to keep the global average temperature rise below 2°C above pre-industrial levels. This means that global greenhouse gas emissions will have to peak and start declining before 2020 towards as close to zero as possible by mid-century.

1.1 the United Nations Climate Convention

Recognising the global threats of climate change, world governments adopted in 1992 the United Nations Framework Convention on Climate Change (UNFCCC), which today has a near-universal membership. International cooperation has since deepened and broadened through the Kyoto Protocol agreed in 1997, the Cancun Agreements adopted in 2010, and the Doha amendment to the Kyoto Protocol agreed in 2012, along with other decisions.

Today about 100 countries, covering over 80 percent of global emissions and around 90 percent of the global economy, have pledged to reduce or limit their emissions by 2020. Unfortunately, these pledges fall short on keeping warming below 2°C and their poor implementation could lead to even less emission cuts. Currently we are on a path towards 4°C warming by the end of this century.[5] Clearly, the progress to date with small, incremental changes won't protect us from climate chaos. Action needs to be taken to a whole different level.

At the 2011 Conference of the Parties in Durban, governments decided to negotiate a new agreement on post-2020 emission cuts by 2015. This deal must not repeat the mistakes of the previous agreements. Instead it must ensure broad participation of all major emitters, fair sharing of effort, strong measures on adaptation, faster emission cuts before 2020 and new post-2020 emission reduction commitments that are fair and sufficient to keep warming as far below two degrees Celsius as possible. The Paris agreement needs to mark the beginning of an end to the fossil fuel era.

Ahead of the Paris climate conference in 2015, the EU must do its homework and prove that low-carbon development can go hand in hand with achieving energy security and the environmental and economic goals of the European Union. In 2009, the EU leaders agreed on a GHG emissions reduction goal of 80-95% below 1990 levels by 2050. Now it's time to show that the EU is serious in pursuing this pathway.

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. Most EU governments have implemented a form of support policy to compensate for market failures and to help maturing renewable energy technologies to realise their full potential. However, some support systems, such as "Feed in Tariffs", have shown to be more effective in promoting renewable energy than others.

1.3 polish energy policy

In Poland, it is necessary to initiate changes that will enable the development of 'energy democracy' involving the opening of the energy market for so-called 'prosumers': private investors who are producers and consumers of energy in one.

European Commission releases more and more demanding directives promoting environmentally friendly solutions, energy efficiency and renewable energy sources. Polish government implements them with a long delay and on the minimum possible level.

The updated Energy Policy for Poland should support Poland's implementation of the EU Renewable Energy Directive and delivery of Poland's 2020 renewable energy target. The policy should call for an ambitious, binding EU 2030 climate and energy package, including binding targets of at least 55% greenhouse gas emission reductions, a 45% share of renewable energy and 40% energy savings. In order to implement renewable energy targets, support schemes like "Feed-in tariffs" for microgeneration are required. To move Poland towards an Energy [R]evolution, the following policy changes are necessary:

- The Polish government should revise *Energy Policy of Poland until 2030 (EPP 2030)*, taking into account the results of costs calculations and analysis presented in this report. The government should carry out reliable public consultations on the draft policy including residents, local government and local communities, particularly those affected by the plans for new lignite open pit mines or by increased air pollution.
- The Polish government should immediately withdraw plans for new lignite open pit mines and abandon its nuclear program.
- The Polish government must ensure the full transposition and implementation of EU climate and energy legislation, including measures aimed to liberalise the Polish energy market and allow new entrants. It should support the European Commission and other European member states in their work on a 2030 climate and energy policy framework.

reference
5 WORLD BANK (2012) TURN DOWN THE HEAT. WHY A 4°C WARMER WORLD MUST BE AVOIDED.

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

© LANGROCK/ZENIT/GP

- The Polish government must adopt a law on renewable energy sources (based on the draft regulation of October 2012) without delay to remove market barriers for renewable energy andallow them to become truly competitive in the Polish energy market. This law should limit support for co-firing of biomass with coal, stimulate the development of micro generation and facilitate prosumerism (i.e. by introducing feed-in tariffs scheme for microgeneration that will allow a good return on investment).
- Poland should fully apply the EU Energy Efficiency Directive in order to unlock the large potential for energy savings across the country, particularly in the heating sector.
- The Polish coal and lignite sector benefits from generous subsidies, which are environmentally harmful and distort the market. These subsidies should be phased out.
- All future energy cost calculations must include external costs, including the health costs of coal energy generation.

1.4 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,[6] the European Solar Thermal Power Industry Association[7] and the Global Wind Energy Council,[8] 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.

1.5 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[9] 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.

references

6 'SOLARGENERATION IV', SEPTEMBER 2009.
7 'GLOBAL CONCENTRATED SOLAR POWER OUTLOOK – WHY RENEWABLES ARE HOT!' MAY, 2009.
8 'GLOBAL WIND ENERGY OUTLOOK 2008', OCTOBER 2008.
9 'IEA WORLD ENERGY OUTLOOK 2011', PARIS NOVEMBER 2011, CHAPTER 14, PAGE 507.

2

the energy [r]evolution concept

KEY PRINCIPLES

THE "3 STEP IMPLEMENTATION"

THE NEW ELECTRICITY GRID

2

"smart use, generation and distribution are at the core of the concept"

© NASA / JEFF SCHMALTZ,

image CENTRAL AND EASTERN EUROPE.

The expert consensus is that a fundamental shift in the way we consume and generate energy must begin immediately and be well underway within the next ten years in order to avert the worst impacts of climate change.[10] 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.[11]

   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

10 IPCC – SPECIAL REPORT RENEWABLES, CHAPTER 1, MAY 2011.
11 REN 21, RENEWABLE ENERGY STATUS REPORT 2012, JUNE 2012.

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.[12]

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.

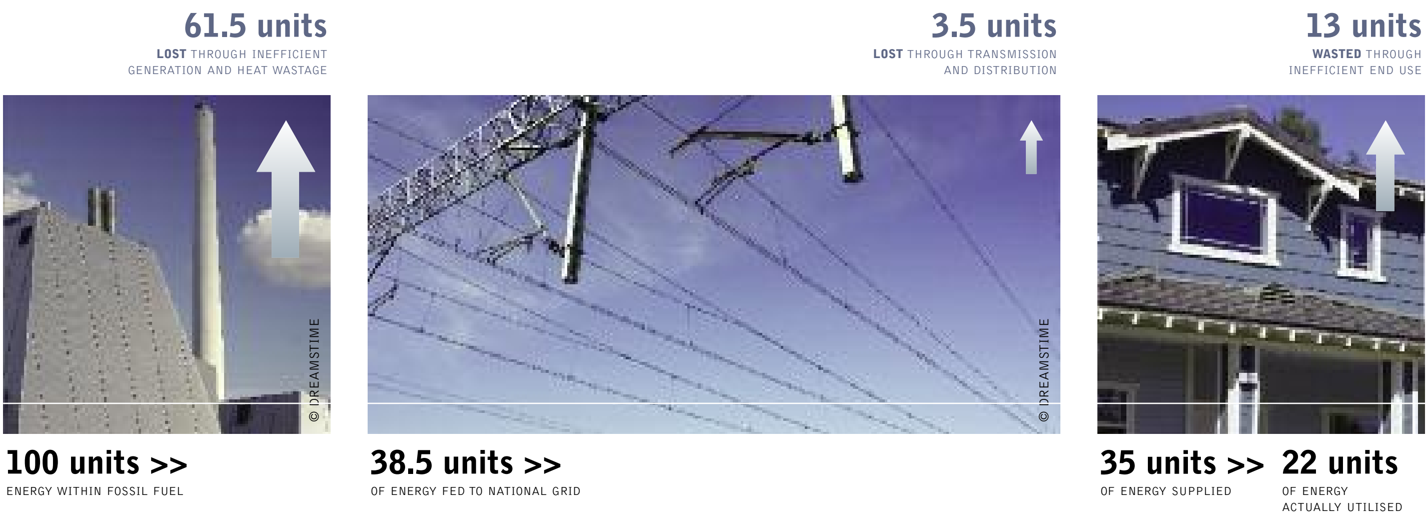
A transition phase is required to build up the necessary infrastructure because it is not possible to switch directly from a large scale fossil and nuclear fuel based energy system to a full renewable energy supply. Whilst remaining firmly committed to the promotion of renewable sources of energy, we 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



reference
12 IEA WORLD ENERGY OUTLOOK 2011, PARIS NOVEMBER 2011.

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.

Step 2: the renewable energy [r]evolution **Decentralised energy and large scale renewables** In order to achieve higher fuel efficiencies and reduce distribution losses, the Energy [R]evolution scenario makes extensive use of Decentralised Energy (DE).This term refers to energy generated at or near the point of use.

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

Decentralised energy also includes stand-alone systems entirely separate from the public networks, for example heat pumps, solar thermal panels or biomass heating. These can all be commercialised for domestic users to provide sustainable, low emission heating. Some consider decentralised energy technologies 'disruptive' because they do not fit the existing electricity market and system. However, with appropriate changes they can grow exponentially with overall benefit and diversification for the energy sector.

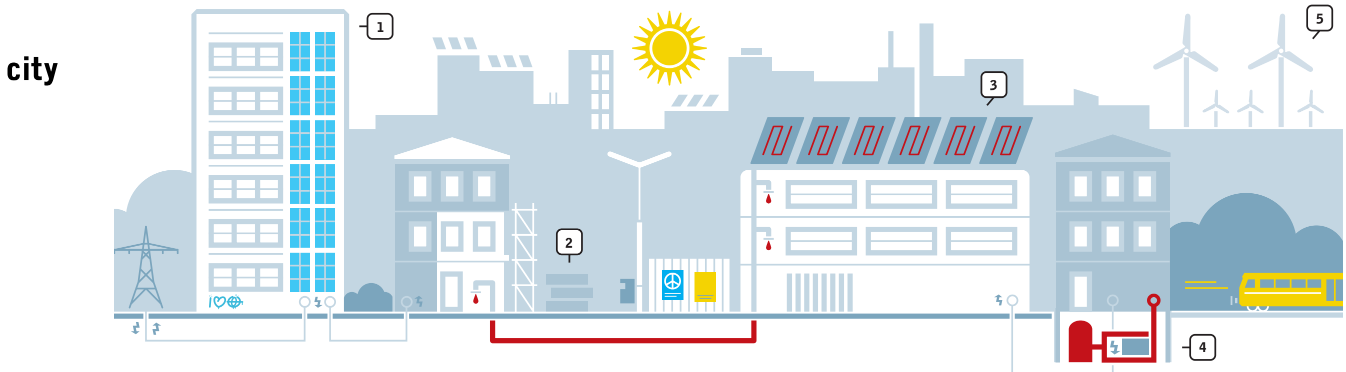
A huge proportion of global energy in 2050 will be produced by decentralised energy sources, although large scale renewable energy supply will still be needed for an energy revolution. Large offshore wind farms and concentrating solar power (CSP) plants in the sunbelt regions of the world will therefore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

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

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

figure 2.2: **a decentralised energy future**

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



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

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

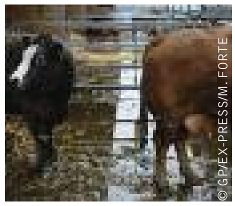


image COWS FROM A FARM WITH A BIOGAS PLANT IN ITTIGEN BERN, SWITZERLAND. THE FARMER PETER WYSS PRODUCES ON HIS FARM WITH A BIOGAS PLANT, GREEN ELECTRICITY WITH DUNG FROM COWS, LIQUID MANURE AND WASTE FROM FOOD PRODUCTION.

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.

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 25).

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 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.

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.

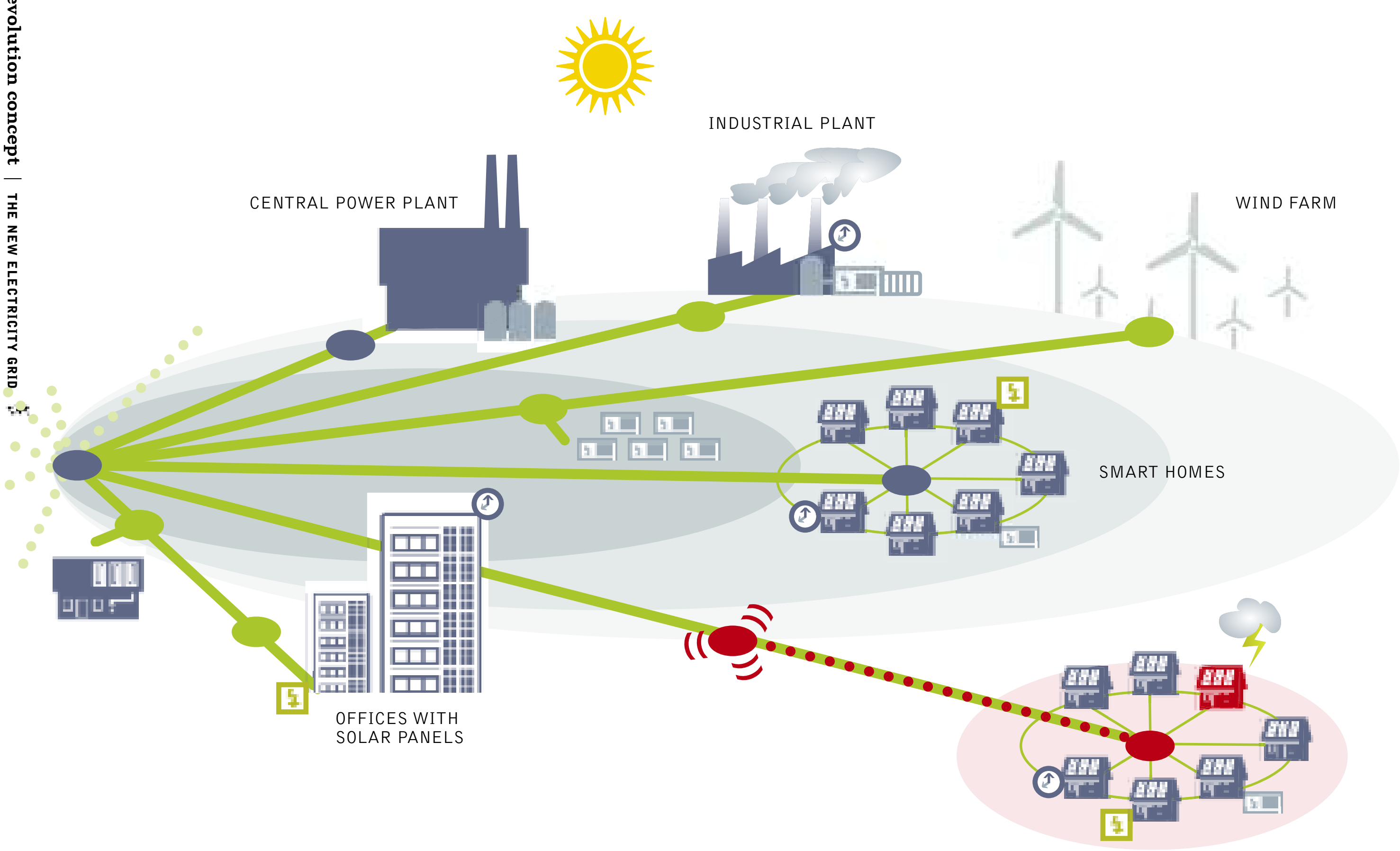
Creating Virtual Power Plants (VPP). Virtual power plants interconnect a range of real power plants (for example solar, wind and hydro) as well as storage options distributed in the power system using information technology. A real life example of a VPP is the Combined Renewable Energy Power Plant developed 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

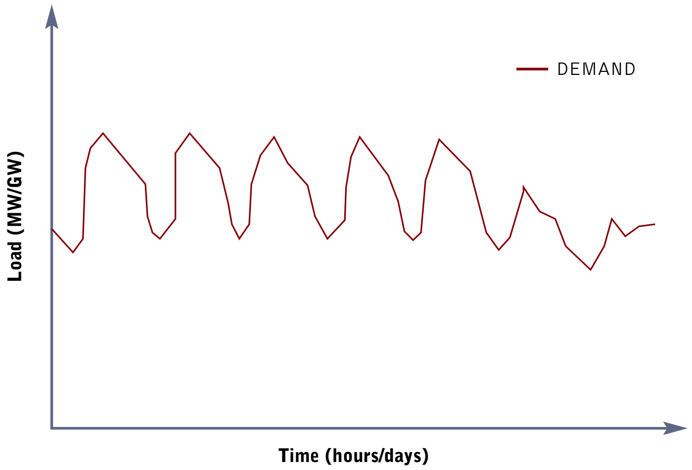
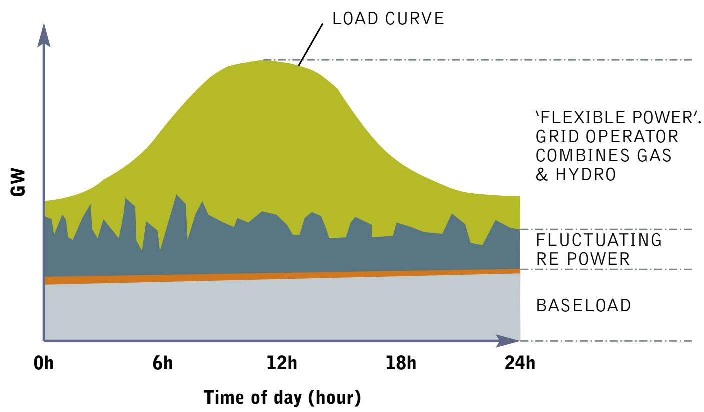


figure 2.5: the evolving approach to grids

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.

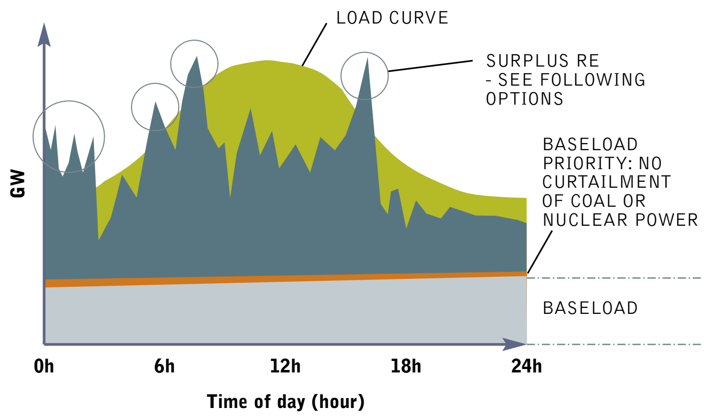


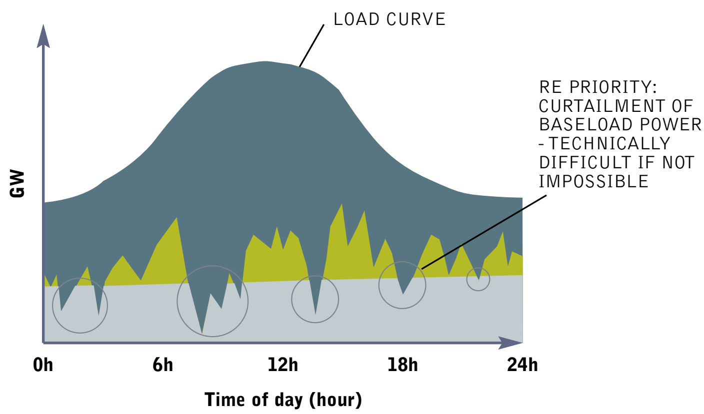
image GREENPEACE OPENS A SOLAR ENERGY WORKSHOP IN BOMA. A MOBILE PHONE GETS CHARGED BY A SOLAR ENERGY POWERED CHARGER.

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.

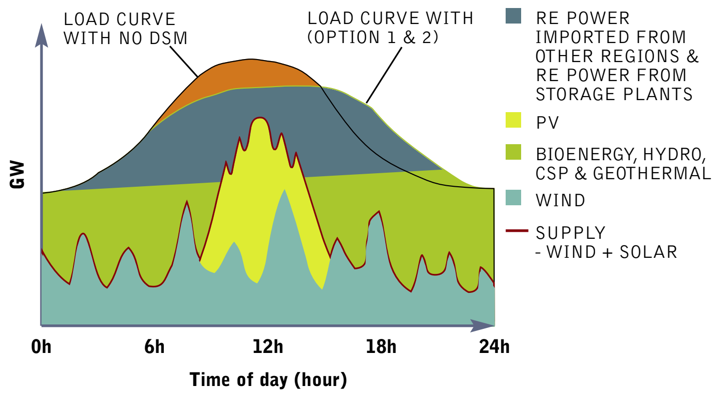
Technically difficult, not a solution.



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

3

RENEWABLE ENERGY PROJECT PLANNING BASICS

RENEWABLE ENERGY FINANCING BASICS

"investments in renewables are investments in the future."

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).

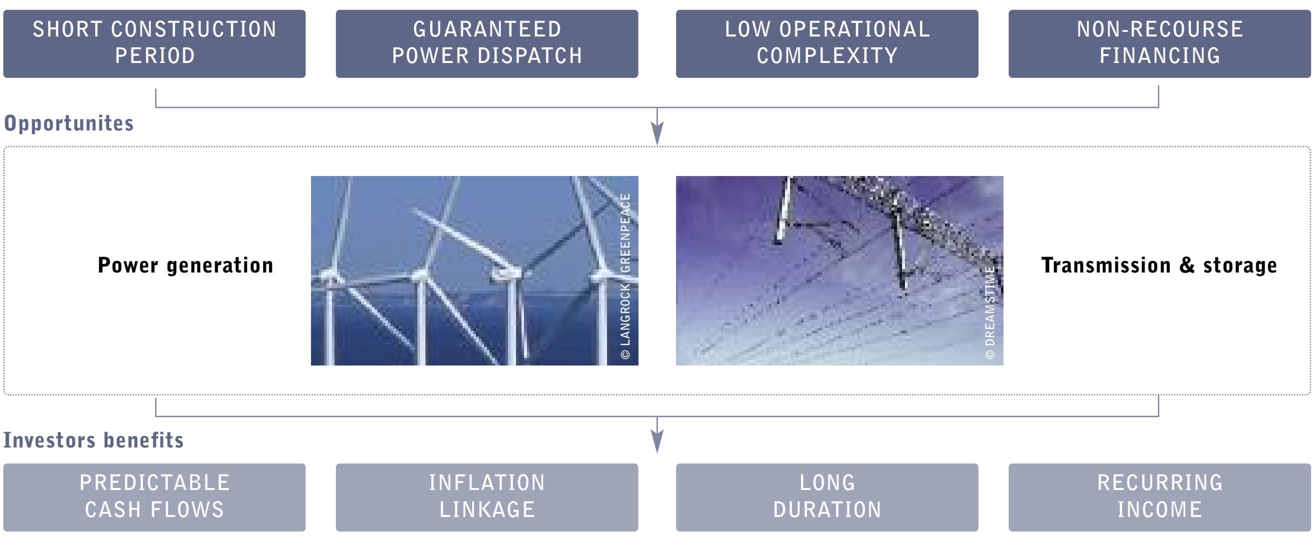
P = Project developer, **M** = Meteorological Experts, **I** = Investor, **U** = utility.

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

figure 3.1: return characteristics of renewable energies



source
SWISS RE PRIVATE EQUITY PARTNERS.

image A LARGE SOLAR SYSTEM OF $63M^2$ 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

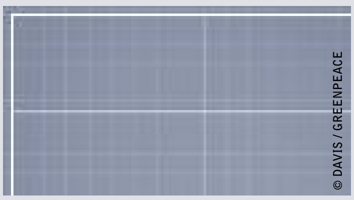
RISKS

Higher — Lower

Stage

DEVELOPMENT	CONSTRUCTION	OPERATIONS

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).

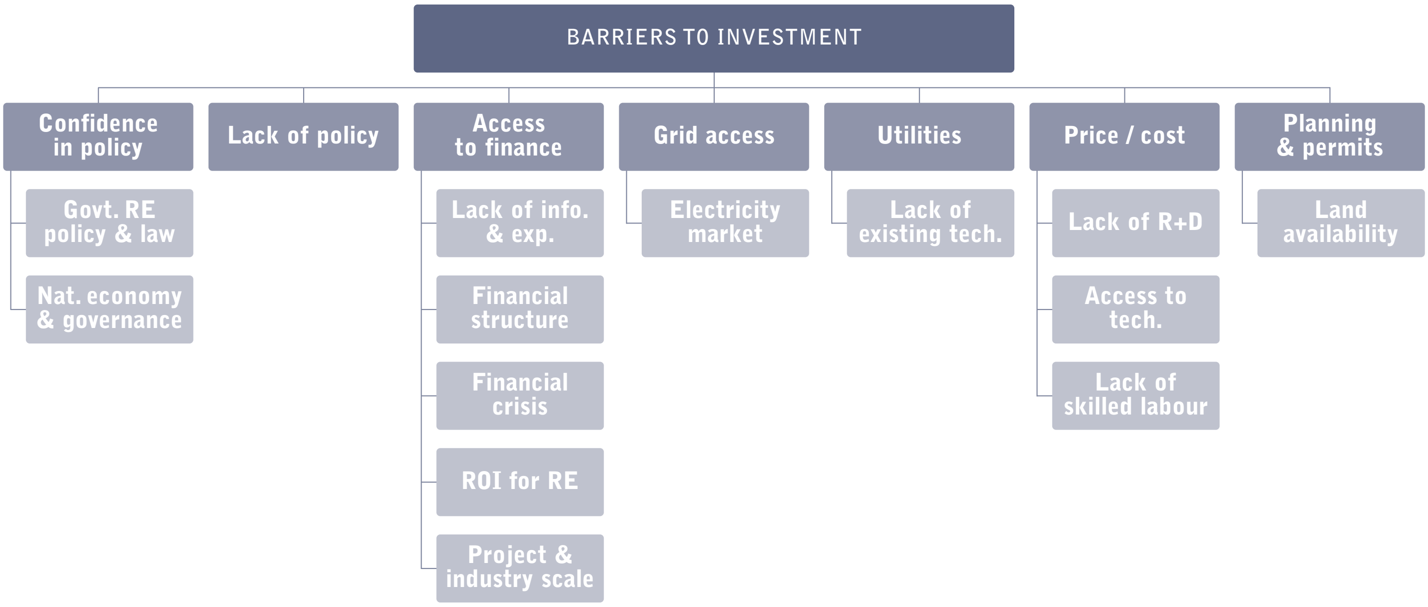
Concerns over planning and permit issues are significant, though vary significantly in their strength and nature depending on the jurisdiction.

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



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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

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 for Poland is based on government projections, current new power plant projects and formal announcements of planned or proposed power plant development projects. This research is based on the Institute for Renewable Energy (IEO)/ Warsaw and has been implemented in the energy modeling software (MESAP/PlaNet) by DLR. For the reference scenario it is assumed that there will be on change of energy policy in Poland and therefore renewable energy sources will remain disadvantaged while centralized coal power generation will remain the dominating technology.

This provides a baseline for comparison with the Energy [R]evolution scenario.

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

This global carbon dioxide emission reduction target translates into a carbon budget for Europe (EU27) which forms one of the key assumption for the Energy [R]evolution for Europe (EU27) Poland. 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[22] have been taken into account. The fast introduction of electric vehicles, combined with the implementation of smart grids and fast expansion of super grids allows a high share of fluctuating renewable power generation (photovoltaic and wind) to be employed. In the global secenario, renewable energy would pass 30% of the global energy supply just after 2020. The EU 27 Energy [R]evolution scenario shows that renewable energy would pass 20% of the EU's energy supply before 2020.

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

reference
22 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.[23] The new energy demand projections were developed from the University of Utrecht, Netherlands, based on an analysis of the future potential for energy efficiency measures in 2012. The biomass potential calculated for previous editions, judged according to Greenpeace sustainability criteria, has been developed by the German Biomass Research Centre in 2009 and has been further reduced for precautionary principles. The future development pathway for car technologies is based on a special report produced in 2012 by the Institute of Vehicle Concepts, DLR for Greenpeace International. Finally the Institute for Sustainable Futures (ISF) analysed the employment effects of the Energy [R]evolution and Reference scenarios.

4.1.1 status and future projections for renewable heating technologies

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

4.2 population development

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

table 4.1: population development projections

(IN MILLIONS)

	2010	2015	2020	2025	2030	2040	**2050**
Poland	38	38	38	38	38	36	**35**

source THE 2012 AGEING REPORT. ECONOMIC AND BUDGETARY PROJECTIONS FOR THE 27 EU MEMBER STATES (2010-2060)". EUROPEAN COMISSION, FEBRUARY 2012 AND - UNEP WORLD POPULATION PROSPECT 2010 (MEDIUM VARIANT).

4.3 economic growth

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

Although PPP assessments are still relatively imprecise compared to statistics based on national income and product trade and national price indexes, they are considered to provide a better basis for a scenario development.[24] 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 around 1.6% per year over the projection period till 2050. For Poland both scenarios assume an average GDP growth rate of 3.5% per annum till 2020 and 2.8% per annum over the entire time frame.

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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	2010-2020	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%
Poland	3.5%	2.7%	2.3%	2.8%
Eastern Europe/ Eurasia	4.2%	3.2%	1.9%	3.0%
India	7.6%	5.8%	3.1%	5.3%
China	8.2%	4.2%	2.7%	4.7%
Non OECD Asia	5.2%	3.2%	2.6%	3.5%
Latin America	4.0%	2.8%	2.2%	2.9%
Middle East	4.3%	3.7%	2.8%	3.5%
Africa	4.5%	4.4%	4.2%	4.4%

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

4.4 oil and gas price projections

The recent dramatic fluctuations in global oil prices have resulted in slightly higher forward price projections for fossil fuels. Under the 2004 'high oil and gas price' scenario from the European Commission, for example, an oil price of just €28 per barrel (/bbl) was assumed in 2030. More recent projections of oil prices by 2035 in the IEA's WEO 2011 range from €80/bbl in the 450 ppm scenario up to €116/bbl in current policies scenario.

Since the first Energy [R]evolution study was published in 2007, however, the actual price of oil has reached over €83/bbl for the first time, and in July 2008 reached a record high of more than €116/bbl. Although oil prices fell back to €83/bbl in September 2008 and around €66/bbl in April 2010, prices have increased to more than €91/bbl in early 2012. Thus, the projections in the IEA Current Policies scenario might still be considered too conservative. Taking into account the growing global demand for oil we have assumed a price development path for fossil fuels slightly higher than the IEA WEO 2011 "Current Policies" case extrapolated forward to 2050 (see Table 4.3).

As the supply of natural gas is limited by the availability of pipeline infrastructure, there is no world market price for gas. In most regions of the world the gas price is directly tied to the price of oil. Gas prices are therefore assumed to increase to €20-25/GJ by 2050.

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

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

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

4.5 cost of CO_2 emissions

The costs of CO_2 allowances needs to be included in the calculation of electricity generation costs. Projections of emissions costs are even more uncertain than energy prices, and a broad range of future estimates has been made in studies. Other projections have assumed higher CO_2 costs than than those included in this Energy [R]evolution study (57 €$_{2010}$/tCO_2)[25], reflecting estimates of the total external costs of CO_2 emissions. The CO_2 cost estimates in the 2010 version of the global Energy [R]evolution were rather conservative (42 €$_{2008}$/t). CO_2 costs are applied in Kyoto Protocol Non-Annex B countries only from 2030 on.

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

(€2010/tCO_2)

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

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

Further cost reduction potentials are assumed for fuel power technologies in use today for coal, gas, lignite and oil. Because they are at an advanced stage of market development the potential for cost reductions is limited, and will be achieved mainly through an increase in efficiency.[26]

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[27], while a 2007 US Department of Energy report found installing carbon capture systems to most modern plants resulted in a near doubling of costs.[28] These costs are estimated to increase the price of electricity in a range from 21-91%.[29]

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.[30] 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.[31]

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.[32] 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.[33]

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

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

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

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

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

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

4.7 cost projections for renewable energy technologies

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

It is possible to develop a wide spectrum of options to market maturity, using the individual advantages of the different technologies, and linking them with each other, and integrating them step by step into the existing supply structures. This approach will provide a complementary portfolio of environmentally friendly technologies for heat and power supply and the provision of transport fuels.

Many of the renewable technologies employed today are at a relatively early stage of market development. As a result, the costs of electricity, heat and fuel production are generally higher than those of competing conventional systems - a reminder that the environmental and social costs of conventional power production are not reflected in market prices. It is expected, however that large cost reductions can come from technical advances, manufacturing improvements and large-scale production, unlike conventional technologies. The dynamic trend of cost developments over time plays a crucial role in identifying economically sensible expansion strategies for scenarios spanning several decades.

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

Assumptions on future costs for renewable electricity technologies in the Energy [R]evolution scenario are derived from a review of learning curve studies, for example by Lena Neij and others[34], from the analysis of recent technology foresight and road mapping studies, including the European Commission funded NEEDS project (New Energy Externalities Developments for Sustainability)[35] 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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4.7.1 photovoltaics (PV)

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

The learning factor for PV modules has been fairly constant over the last 30 years with costs reducing by 20% each time the installed capacity doubles, indicating a high rate of technical learning. Assuming a globally installed capacity of 1,500 GW by between 2030 and 2040 in the Energy [R]evolution scenario, and with an electricity output of 2,600 TWh/a, we can expect that generation costs of around 4-8 €cents/kWh (depending on the region) will be achieved. During the following five to ten years, PV will become competitive with retail electricity prices in many parts of the world, and competitive with fossil fuel costs by 2030.

4.7.2 concentrating solar power (CSP)

Solar thermal 'concentrating' power stations (CSP) can only use direct sunlight and are therefore dependent on very sunny locations. Southern Europe has a technical potential for this technology which far exceeds local demand. The various solar thermal technologies have good prospects for further development and cost reductions. Because of their more simple design, 'Fresnel' collectors are considered as an option for additional cost trimming. The efficiency of central receiver systems can be increased by producing compressed air at a temperature of up to 10,000C°, which is then used to run a combined gas and steam turbine.

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

Depending on the level of irradiation and mode of operation, it is expected that long term future electricity generation costs of 5-8 €cents/kWh can be achieved. This presupposes rapid market introduction in the next few years.

table 4.6: photovoltaics (PV) cost assumptions

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

SCENARIO	2009	2015	2020	2030	2040	2050
E[R]						
Investment costs (€/kWp)	2,817	1,200	950	850	780	750
O & M costs €/(kW/a)	40	29	16	11	11	11

O & M = Operation and maintenance.

table 4.7: concentrating solar power (CSP) cost assumptions

INCLUDING COSTS FOR HEAT STORAGE AND ADDITIONAL SOLAR FIELDS

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

O & M = Operation and maintenance.

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

4.7.3 wind power

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

4.7.4 biomass

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

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

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

table 4.8: wind power cost assumptions

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

SCENARIO	2009	2015	2020	2030	2040	2050
E[R]						
Wind turbine offshore						
Investment costs (€/kWp)	4,875	3,500	2,200	1,800	1,600	1,500
O & M costs €/(kW · a)	173	155	122	99	94	81
Wind turbine onshore						
Investment costs (€/kWp)	1,422	1,125	975	967	972	1,016
O & M costs €/(kW/a)	51	42	41	42	44	46

O & M = Operation and maintenance.

table 4.9: biomass cost assumptions

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

O & M = Operation and maintenance.

4.7.5 geothermal

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

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

- for conventional geothermal power, from 12 €cents/kWh to about 7 €cents/kWh;
- for EGS, despite the presently high figures (about 17 – 25 €cents/kWh), electricity production costs - depending on the payments for heat supply - are expected to come down to around 6 €cents/kWh in the long term.

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

4.7.6 ocean energy

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

The cost of energy from initial tidal and wave energy farms has been estimated to be in the range of 20-80 €cents/kWh[36], and for initial tidal stream farms in the range of 11-22 €cents/kWh. Generation costs of 7-8 €cents/kWh are expected by 2030. Key areas for development will include concept design, optimisation of the device configuration, reduction of capital costs by exploring the use of alternative structural materials, economies of scale and learning from operation. According to the latest research findings, the learning factor is estimated to be 10-15% for offshore wave and 5-10% for tidal stream. In the long term, ocean energy has the potential to become one of the most competitive and cost effective forms of generation. In the next few years a dynamic market penetration is expected, following a similar curve to wind energy.

Because of the early development stage any future cost estimates for ocean energy systems are uncertain. Present cost estimates are based on analysis from the European NEEDS project.[37]

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.

references
36 G.J. DALTON, T. LEWIS (2011): PERFORMANCE AND ECONOMIC FEASIBILITY ANALYSIS OF 5 WAVE ENERGY DEVICES OFF THE WEST COAST OF IRELAND; EWTEC 2011.
37 WWW.NEEDS-PROJECT.ORG.

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

4.7.7 hydro power

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

table 4.12: hydro power cost assumptions

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

O & M = Operation and maintenance.

4.7.8 summary of renewable energy cost development

Figure 4.1 summarises the cost trends for renewable power technologies derived from the respective learning curves. It is important to note that the expected cost reduction is not a function of time, but of cumulative capacity (production of units), so dynamic market development is required. Most of the technologies will be able to reduce their specific investment costs to between 30% and 60% of current once they have achieved full maturity (after 2040).

Reduced investment costs for renewable energy technologies lead directly to reduced heat and electricity generation costs, as shown in Figure 4.2. Generation costs today are around 7 to 29 €cents/kWh for the most important technologies, including photovoltaic. In the long term, costs are expected to converge at around 5 to 10 €cents/kWh. These estimates depend on site-specific conditions such as the local wind regime or solar irradiation, the availability of biomass at reasonable prices or the credit granted for heat supply in the case of combined heat and power generation.

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

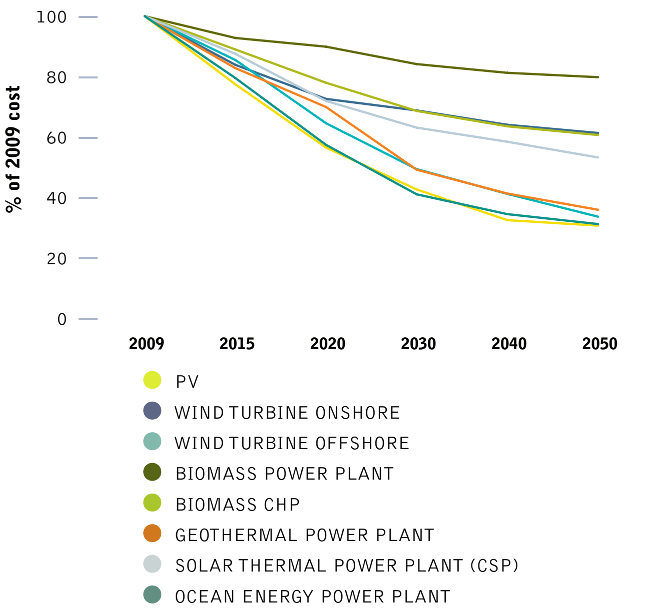
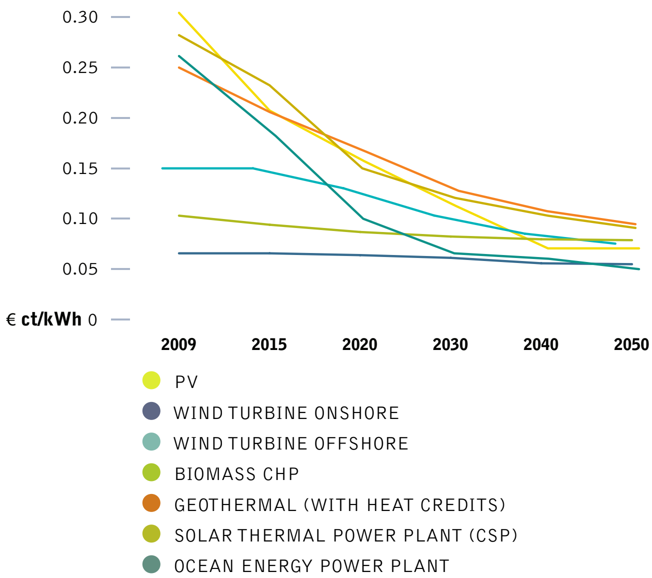


figure 4.2: expected development of electricity generation costs from fossil fuel and renewable options
EXAMPLE FOR OECD EUROPE



4.8 cost projections for renewable heating technologies

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

4.8.1 solar thermal technologies

Solar collectors depend on direct solar irradiation, so the yield strongly depends on the location. In very sunny regions, simple thermosiphon systems can provide total hot water demand in households at around 400 €/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.

4.8.2 deep geothermal applications

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

4.8.3 heat pumps

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

4.8.4 biomass applications

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

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

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

Main biomass input into renewable heating today is solid biomass – wood in various specifications from waste wood and residues to pellets from short rotation forestry. Biomass costs are as versatile: In Europe biomass costs ranged from 1-6 €/GJ for sawmill products, over 2-7 €/GJ for log wood to 6-18 €/GJ for wood pellets.[38]

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

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

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

* WITHOUT NETWORK

references

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

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

4.9 assumptions for fossil fuel phase out

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

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

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

4.9.1 oil – production decline assumptions

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

4.9.2 coal – production decline assumptions

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

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

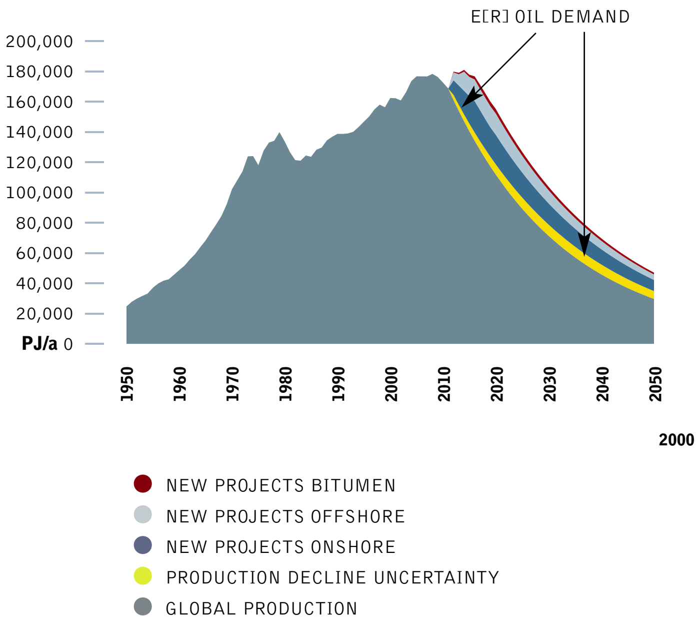
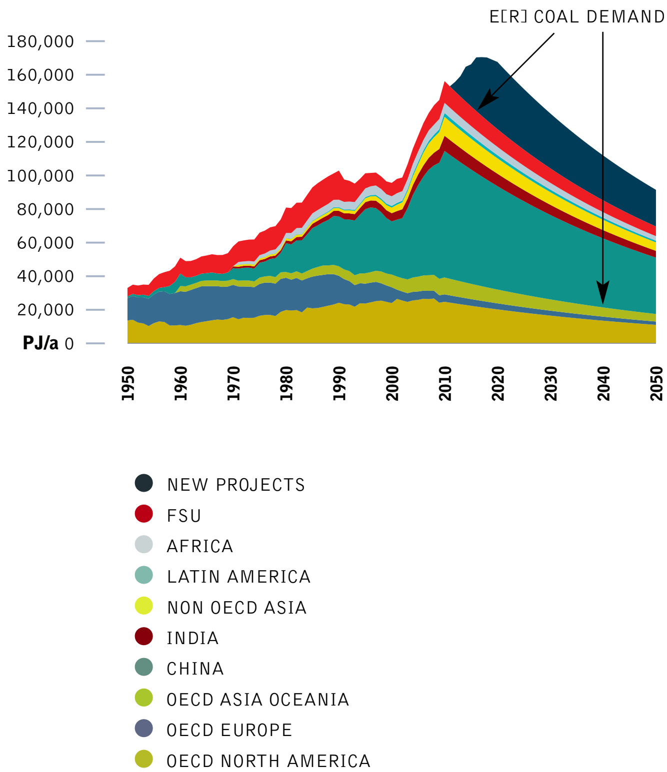


figure 4.4: coal scenario: base decline of 2% per year and new projects



4.10 review: greenpeace scenario projections of the past

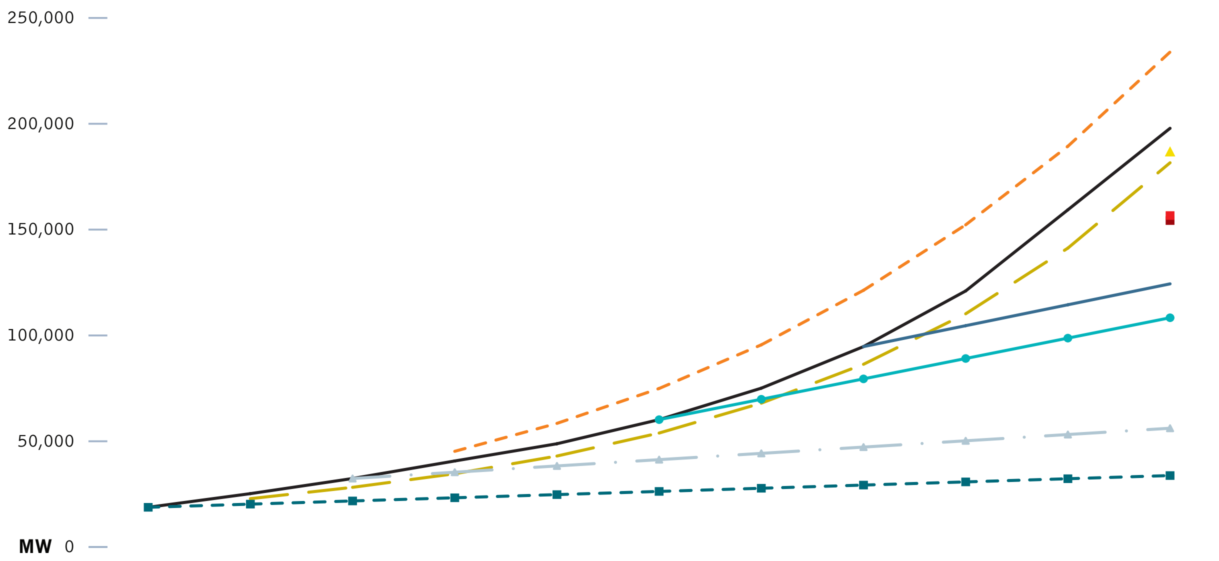
Greenpeace has published numerous projections in cooperation with renewable industry associations and scientific institutions in the past decade. This section provides an overview of the projections between 2000 and 2011 and compares them with real market developments and projections of the IEA World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

4.10.1 the development of the global wind industry

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

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

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



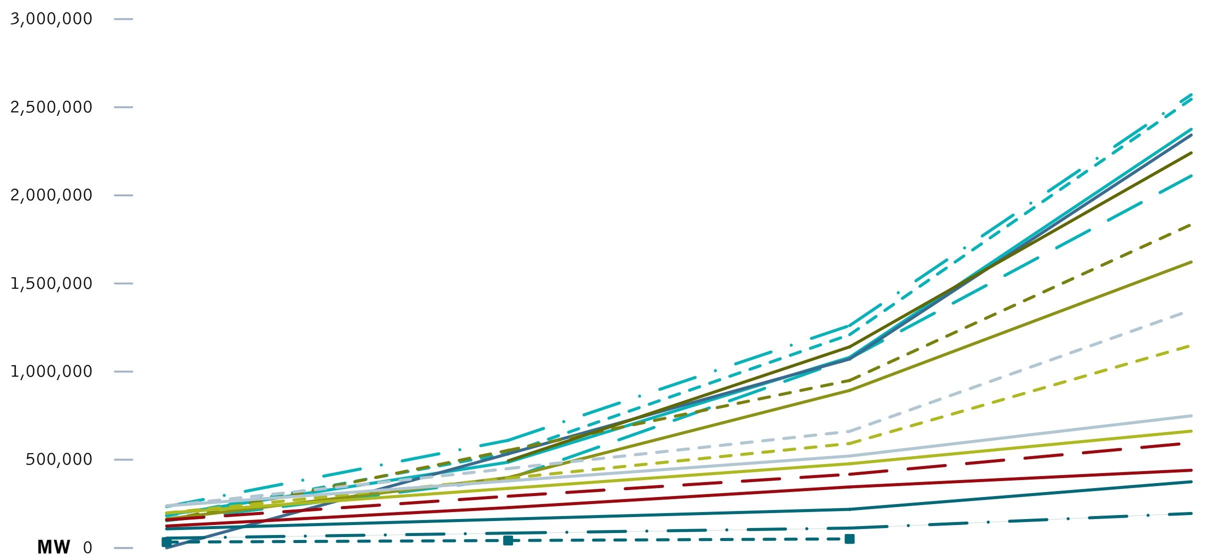
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
REAL	17,400	23,900	31,100	39,431	47,620	59,091	74,052	93,820	120,291	158,864	197,637
WF 10 (1999)		21,510	26,901	33,371	41,781	52,715	66,929	85,407	109,428	140,656	181,252
WF 12 (2002)				44,025	57,306	73,908	94,660	120,600	151,728	189,081	233,905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

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

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

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

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



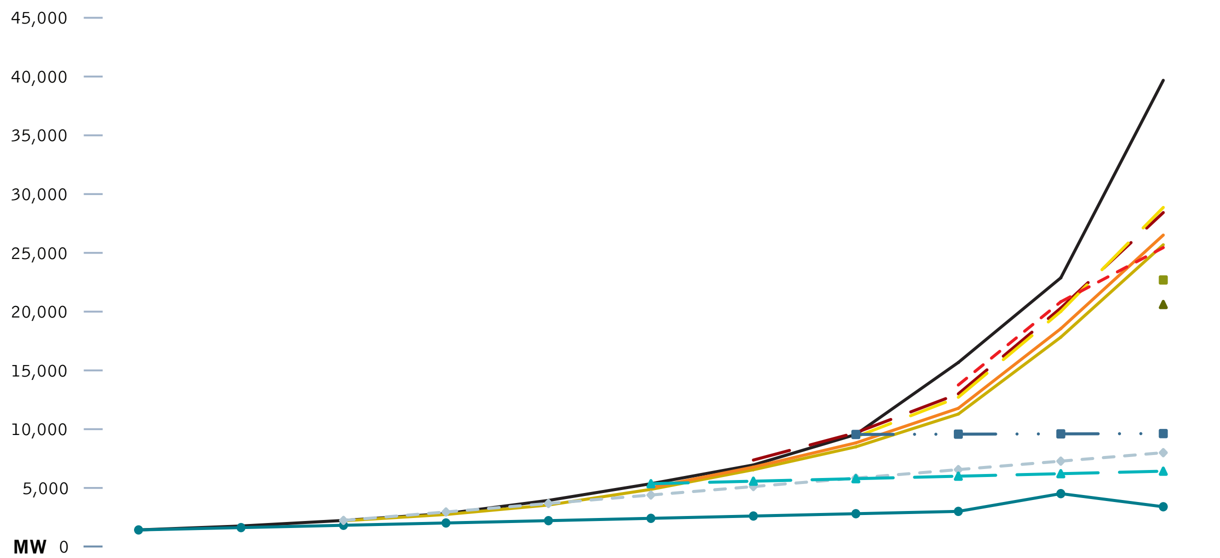
	2010	2015	2020	2030
WF 10 (1999)	181,252	537,059	1,209,466	2,545,232
WF 12 (2002)	233,905	610,000	1,261,157	2,571,000
GWEO 2006 (Advanced)	153,759	391,077	1,074,835	2,110,401
GWEO 2008 (Advanced)	186,309	485,834	1,080,886	2,375,000
GWEO 2008 (Advanced)	0	533,233	1,071,415	2,341,984
E[R] 2007	156,149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

4.10.2 the development of the global solar photovoltaic industry

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

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

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



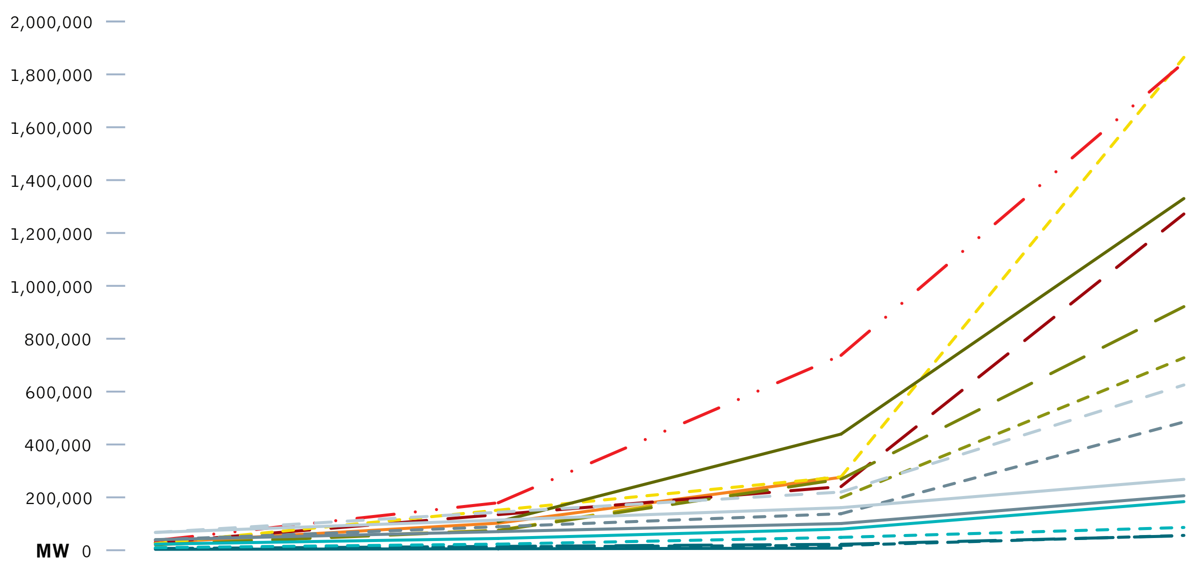
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
REAL	1,428	1,762	2,236	2,818	3,939	5,361	6,956	9,550	15,675	22,878	39,678
SG I 2001			2,205	2,742	3,546	4,879	6,549	8,498	11,285	17,825	25,688
SG II 2004						5,026	6,772	8,833	11,775	18,552	26,512
SG III 2006							7,372	9,698	13,005	20,305	28,428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

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

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

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

figure 4.8: photovoltaic: long term market projects until 2030



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

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

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

Four future pathways, the following models were assessed intensively:

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

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

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

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

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

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

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

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

key results of the poland energy [r]evolution scenario

ENERGY DEMAND BY SECTOR

ELECTRICITY GENERATION

FUTURE COSTS OF ELECTRICITY GENERATION

FUTURE INVESTMENTS IN THE POWER SECTOR

HEATING SUPPLY

FUTURE INVESTMENTS IN THE HEAT SECTOR

FUTURE EMPLOYMENT IN THE ENERGY SECTOR

TRANSPORT

DEVELOPMENT OF CO_2 EMISSIONS

PRIMARY ENERGY CONSUMPTION

image SEVERE FLOODING RAISED POLAND'S RIVERS TO THEIR HIGHEST LEVELS IN OVER A CENTURY, UNITED PRESS INTERNATIONAL REPORTED ON MAY 26, 2010. THE ASSOCIATED PRESS REPORTED THAT HEAVY RAINS, BEGINNING IN MID-MAY, HAD PUSHED RIVERS OVER THEIR BANKS THROUGHOUT SOUTHERN POLAND. PARTS OF HUNGARY, SLOVAKIA, AND THE CZECH REPUBLIC ALSO EXPERIENCED FLOODING.

5.1 energy demand by sector

Combining the projections on population development, GDP growth and energy intensity results in future development pathways for Poland'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 increases by 11% from the current 2,718 PJ/a to 3,017 PJ/a in 2050. In the Energy [R]evolution scenario, final energy demand decreases by 32% compared to current consumption and it is expected to reach 1,855 PJ/a by 2050.

Under the Energy [R]evolution scenario, due to economic growth, increasing living standards and electrification of the transport sector, electricity demand is expected to increase in the industry sector, as well as in the residential, service and transport sectors. Total electricity demand will rise from 119 TWh/a to 214 TWh/a by the year 2050. Compared to the Reference scenario, efficiency measures in the industry, residential and service sectors avoid the generation of about 46 TWh/a. This reduction can be achieved in particular by introducing highly efficient electronic appliances using the best available technology in all demand sectors.

Efficiency gains in the heating and cooling sector are even larger. Under the Energy [R]evolution scenario, demand for heating and cooling is expected to increase until 2015 and drop significantly afterwards (see Figure 5.4). Compared to the Reference scenario, consumption equivalent to 395 PJ/a is avoided through efficiency gains by 2050. As a result of energy-related renovation of the existing stock of residential buildings, the introduction of low energy standards and 'passive climatisation' for new buildings, as well as highly efficient air conditioning systems, 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)

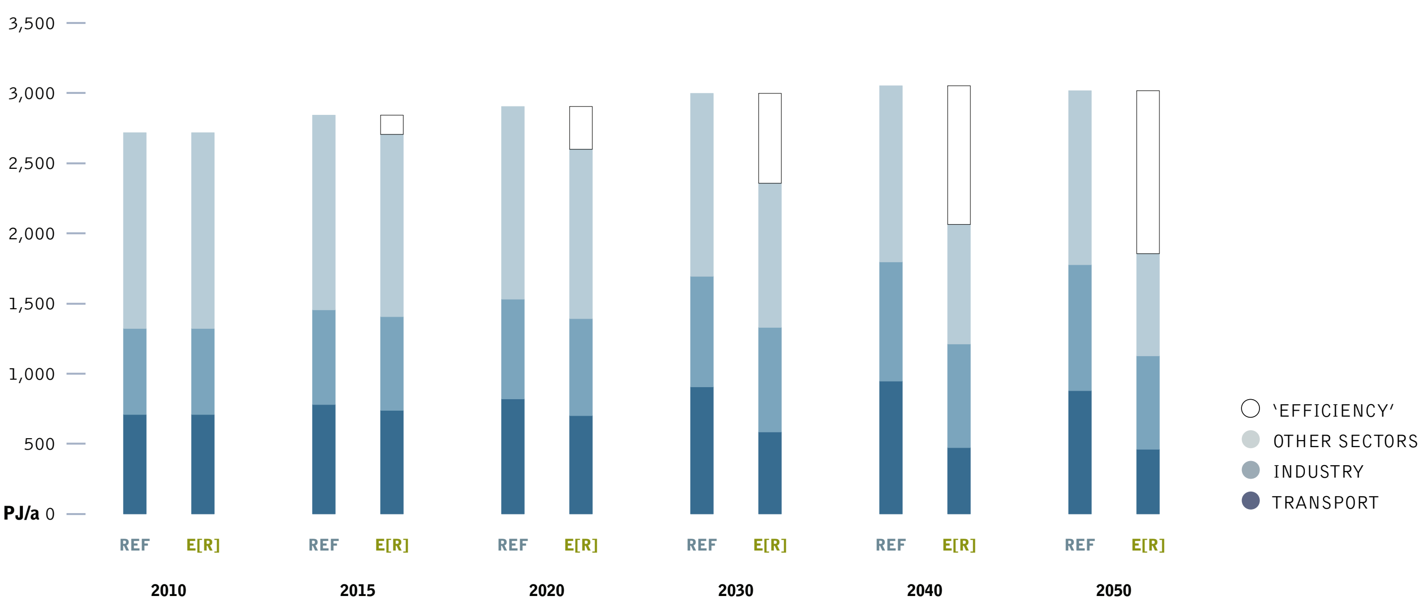


image DAM IN WLOCLAWEK, POLAND.

image TURBINES ON A WIND FARM, POLAND.

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

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

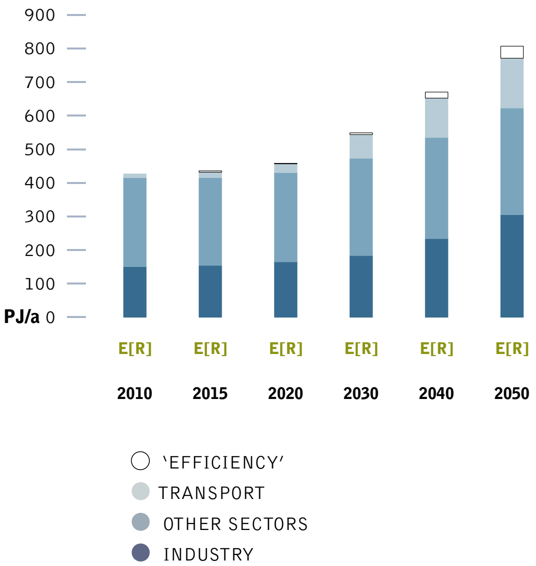


figure 5.4: development of heat demand by sector in the energy [r]evolution scenario

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

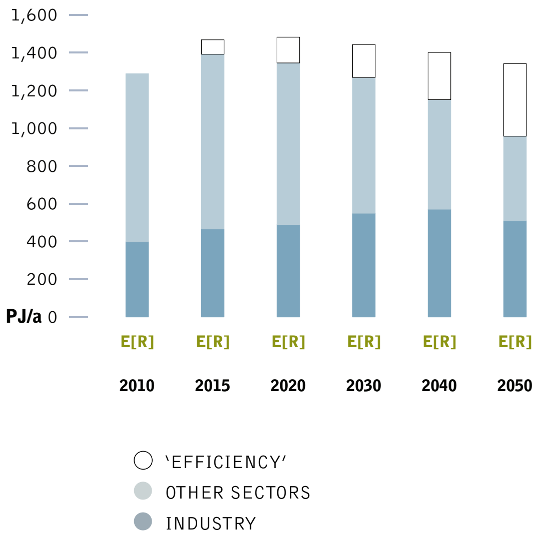
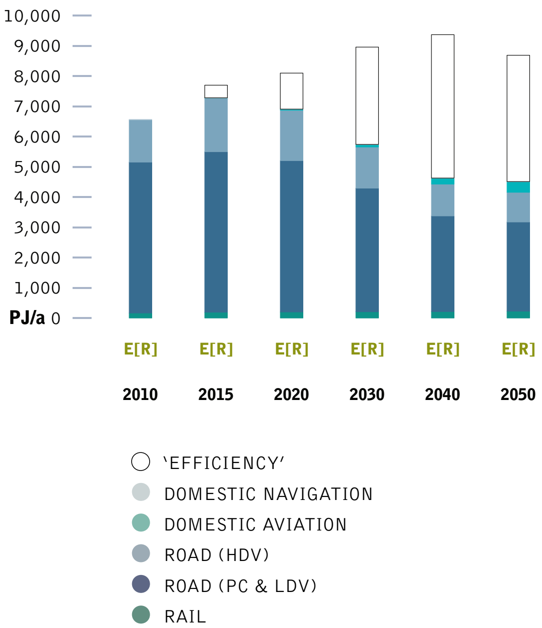


figure 5.3: development of the transport demand by sector in the energy [r]evolution scenario



5.2 electricity generation

The development of the electricity supply market under the Energy [R]evolution scenario is characterised by a dynamically growing renewable energy market. This will compensate for the decision not to rely on nuclear reactors and reduce the number of fossil fuel-fired power plants required for grid stabilisation. By 2050, 88% of the electricity produced in Poland will come from renewable energy sources. 'New' renewables – mainly wind and PV – will contribute 54% of electricity generation. The Energy [R]evolution scenario projects an immediate market development with high annual growth rates achieving a renewable electricity share of 23% already by 2020 and 52% by 2030. The installed capacity of renewables will reach 48 GW in 2030 and 119 GW by 2050.

Table 5.1 shows the comparative evolution of the different renewable technologies in Poland over time. Up to 2020 wind will remain the main contributor of the growing market. After 2020, the continuing growth of wind will be complemented by electricity from biomass and photovoltaics. The Energy [R]evolution scenario will lead to a high share of fluctuating power generation sources (photovoltaic, wind and ocean) of 41% by 2030 and 75% by 2050, 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	1	1	1	1	1
	E[R]	1	1	1	1	1
Biomass	REF	1	2	1	2	2
	E[R]	1	2	4	7	12
Wind	REF	1	5	10	10	9
	E[R]	1	9	27	51	74
Geothermal	REF	0	0	0	0	0
	E[R]	0	0	1	1	1
PV	REF	0	0	2	3	4
	E[R]	0	2	16	26	28
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	1	3
Total	**REF**	**3**	**8**	**14**	**15**	**16**
	E[R]	**3**	**15**	**48**	**87**	**119**

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)

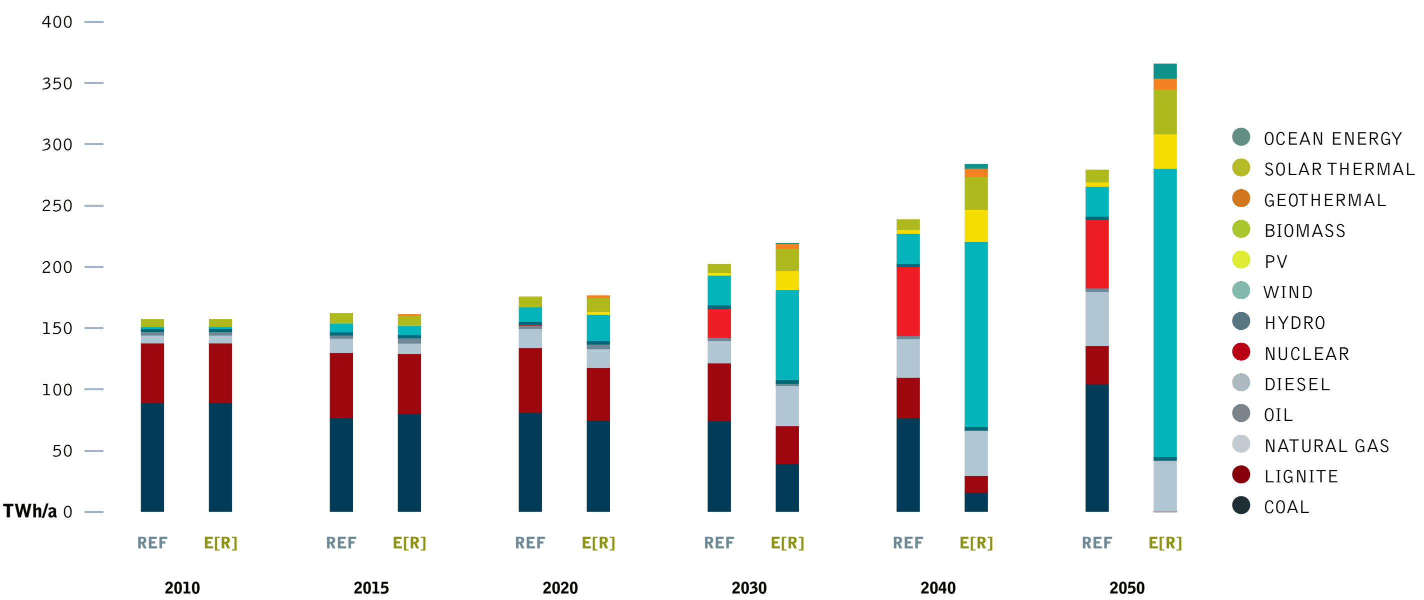


image AN OUTFLOW PIPE NEAR THE PATNÓW COAL FIRED POWER STATION WHOSE SMOKE STACKS ARE VIEWABLE IN THE BACKGROUND. THE POLLUTED WATER HAS A PH OF 14 AS A RESULT OF CLEANING OPERATIONS CARRIED OUT AT THE POWER STATION.

image SOLAR PANELS NEXT TO THE CONSTRUCTION SITE OF THE GREENPEACE FOUR-STOREY GLOBE REPLICA CLIMATE RESCUE STATION, SITUATED NEXT TO THE JOZWIN IIB OPEN-CAST COAL MINE NEAR KONIN, POLAND.

5.3 future costs of electricity generation

Figure 5.6 shows that the introduction of renewable technologies under the Energy [R]evolution scenario is possible while keeping costs per kWh of electricity generation similar to the reference scenario until 2030. The difference between the two scenarios will be less than 0.2 €ct/kWh up to 2020. Because of high prices for conventional fuels and the lower CO_2 intensity of electricity generation, from 2040 on electricity generation costs will become economically favourable under the Energy [R]evolution scenario and by 2050 costs will be 3.6 €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 supply costs rising from today's €10 billion per year to more than €36 billion in 2050, compared to €34 billion in the Energy [R]evolution scenario. Figure 5.6 shows that the Energy [R]evolution scenario not only complies with Poland'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 more than 7% lower than in the Reference scenario.

5.4 future investments in the power sector

It would require €264 billion in investment for the Energy [R]evolution scenario to become reality (including investments for replacement after the economic lifetime of the plants) - approximately €6.4 billion per year or €132 billion more than in the Reference scenario (€132 billion). Under the Reference version, the levels of investment in conventional power plants add up to almost 57% while approximately 43% change to "would be invested in renewable energy and CHP plants until 2050.

Under the Energy [R]evolution scenario, however, Poland would shift almost 90% of the entire investment towards renewables and CHP. Until 2030, the fossil fuel share of power sector investment would be focused mainly on gas power plants.

Because renewable energy has no fuel costs, the fuel cost savings in the Energy [R]evolution scenario reach a total of €98 billion up to 2050, or €2.5 billion per year. The total fuel cost savings therefore would cover 74% 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 the national economy.

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

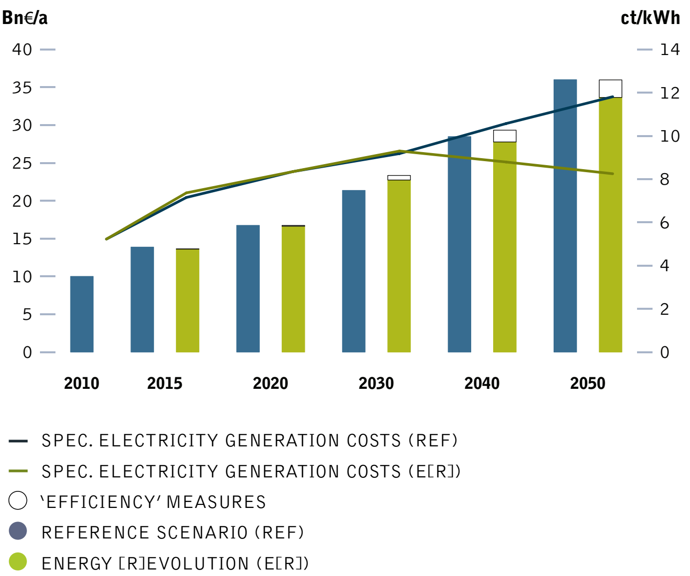
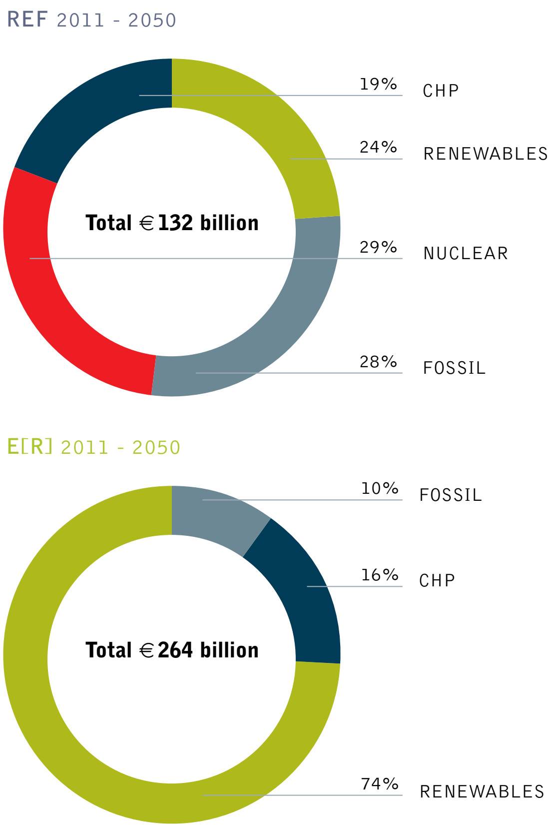


figure 5.7: investment shares - reference scenario versus energy [r]evolution scenario



5.5 heating supply

Today, renewables meet 11% of Poland's energy demand for heating and cooling, the main contribution coming from the use of biomass. Dedicated support instruments are required to ensure a dynamic development in particular for environmental heat (from heat pumps) and solar thermal heat for space heating and hot water as well as for renewable process heat production. In the Energy [R]evolution scenario, renewables provide 31% of Poland's total heat demand in 2030 and 76% in 2050.

- Energy efficiency measures help to reduce the currently growing energy demand for heating and cooling by 28% in 2050 (relative to the reference scenario), in spite of improving living standards and economic growth.
- In the industry sector solar collectors, geothermal energy (incl. heat pumps) as well as electricity and hydrogen 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 and cooling in Poland over time. Biomass will remain the main contributor to the growing market. From 2020 on, the continuing growth of solar collectors, a growing share of geothermal and environmental heat as well as heat from renewable hydrogen 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	151	164	173	193	216
	E[R]	151	153	157	178	191
Solar (heating & cooling)	REF	0	8	13	17	20
	E[R]	0	22	92	139	180
Geothermal heat and heat pumps	REF	1	2	5	8	11
	E[R]	1	35	107	174	203
Hydrogen	REF	0	0	0	0	0
	E[R]	0	0	4	11	28
Total	**REF**	**152**	**174**	**191**	**218**	**247**
	E[R]	**152**	**210**	**360**	**502**	**602**

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

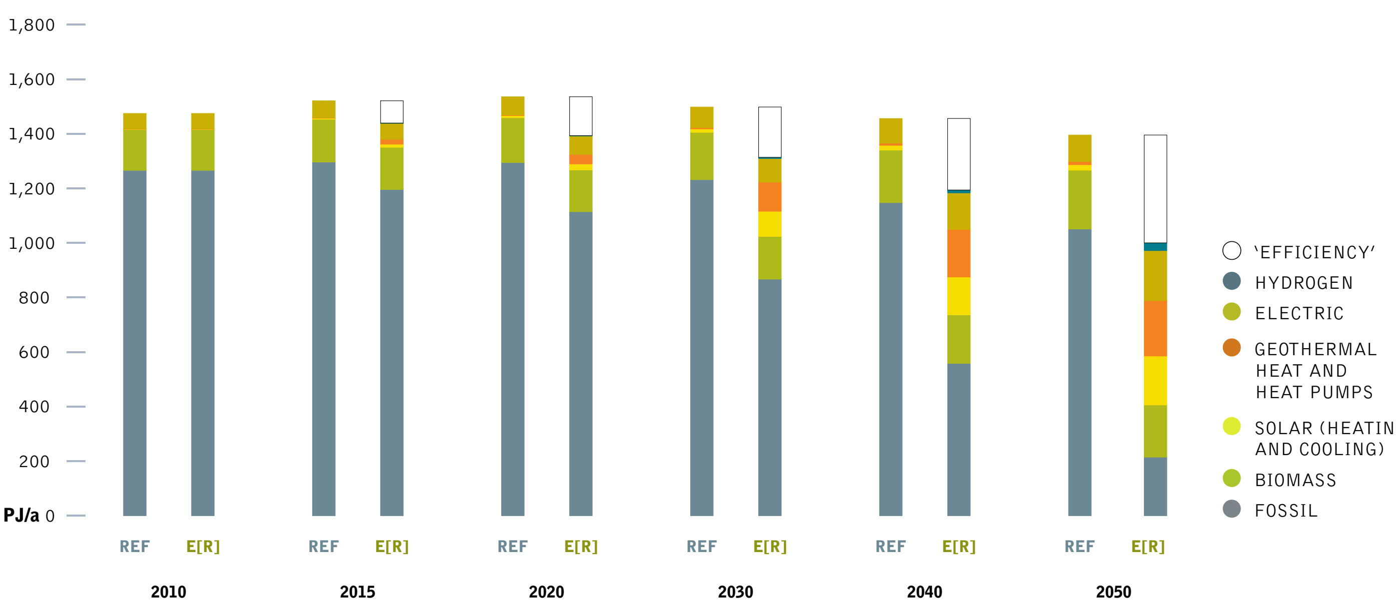


image WATER POWER PLANT PIPES, POLAND.

image WIND FARM IN POLAND.

5.6 future investments in the heat sector

Also in the heating and cooling sector the Energy [R]evolution scenario would require a major revision of current investment strategies in heating technologies. Especially solar thermal, solar cooling and geothermal and heat pump technologies need enormous increase in installations, if these potentials are to be tapped for the heat sector. These technologies are practically non-existent in Poland today. The use of biomass for heating purposes will be substantially reduced in the Energy [R]evolution scenario and be replaced by more effcient and sustainable renewable heating technologies.

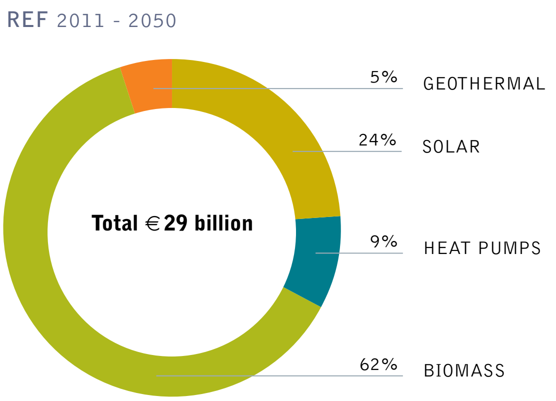
Renewable heating technologies are extremely variable, from low tech biomass stoves and unglazed solar collectors to very sophisticated enhanced geothermal systems and solar cooling systems. Thus it can only roughly be calculated, that the Energy [R]evolution scenario in total requires around €100 billion 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.

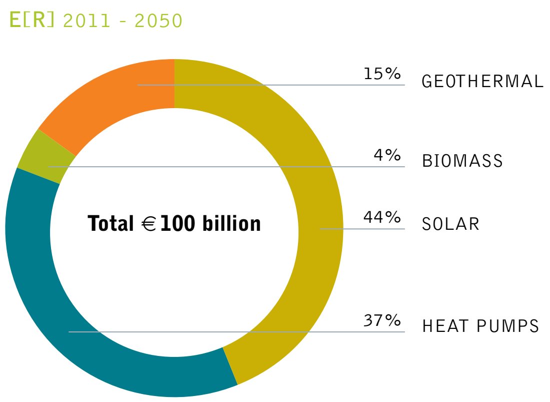
table 5.3: renewable heat generation capacities under the reference scenario and the energy [r]evolution scenario IN GW

		2010	2020	2030	2040	2050
Biomass	REF	28	32	33	33	33
	E[R]	28	27	18	13	11
Geothermal	REF	0	0	0	1	1
	E[R]	0	1	2	3	10
Solar thermal	REF	0	2	4	5	6
	E[R]	0	6	27	40	49
Heat pumps	REF	0	0	1	1	2
	E[R]	0	3	11	21	20
Total[1)]	**REF**	**28**	**35**	**38**	**40**	**42**
	E[R]	**28**	**37**	**58**	**77**	**89**

1) excluding direct electric heating

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





5.8 transport

A key target in Poland is to introduce incentives for people to drive smaller cars. In addition, it is vital to shift transport use to efficient modes like rail, light rail and buses, especially in the expanding large metropolitan areas. Together with rising prices for fossil fuels, these changes reduce the huge growth in car sales projected under the Reference scenario. Due to population increase, GDP growth and higher living standards, energy demand from the transport sector is expected to increase in the reference scenario by 24% to 879 PJ/a in 2050, 170 PJ/a higher than today's levels (709 PJ/a). However, in 2050 efficiency measures and mode shifts will save 48% compared to the Reference scenario (879 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 12% of the transport sector's total energy demand in the Energy [R]evolution, while in 2050 the share will be 32%.

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	17	17	19	20	22
	E[R]	17	20	21	21	23
Road	REF	640	788	865	889	797
	E[R]	640	667	545	422	393
Domestic aviation	REF	0	5	12	28	50
	E[R]	0	4	8	20	35
Domestic navigation	REF	0	0	0	0	0
	E[R]	0	0	0	0	0
Total	**REF**	**656**	**810**	**896**	**937**	**869**
	E[R]	**656**	**691**	**574**	**463**	**451**

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

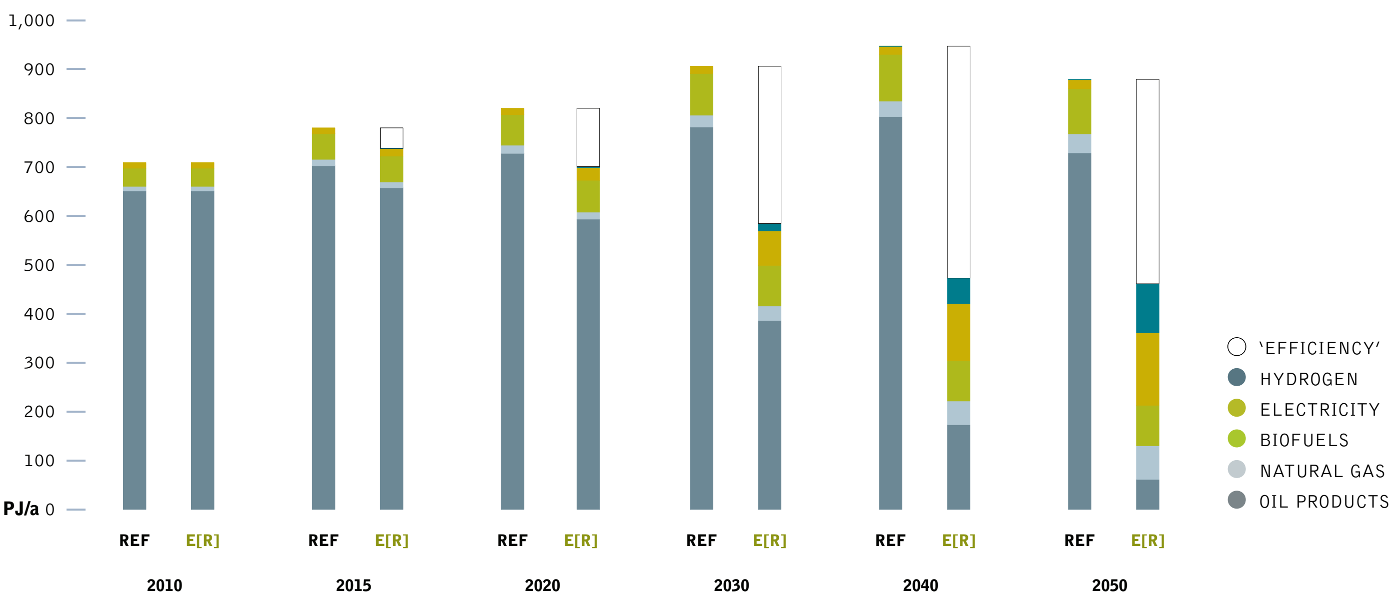


image AERIAL VIEW OF WIND TURBINES IN POLAND NEAR OTMUCHOW CITY.

image FORESTRY AND TIMBER HARVESTING IN POLAND.

5.9 development of CO_2 emissions

While Poland's emissions of CO_2 will decrease by 16% between 2010 and 2050 under the Reference scenario, under the Energy [R]evolution scenario they will decrease from 309 million tonnes in 2010 to 36 million tonnes in 2050. Annual per capita emissions will drop from 8 tonnes to 1 tonne. In spite of the abstinence of nuclear power production and increasing power 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 also in the transport sector. With a share of 38% of CO_2, the industry sector will be the largest sources of emissions in 2050. By 2050, Poland's CO_2 emissions are 90% below 1990 levels.

5.10 primary energy consumption

Taking into account the assumptions discussed above, the resulting primary energy consumption under the Energy [R]evolution scenario is shown in Figure 5.11. Under the Energy [R]evolution scenario, primary energy demand will decrease by 27% from today's 4,224 PJ/a to 3,085 PJ/a. Compared to the Reference scenario, overall primary energy demand will be reduced by 40% in 2050 under the Energy [R]evolution scenario (Reference scenario: 5,133 PJ in 2050).

The Energy [R]evolution version aims to phase out coal and oil as fast as technically and economically possible. This is made possible mainly by replacement of coal power plants with renewables and a fast introduction of very efficient electric vehicles in the transport sector to replace oil combustion engines. This leads to an overall renewable primary energy share of 27% in 2030 and 66% in 2050. In contrast to the Reference scenario, no nuclear power plants will be built in Poland in the Energy [R]evolution scenario.

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

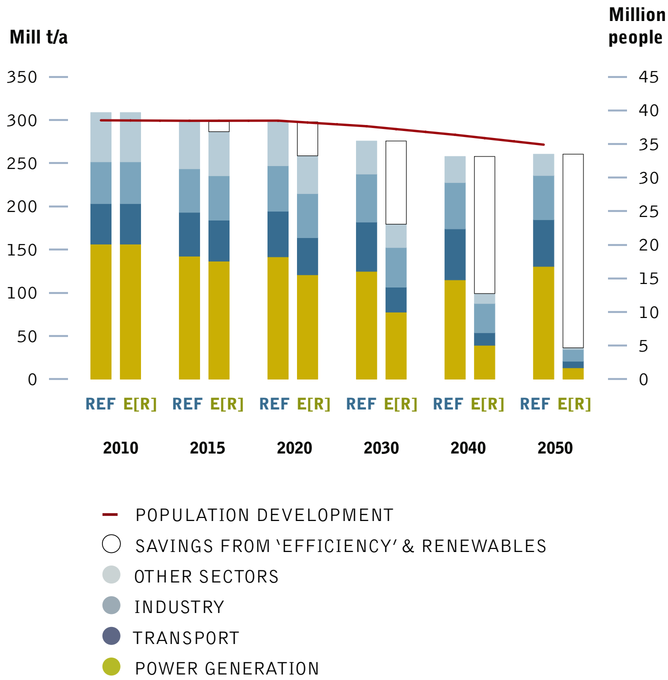


figure 5.11: primary energy consumption under the reference scenario and the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

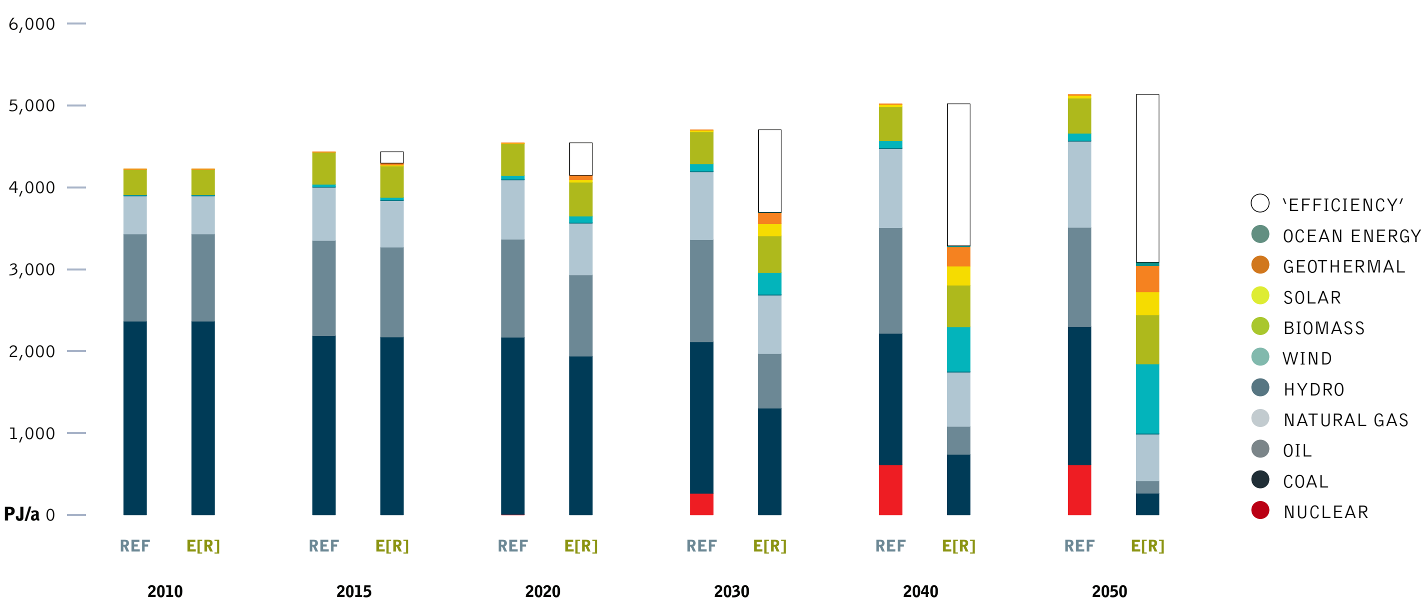


table 5.6: investment costs for electricity generation and fuel cost savings under the energy [r]evolution scenario compared to the reference scenario

ACCUMULATED INVESMENT COSTS		2011 - 2020	2021 - 2030	2031 - 2040	2041 - 2050	2011 - 2050	2011 - 2050 AVERAGE PER ANNUM
DIFFERENCE REF MINUS E[R]							
Conventional (fossil + nuclear)	billion €	-0.4	13.8	28.1	6.8	48.3	1.2
Renewables (incl. CHP)	billion €	-6.7	-36.2	-58.1	-79.4	-180.4	-4.5
Total	billion €	-7.1	-22.4	-30.1	-72.5	-132.1	-3.3

ACCUMULATED FUEL COST SAVINGS							
SAVINGS CUMULATIVE E[R] VERSUS REF							
Fuel oil	billion €	-1.6	-0.2	4.8	6.3	9.4	0.2
Gas	billion €	2.4	-9.0	-13.6	-1.8	-22.0	-0.5
Hard coal	billion €	1.2	12.0	25.4	47.9	86.5	2.2
Lignite	billion €	0.6	1.7	2.1	4.2	8.7	0.2
Nuclear energy	billion €	0.0	1.4	6.0	8.1	15.5	0.4
Total	billion €	2.7	5.9	24.7	64.7	98.0	2.5

table 5.7: accumulated investment costs for heat generation and fuel cost savings under the energy [r]evolution scenario compared to the reference scenario

ACCUMULATED INVESTMENT COSTS							
DIFFERENCE E[R] MINUS REF							
Renewable	billion €	-0.6	21.1	27.8	22.7	71.0	1.8

employment projections

6

"economy and ecology goes hand in hand with new employment."

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

6.1 methodology to calculate jobs

Greenpeace International and the European Renewable Energy Council have published four global Energy [R]evolution scenarios. These compare a low-carbon Energy [R]evolution scenario to a Reference scenario based on the International Energy Agency (IEA) "business as usual" projections (from the 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 Poland's Energy [R]evolution and Reference scenario.

Employment is projected for Poland 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 & Harris (2012a).

6.1.1 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 include:

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

A "regional job multiplier" is used to adjust the Organisation for Economic Co-operation and Development (OECD) employment factors for the likely effects of energy developments in Poland. The multiplier is based on how labour-intensive economic activity is in Poland compared to the OECD average, and is used to adjust employment factors to reflect the fact that more employment will tend to be created per project in economies which are more labour intensive. It would be preferable to use local factors, but there is insufficient employment data for most technologies.

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

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

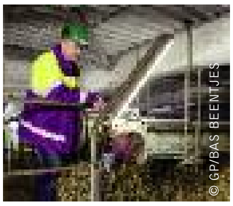


table 6.1: methodology overview

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

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

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

6.1.2 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 cases. There are also some significant areas of employment that are not included, including replacement of generating plant, and energy efficiency jobs. However, within the limits of data availability, the figures presented are indicative of employment levels in the electricity and heat sectors under the two scenarios.

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.

6.1.3 employment factors

The employment factors used in the 2013 Poland analysis are shown in Table 6.3 on the following page, with the main source given in the notes. Local factors are used for coal, lignite, and biomass fuel supply, geothermal heat, and solar thermal heat. All other factors are the OECD factors from the 2012 global analysis (Rutovitz & Harris 2012a).

A regional multiplier is applied to each of the non-local factors in the employment calculation, to adjust for the fact that labour productivity in Poland is lower than the OECD average.

6.1.4 coal, gas and renewable technology trade

It is assumed that all manufacturing for energy technologies, other than wind and PV, occurs within Poland, and that only 30% of manufacturing for these two technologies occurs within the country.

The projection for gas produced within Poland is shown in Table 6.2 for both scenarios. This is calculated by assuming gas production remains constant, and comparing this to the gas consumption in the two energy scenarios.

It is assumed that coal production matches coal consumption for the study period, although there was a small amount of coal import during 2010.

table 6.2: proportion of fuel produced within poland

	REFERENCE				ENERGY [R]EVOLUTION			
	2010	2015	2020	2030	2010	2015	2020	2030
Gas	26%	19%	12%	7%	26%	22%	16%	11%

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.

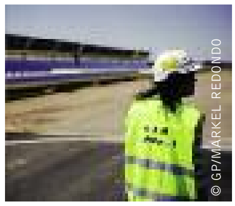


table 6.3: employment factors used in the 2013 analysis for poland

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	53.1	Note 1
Lignite	5	7.7	3.5	0.1	24.5	Note 1
Gas	2	1.7	1.0	0.1	21.9	Note 2
Nuclear	10	13.7	1.3	0.3	0.001 jobs per GWh (not PJ)	Note 3
Biomass	2	14.0	2.9	1.5	82.9	Note 4
Hydro	2	6.0	1.5	0.3		Note 5
Wind onshore	2	2.5	6.1	0.2		Note 6
Wind offshore	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	11.3 job years/MW (based on annual installations)					Note 11
Solar – heat	10.6 job years/MW (based on annual installations)					Note 12
Combined Heat and Power (CHP)	CHP technologies use the factor for the technology, i.e. coal, gas, biomass, geothermal, etc., increased by a factor of 1.5 for O&M only.					
Oil and diesel	Use the employment factors for gas					

sources for employment factors

1. Coal and lignite: coal mining employment per PJ is from calculated national statistics for 2012 (State Mining Authority 2012), using data from Eurocoal for the energy content per tonne of coal (Euracoal 2011). Construction, manufacturing and O&M factors are from the Jobs and Economic Development Impact model (JEDI) model (National Renewable Energy Laboratory 2011a).

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

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

4. Bioenergy: Fuel employment per PJ primary energy is derived from the average reported values for employment and energy supply for the solid biomass sector in 2010 and 2011 (EurObserv'ER 2012). Employment factors for construction, manufacturing and O&M use the average values of several European and USA studies (Kjaer 2006; Thornley 2006; Thornley et al. 2008; Tourkolias & Mirasgedis 2011; Moreno & López 2008; Thornley et al. 2009).

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

6. Wind: 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 European Wind Energy Association (European Wind Energy Association 2009). The O&M factor is an average of eight reports from USA, Europe, the UK and Australia (Rutovitz & Harris 2012a).

7. Solar PV: The solar PV installation employment factor is the average of five estimates in Germany and the USA, 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, and O&M factor is derived from a study conducted by Sinclair Knight Merz (2005). The O&M factors are the weighted averages from employment data reported for thirteen power stations, totalling 1050 MW in the USA, Canada, Greece and Australia (some of them hypothetical). The manufacturing factor is derived from a USA study (Geothermal Energy Association 2010).

9. Solar thermal power: OECD figures for construction and O&M were derived from a weighted average of 19 reported power plants (3223 MW) in the USA, Spain and Australia (Rutovitz & Harris, 2012a). The manufacturing factor came from the European Renewable Energy Council (2008, page 16).

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

11. Geothermal and heat pumps: One overall factor has been used for jobs per MW installed each year, from the annual reported employment and increase in capacity for 2010 (EurObserv'ER 2012). Annual employment is decreased by 20% to exclude what may be indirect jobs, using an approximation of 20% based on the proportion of costs assigned to pumps and ducting (Goetzler et al. 2009).

12. Solar thermal heating: One overall factor has been used for jobs per MW installed from the annual reported employment and increase in capacity for 2010 (EurObserv'ER 2012). Reported employment is decreased by 15% to exclude what may be indirect jobs, assuming that half of manufacturing is non-sector specific.

6.1.5 regional adjustment factor

Most available employment factors are for those OECD countries with significant renewable energy development. Many are from the USA or Germany, which also have high labour productivity (defined as the GDP created per worker). These employment factors may require adjustment for differing stages of economic development.

Labour productivity per person in Poland in 2010 was 46% lower than in the OECD as a whole. Broadly, the lower the cost of labour in a country, the greater the number of workers that will be employed to produce a unit of any particular output, be it manufacturing, construction or agriculture. This is because when labour costs are low, labour is relatively affordable compared to mechanised means of production.

Low average labour costs are closely associated with low GDP per capita, a key indicator of economic development. This means changes to levels of production in any given sector of the economy are likely to have a greater impact on jobs in countries with lower GDP per person. Ideally, employment factors would be derived for all the technologies using local data. In practice, data is frequently not available.

Regional multipliers based on the ratio of labour productivity in Poland to labour productivity in the OECD of 1.7 in 2010, 1.7 in 2015, and 1.4 in 2030, were derived for this study. Economy-wide average labour productivity (excluding agriculture) is derived from the Key Indicators of the Labour Market (KILM) database (International Labour Organization 2011). The projected growth in GDP is taken from the OECD projections until 2014, and then from Price Waterhouse Coopers projection of GDP growth to 2015 (PWC Economics 2013), with population projections taken from Poland's Central Statistics Office (Central Statistical Office 2013).

The derived local employment factors are compared to OECD factors in Table 6.4. The average value of the ratio is 2.5, somewhat higher than the regional multiplier for 2010 derived from labour productivity. We have conservatively used the calculated factor.

table 6.4: comparison of local employment factors and OECD factors

	UNIT	POLAND	OECD	RATIO
Coal	Jobs/PJ	53.1	22.8	2.3
Biomass	Jobs/PJ	82.9	32.2	2.6
Geothermal - heat	Job years/MW	11.3	3.0	3.8
Solar thermal	Job years/MW	10.6	7.4	1.4
Average ratio				2.5

6.1.6 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 6.5 below. These declines rates are calculated directly from the cost data used in the Energy [R]evolution modelling for Poland.

table 6.5: technology cost decline factors

	ANNUAL DECLINE IN JOB FACTORS		
	2010-2015	2015-2020	2020-30
Coal	0.3%	0.3%	0.5%
Lignite	0.4%	0.4%	0.4%
Gas	0.5%	0.5%	1.0%
Oil	0.4%	0.4%	0.8%
Diesel	0.0%	0.0%	0.0%
Nuclear	0.0%	0.0%	0.0%
Biomass	1.6%	1.1%	0.7%
Hydro - large	-0.6%	-0.6%	-0.9%
Hydro – small	-0.6%	-0.6%	-0.9%
Wind onshore	1.6%	2.2%	0.2%
Wind offshore	6.4%	8.9%	3.9%
Solar PV	12.0%	4.6%	2.2%
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	0.3%	0.3%	0.5%
Gas CHP	0.9%	1.0%	1.0%
Oil CHP	0.4%	0.4%	0.8%
Biomass CHP	2.0%	2.2%	2.2%
Geothermal CHP	2.6%	3.2%	4.5%
Geothermal - heat	0.0%	0.2%	0.9%
Solar thermal heat	0.0%	0.9%	1.8%

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

6.2 future employment in the energy sector

Energy sector jobs in Poland are higher in the Energy [R]evolution scenario at every stage in the projection. The coal sector continues the decline of the last decades in both scenarios. In 2015, strong growth in renewable energy in the Energy [R]evolution scenario mean overall energy employment increases by 29,400 (17%), while jobs in the Reference scenario drop by 10,700. Jobs in the Energy [R]evolution drop between 2015 and 2030, but remain 6,000 above 2010 levels. Jobs in the Reference scenario are 38,000 below 2010 levels by 2030.

- At 2015, jobs in the Energy [R]evolution scenario have increased by 17% to 198,000, while jobs in the Reference scenario have dropped by 6% to 157,000.
- In 2020, there are nearly 168,000 jobs in the Energy [R]evolution scenario and 150,000 in the Reference scenario.
- In 2030, there are approximately 174,000 jobs in the Energy [R]evolution scenario and 130,000 jobs 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 drop gradually until 2020, and then reduce more steeply to 2030, when jobs are 23% below 2010 levels.

In the Energy [R]evolution scenario, jobs increase by 17% by 2015, and then drop again by 2030. However, jobs at 2030 remain 4% above 2010 levels. Renewable energy accounts for 62% of energy jobs by 2030, with biomass having the greatest share (21%), followed by solar heating and geothermal heating.

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

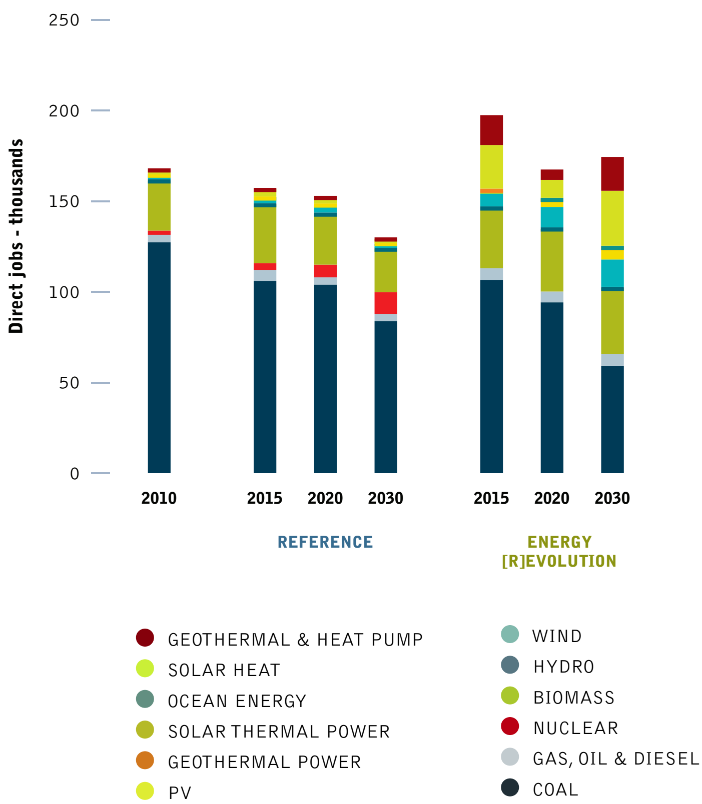


table 6.6: total employment in the energy sector

		REFERENCE			ENERGY [R]EVOLUTION		
	2010	2015	2020	2030	2015	2020	2030
Coal	127,300	106,100	104,000	83,900	106,600	94,200	59,300
Gas, oil & diesel	6,300	6,000	4,000	3,900	6,400	6,000	6,600
Nuclear	200	3,700	7,000	12,000	-	-	-
Renewable	34,300	41,500	37,900	30,200	84,400	67,300	108,600
Total Jobs	**168,100**	**157,400**	**153,000**	**130,100**	**197,500**	**167,500**	**174,400**
Construction and installation	16,300	9,900	12,200	13,500	36,400	23,900	49,700
Manufacturing	7,100	3,000	3,000	2,400	17,200	10,300	21,900
Operations and maintenance	12,800	15,900	14,500	13,200	15,500	16,800	19,900
Fuel supply (domestic)	132,000	128,400	123,300	101,000	128,300	116,600	82,800
Coal and gas export	-	-	-	-	-	-	-
Total Jobs	**168,100**	**157,400**	**153,000**	**130,100**	**197,500**	**167,500**	**174,400**

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

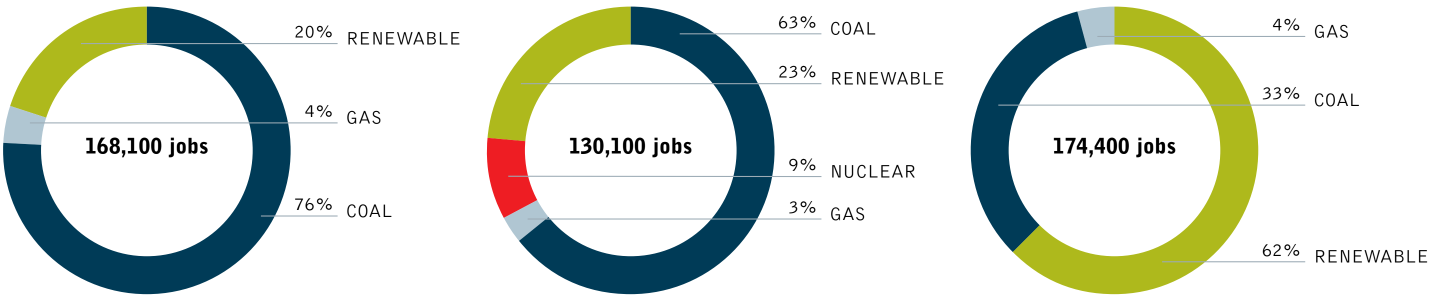


table 6.7: employment in the energy sector by technology, under the reference and energy [r]evolution scenarios

		REFERENCE			ENERGY [R]EVOLUTION		
By sector	2010	2015	2020	2030	2015	2020	2030
Construction and installation	14,300	6,500	9,100	11,700	9,000	13,200	16,300
Manufacturing	6,200	1,800	1,900	1,600	4,100	5,300	6,300
Operations and maintenance	12,800	15,900	14,500	13,200	15,500	16,800	19,900
Fuel supply (domestic)	132,000	128,400	123,300	101,000	128,300	116,600	82,800
Coal and gas export	-	-	-	-	-	-	-
Solar and geothermal heat	2,900	4,700	4,200	2,600	40,500	15,600	49,000
Total jobs	**168,200**	**157,300**	**153,000**	**130,100**	**197,400**	**167,500**	**174,400**
By technology							
Coal	127,300	106,100	104,000	83,900	106,600	94,200	59,300
Gas, oil & diesel	6,300	6,000	4,000	3,900	6,400	6,000	6,600
Nuclear	200	3,700	7,000	12,000	-	-	-
Renewable	**34,400**	**41,400**	**38,000**	**30,200**	**84,500**	**67,200**	**108,700**
Biomass	*27,500*	*32,500*	*28,200*	*24,100*	*33,400*	*34,500*	*36,400*
Hydro	*800*	*600*	*600*	*500*	*700*	*800*	*600*
Wind	*2,900*	*3,300*	*4,200*	*2,100*	*8,300*	*11,300*	*15,100*
PV	*300*	*300*	*800*	*900*	*1,000*	*4,500*	*7,200*
Geothermal power	-	-	-	-	*500*	*500*	*300*
Solar thermal power	-	-	-	-	-	-	-
Ocean	-	-	-	-	-	-	*100*
Solar - heat	*1,800*	*4,300*	*3,700*	*1,700*	*24,100*	*9,900*	*30,300*
Geothermal & heat pump	*1,100*	*400*	*500*	*900*	*16,500*	*5,700*	*18,700*
Total jobs	**168,100**	**157,300**	**153,000**	**130,100**	**197,400**	**167,500**	**174,400**

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

6.3 employment in the renewable heating sector

Employment in the renewable heat sector includes jobs in installation, manufacturing and fuel supply. However, this analysis does not capture jobs associated with export of solar thermal heating systems, so may be an underestimate of jobs in this sector.

6.3.1 employment in solar heating

In the Energy [R]evolution scenario, solar heating would provide 8% of total heat supply by 2030, and would employ approximately 30,300 people. This sector declines in the Reference scenario, with solar heating providing only 0.9% of heat supply. Capacity declines by 90 MW, and employment by 2,600 jobs.

6.3.2 employment in geothermal and heat pump heating

In the Energy [R]evolution scenario, geothermal and heat pump heating would provide 9% of total heat supply by 2030, and employ approximately 18,700 people. Growth is very slow in the Reference Scenario, with geothermal and heat pump heating providing 0.3% of heat supply, and only employing about 900 people.

6.3.3 employment in biomass heat supply

The Energy [R]evolution and the Reference scenarios are similar, with biomass heating providing between 11% and 13% of the total heat supply, and employing from 10,500 to 12,000 people.

table 6.8: solar heating: capacity, heat supplied and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	1.2	2.4	3.9	3	6	27
Heat supplied	PJ	4	8	13	12	22	92
Share of total supply	%	0.3%	0.5%	0.9%	0.8%	2%	8%
Annual increase in capacity	MW	237	230	147	1,336	609	2,557
Employment							
Direct jobs in installation and manufacture	jobs	4,300	3,700	1,700	24,100	9,900	30,300

table 6.9: 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	GW	0.3	0.4	0.9	1.9	3.5	13.0
Heat supplied	PJ	1	2	5	18	35	107
Share of total supply	%	neg	0.1%	0.3%	1.3%	2.7%	8.7%
Annual increase in capacity	MW	22	25	60	858	319	1,302
Employment							
Direct jobs in installation and manufacture	jobs	400	500	900	16,500	5,700	18,700

table 6.10: biomass heat: direct jobs in fuel supply

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Heat supplied	PJ	156.7	164.0	173.4	154.5	152.9	156.6
Share of total supply	%	11%	11%	12%	11%	12%	13%
Employment							
Direct jobs in fuel supply	jobs	12,000	11,800	11,700	11,800	11,000	10,500

6.4 renewable electricity: employment, generation and capacities

6.4.1 employment in biomass

Electricity generation from biomass doubles in the Energy [R]evolution scenarios, with biomass generation increasing from 4% in 2010, to 8% in 2030. Job numbers in biomass for electricity and heat combined reach 36,000 in 2030, 32% higher than in 2010.

In the Reference scenario, biomass generation stays relatively constant, and provides only 3% of electricity in 2030. Jobs increase by 18% to 33,000 in 2015, but then fall to 24,000 by 2030, 12% below 2010 levels. Jobs in biomass fuels for heating are included here.

6.4.2 employment in solar photovoltaics

In the Energy [R]evolution scenario, solar photovoltaics grow from a very small base in 2010, to provide 7.1% of electricity by 2030. Employment increases steadily, and reaches 7,200 by 2030.

In the Reference scenario, growth is very modest. Solar photovoltaics provides 1.0% of generation in 2030, and employs 900 people, modest growth from 2010 figures.

6.4.3 employment in wind energy

In the Energy [R]evolution scenario, wind energy grows very strongly and would provide 34% of total electricity generation by 2030, employing approximately 15,000 people. Growth is very modest in the Reference scenario, with wind energy providing 12% of generation, and employing approximately 2,000 people.

table 6.11: biomass: capacity, generation and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	1.8	1.6	1.3	1.5	2.2	3.8
Total generation	TWh	8.0	8.1	7.0	7.8	11.1	17.9
Share of total supply	%	4.9%	4.6%	3.5%	4.9%	6.3%	8.2%
Annual increase in capacity	MW	-	-	42	126	156	258
Employment							
Direct jobs in construction, manufacture, operation and maintenance, and fuel supply (includes biomass for heat)	jobs	32,500	28,200	24,100	33,400	34,500	36,400

table 6.12: solar photovoltaics: capacity, generation and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	0.1	0.4	2.1	0.1	2.3	15.6
Total generation	TWh	0.1	0.4	2.1	0.1	2.3	15.6
Share of total supply	%	0%	0.2%	1.0%	0.1%	1.3%	7.1%
Annual increase in capacity	GW	-	0.1	0.1	0.1	0.5	0.8
Employment							
Direct jobs in construction, manufacture, operation and maintenance	jobs	300	800	900	1,000	4,500	7,200

table 6.13: wind energy: capacity, generation and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	3.6	5.4	10.0	3.8	9.4	27.3
Total generation	TWh	7.6	12.1	24.4	8.2	21.7	73.6
Share of total supply	%	5%	7%	12%	5%	12%	34%
Annual increase in capacity	GW	0.7	0.5	-	1.0	1.4	2.1
Employment							
Direct jobs in construction, manufacture, operation and maintenance	jobs	3,300	4,200	2,100	8,300	11,300	15,100

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

6.5 fossil fuels and nuclear energy - employment, generation and capacities

6.5.1 employment in coal

Employment in coal mining declined by 70% from the early 1990s to 2010, and this decline continues in both the Reference and the Energy [R]evolution scenarios. In the Reference scenario, jobs fall by 34% from 2010, to reach 83,900 in 2030. In the same period, generation drops from 87% to 60% of total supply.

Coal sector employment in the Energy [R]evolution scenario falls by 53% from 2010, to reach 59,300 in 2030. In the same period, generation drops to 32% of total supply.

Coal jobs in both scenarios include coal used for heat supply.

6.5.2 employment in gas, oil & diesel

Gas-fired generation grows very strongly in the Energy [R]evolution scenario, increasing 12-fold between 2010 and 2030. Employment stays nearly constant, despite this increase in output.

In the Reference scenario, gas-fired generation also grows strongly, increasing 7-fold between 2010 and 2030. Employment is projected to fall to 3,900 in 2030, 38% below 2010 levels.

6.5.3 employment in nuclear energy

There are no nuclear power stations in Poland. In the Reference scenario, nuclear power is projected to provide 12% of Poland's electricity by 2030. The sector would employ approximately 12,000 people. In the Energy [R]evolution scenario, nuclear power is not developed.

table 6.14: fossil fuels and nuclear energy: 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	106,100	104,000	83,900	106,600	94,200	59,300
gas, oil & diesel	jobs	6,000	4,000	3,900	6,400	6,000	6,600
nuclear energy	jobs	3,700	7,000	12,000	-	-	-
COAL							
Installed capacity	GW	31	30	24	31	26	15
Total generation	TWh	130	133	121	129	117	70
Share of total supply	%	80%	76%	60%	80%	67%	32%
Annual increase in capacity	GW	-0.3	-0.2	-1.0	-1.1	-0.9	-1.0
GAS, OIL & DIESEL							
Installed capacity	GW	4	4	7	4	5	12
Total generation	TWh	14	18	21	13	19	35
Share of total supply	%	9%	10%	10%	8%	11%	16%
Annual increase in capacity	GW	0.1	0.0	0.4	0.2	0.3	0.8
NUCLEAR ENERGY							
Installed capacity	GW	-	0.1	3	-	-	-
Total generation	TWh	-	0.4	24	-	-	-
Share of total supply	%	-	0%	12%	-	-	-
Annual increase in capacity	GW	0.0	0.1	1	-	-	-

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abbreviations

CHP Combined Heat and Power
EIA Energy Information Administration (USA)
FTE Full Time Equivalent
GDP Gross Domestic Product
GWh Gigawatt hour
IEA International Energy Agency
ISF Institute for Sustainable Futures
JEDI Jobs and Economic Development Impact
MW Megawatt
NREL National Renewable Energy Laboratories (USA)
O&M Operations and Maintenance
OECD Organisation for Economic Co-operation and Development
PJ Petajoules
PV Photovoltaic
TWh Terawatt hour

the silent revolution
– past and current market developments

THE POWER PLANT MARKET 1970 TO 2012

POWER PLANT MARKETS IN THE US, EUROPE AND CHINA

GLOBAL MARKET SHARES IN THE POWER PLANT MARKET: RENEWABLE GAINING GROUND

THE GLOBAL RENEWABLE ENERGY MARKET IN 2012

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 power plant market 1970 to 2012

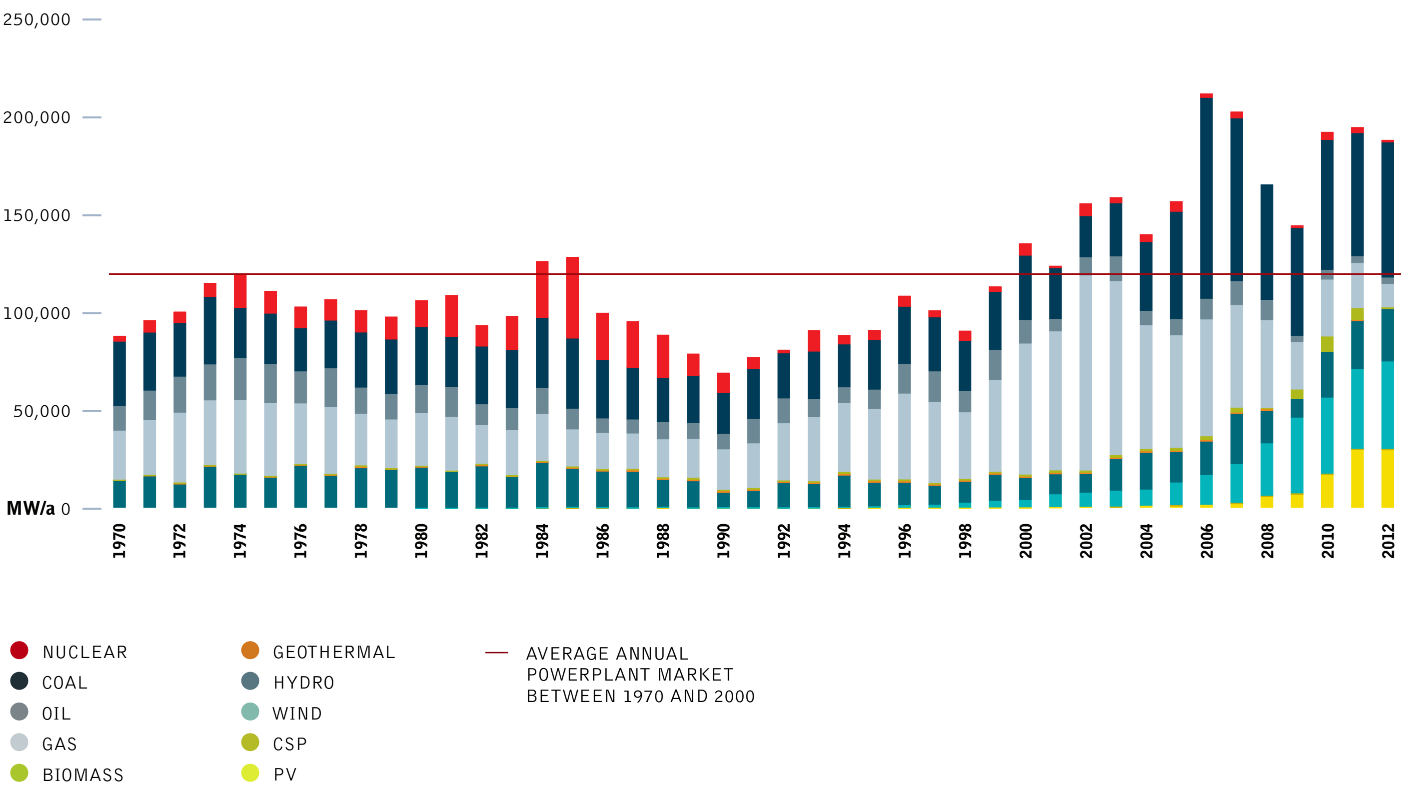
A new analysis of the global power plant market shows that since the late 1990s, renewable energy especially wind and solar photovoltaic installations grew faster than any other power plant technology across the world – over 630,000 MW total new installed capacities between 2000 and 2012. However, it is too early to claim the end of the fossil fuel based power generation, because more than 695,000 MW of new coal power plants were built with embedded cumulative emissions of 78 billion tonnes CO_2 over their technical lifetime.

The global market volume of renewable energies in 2012 was on average, as much as the total global energy market volume 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 closes within the next years without good renewable energy policies and legally binding CO_2 reduction targets.

Between 1970 and 1990, the global power plant market was dominated by OECD[39] 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 7.1: global power plant market 1970-2012



source Platts, REN21, EWEA, GWEC, EPIA, National Statistics, IEA, Breyer, Teske.

reference
39 ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT.

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

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 ASEAN region 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 significant decline of new coal power plant projects since the late 1990s with growing gas and renewable generation, particularly wind.

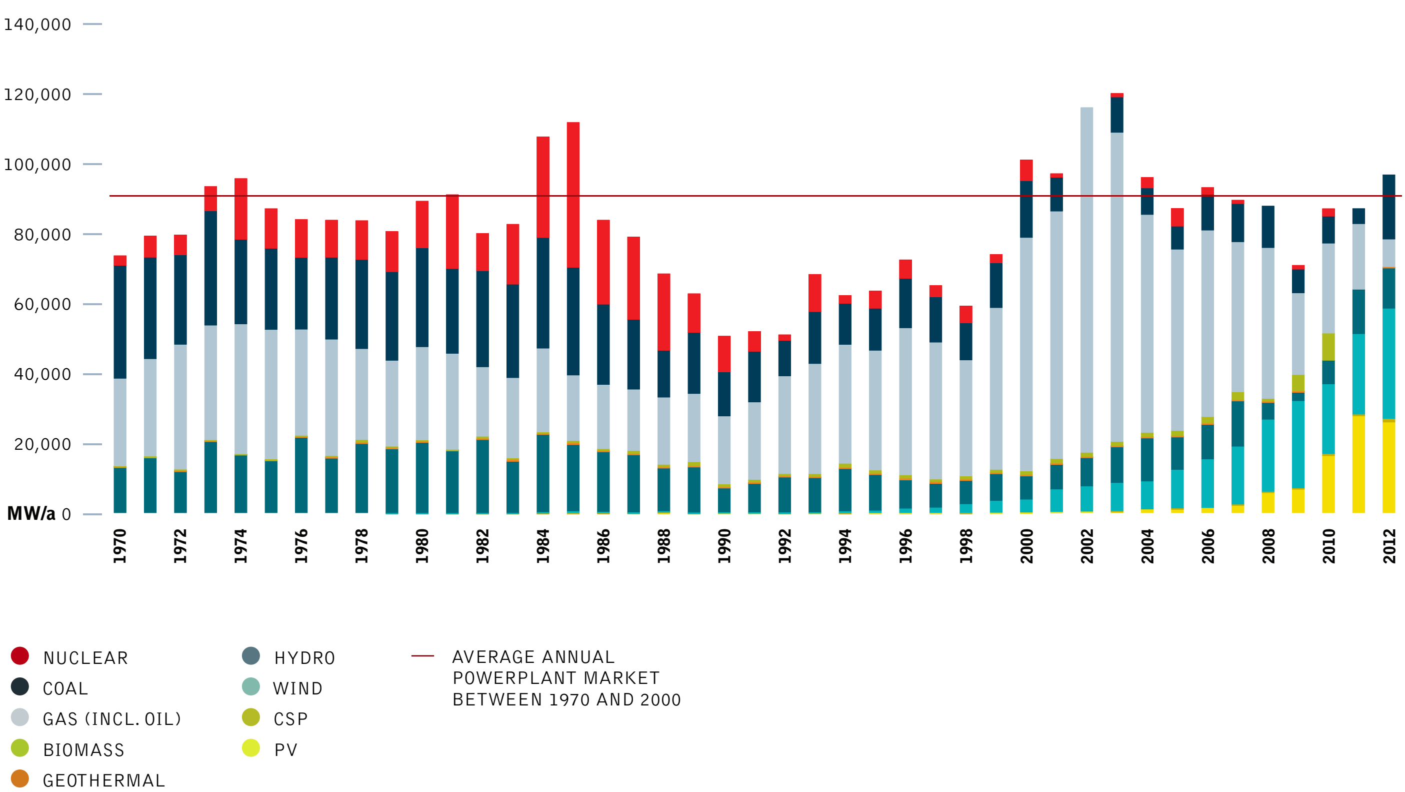
7.2 power plant markets in the US, Europe and China

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.

US: 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 make up an increasing share of the new installed capacities as a result of mainly state-based renewable energy support programmes. However until end 2012, USA renewable energy policy has been very insecure therefore market volumes especially for solar and wind power fluctuate significantly. 2012 was a particular good year both for solar photovoltaic and onshore wind.

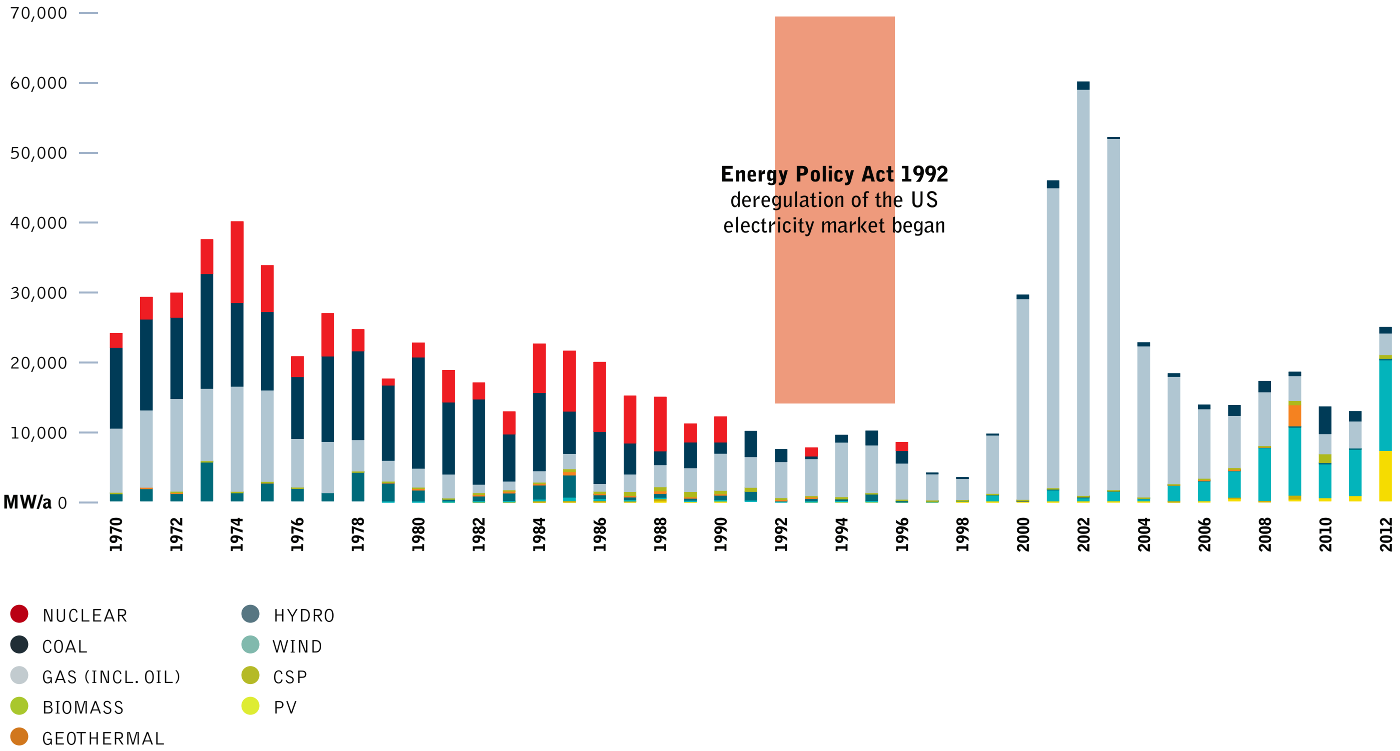
Europe: About five years after the US began deregulating the power sector, the European Community started a similar process with similar effect on the power plant market. Investors backed fewer new power plants and extended the lifetime of the existing ones. New coal and nuclear power plants have seen 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 be the aged power plant fleet in Europe needed re-powering.

figure 7.2: global power plant market 1970-2012, excluding china



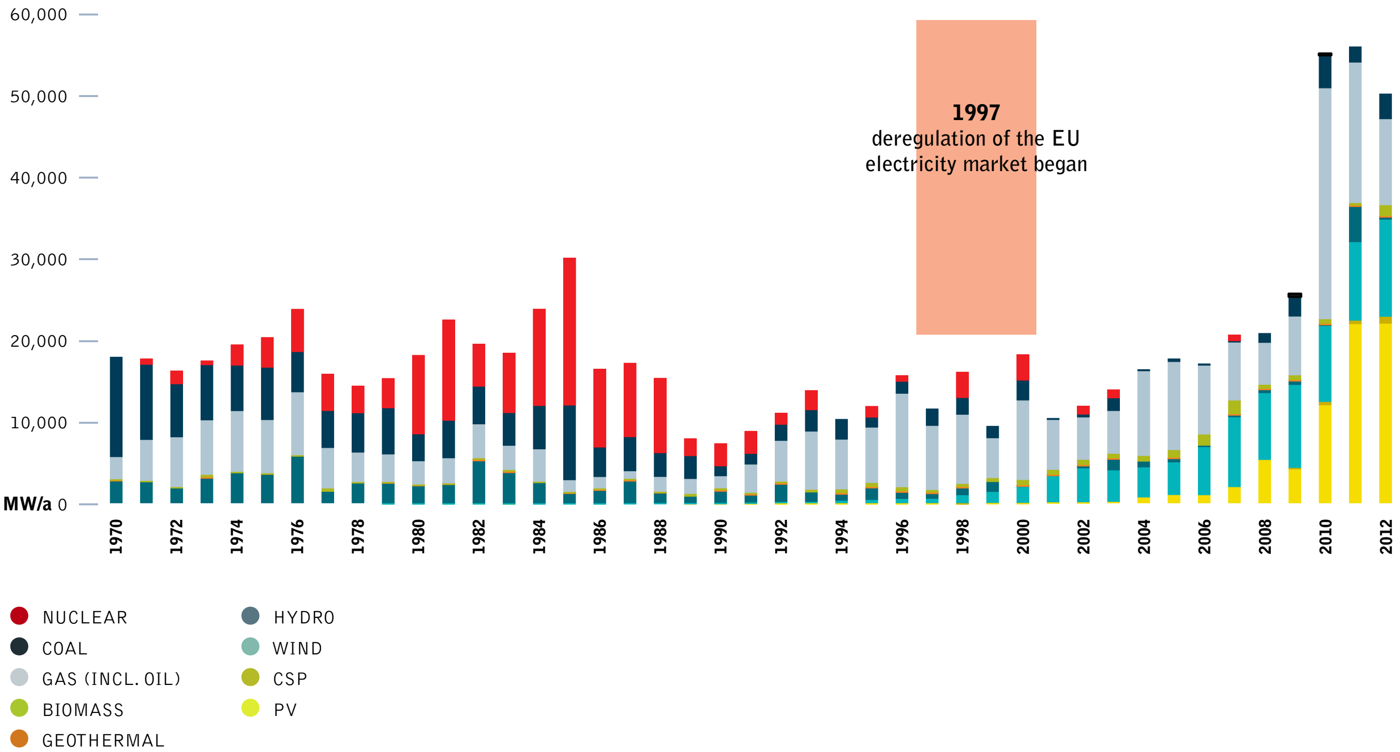
source Platts, REN21, EWEA, GWEC, EPIA, National Statistics, IEA, Breyer, Teske.

figure 7.3: usa: annual power plant market 1970-2012



source Platts, REN21, EWEA, GWEC, EPIA, National Statistics, IEA, Breyer, Teske.

figure 7.4: europe (eu27): annual power plant market 1970-2012



source Platts, REN21, EWEA, GWEC, EPIA, National Statistics, IEA, Breyer, Teske.

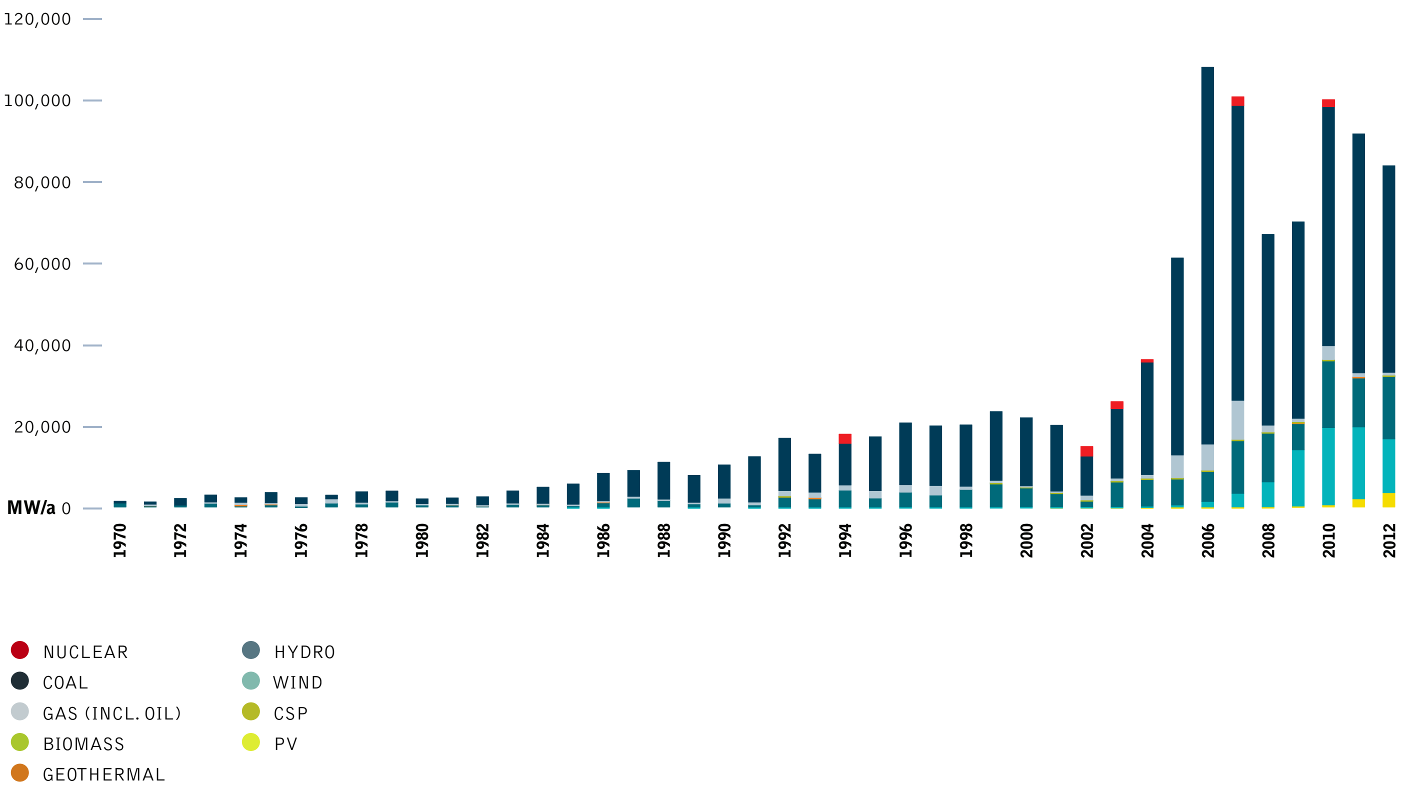
image THE SAN GORGONIO PASS WIND FARM IS LOCATED IN THE COACHELLA VALLEY NEAR PALM SPRINGS, ON THE EASTERN SLOPE OF THE PASS IN RIVERSIDE COUNTY, JUST EAST OF WHITE WATER. DEVELOPMENT BEGUN IN THE 1980S, THE SAN GORGONIO PASS IS ONE OF THE WINDIEST PLACES IN SOUTHERN CALIFORNIA. THE PROJECT HAS MORE THAN 4,000 INDIVIDUAL TURBINES AND POWERS PALM SPRINGS AND THE REST OF THE DESERT VALLEY.

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 76,825 MW of small coal power plants were phased out under the 11th Five Year Programme. While coal still dominates the new added capacity with an annual new installed capacity of around 50 GW each year between 2005 and 2012, wind power is rapidly growing as well. Since 2003 the wind market doubled each year to a record high of about 18,000 MW[40] by 2010, 49% of the global wind market. The following years 2011 and 2012 the market was smaller at 17.6 GW and 13.2 GW. Since 2012, a new policy for grid connected solar photovoltaic is in force and market growth is expected to follow the development of the wind industry between 2003 and 2010.

7.3 the global market shares in the power plant market: renewables gaining ground

Since the year 2000, the wind power market gained a growing market share within the global power plant market. Initially only a handful of countries, namely Germany, Denmark and Spain, dominated the wind market, by the end of 2012 however the wind industry is present in 79 countries around the world. Following the example of the wind industry, the solar photovoltaic industry experienced an equal growth since 2005. Between 2000 and 2012, 29% of all new power plants worldwide were renewable-powered – mainly wind – and 37% 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 1.7% of the global market share.

figure 7.5: china: annual power plant market 1970-2012



source Platts, REN21, EWEA, GWEC, EPIA, National Statistics, IEA, Breyer, Teske.

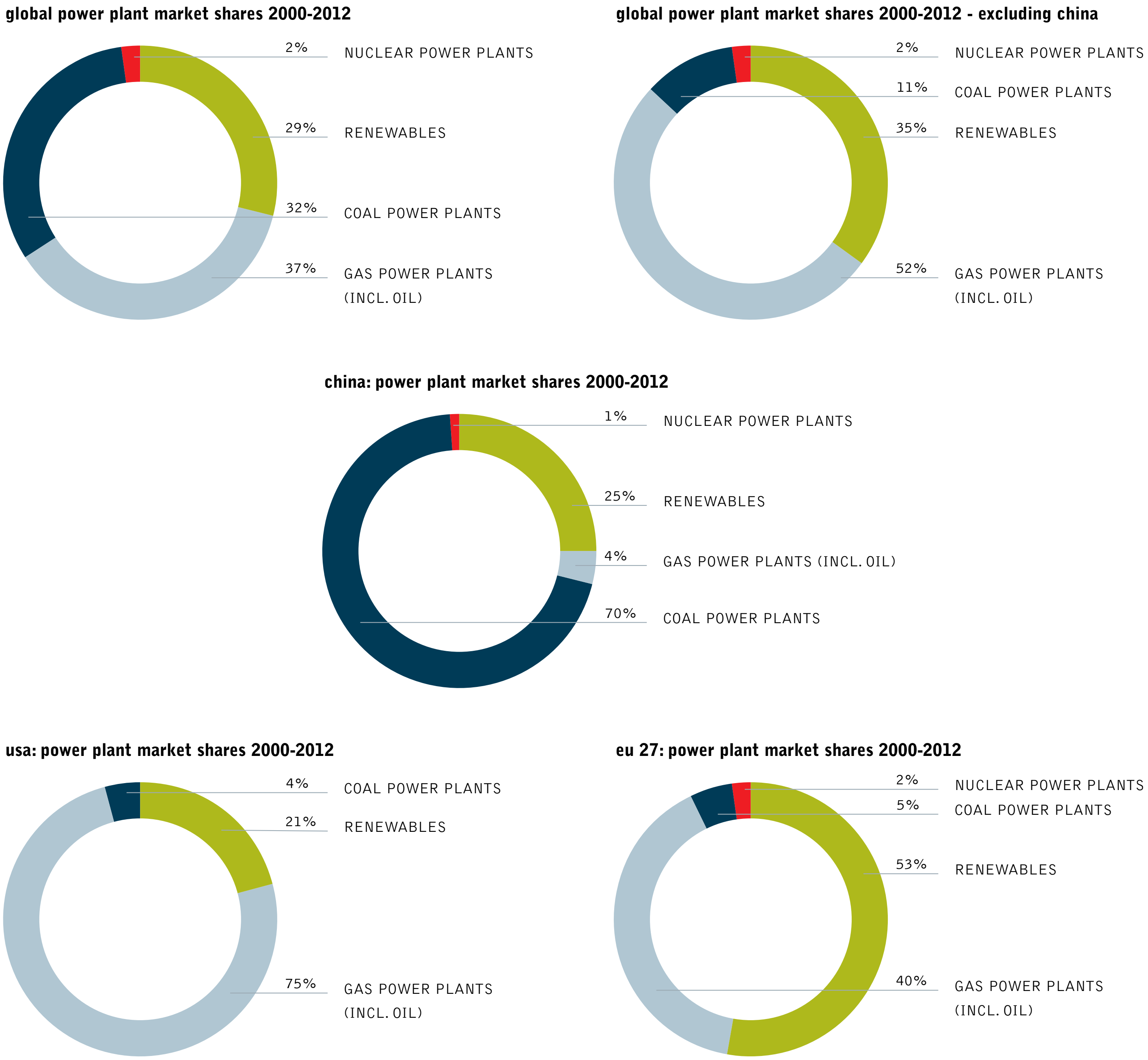
reference

40 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.

About 633,000 MW of new renewable energy capacity has been installed over the last decade, while 695,000 MW of new coal, with embedded cumulative emissions of more than 78 billion tonnes CO_2 over their technical lifetime, came online – 81% or 563,000 MW in China.

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 country with where the majority of coal expansion takes place. About 35% of all *new* power plants since 2000 have been renewables and 52% have been gas power plants (87% in total). Coal gained a market share of only 11% globally, if China is excluded in this calculation. Between 2000 and 2012, China has added over 560,000 MW of new coal capacity: four times 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.

figure 7.6: power plant market shares



source PLATTS, IEA, BREYER, TESKE.

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

7.4 the global renewable energy market in 2012

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 (2013) shows how the technologies have grown. The following text has been taken from the Renewables 2013 – Global Status Report– published in June 2013 with the permit of REN 21 and is a shortened version of the executive summary.

7.4.1 continued renewable energy capacity growth

Global demand for renewable energy continued to rise during 2011 and 2012, supplying an estimated 19% of global final energy consumption in 2011 (the latest year for which data are available), with a little less than half from traditional biomass. Useful heat energy from modern renewable sources accounted for an estimated 4.1% of total final energy use, hydropower made up about 3.7%, and an estimated 1.8% was provided by wind, solar, geothermal, biomass power, and biofuels.

Total renewable power capacity worldwide exceeded 1,470 GW in 2012, up about 8.5% from 2011. Hydropower rose 3% to an estimated 990 GW, while other renewables grew 21.5% to exceed 480 GW. Globally, wind power accounted for about 39% of renewable power capacity added in 2012, followed by hydropower and solar PV, each accounting for approximately 26%. Renewables made up just over half of total net additions to electric generating capacity from all sources in 2012. By year's end, they comprised more than 26% of global generating capacity and supplied an estimated 21.7% of global electricity, with 16.5% of electricity provided by hydropower. Industrial, commercial and residential consumers are increasingly becoming producers of renewable power in a growing number of countries.

Demand continued to rise in the heating and cooling sector, which offers an immense, yet mostly untapped, potential for renewable energy deployment. Already, heat from modern biomass, solar, and geothermal sources represents a significant portion of the energy derived from renewables, and the sector is slowly evolving as countries begin to enact support policies. Trends in the sector include the use of larger systems, increasing use of combined heat and power (CHP), the feeding of renewable heat and cooling into district schemes, and the growing use of modern renewable heat for industrial purposes. After years of rapid growth, biodiesel production continued to expand in 2012 but at a much slower rate; fuel ethanol production peaked in 2010 and has since declined. Small but growing quantities of gaseous biofuels are being used to fuel vehicles, and there are limited but increasing initiatives to link electric transport systems with renewable energy. Most technologies continued to see expansion in manufacturing and global demand during 2012. However, uncertain policy environments and declining policy support affected investment climates in a number of established markets, slowing momentum in Europe, China and India.

Solar PV and onshore wind power experienced continued price reductions due to economies of scale and technology advances, but also due to a production surplus of modules and turbines. Combined with the international economic crisis and ongoing tensions in international trade, these developments have created new challenges for some renewable industries and equipment manufacturers, leading to industry consolidation. However, they also have opened up new opportunities and pushed companies to explore new markets. Subsequently, renewables are becoming more affordable for a broader range of consumers in developed and developing countries alike. Renewables are picking up speed across Asia, Latin America, the Middle East, and Africa, with new investment in all technologies. The Middle East-North Africa region (MENA) and South Africa, in particular, witnessed the launch of ambitious new targets in 2012, and the emergence of policy frameworks and renewables deployment. Markets, manufacturing, and investment shifted increasingly towards developing countries during 2012.

The top countries for renewable power capacity at year's end were China, the United States, Brazil, Canada and Germany; the top countries for non-hydro capacity were China, the United States and Germany, followed by Spain, Italy and India. By region, the BRICS nations accounted for 36% of total global renewable power capacity and almost 27% of non-hydro renewable capacity. The EU had the most non-hydro capacity at the end of 2012, with approximately 44% of the global total. Renewables represent a rapidly growing share of energy supply in a growing number of countries and regions:

- In China, wind power generation increased more than generation from coal and passed nuclear power output for the first time.
- In the European Union, renewables accounted for almost 70% of additions to electric capacity in 2012, mostly from solar PV and wind power. In 2011 (the latest data available), renewables met 20.6% of the region's electricity consumption and 13.4% of gross final energy consumption.
- In Germany, renewables accounted for 22.9% of electricity consumption (up from 20.5% in 2011), 10.4% of national heat use, and 12.6% of total final energy demand.
- The United States added more capacity from wind power than any other technology, and all renewables made up about half of total electric capacity additions during the year.
- Wind and solar power are achieving high levels of penetration in countries like Denmark and Italy, which in 2012 generated 30% of electricity with wind and 5.6% with solar PV, respectively.

As their shares of variable wind and solar power increase, a number of countries (including Denmark, Germany and Spain) have begun to enact policies and measures to successfully transform their energy systems to accommodate even larger shares. Impacts of all of these developments on jobs in the renewable energy sector have varied by country and technology, but, globally, the number of people working in renewable industries has continued to rise. An estimated 5.7 million people worldwide work directly or indirectly in the sector.

7.4.2 an evolving policy landscape

At least 138 countries had renewable energy targets by the end of 2012. As of early 2013, renewable energy support policies were identified in 127 countries, more than two-thirds of which are developing countries or emerging economies. The rate of adoption of new policies and targets has remained slow relative to the early to mid-2000s. As the sector has matured, revisions to historic policies have become increasingly common. In response to rapidly changing market conditions for renewable technologies, tight national budgets, and the broader impacts of the global economic crisis, some countries undertook extensive revisions to existing laws, some of which were imposed retroactively. Others increased support for renewables, and several countries around the world adopted ambitious new targets.

Most policies to support renewable energy target the power sector, with Feed-in tariffs (FITs) and renewable portfolio standards (RPS) used most frequently. During 2012, FIT policies were enacted in five countries, all in Africa and the Middle East; the majority of FIT-related changes involved reduced support. New RPS policies were enacted in two countries. An increasing number of countries turned to public competitive bidding, or tendering, to deploy renewables.

In the heating and cooling sector, promotion policies and targets continued to be adopted at a slower rate than in the power sector, although their adoption is increasing steadily. As of early 2013, 20 countries had specific renewable heating targets in place while at least 19 countries and states mandated the use of renewable heat technologies. Renewable heating and cooling are also supported through building codes and other measures. Biofuel blend mandates were identified at the national level in 27 countries and in 27 states/provinces. Despite increasing pressure in major markets such as Europe and the United States, due to growing debate over the overall sustainability of first generation biofuels, regulatory policies promoting the use of biofuels existed in at least 49 countries as of early 2013.

Thousands of cities and towns around the world have developed their own plans and policies to advance renewable energy, and momentum accelerated in 2012. To achieve ambitious targets, local governments adopted a range of measures, including: FITs or technology-specific capacity targets; fiscal incentives to support renewable energy deployment; and new building codes and standards, including solar heat mandates. Others developed renewable district heating and cooling systems; promoted the use of renewably-powered electric transport; formed consortia to fund projects; or advanced advocacy and information sharing. Several cities are working with their national governments to promote renewable energy, while others have begun to organize from the bottom up. In Europe, 1,116 new cities and towns joined the Covenant of Mayors in 2012, committing to a 20% CO_2 reduction target and plans for climate mitigation, energy efficiency, and renewable energy.

7.4.3 investment trends

Global new investment in renewable power and fuels was US$ 244 billion in 2012, down 12% from the previous year's record. The total was still the second highest ever and 8% above the 2010 level. If the unreported investments in hydropower projects larger than 50 MW and in solar hot water collectors are included, total new investment in renewable energy exceeded US$ 285 billion.

The decline in investment—after several years of growth—resulted from uncertainty about support policies in major developed economies, especially in Europe (down 36%) and the United States (down 35%). Nonetheless, considering only net additions to electric generating capacity (excluding replacement plants) in 2012, global investment in renewable power was ahead of fossil fuels for the third consecutive year.

The year 2012 saw the most dramatic shift yet in the balance of investment activity between developed and developing economies. Outlays in developing countries reached US$ 112 billion, representing 46% of the world total; this was up from 34% in 2011, and continued an unbroken eight-year growth trend. By contrast, investment in developed economies fell 29% to US$ 132 billion, the lowest level since 2009. The shift was driven by reductions in subsidies for solar and wind project development in Europe and the United States; increased investor interest in emerging markets with rising power demand and attractive renewable energy resources; and falling technology costs of wind and solar PV. Europe and China accounted for 60% of global investment in 2012.

Solar power was the leading sector by far in terms of money committed in 2012, receiving 57% of total new investment in renewable energy (96% of which went to solar PV). Even so, the USD 140.4 billion for solar was down 11% from 2011 levels, due to a slump in financing of CSP projects in Spain and the United States, as well as sharply lower PV system prices. Solar was followed by wind power (USD 80.3 billion) and hydropower projects larger than 50 MW (estimated at USD 33 billion).

7.4.4 rural renewable energy

The year 2012 saw improved access to modern energy services through the use of renewables. Rural use of renewable electricity has increased with greater affordability, improved knowledge about local renewable resources, and more sophisticated technology applications. Attention to mini-grids has risen in parallel with price reductions in solar, wind, inverter, gasification and metering technologies. Technological progress also advanced the use of renewables in the rural heating and cooking sectors. Rural renewable energy markets show significant diversity, with the levels of electrification, access to clean cookstoves, financing models, actors, and support policies varying greatly among countries and regions.

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.

table 7.1: 2013 selected indicators

		2010	2011	2012
Investment in new renewable capacity (annual)[a]	billion USD	227	279	244
Renewable power capacity (total, not including hydro)	GW	315	395	480
Renewable power capacity (total, including hydro)	GW	1,250	1,355	1,470
Hydropower capacity (total)[b]	GW	935	960	990
Biopower generation	GWh	313	335	350
Solar PV capacity (total)	GW	40	71	100
Concentrating solar thermal power (total)	GW	1.1	1.6	2.5
Wind power capacity (total)	GW	198	238	283
Solar how water capacity (total)[c]	GW	195	223	255
Ethanol production (annual)	billion litres	85	84.2	83.1
Biodiesel production (annual)	billion litres	18.5	22.4	22.5
Countries with policy targets	#	109	118	139
States/provinces/countries with feed-in policies	#	88	94	99
States/provinces/countries with RPS/quota policies	#	72	74	76
States/provinces/countries with biofuel mandates[d]	#	71	72	76

notes

a INVESTMENT DATA ARE FROM BLOOMBERG NEW ENERGY FINANCE AND INCLUDE BIOMASS, GEOTHERMAL, AND WIND GENERATION PROJECTS OF MORE THAN 1 MW; ALL HYDRO PROJECTS OF BETWEEN 1 AND 50 MW; ALL SOLAR POWER PROJECTS, WITH THOSE LESS THAN 1 MW ESTIMATED SEPARATELY AND REFERRED TO AS SMALL-SCALE PROJECTS OR SMALL DISTRIBUTED CAPACITY; ALL OCEAN ENERGY PROJECTS; AND ALL B BIOFUEL PROJECTS WITH AN ANNUAL PRODUCTION CAPACITY OF 1 MILLION LITRES OR MORE.

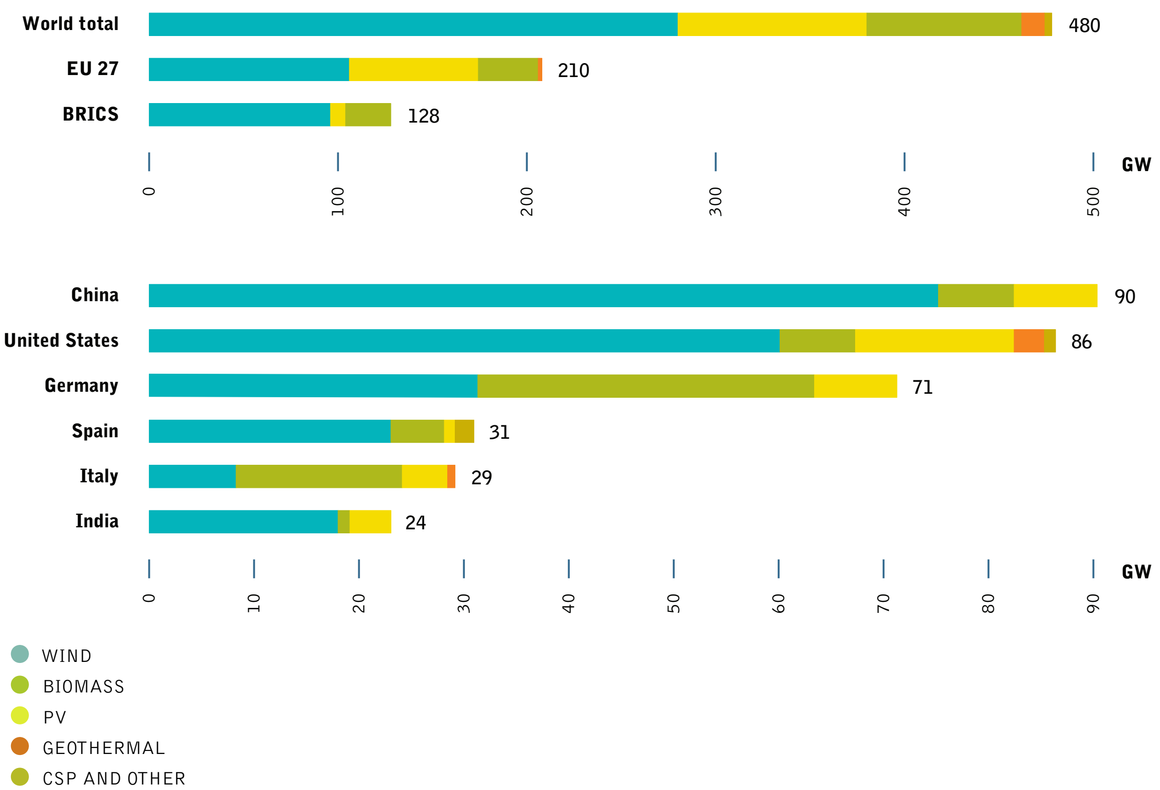
b HYDROPOWER DATA DO NOT INCLUDE PUMPED STORAGE-CAPACITY. FOR MORE INFORMATION, SEE NOTE ON REPORTING AND ACCOUNT ON PAGE XX.

c SOLAR HOT WATER CAPACITY DATA INCLUDE GLAZED WATER COLLECTORS ONLY.

d BIOFUEL POLICIES INCLUDE POLICES LISTED BOTH UNDER THE BIOFUELS OBLIGATION/MANDATE COLUMN IN TABLE 3 (RENEWABLE ENERGY SUPPORT POLICIES) AND IN REFERENCE TABLE R15 (NATIONAL AND STATE/PROVINCIAL BIOFUEL BLEND MANDATES).

NOTE NUMBERS ARE ROUNDED. RENEWABLE POWER CAPACITY (INCLUDING AND NOT INCLUDING HYDROPOWER) AND HYDROPOWER CAPACITY DATA ARE ROUNDED TO NEAREST 5 GW; OTHER CAPACITY NUMBERS ARE ROUNDED TO NEAREST 1 GW EXCEPT FOR VERY SMALL NUMBERS AND BIOFUELS, WHICH ARE ROUNDED TO ONE DECIMAL POINT.

figure 7.7: renewable power capacities in world, eu 27, BRICS, and top six countries, 2012 NOT INCLUDING HYDROPOWER



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transport

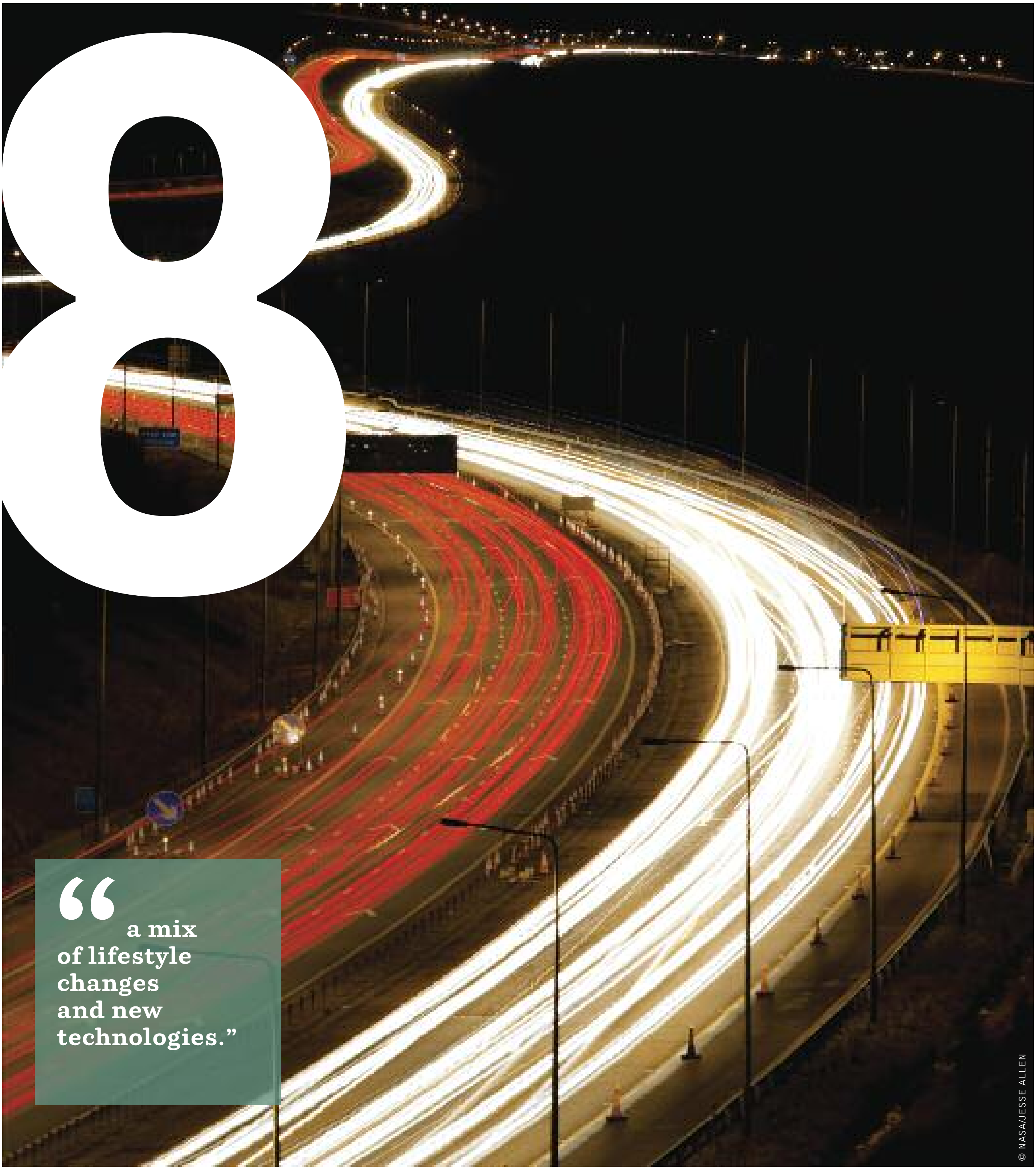
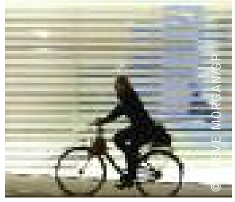


image THE SUNDARBANS OF INDIA AND BANGLADESH IS THE LARGEST REMAINING TRACT OF MANGROVE FOREST IN THE WORLD. A TAPESTRY OF WATERWAYS, MUDFLATS, AND FORESTED ISLANDS AT THE EDGE OF THE BAY OF BENGAL. HOME TO THE ENDANGERED BENGAL TIGER, SHARKS, CROCODILES, AND FRESHWATER DOLPHINS, AS WELL AS NEARLY TWO HUNDRED BIRD SPECIES, THIS LOW-LYING PLAIN IS PART OF THE MOUTHS OF THE GANGES. THE AREA HAS BEEN PROTECTED FOR DECADES BY THE TWO COUNTRIES AS A NATIONAL PARK.

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

image CYCLING THROUGH FRANKFURT.



8.1 the future of the transport sector in the energy [r]evolution scenario

Sustainable transport is needed to reduce the level of greenhouse gases in the atmosphere, just as much as a shift to renewable electricity and heat production. Today, about one third (30%) of current energy use comes from the transport sector, mainly road transport (93%) but also from trains (4.7%) and domestic aviation (0.6%). However the most efficient form of transport, railways, currently only has a market share of less than 5% (4.7%).This chapter provides an overview of the selected measures required to develop a more energy efficient and sustainable transport system in the future, with a focus on:

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

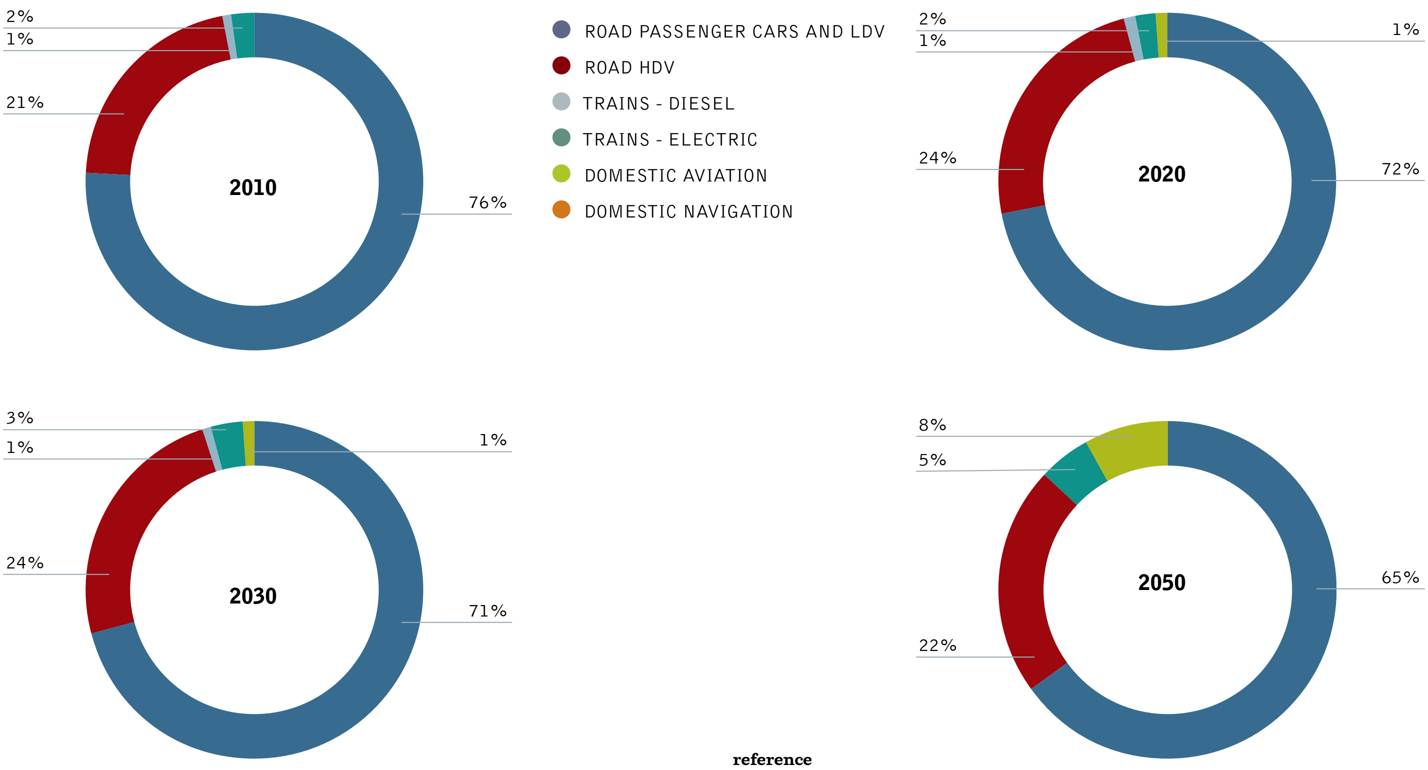
The section provides the assumptions for Polands transport sector energy demand calculations used in the Reference and the Energy [R]evolution scenarios including projections for the passenger vehicle market (light duty vehicles). Overall, some technologies will have to be adapted for greater energy efficiency. In other situations, a simple modification will not be enough. The transport of people in megacities and urban areas will have to be almost entirely re-organized and individual transport must be complemented or even substituted by public transport systems. Car sharing and public transport on demand are only the beginning of the transition needed for a system that carries more people more quickly and conveniently to their destination while using less energy. For the 2013 Energy [R]evolution scenario, The Energy [R]evolution scenario is based on an analysis by the German DLR Institute of Vehicle Concepts of the entire global transport sector, broken down to the ten IEA regions. This report outlines the key findings of the analysis' calculations for Poland.

The definitions of the transport modes for the scenarios[41] are:

- Light duty vehicles (LDV) are four-wheel vehicles used primarily for personal passenger road travel. These are typically cars, Sports Utility Vehicles (SUVs), small passenger vans (up to eight seats) and personal pickup trucks. Light-duty vehicles are also simply called 'cars' within this chapter.
- Heavy Duty Vehicles (HDV) are as long haul trucks operating almost exclusively on diesel fuel. These trucks carry large loads with lower energy intensity (energy use per tonne-kilometre of haulage) than medium duty trucks such as delivery trucks.
- Medium Duty Vehicles (MDV) include medium haul trucks and delivery vehicles.
- Aviation in each region denotes domestic air travel (intraregional and international air travel is provided as one figure).
- Inland navigation denotes freight shipping with vessels operating on rivers and canals or in coastal areas for domestic transport purposes.

Figure 8.1 shows the breakdown of final energy demand for the transport modes in 2009 and 2050 in the Reference scenario.

figure 8.1: poland's final energy use per transport mode 2010/2050 – energy [r]evolution scenario



reference
41 FULTON & EADS (2004).

As can be seen from Figure 8.1, the largest share of energy demand comes from road transport (mainly transport by car anfd trucks), although the share decreases while the share of rail transport increase in the Energy [R]evolution scenario between 2010 and 2050.

In the Reference Scenario, overall energy demand in the transport sector adds up to 869 PJ/by 2050 compared to 700 PJ/a in 2010, an overal decrease of 24%. In the Energy [R]evolution Scenario, implying the implementation of more efficiency and behavioral measures, we calculated a possible reduction of 250 PJ/a or 35% between 2010 and 2050.

8.2 technical and behavioural measures to reduce transport energy consumption

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

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

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

Table 8.1 summarises these options and the indicators used to quantify them.

8.2.1 step 1: reduction of transport demand

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

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

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

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

In the Reference Scenario, there is a forecast of a sharp increase in passenger-km up to 2050, whereas in the 2050 Energy [R]evolution Scenario the increase is moderate in individual transport on a per capita basis. The reduction in passenger-km per capita in the Energy [R]evolution scenario compared to the Reference scenario comes with a general reduction in car use due to behavioural and traffic policy changes and partly with a shift of transport to public modes. A shift from energy-intensive individual transport to low-energy demand public transport of course aligns with an increase in low-energy public transport p-km.

table 8.1: selection of measures and indicators

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

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

image PARKING SPACE FOR HYBRIDS ONLY.

8.2.2 step 2: changes in transport mode

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

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

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

Passenger transport Travelling by rail is the most efficient – but car transport improves strongly. Figure 8.2 shows the average specific energy consumption (energy intensity) by transport mode in 2009 and in the Energy [R]evolution scenario in 2050. Passenger transport by rail will consume on a per p-km basis 28% less energy in 2050 than car transport and 85% less than aviation which shows that shifting from road to rail can make large energy savings.

Figure 8.2 shows that in order to reduce transport energy demand, passengers will need to shift from cars and especially air transport to the lower energy intensive passenger rail transport.

In the Energy [R]evolution scenario it is assumed that a certain portion of passenger kilometer of domestic air traffic is suitable to be substituted by better railway services. For international aviation there is obviously no substitution potential to other modes whatsoever.

Freight transport Similar to Figure 8.2 which showed average specific energy consumption for passenger transport modes, Figure 8.3 shows the respective energy consumption for various freight transport modes in 2009 and in the Energy [R]evolution scenario 2050. The values are weighted according to stock-and-traffic performance. The energy intensity of all modes of transport is expected to decrease by 2050. In absolute terms, road transport shows the largest efficiency gains whereas transport on rail and water remain the modes with the lowest relative energy demand per tonne-km. Rail freight transport will consume 85% less energy per tonne-km in 2050 than long haul HDV. This shows the large energy savings achievable by a modal shift from road to rail.

figure 8.2: stock-weighted passenger transport energy intensity for 2009 and 2050

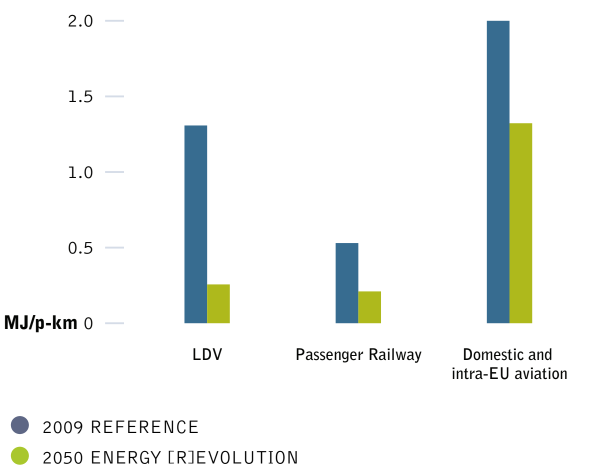
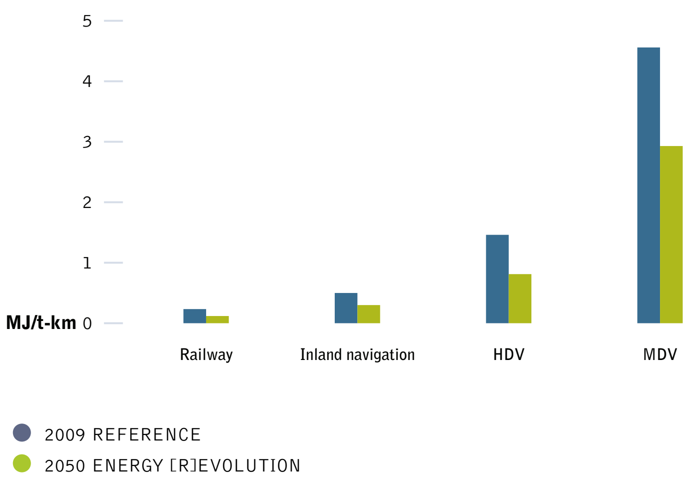


figure 8.3: average (stock-weighted) freight transport energy intensity in the energy [r]evolution scenario



Modal shifts for transporting goods in the Energy [R]evolution scenario The figures above indicate that as much road freight as possible should be shifted from road-bound freight transport to less energy intensive freight rail, in order to achieve maximum energy savings from modal shifts. Since the use of ships largely depends on the geography of a country, no modal shift is proposed for inland navigation but instead a shift towards freight rail. As the goods transported by medium-duty vehicles are mainly going to regional destinations (and are therefore unsuitable for the long distance nature of freight rail transport), no modal shift to rail is assumed for this type of transport. For long-haul heavy-duty vehicle transport, however, especially low value density, heavy goods that are transported on a long range are suitable for a modal shift to railways.[42]

8.2.3 step 3: efficiency improvements

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

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

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

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

- Aerodynamic adaptations to reduce the drag of the aircraft, for example by improved control of laminar flow, the use of riblets and multi-functional structures, the reduction in fasteners, flap fairings and the tail size as well as by advanced supercritical airfoil technologies.
- Structural technologies to reduce the weight of the aircraft while at the same time increasing the stiffness. Examples include the use of new lightweight materials like advanced metals, composites and ceramics, the use of improved coatings as well as the optimised design of multi-functional, integrated structures.
- Subsystem technologies including, for example, advanced power management and generation as well as optimised flight avionics and wiring.
- Propulsion technologies like advanced gas turbines for powering the aircraft more efficiently; this could also include:
  - improved combustion emission measures, improvements in cold and hot section materials, and the use of turbine blade/vane technology;
  - investigation of all-electric, fuel-cell gas turbine and electric gas turbine hybrid propulsion devices;
  - the usage of electric propulsion technologies comprise advanced lightweight motors, motor controllers and power conditioning equipment.[43]

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

- reducing the total weight of a train; this is seen as the most significant measure to reduce traction energy consumption. By using lightweight structures and lightweight materials, the energy needed to overcome inertial and grade resistances as well as friction from tractive resistances can be reduced.
- aerodynamic improvements to reduce aerodynamic drag, especially important when running at high velocity. A reduction of aerodynamic drag is typically achieved by streamlining the profile of the train.
- switch from diesel-fuelled to more energy efficient electrically powered trains.
- improvements in the traction system to further reduce frictional losses. Technical options include improvements of the major components as well as improvements in the energy management software of the system.
- regenerative braking to recover waste energy. The energy can either be transferred back into the grid or stored on-board in an energy storage device. Regenerative braking is especially effective in regional traffic with frequent stops.
- improved space utilisation to achieve a more efficient energy consumption per passenger-kilometre. The simplest way to achieve this is to transport more passengers per train. This can either be achieved by a higher average load factor, more flexible and shorter trainsets or by the use of double-deck trains on highly frequented routes.
- improved accessory functions, e.g. for passenger comfort. A substantial amount of energy in a train needed is to ensure the comfort of the train's passengers by heating and cooling. Strategies to enhance efficiency include adjustments to the cabin design, changes to air intakes and using waste heat from the propulsion system.

reference
42 TAVASSZY AND VAN MEIJEREN 2011.
43 IBIDEM.

image ITALIAN EUROSTAR TRAIN.

image TRAFFIC IN AUCKLAND.

By research on developing an advanced high-speed train, DLR's 'Next Generation Train' project aims to reduce the specific energy consumption per passenger-kilometre by 50% relative to today's state-of-the-art high speed trains.[44]

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

Electric trains as of today are about 2 to 3.5 times less energy intensive (from a tank-to-wheel-perspective) than diesel trains depending on the specific type of rail transport, so the projections to 2050 maintain the dominance of electric trains in the Energy [R]evolution 2050 scenario.

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

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

Adding up each technology's effectiveness as stated by ICCT (2011), these technologies have an overall potential to improve energy efficiency of new vessels between 18.4% and about 57%. Another option to reduce energy demand of ships is simply to reduce operating speeds. Up to 36% of fuel consumption can be saved by reducing the vessel's speed by 20%.[45] Eyring et al. (2005) report that a 25% reduction of fuel consumption for an international marine diesel fleet is achievable by using more efficient alternative propulsion devices only.[46] Up to 30% reduction in energy demand is reported by Marintek (2000) only by optimising the hull shape and propulsion devices of new vessels.[47]

The model assumes a total of 40% energy efficiency improvement potential for international shipping.

8.3 light-duty vehicles

8.3.1 projection of the CO_2 emission development

This section draws on a study on future vehicle technologies conducted by the DLR's Institute of Vehicle Concepts. The approach shows the potential of different technologies to increase the energy efficiency of future cars (light-duty vehicles) and gives a detailed analysis of possible cost developments.[48]

Many technologies can be used to improve the fuel efficiency of conventional passenger cars. Examples include improvements in engines, weight reduction as well as friction and drag reduction.[49] The impact of the various measures on fuel efficiency can be substantial. The introduction of hybrid vehicles, combining a conventional internal combustion engine with an electric motor and a battery, can further reduce fuel consumption. Applying advanced lightweight materials, in combination with new propulsion technologies, can bring fuel consumption levels down to 1 litre ge/100 km.

8.3.2 projection of the future vehicle segment split

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

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

8.2.3 projection of the future technology mix

To achieve the substantial CO_2-reduction targets in the Energy [R]evolution scenario requires a radical implementation of efficiency measures and a shift in fuels for cars and other light duty vehicles. For viable electrification based on renewable energy sources, the model assumes that petrol and diesel fuelled autonomous hybrids and plug-in hybrids that we have today are substituted to a large extent already by 2050. That is, two generations of hybrid technologies will pave the way for a significant market share of light duty vehicles with full battery electric or hydrogen fuel cell powertrains. In the far future it may not be possible to power LDVs for all purposes by rechargeable batteries only. Therefore, hydrogen is required as an additional renewable fuel especially for larger LDVs incl. light commercial vehicles. Biofuels – mainly ethanol - and remaining oil will be used especially in other sectors where a substitution is even harder than for LDVs. Figure 8.5 shows the development of vehicle stock over time for small, medium and large LDVs up to 2050 under the Energy [R]evolution by technologies.

references

44 WWW.DLR.DE/NGT.
45 ICCT, 2011.
46 EYRING ET AL., 2005.
47 MARINTEK, 2000.
48 DLR, 2011.
49 DECICCO ET AL., 2001.

figure 8.4: development of the powertrain vehicle stock for small, medium and large LDVs up to 2050 under the energy [r]evolution by technologies

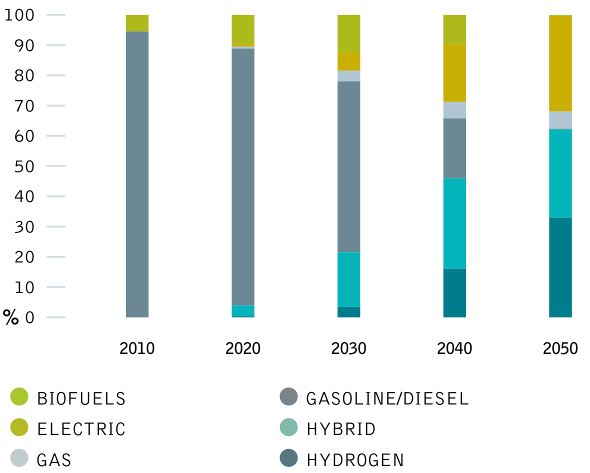
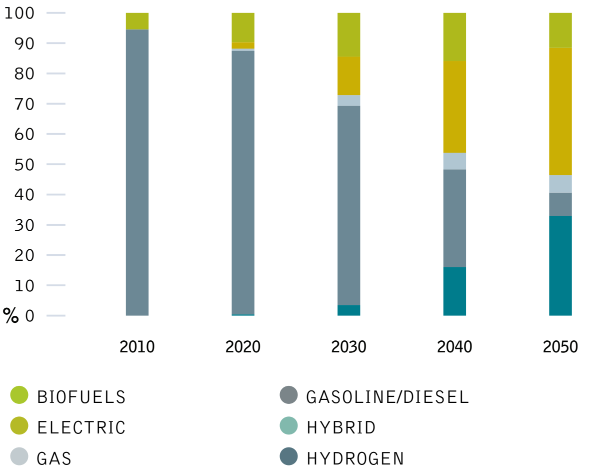


figure 8.5: development of the powertrain vehicle stock for small, medium and large LDVs up to 2050 under the energy [r]evolution by fuels.



8.2.4 renewable energy in the transport sector

While in the Energy [R]evolution scenario, 30% of the CO_2 reduction in the transport sector is achieved through a reduction in transport energy demand by 2020, through both behavioural measures and vehicle efficiency improvements, the remaining energy demand needs to be covered by renewable sources, to achieve the CO_2 reductions needed. By 2050, 65% of transport energy comes from renewable sources, compared to 5.3% in 2010.

The Energy [R]evolution assumes that the potential for sustainable biomass is limited. For Polands's transport sector, therefore the focus for renewable energy use in the transport sector is on electricity, given that other sectors such as power and heat production also partly rely on biomass energy.

8.3 conclusion

The aim of this chapter was to show ways on how to significantly reduce energy demand in general and the dependency on climate-damaging fossil fuels in particular in the transport sector, also in view of ever rising transport energy demand in other world regions.

The findings of our scenario calculations show that in order to reach the ambitious energy reduction goals of the Energy [R]evolution scenario a combination of behavioral changes and tremendous technical efforts is needed:

- a decrease of passenger- and freight-kilometres on a per capita base,
- a massive shift to electrically and hydrogen powered vehicles whose energy sources are produced from renewable sources,
- a gradual decrease of all modes' energy intensities,
- a modal shift from aviation to rail and from road freight to rail freight.

These measures should be accompanied by major efforts on the installation and extension of the necessary infrastructures, e. g. improved public transport systems in urban areas, charging and fueling infrastructure for electric vehicles, just to mention a few.

The government which plays a particular role in regulating the vehicle and fuel market, should support these efforts by tightening existing vehicle efficiency legislation and introducing new standards for trucks and other vehicle categories. In parallel, it should adopt regulations to control both fossil and renewable fuel production such that the decreasing energy demand is met by truly sustainable, low carbon energy.

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glossary & appendix

GLOSSARY OF COMMONLY USED TERMS AND ABBREVIATIONS

DEFINITION OF SECTORS

POLAND: 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.”

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 9.1: 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.

poland: scenario results data

image THIS RARE CLOUD-FREE SCENE OF POLAND, SLOVAKIA, AND THE CZECH REPUBLIC. OTHER COUNTRIES IN THE IMAGE ARE LITHUANIA AND THE KALININGRAD PROVINCE OF RUSSIA. THE CARPATHIAN MOUNTAINS ARC THROUGH SLOVAKIA, APPEARING DARKER THAN THE REST OF THE LANDSCAPE BECAUSE THEY PROTRUDE ABOVE THE HAZE THAT COVERS MUCH OF THE REGION. TO THE NORTHEAST IS THE BALTIC SEA, WHICH SEPARATES THESE COUNTIRES FROM SCANDINAVIA.

poland: reference scenario

table 9.3: poland: electricity generation

TWh/a	2010	2015	2020	2030	2040	2050
Power plants	**128**	**124**	**129**	**157**	**192**	**234**
Hard coal (& non-renewable waste)	71	54	56	53	57	87
Lignite	48	52	52	47	33	31
Gas	1	3	2	3	12	24
of which from H_2	0	0	0	0	0	0
Oil	2	1	1	1	2	2
Diesel	0	0	0	0	0	0
Nuclear	0	0	0	24	56	56
Biomass (& renewable waste)	3	3	2	1	2	3
Hydro	2	3	3	3	3	3
Wind	2	8	12	24	24	24
of which wind offshore	0	0	0	5	5	5
PV	0	0	0	2	3	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	**29**	**38**	**46**	**45**	**47**	**45**
Hard coal (& non-renewable waste)	17	22	24	22	19	17
Lignite	1	1	0	0	0	0
Gas	5	9	13	15	19	20
of which from H_2	0	0	0	0	0	0
Oil	1	1	1	1	1	1
Biomass (& renewable waste)	4	5	6	6	7	7
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	24	34	42	40	41	39
Autoproducers	5	4	4	5	6	6
Total generation	**157**	**162**	**175**	**202**	**238**	**279**
Fossil	147	144	152	142	144	182
Hard coal (& non-renewable waste)	89	76	81	74	76	104
Lignite	49	53	53	47	33	31
Gas	6	12	16	18	31	44
Oil	3	3	3	2	3	3
Diesel	0	0	0	0	0	0
Nuclear	0	0	0	24	56	56
Hydrogen	0	0	0	0	0	0
Renewables	**10**	**18**	**23**	**36**	**39**	**41**
Hydro	2	3	3	3	3	3
Wind	2	8	12	24	24	24
PV	0	0	0	2	3	4
Biomass (& renewable waste)	6	8	8	7	9	10
Geothermal	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Distribution losses	12	12	13	15	17	20
Own consumption electricity	25	29	35	35	35	35
Electricity for hydrogen production	0	0	0	0	0	0
Final energy consumption (electricity)	**119**	**121**	**127**	**152**	**186**	**224**
Fluctuating RES (PV, Wind, Ocean)	2	8	12	26	27	28
Share of fluctuating RES	1.1%	4.7%	7.1%	13.1%	11.5%	10.0%
RES share (domestic generation)	**6.6%**	**11.2%**	**13.2%**	**17.9%**	**16.2%**	**14.6%**

table 9.4: poland: heat supply

PJ/a	2010	2015	2020	2030	2040	2050
District heating	**134**	**109**	**111**	**114**	**103**	**99**
Fossil fuels	133	107	109	111	100	95
Biomass	2	1	1	1	1	1
Solar collectors	0	0	0	0	0	0
Geothermal	0	0	0	1	2	3
Heat from CHP	**210**	**241**	**244**	**250**	**260**	**254**
Fossil fuels	199	225	224	225	228	212
Biomass	11	16	20	26	32	42
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
Direct heating[1)]	**1,131**	**1,171**	**1,181**	**1,134**	**1,093**	**1,043**
Fossil fuels	935	964	962	896	820	744
Biomass	138	139	143	146	159	172
Solar collectors	0	4	8	13	17	20
Geothermal	0	0	0	0	0	0
Heat pumps[2)]	1	1	1	3	6	8
Electric direct heating[3)]	57	63	67	76	91	98
Hydrogen	0	0	0	0	0	0
Total heat supply[1)]	**1,475**	**1,521**	**1,536**	**1,498**	**1,456**	**1,396**
Fossil fuels	1,266	1,296	1,295	1,232	1,148	1,051
Biomass	151	157	164	173	193	216
Solar collectors	0	4	8	13	17	20
Geothermal	0	0	0	1	2	3
Heat pumps[2)]	1	1	1	3	6	8
Electric direct heating[3)]	57	63	67	76	91	98
Hydrogen	0	0	0	0	0	0
RES share (including RES electricity)	**10.6%**	**11.1%**	**11.9%**	**13.7%**	**16.1%**	**18.8%**
Electricity consumption heat pumps (TWh/a)	0.1	0.1	0.1	0.3	0.4	0.6

1) and air conditioning 2) heat from ambient energy and electricity use; 3) heat from electric direct heating.

table 9.5: poland: CO_2 emissions

MILL t/a	2010	2015	2020	2030	2040	2050
Condensation power plants	**132**	**109**	**105**	**92**	**83**	**102**
Hard coal (incl. non-renewable waste)	69	50	49	44	46	62
Lignite	61	58	54	46	32	30
Gas	1	1	1	1	4	8
Oil	1	1	1	1	1	2
Diesel	0	0	0	0	0	0
Combined heat & power production	**26**	**35**	**39**	**36**	**36**	**33**
Hard coal (incl. non-renewable waste)	22	29	31	27	25	22
Lignite	1	1	0	0	1	1
Gas	3	4	7	8	9	10
Oil	1	1	1	1	1	1
CO_2 emissions power generation (incl. CHP public)	**158**	**145**	**144**	**128**	**119**	**135**
Hard coal (incl. non-renewable waste)	91	79	80	71	70	84
Lignite	62	58	55	47	33	31
Gas	3	6	8	9	14	18
Oil & diesel	2	2	2	2	2	2
CO_2 emissions by sector	**309**	**298**	**298**	**276**	**258**	**260**
% of 1990 emissions (351.9 Mill t)	88%	85%	85%	78%	73%	74%
Industry[1)]	28	31	33	35	34	33
Other sectors[1)]	57	55	51	38	30	25
Transport	47	51	53	57	59	54
Power generation[2)]	156	142	142	125	115	131
Other conversion[3)]	20	19	20	20	19	18
Population (Mill.)	38.5	38.5	38.5	37.7	36.4	34.9
CO_2 emissions per capita (t/capita)	**8.0**	**7.8**	**7.7**	**7.3**	**7.1**	**7.5**

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

table 9.6: poland: installed capacity

GW	2010	2015	2020	2030	2040	2050
Power plants	**26**	**31**	**32**	**36**	**43**	**54**
Hard coal	15	15	14	10	11	17
Lignite	8	9	9	8	5	5
Gas (incl. H_2)	1	1	1	1	4	8
Oil	1	1	0	0	1	1
Diesel	0	0	0	0	0	0
Nuclear	0	0	0	3	8	8
Biomass	1	1	0	0	0	1
Hydro	1	1	1	1	1	1
Wind	1	4	5	10	10	9
of which wind offshore	0	0	0	1	1	1
PV	0	0	0	2	3	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 production	**7**	**10**	**11**	**13**	**13**	**13**
Hard coal	5	7	7	6	5	4
Lignite	0	0	0	0	0	0
Gas (incl. H_2)	1	2	2	5	6	6
Oil	0	1	1	1	1	0
Biomass	1	1	1	1	1	2
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	6	9	10	12	12	11
Autoproducers	1	1	1	2	2	2
Total generation	**33**	**41**	**43**	**49**	**57**	**66**
Fossil	30	35	34	31	33	42
Hard coal	20	22	21	17	17	21
Lignite	8	9	9	8	5	5
Gas (w/o H_2)	1	2	3	6	10	15
Oil	1	1	1	1	1	1
Diesel	0	0	0	0	0	0
Nuclear	0	0	0	3	8	8
Hydrogen (fuel cells, gas power plants & CHP)	0	0	0	0	0	0
Renewables	**3**	**6**	**8**	**14**	**15**	**16**
Hydro	1	1	1	1	1	1
Wind	1	4	5	10	10	9
PV	0	0	0	2	3	4
Biomass	1	2	2	1	2	2
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)	1	4	6	12	13	13
Share of fluctuating RES	3.5%	8.8%	13.6%	24.8%	22.0%	19.2%
RES share (domestic generation)	**9.6%**	**15.7%**	**19.8%**	**29.8%**	**27.1%**	**24.2%**

table 9.7: poland: primary energy demand

PJ/a	2010	2015	2020	2030	2040	2050
Total	**4,224**	**4,433**	**4,543**	**4,702**	**5,019**	**5,133**
Fossil	**3,894**	**3,999**	**4,085**	**3,927**	**3,860**	**3,950**
Hard coal (& non-renewable waste)	1,775	1,633	1,641	1,404	1,289	1,390
Lignite	590	555	523	447	316	297
Natural gas	464	649	725	828	965	1,052
Crude oil	1,066	1,162	1,196	1,247	1,291	1,211
Nuclear	**0**	**0**	**5**	**262**	**611**	**611**
Renewables	**330**	**434**	**453**	**513**	**548**	**572**
Hydro	9	9	9	10	10	10
Wind	6	27	43	88	88	88
Solar	0	4	9	20	28	33
Biomass (& renewable waste)	314	392	389	391	415	430
Geothermal/ambient heat	1	1	2	5	8	12
Ocean energy	0	0	0	0	0	0
RES share	**7.8%**	**9.8%**	**10.0%**	**10.9%**	**10.9%**	**11.1%**

table 9.8: poland: final energy demand

PJ/a	2010	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**2,918**	**3,089**	**3,182**	**3,333**	**3,480**	**3,530**
Total (energy use)	**2,718**	**2,843**	**2,905**	**2,998**	**3,052**	**3,017**
Transport	**709**	**780**	**820**	**906**	**947**	**879**
Oil products	651	703	728	782	803	729
Natural gas	9	13	17	24	32	39
Biofuels	37	52	62	85	95	92
Electricity	11	12	13	15	17	19
RES electricity	1	1	2	3	3	3
Hydrogen	0	0	0	0	0	0
RES share Transport	**5.3%**	**6.9%**	**7.8%**	**9.7%**	**10.4%**	**10.8%**
Industry	**613**	**675**	**711**	**788**	**850**	**898**
Electricity	151	158	167	193	246	300
RES electricity	10	18	22	34	40	44
District heat	59	63	66	74	82	93
RES district heat	2	3	4	5	7	10
Hard coal + lignite	161	177	182	178	139	118
Oil products	48	56	56	55	50	43
Gas	153	174	192	237	278	288
Solar	0	0	0	2	5	6
Biomass and waste	42	48	48	51	51	51
Geothermal/ambient heat	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
RES share Industry	**8.8%**	**10.2%**	**10.4%**	**11.8%**	**12.1%**	**12.3%**
Other Sectors	**1,396**	**1,388**	**1,374**	**1,304**	**1,255**	**1,240**
Electricity	265	266	278	341	407	488
RES electricity	17	30	37	61	66	71
District heat	233	233	235	235	226	207
RES district heat	7	11	14	17	20	23
Hard coal + lignite	388	346	294	163	109	83
Oil products	132	129	122	101	82	62
Gas	235	263	286	298	261	226
Solar	0	4	8	11	13	14
Biomass and waste	143	146	150	153	152	154
Geothermal	1	1	1	2	4	6
Hydrogen	0	0	0	0	0	0
RES share Other Sectors	**12.0%**	**13.8%**	**15.3%**	**18.7%**	**20.4%**	**21.6%**
Total RES	**260**	**314**	**348**	**425**	**457**	**474**
RES share	**9.6%**	**11.0%**	**12.0%**	**14.2%**	**15.0%**	**15.7%**
Non energy use	**200**	**246**	**277**	**335**	**428**	**513**
Oil	128	154	173	203	251	290
Gas	69	89	100	127	171	215
Coal	3	3	4	5	6	8

poland: energy [r]evolution scenario

table 9.9: poland: electricity generation

TWh/a	2010	2015	2020	2030	2040	2050
Power plants	**128**	**129**	**142**	**180**	**241**	**320**
Hard coal (& non-renewable waste)	71	63	60	30	12	0
Lignite	48	48	42	31	14	0
Gas	1	2	7	20	17	19
of which from H_2	0	0	0	0	0	0
Oil	2	2	1	1	0	0
Diesel	0	0	0	0	0	0
Nuclear	0	0	0	0	0	0
Biomass (& renewable waste)	3	3	4	6	11	19
Hydro	2	3	3	3	3	3
Wind	2	8	22	74	151	235
of which wind offshore	0	0	3	34	87	152
PV	0	0	2	16	26	28
Geothermal	0	0	0	1	2	4
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	0	0	0	0	3	12
Combined heat & power plants	**29**	**32**	**34**	**39**	**43**	**47**
Hard coal (& non-renewable waste)	17	17	15	9	3	0
Lignite	1	1	1	0	0	0
Gas	5	6	8	13	20	24
of which from H_2	0	0	0	0	0	1
Oil	1	2	2	1	0	0
Biomass (& renewable waste)	4	5	7	12	16	18
Geothermal	0	1	2	4	4	5
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	24	25	26	28	29	32
Autoproducers	5	7	9	11	14	15
Total generation	**157**	**161**	**176**	**219**	**284**	**367**
Fossil	147	142	137	105	66	42
Hard coal (& non-renewable waste)	89	80	74	39	16	0
Lignite	49	49	43	31	14	0
Gas	6	9	15	33	37	41
Oil	3	4	4	1	0	0
Diesel	0	0	0	0	0	0
Nuclear	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	2
Renewables	**10**	**19**	**40**	**115**	**217**	**324**
Hydro	2	3	3	3	3	3
Wind	2	8	22	74	151	235
PV	0	0	2	16	26	28
Biomass (& renewable waste)	6	8	11	18	27	37
Geothermal	0	1	2	4	7	9
Solar thermal	0	0	0	0	0	0
Ocean energy	0	0	0	0	3	12
Distribution losses	12	12	13	15	17	19
Own consumption electricity	25	29	35	35	35	35
Electricity for hydrogen production	0	0	1	8	24	51
Final energy consumption (electricity)	**119**	**120**	**127**	**151**	**181**	**214**
Fluctuating RES (PV, Wind, Ocean)	2	8	24	89	180	275
Share of fluctuating RES	1.1%	5.2%	13.6%	40.8%	63.6%	74.9%
w/o exported offshore wind				37.9%	59.9%	71.1%
RES share (domestic generation)	**6.6%**	**12.0%**	**22.5%**	**52.3%**	**76.5%**	**88.1%**
'Efficiency' savings (compared to Ref.)	**0**	**2**	**4**	**17**	**33**	**46**

table 9.10: poland: heat supply

PJ/a	2010	2015	2020	2030	2040	2050
District heating	**134**	**129**	**131**	**107**	**95**	**69**
Fossil fuels	133	125	124	92	73	0
Biomass	2	2	3	2	2	0
Solar collectors	0	1	1	6	10	35
Geothermal	0	1	3	6	9	35
Heat from CHP	**210**	**192**	**200**	**224**	**239**	**265**
Fossil fuels	199	171	158	128	103	95
Biomass	11	14	27	63	95	112
Geothermal	0	7	15	32	40	49
Hydrogen	0	0	0	1	1	10
Direct heating[1]	**1,131**	**1,118**	**1,062**	**982**	**860**	**666**
Fossil fuels	935	900	832	646	382	120
Biomass	138	138	123	91	81	79
Solar collectors	0	11	21	86	128	145
Geothermal	0	0	0	0	0	0
Heat pumps[2]	1	10	18	68	125	120
Electric direct heating[3]	57	60	69	87	134	184
Hydrogen	0	0	0	4	9	19
Total heat supply[1]	**1,475**	**1,439**	**1,393**	**1,314**	**1,194**	**1,000**
Fossil fuels	1,266	1196	1114	867	558	215
Biomass	151	155	153	157	178	191
Solar collectors	0	12	22	92	139	180
Geothermal	0	8	18	39	49	83
Heat pumps[2]	1	10	18	68	125	120
Electric direct heating[3]	57	60	69	87	134	184
Hydrogen	0	0	0	4	11	28
RES share (including RES electricity)	**10.6%**	**13.5%**	**16.5%**	**31.4%**	**51.1%**	**76.4%**
Electricity consumption heat pumps (TWh/a)	0.1	0.8	1.5	5.3	9.3	8.3
'Efficiency' savings (compared to Ref.)		**82**	**143**	**185**	**262**	**395**

1) and air conditioning 2) heat from ambient energy and electricity use; 3) heat from electric direct heating.

table 9.11: poland: CO_2 emissions

MILL t/a	2010	2015	2020	2030	2040	2050
Condensation power plants	**132**	**113**	**101**	**64**	**30**	**7**
Hard coal (incl. non-renewable waste)	69	58	52	25	10	0
Lignite	61	53	44	31	13	0
Gas	1	1	3	8	6	6
Oil	1	1	1	1	0	0
Diesel	0	0	0	0	0	0
Combined heat & power production	**26**	**27**	**24**	**18**	**14**	**11**
Hard coal (incl. non-renewable waste)	22	21	18	11	4	0
Lignite	1	1	1	0	0	0
Gas	3	3	4	7	10	11
Oil	1	2	1	0	0	0
CO_2 emissions power generation (incl. CHP public)	**158**	**140**	**125**	**82**	**44**	**18**
Hard coal (incl. non-renewable waste)	91	79	70	36	14	0
Lignite	62	54	45	31	13	0
Gas	3	4	7	14	16	18
Oil & diesel	2	3	3	1	0	0
CO_2 emissions by sector	**309**	**286**	**259**	**179**	**99**	**36**
% of 1990 emissions (351.9 Mill t)	88%	81%	73%	51%	28%	10.3%
Industry[1]	28	31	31	30	22	10
Other sectors[1]	57	51	44	27	11	2
Transport	47	47	43	29	15	8
Power generation[2]	156	137	121	78	39	13
Other conversion[3]	20	21	20	16	12	4
Population (Mill.)	38.5	38.5	38.5	37.7	36.4	34.9
CO_2 emissions per capita (t/capita)	**8.0**	**7.4**	**6.7**	**4.8**	**2.7**	**1.0**
'Efficiency' savings (compared to Ref.)	**0**	**12**	**39**	**96**	**159**	**224**

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

table 9.12: poland: installed capacity

GW	2010	2015	2020	2030	2040	2050
Power plants	**26**	**33**	**38**	**66**	**104**	**133**
Hard coal	15	18	15	7	3	0
Lignite	8	8	7	5	2	0
Gas (incl. H_2)	1	1	2	7	16	20
Oil	1	1	1	0	0	0
Diesel	0	0	0	0	0	0
Nuclear	0	0	0	0	0	0
Biomass	1	0	1	1	3	6
Hydro	1	1	1	1	1	1
Wind	1	4	9	27	51	74
of which wind offshore	0	0	1	10	24	40
PV	0	0	2	16	26	28
Geothermal	0	0	0	0	0	1
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	0	0	0	0	1	3
Combined heat & power production	**7**	**8**	**8**	**10**	**12**	**14**
Hard coal	5	5	4	3	1	0
Lignite	0	0	0	0	0	0
Gas (incl. H_2)	1	1	1	4	6	8
Oil	0	1	1	0	0	0
Biomass	1	1	2	2	4	6
Geothermal	0	0	0	1	1	1
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	6	6	6	7	8	10
Autoproducers	1	2	2	3	4	4
Total generation	**33**	**41**	**47**	**76**	**116**	**147**
Fossil	30	35	32	27	28	27
Hard coal	20	23	19	10	4	0
Lignite	8	9	7	5	2	0
Gas (w/o H_2)	1	2	4	11	22	27
Oil	1	2	2	1	0	0
Diesel	0	0	0	0	0	0
Nuclear	0	0	0	0	0	0
Hydrogen (fuel cells, gas power plants & CHP)	0	0	0	0	0	1
Renewables	**3**	**7**	**15**	**48**	**87**	**119**
Hydro	1	1	1	1	1	1
Wind	1	4	9	27	51	74
PV	0	0	2	16	26	28
Biomass	1	2	2	4	7	12
Geothermal	0	0	0	1	1	1
Solar thermal	0	0	0	0	0	0
Ocean energy	0	0	0	0	1	3
Fluctuating RES (PV, Wind, Ocean)	1	4	12	43	78	105
Share of fluctuating RES	3.5%	9.5%	25.0%	56.5%	67.7%	71.1%
RES share (domestic generation)	**9.6%**	**16.0%**	**32.7%**	**63.9%**	**75.6%**	**81.0%**

table 9.13: poland: primary energy demand

PJ/a	2010	2015	2020	2030	2040	2050
Total	**4,224**	**4,295**	**4,145**	**3,695**	**3,285**	**3,085**
Fossil	**3,894**	**3,837**	**3,560**	**2,682**	**1,742**	**985**
Hard coal	1,775	1,668	1,517	1,016	613	263
Lignite	590	505	421	287	125	0
Natural gas	464	568	630	713	662	569
Crude oil	1,066	1,097	992	666	342	152
Nuclear	**0**	**0**	**0**	**0**	0	**0**
Renewables	**330**	**458**	**585**	**1,013**	**1,544**	**2,100**
Hydro	9	9	10	11	11	11
Wind	6	30	78	265	543	847
Solar	0	12	30	149	233	281
Biomass	314	384	413	448	508	600
Geothermal/ambient heat	1	23	53	139	236	319
Ocean energy	0	0	0	1	12	42
RES share	**7.8%**	**10.8%**	**14.1%**	**26.8%**	**45.6%**	**66.3%**
'Efficiency' savings (compared to Ref.)	**0**	**138**	**398**	**1,007**	**1,734**	**2,048**

table 9.14: poland: final energy demand

PJ/a	2010	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**2,918**	**2,939**	**2,849**	**2,625**	**2,363**	**2,163**
Total (energy use)	**2,718**	**2,706**	**2,599**	**2,357**	**2,064**	**1,855**
Transport	**709**	**738**	**701**	**584**	**473**	**461**
Oil products	651	657	593	386	173	61
Natural gas	9	12	14	30	48	69
Biofuels	37	53	65	83	82	83
Electricity	11	16	26	71	117	148
RES electricity	1	2	6	37	90	131
Hydrogen	0	0	2	15	52	100
RES share Transport	**5.3%**	**7.4%**	**10.2%**	**21.9%**	**44.7%**	**65.4%**
Industry	**613**	**668**	**691**	**746**	**739**	**666**
Electricity	151	154	165	184	234	305
RES electricity	10	19	37	96	179	269
District heat	59	67	73	91	105	103
RES district heat	2	5	10	30	50	78
Hard coal + lignite	161	159	156	145	79	0
Oil products	48	53	48	33	13	6
Gas	153	181	188	208	191	114
Solar	0	2	4	12	21	28
Biomass and waste	42	51	53	58	67	70
Geothermal/ambient heat	0	2	3	10	17	21
Hydrogen	0	0	0	4	10	20
RES share Industry	**8.8%**	**11.6%**	**15.6%**	**27.9%**	**46.4%**	**72.6%**
Other Sectors	**1,396**	**1,299**	**1,207**	**1,027**	**852**	**728**
Electricity	265	261	266	289	301	317
RES electricity	17	31	60	151	230	280
District heat	233	207	210	195	186	188
RES district heat	7	15	29	64	88	144
Hard coal + lignite	388	344	280	167	66	0
Oil products	132	111	87	40	8	1
Gas	235	221	220	155	73	11
Solar	0	9	17	74	107	117
Biomass and waste	143	141	118	69	36	25
Geothermal	1	5	9	38	74	69
Hydrogen	0	0	0	0	0	0
RES share Other Sectors	**12.0%**	**15.5%**	**19.3%**	**38.6%**	**62.9%**	**87.1%**
Total RES	**260**	**334**	**412**	**733**	**1,090**	**1,419**
RES share	**9.6%**	**12.4%**	**15.9%**	**31.1%**	**52.8%**	**76.5%**
Non energy use	**200**	**234**	**249**	**268**	**300**	**308**
Oil	128	145	150	150	129	77
Gas	69	86	92	94	105	108
Coal	3	2	7	24	66	123

poland: investment & employment

table 9.15: poland: 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)	**8,417**	**17,493**	**33,163**	**16,425**	**75,498**	**1,887**
Renewables	**6,785**	**9,395**	**6,632**	**9,304**	**32,116**	**803**
Biomass	1,019	532	1,421	1,096	4,068	102
Hydro	767	392	441	444	2,043	51
Wind	4,668	6,980	3,839	6,035	21,522	538
PV	331	1,492	931	1,729	4,482	112
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
Energy [R]evolution						
Conventional (fossil & nuclear)	**8,802**	**3,677**	**5,090**	**9,580**	**27,149**	**679**
Renewables	**14,045**	**41,859**	**59,577**	**78,565**	**194,046**	**4,851**
Biomass	598	2,386	4,520	8,469	15,973	399
Hydro	863	625	430	444	2,363	59
Wind	10,273	27,102	42,327	54,895	134,598	3,365
PV	2,310	11,746	10,312	11,544	35,912	898
Geothermal	0	0	980	632	1,612	40
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	0	0	1,007	2,581	3,588	90

table 9.16: poland: total investment in renewable heating only

(EXCLUDING INVESTMENTS IN FOSSIL FUELS)

MILLION €	2011-2020	2021-2030	2031-2040	2041-2050	2011-2050	2011-2050 AVERAGE PER YEAR
Reference scenario						
Renewables	**13,033**	**7,081**	**4,849**	**3,849**	**28,812**	**720**
Biomass	10,434	5,367	989	937	17,726	443
Geothermal	273	31	584	585	1,473	37
Solar	2,054	1,060	2,542	1,325	6,981	175
Heat pumps	272	623	734	1,002	2,631	66
Energy [R]evolution scenario						
Renewables	**12,391**	**28,188**	**32,688**	**26,561**	**99,828**	**2,496**
Biomass	1,484	1,128	892	200	3,705	93
Geothermal	1,432	269	1,969	11,125	14,795	370
Solar	5,411	14,978	13,315	10,745	44,449	1,111
Heat pumps	4,065	11,813	16,513	4,490	36,880	922

table 9.17: poland: total employment

THOUSAND JOBS		REFERENCE			ENERGY [R]EVOLUTION		
	2010	2015	2020	2030	2015	2020	2030
By sector							
Construction and installation	14,300	6,500	9,100	11,700	9,000	13,200	16,300
Manufacturing	6,200	1,800	1,900	1,600	4,100	5,300	6,300
Operations and maintenance	12,800	15,900	14,500	13,200	15,500	16,800	19,900
Fuel supply (domestic)	132,000	128,400	123,300	101,000	128,300	116,600	82,200
Coal and gas export	-	-	-	-	-	-	-
Solar and geothermal heat	2,900	4,700	4,200	2,600	40,500	15,600	49,000
Total jobs	**168,200**	**157,300**	**153,000**	**130,100**	**197,400**	**167,500**	**174,300**
By technology							
Coal	127,300	106,100	104,000	83,900	106,600	94,200	59,300
Gas, oil & diesel	6,300	6,000	4,000	3,900	6,400	6,000	6,600
Nuclear	200	3,700	7,000	12,000	-	-	-
Total renewables	**34,400**	**41,400**	**38,000**	**30,200**	**84,500**	**67,200**	**108,700**
Biomass	*27,500*	*32,500*	*28,200*	*24,100*	*33,400*	*34,500*	*36,400*
Hydro	*800*	*600*	*600*	*500*	*700*	*800*	*600*
Wind	*2,900*	*3,300*	*4,200*	*2,100*	*8,300*	*11,300*	*15,100*
PV	*300*	*300*	*800*	*900*	*1,000*	*4,500*	*7,200*
Geothermal power	-	-	-	-	*500*	*500*	*300*
Solar thermal power	-	-	-	-	-	-	-
Ocean	-	-	-	-	-	-	*100*
Solar - heat	*1,800*	*4,300*	*3,700*	*1,700*	*24,100*	*9,900*	*30,300*
Geothermal & heat pump	*1,100*	*400*	*500*	*900*	*16,500*	*5,700*	*18,700*
Total jobs	**168,100**	**157,300**	**153,000**	**130,100**	**197,500**	**167,500**	**174,400**

poland: transport

table 9.18: poland: final energy consumption transport

PJ/a	2010	2015	2020	2030	2040	2050
Reference scenario						
Road	**684**	**752**	**788**	**865**	**889**	**797**
Fossil fuels	646	696	718	766	771	676
Biofuels	37	52	62	85	95	92
Natural gas	0	3	7	14	22	29
Hydrogen	0	0	0	0	0	0
Electricity	0	0	0	0	0	0
Rail	**16**	**16**	**17**	**19**	**20**	**22**
Fossil fuels	5	4	4	4	3	3
Biofuels	0	0	0	0	0	0
Electricity	11	12	13	15	17	19
Navigation	**0**	**0**	**0**	**0**	**0**	**0**
Fossil fuels	0	0	0	0	0	0
Biofuels	0	0	0	0	0	0
Aviation	**0**	**2**	**5**	**12**	**28**	**50**
Fossil fuels	0	2	5	12	28	50
Biofuels	0	0	0	0	0	0
Total (incl. pipeline)	**709**	**780**	**820**	**906**	**947**	**879**
Fossil fuels	651	703	728	782	803	729
Biofuels (incl. biogas)	37	52	62	85	95	92
Natural gas	9	13	17	24	32	39
Hydrogen	0	0	0	0	0	0
Electricity	11	12	13	15	17	19
Total RES	**38**	**54**	**65**	**93**	**108**	**109**
RES share	**5.3%**	**6.9%**	**7.8%**	**9.7%**	**10.4%**	**10.8%**
Energy [R]evolution						
Road	**684**	**707**	**667**	**545**	**422**	**393**
Fossil fuels	646	651	585	375	157	43
Biofuels	37	53	65	82	77	65
Natural gas	0	2	4	20	38	59
Hydrogen	0	0	2	15	52	100
Electricity	0	2	11	53	97	126
Rail	**16**	**19**	**20**	**21**	**21**	**23**
Fossil fuels	5	5	5	3	1	0
Biofuels	0	0	0	0	0	0
Electricity	11	14	15	17	20	22
Navigation	**0**	**0**	**0**	**0**	**0**	**0**
Fossil fuels	0	0	0	0	0	0
Biofuels	0	0	0	0	0	0
Aviation	**0**	**1**	**4**	**8**	**20**	**35**
Fossil fuels	0	1	4	8	15	18
Biofuels	0	0	0	1	5	18
Total	**709**	**738**	**701**	**584**	**473**	**461**
Fossil fuels	651	657	593	386	173	61
Biofuels (incl. biogas)	37	53	65	83	82	83
Natural gas	9	12	14	30	48	69
Hydrogen	0	0	2	15	52	100
Electricity	11	16	26	71	117	148
Total RES	**38**	**55**	**71**	**128**	**212**	**301**
RES share	**5.3%**	**7.4%**	**10.2%**	**21.9%**	**44.7%**	**65.4%**

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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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