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REPORT 2005

# ENERGY REVOLUTION: A SUSTAINABLE PATHWAY TO A CLEAN ENERGY FUTURE FOR EUROPE

A EUROPEAN ENERGY  
SCENARIO FOR EU-25

GREENPEACE

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## introduction

Climate change is real and it is happening now; the result of the greenhouse gases we are pumping into the atmosphere, climate change impacts our lives and is expected to destroy many natural environments in the coming years. A rise of the global mean temperature of 2°C or more above pre-industrial levels would mean a dramatic increase in damage to ecosystems and disruption to the climate system. Today, we are already committed to 1.2 or 1.3°C warming, even if all greenhouse emissions were stopped immediately. To keep global mean temperature below the 2°C level, we have a very short time window to act. Within no more than one to two decades, we have to change our energy system to meet this target.

Nuclear power is as radioactive and dangerous as ever. Every part of the nuclear cycle has unacceptable risks, from the mining of uranium, to the production of energy, to the unsolved problem of safely transporting and storing radioactive waste and the threat of nuclear proliferation. Today the nuclear industry tries to present itself as the solution to climate change in a massive green-washing drive. To replace one environmental catastrophe, polluting fossil fuel power, with another environmental disaster, nuclear energy is clearly not the answer.

Within the 25 European Union nations the electricity sector is still dominated by large centralized power plants using fossil and nuclear fuels. This sector is responsible for releasing more than 1.2 billion tons of carbon dioxide (CO<sub>2</sub>) and over 2600 tons of dangerous radioactive waste every year. What's more, only 0.6% of the oil, 2% of the gas, 7.3% of the coal and almost none of the world's uranium lie within the 25 EU member states, so the EU has to import most of its energy. This reliance on imported fossil and nuclear energy means there is no security of supply for the future.

As we face this short time period to act and a sector dominated by fossil and nuclear fuel the power sector also stands at a crossroads. More than half of Europe's operating power plants are over 20 years old and the power sector will decide over the next ten years, whether this new capacity will be fossil and nuclear fuels or the efficient use of renewable energy.

As this repowering debate takes place, the EU is also liberalising the electricity and gas markets, discussing climate reduction targets beyond the first commitment period of the Kyoto Protocol and setting new targets for renewable electricity within a Renewable Electricity directive. These political decisions will largely decide whether we achieve the energy shift needed in Europe to advance the global fight against dangerous climate change! It is vital, that the EU starts an early and rapid conclusion of negotiations for the second commitment period (2013-2017) of the Kyoto Protocol, continuing the absolute emission-reduction caps for industrialized countries and increasing them to at least 30% overall reductions for the third commitment period (2018-2022).

Greenpeace urges the politicians of the EU and the European member states to make all efforts to bring the US and Australia back into the system, but the EU must move ahead regardless of what the US does.

**the Greenpeace energy revolution scenario:** A sustainable pathway to a clean energy future for Europe

Greenpeace and the Institute of Technical Thermodynamics, Department of Systems Analysis and Technology Assessment of the German Aerospace Center (DLR), have developed a blueprint for the EU energy supply that shows how Europe can lead the way to a sustainable pathway to a clean energy future. The Greenpeace energy revolution scenario demonstrates that phasing out nuclear power and massively reducing CO<sub>2</sub>-emissions is possible.

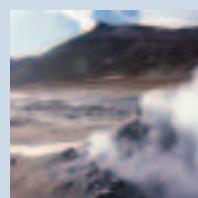
The scenario comes close to a fossil fuels phase-out by aiming for a 80% CO<sub>2</sub> emissions reduction by 2050. The pathway in this scenario achieves this phase-out in a relatively short time-frame without using technological options (such as 'clean coal') that are ultimately dead ends, deflecting resources from the real solutions offered by renewable energy. Whilst there are many technical options that will allow us to meet short-term EU Kyoto targets (-8% GHG by 2010), these may have limited long-term potential. To meet these long term targets (2050) we have to make clear and precise choices today. The Greenpeace Energy Revolution Scenario proves that renewable energy sources, combined with energy efficiency, can deliver!

Europe can switch to clean energy protecting the climate, protecting our economy from global market fluctuations and providing future generations with secure access to energy.

The Greenpeace Energy Revolution Scenario shows that in the long run, renewable energy will be cheaper than conventional energy sources and reduce EU's dependence from world market prices from imported fossil and nuclear fuels. The rapid growth of renewable energy technologies will lead to a large investment in new technologies. This dynamic market growth will result in a shift of employment opportunities from conventional energy-related industries to new occupational fields in the renewable energy industry. Renewable energy is expected to provide about 700,000 jobs in the field of electricity generation from renewable energy sources by 2010.

### **No time to waste!**

The Greenpeace Energy Revolution Scenario also indicates that the EU has very little time left to kick start the renewable energy industry in all member states. A delay of even a few years will make it impossible for the EU to achieve the needed CO<sub>2</sub>-reduction targets! Greenpeace calls for EU politicians, policymakers and the European electricity sector to invest in our future and take action now.



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# ENERGY REVOLUTION: A SUSTAINABLE PATHWAY TO A CLEAN ENERGY FUTURE FOR EUROPE

## A EUROPEAN ENERGY SCENARIO FOR EU-25

### executive summary

#### energy revolution: a sustainable pathway to a clean energy future for Europe

Today, renewable energy sources account for 6% of the EU-25 countries' primary energy production. Biomass, which is used primarily for heating, is the main renewable energy source. The share of renewable energies for electricity generation is 15%, with hydro power plants being the largest source. The contribution of renewables to primary energy demand for heat supply is around 9%. About 80% of the European primary energy supply today still comes from fossil fuels.

The Energy Revolution Scenario describes a development pathway which turns the present situation into a sustainable European energy supply:

- \* Exploitation of existing large energy efficiency potentials will reduce the current primary energy demand from 72,000 PJ/a (2003) to 46,000 PJ/a in 2050. This dramatic reduction in primary energy demand is a crucial prerequisite for achieving a significant share of renewable energy sources in the overall energy supply system, compensating for the phase out of nuclear energy, and for reducing the consumption of fossil fuels.
- \* The increased used of combined heat and power generation (CHP) will increase the supply system's energy conversion efficiency. Fossil fuels for CHP are increasingly being substituted by biomass and geothermal energy. The availability of district heating networks is a key precondition for achieving a high share of decentralised CHP. In the long term, the decreasing heat demand and the large potential for producing heat directly from renewable energy sources will limit the further expansion of combined heat and power generation.
- \* The electricity sector will continue to be the forerunner of RES utilisation. By 2050, more than 70% of the electricity is to be produced from renewable energy sources (including large hydro). A capacity of 720 GW will produce 1,920 TWh/a RES electricity in 2050.
- \* In the heat supply sector, the contribution of renewables will continue to grow to more than 50% in 2050. In particular, this applies to biomass, solar collectors and geothermal energy as substitutes for conventional systems for direct heating and cooling.
- \* Before biofuels are introduced on a massive scale into the transport sector, the existing large efficiency potentials have to be exploited. Due to the more cost-effective use of biomass for CO<sub>2</sub> reduction in stationary applications, the use of biofuels is limited by the availability of biomass within the EU-25 countries.
- \* By 2050, nearly half of the primary energy demand will be covered by using renewable energy sources.

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

**development of CO<sub>2</sub> emissions** While under the Reference Scenario, CO<sub>2</sub> emissions in the EU-25 countries will increase by nearly 50% by 2050 and are thus a long way from a sustainable development path, under the Energy Revolution Scenario CO<sub>2</sub> emissions will be continually reduced from 3,850 Mill. t in 2000 to 1,150 Mill. t in 2050. Annual per capita emissions drop from 7.9 t/capita to 2.7 t/capita. While the phasing out of nuclear energy together with increasing electricity demand will lead to a very small increase in CO<sub>2</sub> emissions in the electricity sector until 2010, efficiency gains and the increased use of renewables for heating in the residential sector will compensate for this increase, thus facilitating a continual decrease in total CO<sub>2</sub> emissions. Although the power sector is currently the largest source of CO<sub>2</sub>-emissions in Europe, it will contribute to less than 20% of total CO<sub>2</sub> emissions in 2050.

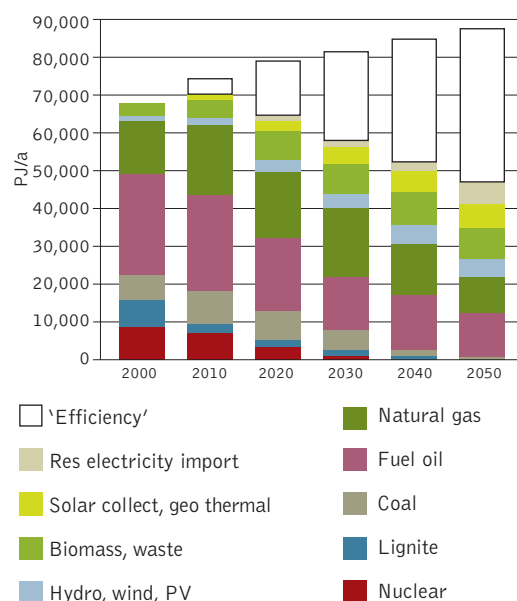
**costs** The slightly higher specific electricity generation costs under the Energy Revolution Scenario are compensated, to a large extent, by the reduced demand for electricity. Assuming average costs of 4.5 ct/kWh for implementing energy efficiency measures, the additional cost for electricity supply under the Energy Revolution Scenario – without considering the costs of CO<sub>2</sub> emissions – will amount to a maximum of 6 billion €/a in 2020. These additional costs, which represent society's investment in a future environmentally benign, safe, and economic energy supply, continue to decrease after 2020, and by 2050 the annual costs of electricity supply will be 10 billion €/a below the electricity supply costs in the Reference Scenario. Inclusion of the costs of CO<sub>2</sub> emissions further emphasises the long-term economic benefits of the Energy Revolution Scenario.

**effects on employment** The rapid growth of renewable energy technologies described under the Energy Revolution Scenario will lead to a large investment in new technologies. This dynamic market growth will result in a shift of employment opportunities from conventional energy-related industries like coal mining to new occupational fields in, for example, the wind and solar industry. In the coming years, the growing contribution of renewables is expected to provide about 700,000 jobs in the field of electricity generation from renewable energy sources. This includes both 'direct' effects related to electricity generation and the production of investment goods, as well as 'indirect' effects covering the upstream production chain. It's anticipated that, under the Energy Revolution Scenario, in 2050 more than 90% of the jobs related to electricity generation will be linked to the process chains of RES technologies.

#### to make the energy revolution real and to avoid dangerous climate change, Greenpeace demands for Europe's energy sector:

- \* The phasing out of all subsidies for fossil fuels and nuclear energy and the internalisation of external costs
- \* The setting out of legally binding targets for renewable energy
- \* The provision of defined and stable returns for investors
- \* Guaranteed and priority access to the grid.

FIGURE 1: DEVELOPMENT OF PRIMARY ENERGY CONSUMPTION UNDER THE ENERGY REVOLUTION SCENARIO ('EFFICIENCY= REDUCTION COMPARED TO THE REFERENCE SCENARIO')



**climate protection** Every day we damage our climate by using fossil fuels (oil, coal and gas) for energy and transport. Climate change is already making an impact on our lives and it will get worse; it will also affect many ecosystems in the coming years. We need to reduce our greenhouse gas emissions significantly. We have already experienced a global mean temperature rise of 0.6°C during the last century and, as a result of the greenhouse gases we have pumped into the atmosphere, we are already committed to 1.2° or 1.3°C warming, even if all emissions were to be stopped tomorrow. The goal of responsible climate policy should be to keep the increase in global mean temperature to less than 2°C above pre-industrial levels. Above 2°C, damage to ecosystems and disruption to the climate system increases dramatically. We have a very short time window, i.e. no more than one to two decades, within which we can change our energy system to meet these targets.

**TABLE 1: THE ANNUAL GLOBAL TEMPERATURE ANOMALIES – RANKED IN ORDER 1990 - 2004**

YEAR	GLOBAL TEMPERATURE ANOMALY	RANK
1998	0.63°C	1
2003	0.56°C	2 (tie)
2002	0.56°C	2 (tie)
2004	0.54°C	4
2001	0.51°C	5
1997	0.47°C	6
1995	0.40°C	7 (tie)
1990	0.40°C	7 (tie)
1999	0.38°C	9
2000	0.37°C	10

SOURCE: National Climatic Data Center  
\*With Respect to 1880-2003 Mean

**an average global warming of two degrees centigrade:**

- \* threatens millions of people with increased risk of hunger, increased risk of malaria, and with increased flooding, and billions with increased risk of water shortages.
- \* mainly damages the poorest and developing countries, particularly in sub-Saharan Africa, South Asia, and parts of Southeast Asia and Latin America.
- \* risks melting the main ice sheets, and the probability of the sea level rising by many metres over several centuries, particularly the Greenland ice sheet (seven metres), and the West Antarctic ice sheet (WAIS) (five to seven metres). Greenland melting is already accelerating.
- \* ensuing rise in sea level threatens large populations everywhere, particularly low-lying areas in developing countries such as Bangladesh, South China, and low-lying island states everywhere, not to mention 'the Low Countries' (Belgium, the Netherlands, NW Germany), and south-east UK.
- \* threatens damage to major ecosystems from the Arctic and Antarctic to the tropics.
- \* loss of forests and species will affect the lives of everyone on earth, with economic costs falling disproportionately on the poor and developing countries.

There is an absolute imperative for global action to rapidly reduce greenhouse gas emissions globally to avoid the catastrophic impacts of climate change which are very likely with a global mean temperature rise

of 2°C or more above pre-industrial levels. Therefore, all efforts must be made to keep the global mean temperature rise below 2°C and then to bring it down as quickly as possible. This means reducing the emissions from industrialized countries to around 30% below 1990 levels by 2020, and by 70% or more by mid-century, while global emissions must be reduced by about 50% by mid-century. The "Energy Revolution Scenario brings us quite close when it comes to CO<sub>2</sub> emissions, which are reduced by 73% as compared with 1990 levels. Other measures, referring to methane, nitrous oxide and F-gases, would be required to meet the 30% overall greenhouse gas emission reductions.

- \* The international community must proceed with broadening and strengthening the international climate regime NOW: both because of the urgency of the problem and the importance of immediate action, and because of the need for continuity. The entry into force of the Kyoto Protocol, inadequate as it is and with all its faults, and the introduction of the European emissions trading system, have sent clear signals to the markets, and the business, industry and financial sectors are responding in ways that will affect the trillions of dollars which are to be invested in the energy sector in the coming two decades. These signals must be continued beyond 2012 and strengthened.

**greenpeace calls for:**

- \* An early start and rapid conclusion of negotiations for the second commitment period (2013-2017) of the Kyoto Protocol, continuing the absolute emission-reduction caps for industrialized countries and increasing them to at least 30% overall reductions for the third commitment period (2018-2022). This must include improving and strengthening the so-called 'flexible mechanisms' of the Protocol, using the price of carbon to drive the development and diffusion of the clean technologies the world so desperately needs. The countries covered by these caps should be broadened somewhat, and all efforts must be made to bring the US and Australia back into the system, but must move ahead regardless of what the US does;
- \* A new 'decarbonisation' track, engaging rapidly industrializing countries such as China, India and Brazil in major programs to 'decarbonise' their economies, to increase their progress to low- and no-carbon technologies faster than 'business-as-usual' while, at the same time, respecting their legitimate aspirations for economic growth and a better standard of living for their citizens. The industrialized countries must help to accelerate the dissemination of low- and no-carbon technology at home and in rapidly industrializing countries in the developing world. Renewable energy, energy efficiency and fuel switching to less carbon-intensive fuels – these are the ways to 'engage' the large emitters in the industrializing world in the global effort to protect the climate;
- \* Serious, concerted global action to help the world's poorest and most vulnerable countries adapt to the impacts of climate change which are already upon us, and which will get much worse in the coming decades. The developed world has a legal, political and moral responsibility to assist these countries to deal with the floods, droughts, storms, disease and famine which are being exacerbated by climate change; on top of the overriding responsibility to limit these impacts as much as is humanly possible. But whatever happens, millions of people will be displaced by climate change, their livelihoods will be disrupted or destroyed, and the tens of thousands who die annually from climate change impacts today will no doubt grow to hundreds of thousands and perhaps millions per year until we get this problem under control.



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## END NUCLEAR THREATS

### 1. URANIUM MINING

Uranium, used in nuclear power plants, is extracted from huge uranium mines in Canada, Australia, Russia and Nigeria. Mining workers can breathe in radioactive gas from which they are in danger of contracting lung cancer. The uranium is extracted by acid from the ore. The product of this process – after another production process – is a concentrate called 'yellow cake'. Uranium mining produces huge quantities of mining debris, including radioactive particles which can contaminate surface water and food.

### 2. URANIUM ENRICHMENT:

Natural uranium and 'yellow cake' contain just 0.7% of fissionable uranium 235. To use the material in a nuclear power plant, the share must go up to 3 to 5%. This process can be carried out in 16 facilities around the world. Eighty percent of the total volume ends up as 'tails', the waste product and becomes uranium waste. Enrichment generates massive amounts of 'depleted uranium' that ends up as long-living radioactive waste or is used in weapons or tank shielding.

### 3. FUEL ROD – PRODUCTION

The enriched material is converted into uranium dioxide and compressed to pellets in fuel rod production facilities. These pellets fill 4m-long tubes called fuel rods. There are 29 fuel rod production facilities globally. The worst accident in this type of facility so far happened in September 1999 in Tokaimura, Japan. Due to an out of control chain reaction two workers died. Several hundred workers and villagers have suffered radioactive contamination.

### 4. NUCLEAR POWER PLANT OPERATION

Uranium nuclei are split in a nuclear power plant. This process releases energy which heats up water. The compressed steam is converted in a turbine and a generator into electricity. This process creates a radioactive 'cocktail' which involves more than 100 radioactive products. One of these is the highly toxic and long-lasting plutonium. Radioactive material can enter the environment through accidents within nuclear power plants. The worst accident to date happened in Chernobyl, in the then Soviet Union in 1986.

**Atomic bomb** A nuclear reactor generates enough plutonium every year for the production for as many as 39 nuclear weapons.

### 5. REPROCESSING

Within the reprocessing procedure, contaminated uranium and plutonium are extracted from the fuel rods by chemical substances. There are now over 230,000 kilograms of plutonium stockpiled around the world from so called peaceful reprocessing - 5 kilograms is sufficient for one devastating nuclear bomb. 'Reprocessing' has nothing to do with recycling: the volume of waste increases many tens of times and millions of litres of radioactive waste are discharged into the sea and into the air each day of reprocessing.

**Transportation** Radioactive material and nuclear waste are transported via ship, rail, air and road transport around the world. An accident or terrorist attack could release vast quantities of nuclear material into the environment. There is no way to guarantee the safety of nuclear transport.

### 6. INTERIM STORAGE

There is not a single final storage facility available globally for nuclear waste. And it is not possible to store high-level radioactive material for thousands of years. Safe secure storage of high level waste over thousands of years remains unproven leaving a deadly legacy of future generations. Despite this the nuclear industry continues to generate more and more each day.

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## energy policy in the european union

The EU-25 must adopt legally binding greenhouse gas reduction targets that are consistent with limiting temperature rise to below 2°C. This translates into targets of at least -30% by 2020 and -80% by 2050 (compared to 1990 levels).

Energy policy is instrumental for achieving these greenhouse gas reductions. Greenpeace demands concrete and ambitious actions in promoting renewable energy sources and energy efficiency measures.

**energy efficiency** The potential for reducing energy consumption within the European Union is significant. It is estimated that current energy demand can be cut in a cost-effective manner by as much as 30%, while the technical potential for improvement of energy use is even higher – as high as 40% of current energy consumption.

During summer 2005, the European institutions are working on a crucial piece of legislation on energy efficiency (Directive on Energy End-use Efficiency and Energy Services). Greenpeace is advocating the need for this Directive to include mandatory efficiency targets, given that these are essential for the creation of a stable legal framework and certainty for investors. The magnitude of these targets is also at stake: Greenpeace criticises the proposed Directive's low mandatory targets for annual energy savings, which equal just 1% of private customer energy use and 1.5% of the amount distributed to the public sector. Greenpeace advises annual targets of at least 2.5% for the private sector and 3% for the public sector.

**renewable energy** Greenpeace demands the adoption of a legally binding target to achieve a minimum of 20% renewable energy from primary energy by 2020 in the EU-25. Within this overall target, sectoral targets are needed for:

- \* Electricity
- \* Heat
- \* Transport

A strong EU Renewable Energy Directive is vital to achieve the pathway we are presenting with this Energy Revolution scenario for the EU-25. At a time when European governments are in the process of liberalising their electricity markets, renewable energy and its increasing competitiveness should lead to higher demand for clean energy equipment. Without political support, however, renewable energy remains at a disadvantage because of distortions in the electricity markets created by decades of massive financial, political and structural support towards conventional polluting and dangerous technologies. New renewable energy generators (excluding large hydroelectric projects) have to compete with old nuclear and fossil fuel power stations. The latter produce electricity at marginal costs, because consumers and taxpayers have already paid both the interest and the depreciation on the investments. Political action is needed to overcome these distortions, and to create a level playing field for renewable energy sources so that they can deliver their full advantages to the environment, the economy and society.

According to the European Commission's Green Paper on Security of Energy Supply, unless Europe changes direction, within 20 years it will be importing 70% of its energy (up from 50% today). Renewable power can plug the gap in European energy supply while at the same time contributing significantly to the goals set out in the Lisbon Strategy: sustainable economic growth, high-quality jobs, technology development, global competitiveness, and European industrial and research leadership.

Furthermore, wind power and other renewable energy technologies will make a large contribution to climate protection and sustainable development.

**recommendations on the review of the renewable energy directive** In recent years, an increasing number of countries have established targets for renewable energy as part of their greenhouse gas reduction policies. These are either expressed in terms of installed capacity or as a percentage of energy consumption. In 2001, the European Union adopted a Renewable Energy Directive establishing national targets for each Member State. Although these targets are not legally binding, they have served as an important catalyst in triggering political initiatives throughout Europe to increase the share of electricity supply from renewable energy sources.

## Europe needs a legally binding target for renewable energy and electricity

The Directive aims to increase the share of renewable electricity from 14% in 1997 to 21% in 2010. If there is uncertainty that this target will be met, the most fundamental measure to correct the EU's course on renewables would be for the European Commission to push for 2010 targets to become mandatory. To guarantee the future of renewable energy, the Commission needs to propose legally binding targets for 2020.

## setting mandatory renewable energy targets

- \* Setting mandatory national targets for 2010 would be appropriate and lead to greater efforts by all Member States.
- \* New ambitious, legally binding, national targets for 2020 would demonstrate the EU's long-term commitment to renewable energy, and would enhance investor confidence significantly. Mandatory 2020 targets would also dramatically increase Europe's likelihood of meeting its 2010 targets.
- \* Achieving technological diversity within the renewable energy sector is crucial and the aim of any support mechanism should be to encourage and strengthen this diversity.
- \* Indicative targets for the share of different renewable energy technologies in 2020 should be set at EU level in a process similar to that which established the overall EU 2010 White Paper targets. That would strengthen the aim of reaching technological diversity in the renewable power sector and enable each of the different technologies to unfold its competitive potential.

**an expansion of renewable energy in European member states** The existing size of the renewable component in electricity generation and primary energy consumption should be taken into account when proposing national targets. Member States that already have a high proportion of renewable electricity generation need to set higher targets than those that currently have a lower proportion. We need to guarantee that there is real expansion rather than just bringing existing facilities into the equation.

**state-specific targets related to previous energy supply** Objectives for individual states must be defined according to the status quo in energy supply. The starting point for calculating targets must be a combination of both the state of primary energy supply (for heating, industrial heat processes, refrigeration and transport) and of the electricity generation structure. In order for the proportion of renewable energy to increase significantly, targets must be set in accordance with the local potential of each technology (wind, solar, available biomass, etc.) and also according to local infrastructure, both existing and still to be built (ease of connection to networks, production and installation capacity, etc.).

# ENERGY REVOLUTION: A SUSTAINABLE PATHWAY TO A CLEAN ENERGY FUTURE FOR EUROPE

## A EUROPEAN ENERGY SCENARIO FOR EU-25

**end subsidies to fossil fuel and nuclear power sources** Conventional energy sources receive an estimated \$250-300 billion in subsidies per year worldwide, heavily distorting markets. The Worldwatch Institute estimates that total world coal subsidies are \$63 billion, while in Germany alone the total is €21 billion, including direct support of more than €85,000 per miner. 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. As the 1998 OECD study "Improving the Environment through Reducing Subsidies" noted:

***"Support is seldom justified and generally deters international trade, and is often given to ailing industries. ...support may be justified if it lowers the long-term marginal costs to society as a whole. This may be the case with support to 'infant industries', such as producers of renewable energy."***

Renewable energy would not need special provisions if markets were not distorted by the fact that it still costs virtually nothing for electricity producers to pollute. Subsidies for fully competitive and polluting technologies are highly unproductive, seriously distort markets and increase the need to support renewables. Removing subsidies from conventional electricity would not only save taxpayers' money and reduce current market distortions in the electricity market, but would also dramatically reduce the need for renewable energy support. In 2004, the European Environment Agency estimated that energy subsidies in the EU-15 for solid fuels, oil and gas amounted to more than €23.9 billion and for renewable energy to €5.3 billion<sup>1</sup>.

**removal of energy market distortions** In addition to market barriers, there are also market distortions which block the expansion of renewable energy. These distortions come in the form of direct and indirect subsidies, and the social cost of externalities currently excluded from costs of traditional, polluting electricity from nuclear power and fossil fuels. A major barrier preventing wind power from reaching its full potential is the fundamental lack of pricing structures in the energy markets that reflect the full costs to society of producing energy. Furthermore, the overall electricity market framework is very different today from the one which existed when coal, gas, and nuclear technologies were introduced. For more than a century, power generation has been characterised by national monopolies with mandates to finance investments in new production capacity through state subsidies and/or levies on electricity bills. As many countries are moving in the direction of more liberalised electricity markets, these options are no longer available, which puts new generating technologies, such as wind power, at a competitive disadvantage relative to existing technologies.

**internalisation of the social and environmental costs of polluting energy** The real cost of energy production by conventional energy includes expenses absorbed by society, such as health impacts and local and regional environmental degradation, ranging from mercury pollution to acid rain – as well as negative global impacts from climate change. Hidden costs also include the waiving of nuclear accident insurance that is too expensive to be covered by the nuclear operators. The Price-Anderson Act, for instance, limits the liability of US nuclear power plants in the case of an accident to a subsidy of up to \$3.4 billion annually. Environmental damage should, as a priority, be rectified at source. Translated into energy generation that would mean that, ideally, production of energy should not pollute and that it is the energy producers' responsibility to prevent it. If they do pollute they should pay an amount equal to the damage caused to society as a whole. The environmental impacts of electricity generation can be difficult to quantify, though. How do we put a price on homes lost on Pacific Islands as a result of melting ice caps or on deteriorating health and human lives?

**introduce the 'polluter pays principle'** The 'polluter pays principle' has been adopted in the EC Treaty and the new European Constitution. As with the other subsidies, external costs must be factored into energy pricing if the market is to be truly competitive. This requires that governments apply a polluter pays system that charges the emitters accordingly, or applies suitable compensation to non-emitters. Adoption of polluter pays taxation to polluting electricity sources, or equivalent compensation to renewable energy sources, and exclusion of renewables from environment-related energy taxation, is important to achieve fairer competition on the world's electricity markets.

**electricity market reform** While some stakeholders in the conventional European power sector are calling for competition amongst renewable energy producers, it should be recalled that effective competition in the more than 95% of the market based on conventional electricity is a far cry from reality, as pointed out in the European Commission's three benchmarking reports on the internal electricity market. It seems premature to call for competition in the renewables power segment at a time of non-competition in conventional power. Renewable energy technologies could already be competitive if they had received the same attention in terms of R&D funding and subsidies, and if external costs were reflected in power prices.

Essential reforms in the electricity sector are necessary if new renewable energy technologies are to be accepted on a larger scale. These reforms include:

**Removal of electricity sector barriers to renewables** Complex licensing procedures for renewable projects constitute one of the greatest obstacles to renewable energy projects. The existing European rules (Art. 6 of the 2001 Renewable Energy Directive) seem to be either too weak or not properly transposed into national law. These rules should be strengthened in favour of renewables. A clear timetable for approving projects should be set for all administrations on all levels. Priority should be given to renewable energy projects. The Commission should propose more detailed procedural guidelines to strengthen existing legislation at EU level and, at the same time, increase the efforts at national level to implement current EU legislation in the sense in which it was intended.

<sup>1</sup> 2005 Commission Communication "Winning the Battle Against Global Climate Change": Similarly, abolishing distorting subsidies will help to create a level playing field among different energy sources. <http://eu.greenpeace.org/downloads/energy/EUSubsidiesReport.pdf>



Current energy legislation on planning, certification and grid access has been built around the existence of large centralised power plants, including extensive licensing requirements and specifications for access to the grid. This favours existing large-scale electricity production and represents a significant market barrier to renewables. Furthermore, it does not recognise the value of not having to transport decentralised power generation over large distances. Legislation needs to reflect the following recent changes:

- \* *In technology:* renewable and gas generation have emerged as the fastest growing electricity generation technologies.
- \* *In fuels:* coal and nuclear power are becoming increasingly less competitive.
- \* *In size:* small modular renewable and gas generating plants are now producing competitively priced power.
- \* *In location:* the new modular technologies can be distributed throughout a network.
- \* *In environmental and social impacts:* fossil fuel and nuclear power sources are now widely acknowledged as causing local and regional environmental and social impacts; fossil fuels also have global impacts on the climate.

Administrative barriers such as long and complex authorisation procedures persist in some

Member States due to insufficient coordination between different administrative bodies. The 2001 Renewable Energy Directive calls upon Member States to implement national laws or best practices to achieve this goal.

**reforms needed to eliminate market barriers to renewables include:**

- \* Streamlined and uniform planning procedures permitting systems and integrated least-cost electricity network planning;
- \* Fair access to the grid at fair, transparent prices, and removal of discriminatory access and transmission tariffs;
- \* Fair and transparent pricing for power throughout a network, with recognition and remuneration for the benefits of embedded generation;
- \* Unbundling of utilities into separate generation and distribution companies;
- \* The costs of grid infrastructure development and reinforcement must be borne by the grid management authority rather than individual renewable energy projects;
- \* Disclosure of fuel mix and environmental impact to end-users to enable consumers to make an informed choice of power source.

**give grid access priority to renewable energies** Rules on grid access, transmission and cost sharing are not sufficient at the European level. Where necessary, grid extension or reinforcement costs should be borne by grid operators and shared between all consumers, because the environmental benefits of renewables are a public good and systems operation is a natural monopoly. A strict legal unbundling and strong regulation should be implemented in this field.

- \* The rules on grid access for and transmission of renewable electricity should be further harmonised and strengthened in favour of renewable energy technologies. Member State transposition of existing legislation on grid access must be secured.
- \* Recommendations from the Commission should be given for national promotion mechanisms that include long-term stability, technological diversity and effectiveness in reaching the national mandatory targets.
- \* For the expansion of offshore wind energy:
  1. More uniform procedures and practices throughout Europe, e.g. EIA, zoning, approval procedures.
  2. Increased transparency, continuity and simplicity of legal procedures.
  3. Measures to reduce the risk for financiers and insurance companies.
  4. Provision of common grid facilities: an offshore grid and high-voltage connections for offshore wind farms.

**greenpeace demands for Europe's energy sector:**

- \* Phase-out of all subsidies for fossil fuels and nuclear energy and internalisation of external costs
- \* Establish legally binding targets for renewable energy
- \* Provide defined and stable returns for investors
- \* Guaranteed and priority access to the grid
- \* No harmonisation of support mechanisms for renewable electricity before market distortions are removed



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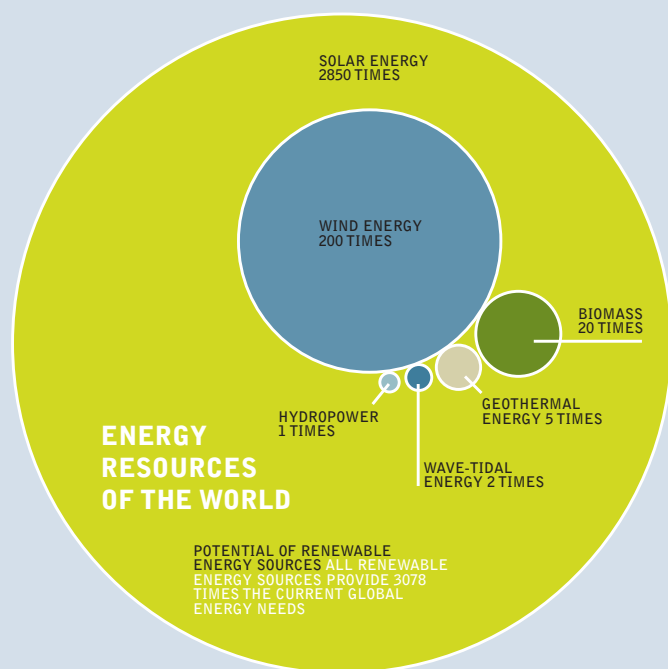
# ENERGY REVOLUTION: A SUSTAINABLE PATHWAY TO A CLEAN ENERGY FUTURE FOR EUROPE

## A EUROPEAN ENERGY SCENARIO FOR EU-25

### I ENERGY TECHNOLOGIES

**unlimited clean energy** Nature offers a variety of options for producing energy. It is mainly a question of how to convert sunlight, wind, biomass or water into electricity, heat or power as efficiently, environmentally friendly, and cost-effectively as possible.

**sunlight becomes energy** On average, the energy in the sunshine that reaches the earth is about one kilowatt per square metre worldwide. According to the results of the Research Association for Solar Power, power is gushing from renewable energy sources at a rate of 2,850 times more energy than is needed in the world today. In one day, the sunlight which reaches the earth produces enough energy to meet the world's current power requirements for eight years. Only a percentage of the potential held by renewable resources is technically accessible. According to scientists and the solar industry, with reference to the current state of technology, this percentage is still enough to provide just under six times more power than the world currently requires.



### TECHNICALLY ACCESSIBLE TODAY

The amount of power that can be accessed with current technologies supplies a total of 5.9 times the global demand for power.

Sun	3.8 times
Geothermal heat	1 time
Wind	0.5 times
Biomass	0.4 times
Hydrodynamic power	0.15 times
Ocean power	0.05 times

SOURCE: Dr. Joachim Nitsch

### i renewable energy technologies – a technical overview

#### sunlight into electricity

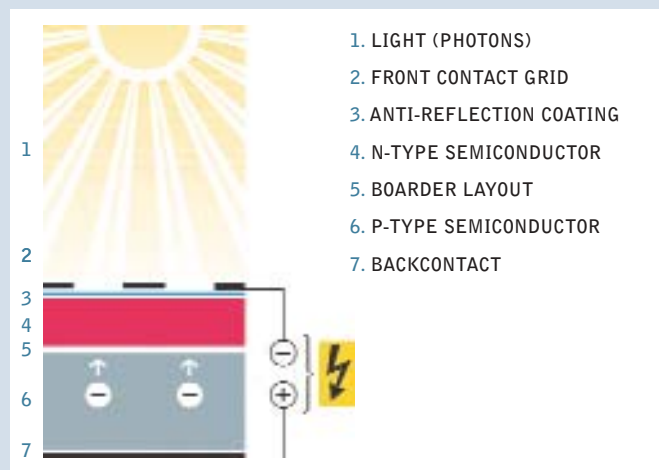
The sun is an inexhaustible source of energy for our future. It is the basis for nearly all natural processes, including human life. It will continue to provide abundant, clean and free energy, available everywhere now and for billions of years to come. Making maximum use of solar thermal energy is a necessary step in securing a sustainable energy supply and safeguarding our planet and the health of future generations. There is more than enough solar radiation available all over the world to satisfy a vastly increased demand for solar power systems. The sunlight, which reaches the earth's surface is enough to provide 2,850 times as much energy as we can currently use. On a global average, each square metre of land is exposed to enough sunlight to produce 1,700 kWh of power every year. In Europe, the average output is between 850 kWh/m<sup>2</sup> in Northern Europe, 1,200 kWh/m<sup>2</sup> in Central Europe and 1,200-2,000 kWh/m<sup>2</sup> in Southern Europe and the Mediterranean.

**5.1.1.1 solar electricity – photovoltaics** The word "photovoltaic" is a marriage of two words – "photo", meaning light, and "voltaic", meaning electricity. So photovoltaic (PV) technology, involves the generation of electricity from light. The secret to this process is the use of a semiconductor material which can be adapted to release electrons, the negatively charged particles that form the basis of electricity. The most common semiconductor material used in photovoltaic cells is silicon, an element most commonly found in sand.

All PV cells have at least two layers of such semiconductors, one positively charged and one negatively charged. When light shines on the semiconductor, the electric field across the junction between these two layers causes electricity to flow, generating DC current. The greater the intensity of the light, the greater the flow of electricity. A photovoltaic system does not therefore need bright sunlight in order to operate. It also generates electricity on cloudy days, the amount of energy output depending on the density of the clouds. Due to the reflection of sunlight, days with only a few clouds may even result in higher energy yields than days with a completely blue sky.

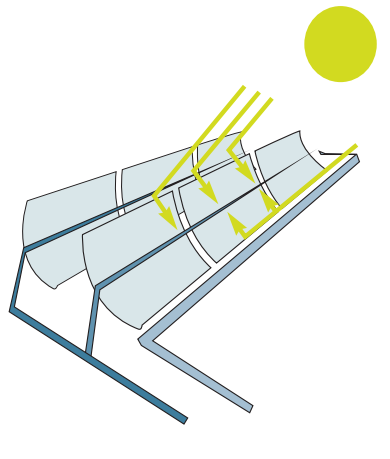
Solar PV is quite different from a solar thermal system where the sun's rays are used to generate heat, usually for hot water in a house, swimming pool, etc.

**time required to recoup initial energy investment:** between one and three years (depending on climate zone/sunlight hours per year).



**5.1.1.2 electricity – solar thermal power plants** Large mirrors concentrate sunlight into a single line or point. The heat created there is used to generate steam. The hot, highly pressurised steam is used to power turbines which generate electricity. In sun-drenched regions, solar thermal power plants can guarantee large shares of electricity production.

### PARABOLIC TROUGH



**parabolic trough** systems use trough-shaped mirror reflectors to concentrate sunlight on to receiver tubes through which a thermal transfer fluid is heated to roughly 400°C and then used to produce superheated steam. They represent the most mature solar thermal power technology, with 354 MWe of plants connected to the Southern California grid since the 1980s and more than 2 million square metres of parabolic trough collectors installed world wide.

**central receiver** (solar tower) systems use a circular array of large individually tracking mirrors (heliostats) to concentrate sunlight on to a central receiver mounted on top of a tower, with heat transferred for power generation through a choice of transfer media. After an intermediate scaling-up to 30 MW capacity, solar tower developers now feel confident that grid-connected tower power plants can be built up to a capacity of 200 MWe solar-only units. Use of heat storage will increase their flexibility.

Although central receiver plants are considered to be further from commercialisation than parabolic trough systems, solar towers have good longer-term prospects for high conversion efficiencies. Projects are being developed in Spain, South Africa and Australia. In the future, central receiver plant projects will benefit from similar cost reductions to those expected from parabolic trough plants.

**parabolic dish** systems are comparatively small units which use a dish-shaped reflector to concentrate sunlight, with super-heated fluid being used to generate power in a small engine at the focal point of the reflector. Their potential lies primarily in decentralised power supply and remote, stand-alone power systems. Projects are currently planned in the United States, Australia and Europe.

**time required to recoup initial energy investment:** about five months

### sunlight into heat or cold

**solar thermal collectors** Solar thermal systems are based on a simple principle known for centuries: the sun heats up water contained in a dark vessel. Solar thermal technologies on the market now are efficient and highly reliable, providing solar energy for a wide range of applications, from domestic hot water and space heating in residential and commercial buildings, to swimming pool heating, solar-assisted cooling, industrial process heat and desalination of drinking water.

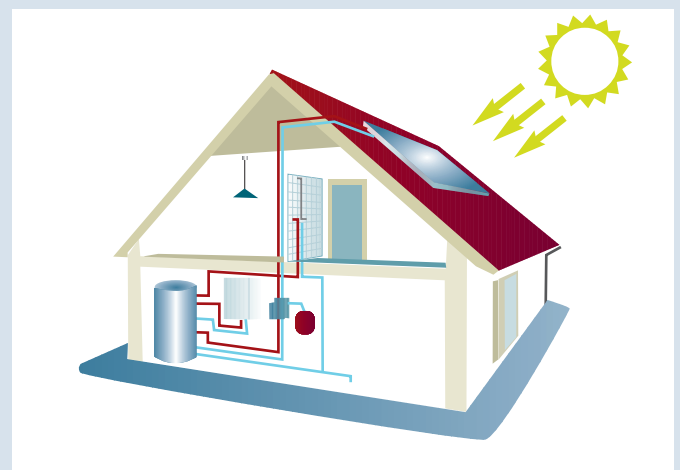
**solar domestic hot water and space heating** Domestic hot water production is the most common application for solar thermal today. In some countries, it is becoming a common feature of residential buildings. Depending on the conditions and the system's configuration, up to nearly 100% of the hot water requirements can be provided by solar energy. Larger systems can additionally cover a substantial part of the energy needed for space heating. There are two main types of technology:

**vacuum tubes:** The absorber inside the vacuum tube absorbs radiation from the sun and heats up the fluid inside, just as in a flat solar panel. Additional radiation is picked up from the reflector behind the tubes. Whatever the sun angle, the round shape of the vacuum tube allows the sun to reach the absorber directly. Even on a cloudy day, when the light is coming from many angles at once, the vacuum tube collector can still be very effective.

**the flat panel solar collector** is basically a box with a glass cover which sits on the roof like a skylight. In this box is a series of copper tubes with copper fins attached. The entire structure is coated in a black substance designed to capture the sun's rays. These rays heat up a water and antifreeze mixture which circulates from the collector down to the water heater in the basement.

**solar assisted cooling** Solar chillers use thermal energy to produce cold and/or dehumidify the air in a similar way to a refrigerator or conventional air-conditioning. This application is well-suited to solar thermal energy, as the demand for cooling is often greatest when there is most sunshine. Solar cooling has been successfully demonstrated. Large-scale use can be expected in the future, as the cost of the technology is reduced, especially for small-scale systems.

**time required to recoup initial energy investment:** one and a half to two years



# ENERGY REVOLUTION: A SUSTAINABLE PATHWAY TO A CLEAN ENERGY FUTURE FOR EUROPE

## A EUROPEAN ENERGY SCENARIO FOR EU-25

### wind becomes energy

Wind energy has come of age. It is a global phenomenon, the world's fastest growing energy source, a clean and effective modern technology providing a beacon of hope for a future based on sustainable, pollution-free technology. Enormous progress has been made in the past decade. Wind energy has come a very long way since the prototypes of just 20 years ago. Today's wind turbines are state-of-the-art modern technology – modular and very quick to install and commission. Turbine size ranges from a few kW to over 5,000 kW, with the largest turbines reaching more than 100m in height. State-of-the-art wind farms today can be as small as a single turbine and as large as several hundred MW.

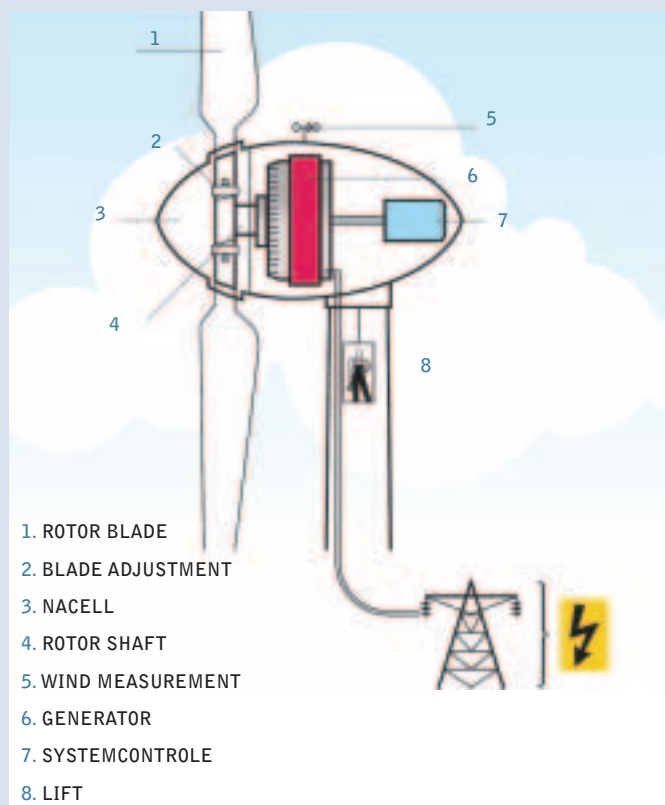
**wind power plants** on land mainly employ triple-blade turbines to harness the wind. One large wind turbine can produce enough electricity for about 5,000 households. Wind turbines can be operated not just in coastal areas, but also countries which are landlocked/with no coastal areas, including regions such as central Eastern Europe, central North and South America, and central Asia.

**wind power turbines at sea** are installed in offshore wind parks. These wind parks also normally use mainly triple-blade turbines which are anchored on the ocean floor. In Denmark, a wind park built in 2002 uses 80 turbines to produce enough electricity for a city with a population of 150,000.

**smaller wind power plants** can produce power efficiently in areas that otherwise have no access to electricity. Normally, the electricity is stored in batteries. A new technology for using the wind's power is being developed for densely populated cities where buildings are virtually stacked on top of one another. This new technology has been dubbed 'urban turbines'.

### time required to recoup initial energy investment:

around four to seven months

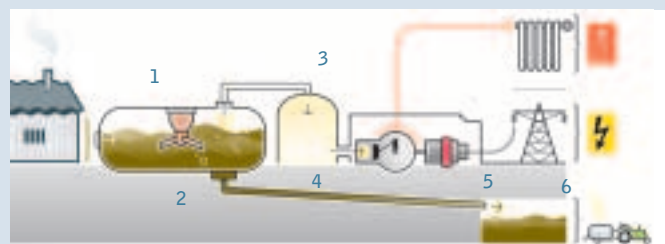


### biomass becomes energy

Biomass is a very broad term which is used to describe material of recent biological origin that can be used as a source of energy. As such, it includes wood, crops, algae and other plants, as well as agricultural and forest residues. Biomass can further be used for a variety of different end-uses: heating, power (electricity) generation or transportation. Therefore, the term 'bio energy' is used for biomass energy systems that produce heat and/or electricity and 'bio fuels' for liquid fuels for transportation. Bio energy can also be used for cooling using absorption chillers that work on the same principle as your refrigerator.

Biomass contains large amounts of stored energy which is being used commercially more and more. Biological power sources are renewable, easily stored, and, if sustainably harvested, CO<sub>2</sub>-neutral, which means they are also climate-friendly.

**electricity:** Biomass power plants basically work just like natural gas or coal power plants, except that the fuel must be processed before it can be burned. These power plants are nowhere near as large as coal power plants because the fuel needs to grow as near to the power plant as possible.



1. HEATED MIXER
2. CONTAINMENT FOR FERMENTATION
3. BIOGAS STORAGE
4. COMBUSTION ENGINE
5. GENERATOR
6. WASTE CONTAINMENT

**heat:** The biomass power plants described above should always try to use the heat produced when burning the fuel. These types of plants are called combined heat and power plants (CHP). Smaller heating systems, such as *pellet heating*, can be used to heat single family homes. Pellet heating uses small pieces of pressed waste wood as fuel, instead of natural gas or oil.

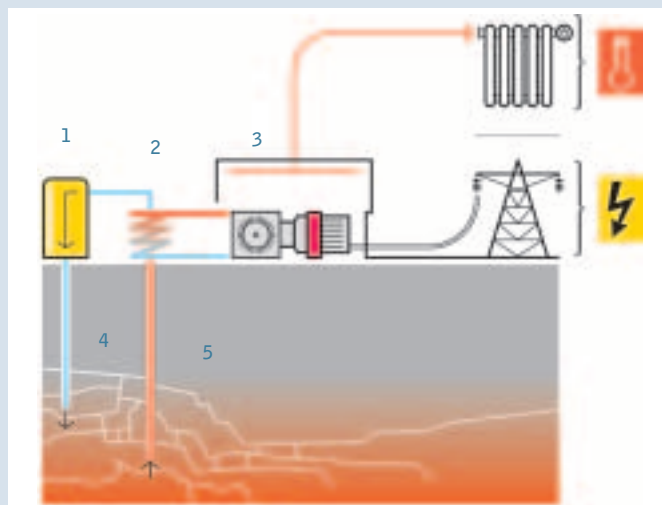
**time required to recoup initial energy investment for power plants for electricity and / or heat production:** around three to six months



### earth's heat becomes energy

Geothermal energy is heat (thermal) derived from the earth (geo). It is the thermal energy contained in the rock and the fluid filling the fractures and pores within the rock in the earth's crust. In most areas, this heat reaches the surface in a very diffuse state. However, due to a variety of geological processes, some areas, including the western part of the USA, west and central eastern Europe, Iceland, Asia and New Zealand are underlain by relatively shallow geothermal resources. These resources can be classified as low temperature (less than 90°C), moderate temperature (90°C - 150°C), and high temperature (greater than 150°C). The uses to which these resources are put are also influenced by temperature. The highest temperature resources are generally used only for electric power generation. Current global geothermal electric power generation totals approximately 8,000 MW – about the same as eight large coal or nuclear power plants. Uses for low- and moderate-temperature resources can be divided into two categories: direct use and ground-source heat pumps.

**5.1.5.1 electricity:** Geothermal power plants use the earth's natural heat to vaporise water or an organic medium. The steam created powers a turbine which produces electricity. In New Zealand and Iceland, this technique has been used extensively for decades. In Germany, where it is necessary to drill many kilometers down to reach the necessary temperatures, this technology is only in the trial stages. There are currently several different systems under development.



1. PUMP
2. HEAT EXCHANGER (PRODUCES STEAM)
3. GAS TURBINE
4. DRILLING HOLE FOR COLDWATER INJECTION
5. GENERATOR
6. WASTE CONTAINMENT

**5.1.5.2 heat:** Geothermal heat plants and geothermal heating require lower temperatures than generating electricity. Geothermal heated water is used directly for heat.

**time required to recoup initial energy investment:**

**electricity:** no data at present

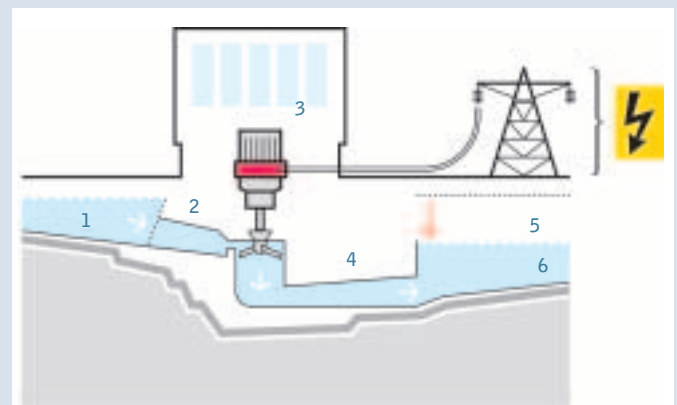
**heat:** around seven to ten months

### water power becomes energy

For millennia, water wheels have powered mills, and mills have ground grain. For about the last century, water has mainly been used to produce electricity. Today, around one-fifth of the world's electricity is produced from hydro power. Large hydroelectric power plants with concrete dams and extensive backwater often have very negative effects on nature the environment. However, smaller, 'run-of-the-river' power stations, which are turbines powered by one section of running water in a river, can produce electricity in an environmentally friendly way.

Small hydro power is not simply a reduced version of large hydro plant. Specific equipment is necessary to meet fundamental requirements with regard to simplicity, high-energy output, maximum reliability, and easy maintenance. The main requirement for hydro power is to create an artificial head so that water, diverted through an intake channel or a pipe into a turbine, discharges back into the river downstream. Small hydro power is mainly 'run-of-the-river' and does not collect significant amounts of stored water which require the construction of large dams and reservoirs. There are two broad categories of turbines: impulse turbines (notably the Pelton) in which a jet of water impinges on the runner designed to reverse the direction of the jet and thereby extract momentum from the water. This turbine is suitable for high heads and 'small' discharges. Reaction turbines (notably Francis and Kaplan), run full of water and, in effect, generate hydrodynamic 'lift' forces to propel the runner blades. These turbines are suitable for medium to low heads, and medium to large discharges.

**time required to recoup initial energy investment:** nine to 13 months



1. INLET
2. SIEVE
3. GENERATOR
4. TURBINE
5. HEAD
6. OUTLET

# ENERGY REVOLUTION: A SUSTAINABLE PATHWAY TO A CLEAN ENERGY FUTURE FOR EUROPE

## A EUROPEAN ENERGY SCENARIO FOR EU-25

**tidal and wave energy** Scientists and engineers, mainly those in Great Britain and the USA, are exploring the use of wave energy. The first prototypes are currently being tested successfully in Scotland.

**time required to recoup initial energy investment:** no data at present  
**current cost:** no data at present

**wave energy** (source: [http://www.eere.energy.gov/RE/ocean\\_wave.html](http://www.eere.energy.gov/RE/ocean_wave.html))

The total power of waves breaking on the world's coastlines is estimated to be 2 to 3 million MWs. Three approaches to capturing wave energy are:

1. Floats or pitching devices generate electricity from the bobbing or pitching action of a floating object. The object can be mounted on a floating raft or on to a device fixed on the ocean floor.
- \* Oscillating water columns (OWC) generate electricity from the wave-driven rise and fall of water in a cylindrical shaft. The rising and falling water column drives air into and out of the top of the shaft, powering an air-driven turbine.
  - \* Wave surge or focusing devices are installed at the shoreline, also called 'tapered channel'. These systems rely on a shore-mounted structure to channel and concentrate the waves, driving them into an elevated reservoir. Water flow out of this reservoir is used to generate electricity, using standard hydro power technologies.

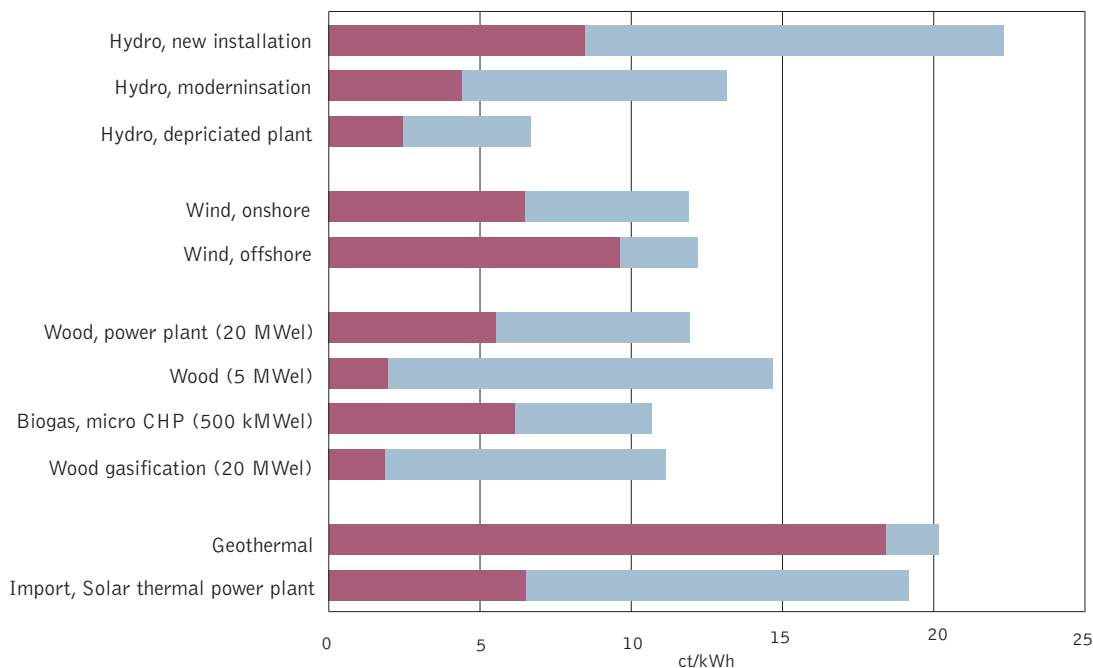
### ii renewable energy - future development of costs

A large number of technologies are available for using the various forms of renewable energy sources. They display marked differences in technological maturity, costs, performance, areas of application and development potential. Whereas hydro power has been used for decades to generate electricity, other technologies, such as geothermal power generation, are just taking their first steps in some European countries through field trials. In the field of biomass utilisation, too, tried-and-tested 'old' technologies exist alongside new methods, such as gasification, which have yet to find their way to final market maturity. Fluctuations in solar and wind energy will induce supply-dependent contributions into the grid, while hydro power and geothermal energy are able to provide energy to meet the basic load more or less independently of meteorological conditions. The capacity of individual systems varies by several orders of magnitude (from 1 kW or less for photovoltaic systems to several 100 MW for hydro power stations). In most cases these are 'distributed' technologies that are used directly at or close to the consumer, but the future will also see large-scale applications in the form of offshore wind parks or solar thermal power stations.

To be able to utilise the individual advantages of the different technologies and link them with each other, the entire spectrum of options available must be developed to market maturity and integrated step by step in the existing supply structures. For the future energy supply situation, this will provide a complementary portfolio of environmentally friendly technologies for heat and power supply and for the provision of fuels.

Most of the renewable technologies employed today are at an early stage of market development. Accordingly, the costs of electricity, heat and fuel production in general are higher today than the costs of competing conventional systems (Figure 2). Costs for RES electricity also depend to a certain extent on local conditions, for example, local wind conditions, the availability of cheap biomass, or efforts to comply site-specific nature conservation requirements when building a new hydro power plant, thus leading to considerable variations in costs within one technology group. However, compared to conventional systems, there is a large potential for cost reduction due to technical developments, manufacturing improvements and large-scale production.

**FIGURE 2: RANGE OF CURRENT ELECTRICITY-GENERATION COSTS FROM RENEWABLE ENERGY SOURCES (EXCLUDING PV WITH COSTS OF 45 TO 80 CT/KWH). COST DIFFERENCES REFLECT DIFFERENT LOCAL CONDITIONS, E.G WIND SPEED, SOLAR RADIATION, ETC.**



To get an indication of long-term cost developments, experience curves are applied which describe the empirical correlation between the cumulated capacity and the development of costs. For many technical systems, the so-called learning factor is in the range of 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 fall by 10% when cumulative production doubles).

### photovoltaics

Although the worldwide photovoltaic market has been growing at over 30% per annum in recent years, the contribution this technology makes to electricity generation is still very small. Development work is focused on improving existing modules and system components and on developing new types of cells in the thin-film sector and new materials for crystalline cells. It is expected that the efficiency of commercial crystalline cells will improve to between 15 and 20% in the next few years, and that thin-film cells using less raw material will become commercially available.

The learning factor for PV modules has been fairly constant over a period of 30 years at around 0.8, indicating a continuously high rate of technical learning and cost reduction. Assuming a globally installed capacity of 2,400 GW in 2050, and a decrease in the learning rate after 2030, we can expect that electricity generation costs of around 10 ct/kWh will be possible in Central Europe by 2050. Compared with other technologies for utilising renewables, photovoltaic power must therefore be classified as a long-term option. Its importance derives from its great flexibility in use, its great technical and economic development prospects, and its enormous technical potential.

### solar thermal power plants

Solar thermal power stations, as concentrator systems, can only use direct sunlight and are thus dependent on high-irradiation locations. For example, North Africa has considerable technical extension potential which far exceeds local demand. In a well-developed common European electricity grid it would be possible to exploit this great, inexpensive potential. The various solar thermal power station concepts (e.g. parabolic trough concentrators, power towers, parabolic dish concentrators) offer good prospects for further technological development and cost reductions. One important technological development objective is the creation of large thermal energy reservoirs in order to extend the operating time of these systems beyond the sunlight period.

Owing to the small number of solar thermal power plants built to date, it is particularly difficult to arrive at reliable learning factors for this sector. Here it is assumed that the learning factor of 0.88 derived from the data for parabolic trough reflectors built in California will change to 0.95 in the course of market introduction up to 2030. The UN's World Energy Assessment expects solar thermal electricity generation will face a dynamic market growth similar to the wind industry, but with a time lag of 20 years. Depending on incident solar radiation and mode of operation (e.g. power generation combined with seawater desalination), electricity production costs of below 5 ct/kWh are expected. The necessary decrease in costs presupposes rapid market introduction in the next few years.

### solar thermal collectors for heating and cooling

Small solar thermal collector systems for water heating and auxiliary heating are well developed today and are used in a wide variety of applications. By contrast, large seasonal heat reservoirs that store heat from the summer until it is needed in the winter are only available as pilot plants at present. Only by means of solar local heating systems with seasonal storage would it be possible to supply large parts of the entire low-temperature heat market with solar energy. Crucial factors for the market launch will be low storage costs and an adequate usable heat yield (minimisation of storage and transportation losses). In the case of systems with seasonal heat storage, the storage facility currently accounts for over 50% of the total cost.

Data for the European collector market indicates a learning factor of nearly 0.90 for solar collectors, which indicates a relatively well-developed system from a technological point of view. By contrast, the construction of seasonal heat reservoirs is expected to show a long-term cost reduction of over 70%, in view of the very small volume of the market at present, which is largely confined to demonstration systems. Even today, however, the solar thermal energy costs of a large solar thermal system with seasonal storage are, in spite of the high storage costs, no higher than for the small water heating systems in widespread use. One major obstacle to the introduction of large systems is the need to make the reservoir so large that it is necessary to connect a large number of consumers via a local heating network, which means that advance investment is required for a considerable period. Depending on the configuration of the system, it will be possible in the long term to achieve solar thermal costs of between 4 and 7 ct/kWh.

### wind power

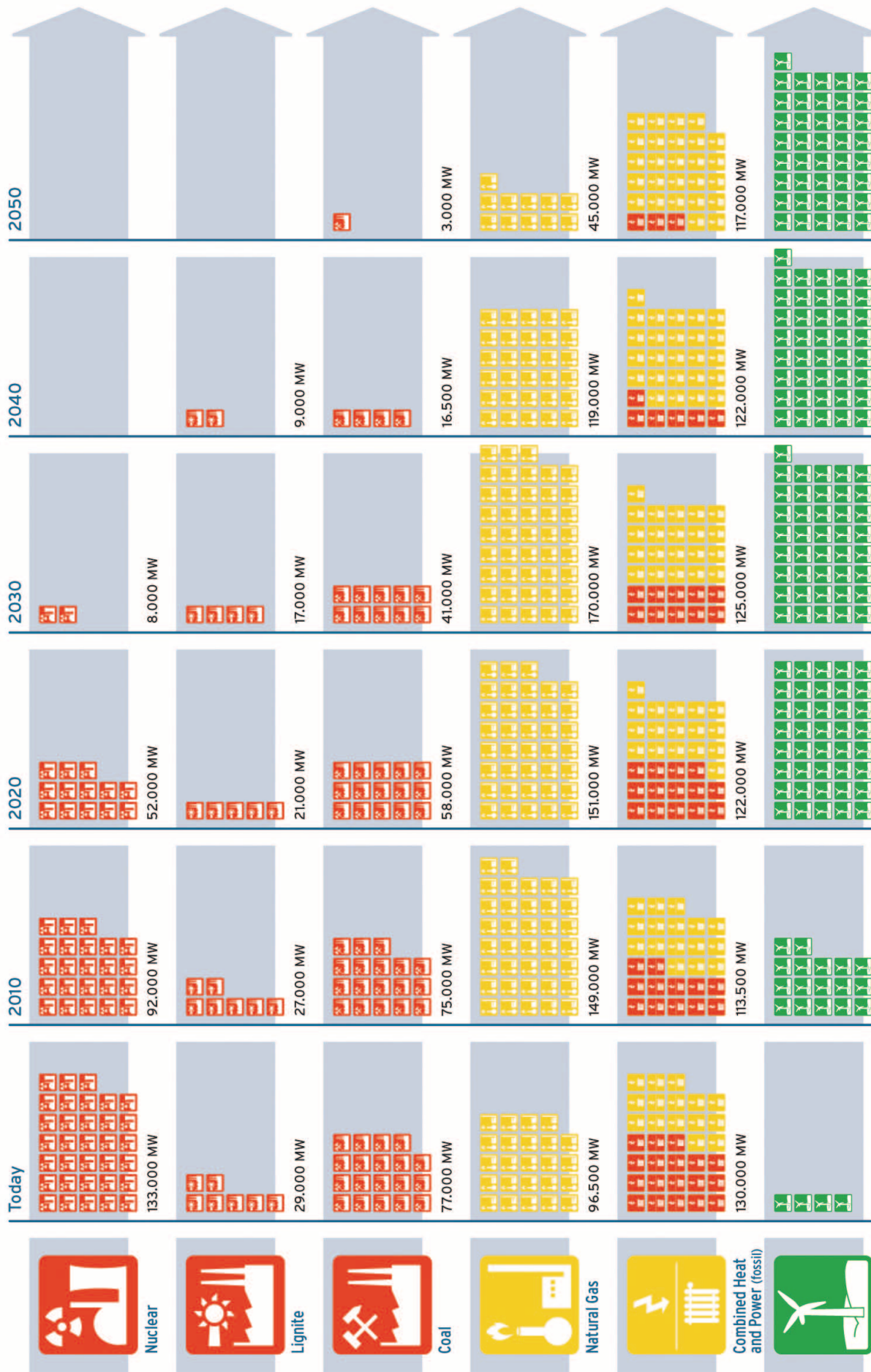
Within a short period of time, the dynamic development of wind power has resulted in the establishment of a market of relevance to the energy economy. In 2004, a 5 MW turbine was installed in Germany, which is currently the largest wind turbine in the world. The cost of new systems has, however, stagnated in some countries in recent years due to the continuing high level of demand and the manufacturers' considerable advance investment in the development and introduction of a succession of new systems, so that the learning factor observed for wind turbines built between 1990 and 2000 in Germany was only 0.94. Nevertheless, since technical developments have led to increases in specific yield, electricity-generation costs could be reduced continuously. Owing to the relative lack of experience in the offshore sector, a larger cost-reduction potential is expected here, and it is anticipated that the learning rate will be correspondingly higher.

While the IEA World Energy Outlook 2004 expects worldwide wind capacity to grow to only 330 GW by 2030, the United Nations World Energy Assessment assumes a saturation of the global wind energy market at around 1,900 GW installed capacity in 2030. The Wind Force 12 Scenario of the European Wind Energy Association and Greenpeace predicts a global potential of more than 3,000 GW. A fairly conservative experience curve for wind turbines is derived by combining the currently observed learning factors with a low market growth assumption, which is oriented towards the World Energy Assessment, indicating that costs for offshore wind turbines will be reduced by 60% by 2050, while costs for onshore turbines are expected to fall to 70% of the current cost level.

# ENERGY REVOLUTION: A SUSTAINABLE PATHWAY TO A CLEAN ENERGY FUTURE FOR EUROPE

A EUROPEAN ENERGY SCENARIO FOR EU-25

## Energy Revolution | A sustainable pathway to a clean energy future for Europe | A European Energy Scenario for EU-25







Note: All datas are rounded to the nearest thousand

# ENERGY REVOLUTION: A SUSTAINABLE PATHWAY TO A CLEAN ENERGY FUTURE FOR EUROPE

## A EUROPEAN ENERGY SCENARIO FOR EU-25

### biomass

Biomass, which is used to supply heat, generate electricity and produce bio fuels, can be utilised with a broad portfolio of technologies. The crucial factor for the economics of biomass utilisation is the cost of the input materials, which today range from 'negative costs' for waste wood (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 favourable options today, in economic terms, is the use of waste wood in steam turbine combined heat and power plants, which today is state of the art. Gasification of solid bio fuels makes it possible to develop a considerably wider range of applications. This option, however, is not yet fully developed and remains relatively expensive at present. In the long term it is expected that very favourable electricity production costs will be achieved by using wood gas both in micro CHP units (engines and fuel cells) and in gas-and-steam power plants. Great potential for the utilisation of solid biomass also exists for heat generation in small systems and larger heating centres and plants with local heating networks. 'Bio diesel' made from rapeseed methyl ester (RME) has become increasingly important in recent years, e.g. in Germany. Processes for obtaining synthetic fuels from biogenic synthesis gases will also play an increasingly important role.

For many biomass technologies, it is expected that the future cost development described by the experience curves depends primarily on the development of the national or the European market. Cost projections for the broad range of different biomass technologies are taken from a recent German study on Material Flow Analysis of Sustainable Biomass Use for Energy [3]. It is assumed that the long-term potential for biomass in the EU-25 countries is around 7,000 PJ, with about 55% coming from residuals, mainly forest residuals, industrial wood waste, and straw, while the rest is from energy crops.

### geothermal

Geothermal energy has long been used in Europe for supplying heat, while electricity generation from geothermal energy is very much limited to a few sites in Europe with specific geological conditions. Further intensive research and development work is still needed to speed up the progress of electricity generation from geothermal energy. In particular, the creation of large underground heat-exchange surfaces (HDR technology) and the improvement of heat-and-power machines with Organic Rankine Cycle (ORC) must be optimised in future projects. Since geothermal power generation is still in its infancy, considerable cost reductions are expected to be achieved in future by using more efficient drilling and simulation methods and by improving the efficiency of the electricity generation system.

As a large share of the costs of a geothermal power plant is due to deep drilling, data on technological learning from the oil sector can be used as an analogy in which high learning rates have been observed with a learning factor of less than 0.8. Assuming a global average market growth for geothermal power capacity of 6% per year until 2020, which is reduced to 3% per year beyond 2030, leads to a learning curve which indicates a cost reduction potential of more than 50% by 2050. Thus, despite the present high level of costs (some 18 to 20 ct/kWh), electricity production costs – depending on payments for heat supply – are expected to come down to between 6 and 8 ct/kWh in the long term. Because of the non-fluctuating energy supply, geothermal energy is considered to be a key element in a future supply structure based on renewable energy sources.

### hydro power

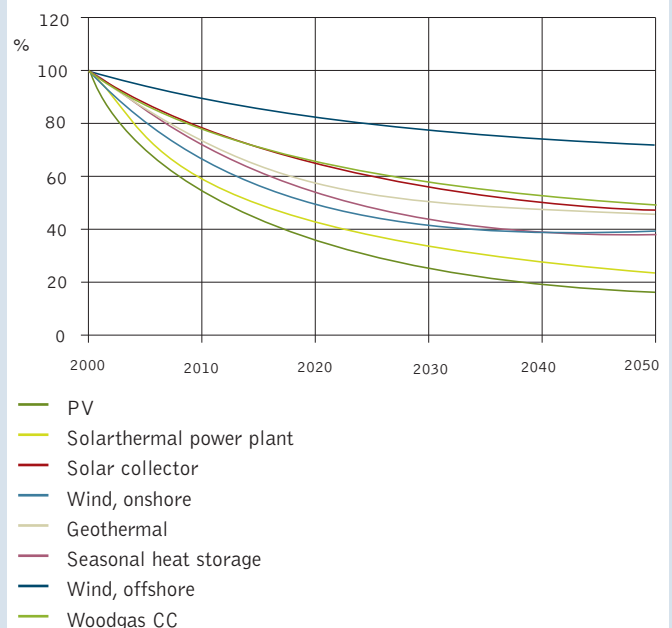
Hydro power is a mature technology that has long been used for economic generation of electricity. Additional potential can be exploited primarily by modernising and expanding existing systems. The remaining limited cost reduction potential will probably be offset by the increasing site development problems and growing environmental requirements. It may be assumed that for small-scale systems, where power generation costs are generally higher in any case, the necessity to comply with minimum ecological requirements will tend to involve proportionately higher costs than for large systems.

### summary – cost development of renewable energy technologies

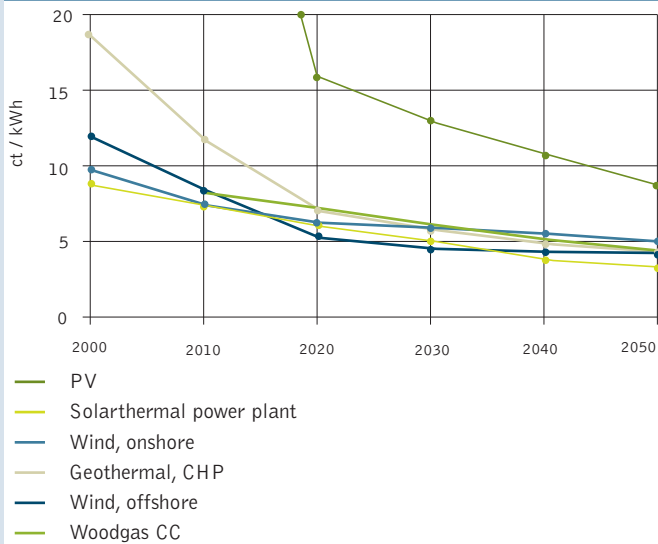
Figure 3 summarises the cost trends of renewable energy technologies as derived from the respective learning curves. It may be emphasised again that the expected cost reduction is of course basically not a function of time, but of cumulated capacity, thus a dynamic market development is required to facilitate the exploitation of the cost reduction potentials. Most of the renewable energy technologies will be able to reduce their specific investment costs to a level of between 30 and 60% of current costs by 2020, and to between 20 and less than 50% in a more or less fully developed state (after 2040).

Reduced investment costs for renewable energy technologies lead directly to reduced heat and electricity generation costs, as shown in Figure 4. Electricity generation costs today are around 8 to 20 ct/kWh for the most important RES technologies, with the exemption of photovoltaics which is still characterised by higher generation costs. In the long term, the specific generation costs of the different technologies are expected to converge at around 3 to 6 ct/kWh, and PV electricity will also be available at costs around 10 ct/kWh. These cost estimates depend on site-specific conditions like e.g. local wind conditions 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 3: FUTURE DEVELOPMENT OF SPECIFIC INVESTMENT COSTS (NORMALISED TO CURRENT LEVELS) FOR RENEWABLE ENERGY TECHNOLOGIES, DERIVED FROM LEARNING CURVES



**FIGURE 4: EXPECTED DEVELOPMENT OF SPECIFIC ELECTRICITY GENERATION COSTS FOR SELECTED RES-ELECTRICITY GENERATION TECHNOLOGIES. (NOTE: ELECTRICITY-GENERATION COSTS DEPEND PARTLY ON SITE-SPECIFIC FUEL COSTS AND HEAT CREDITS.)**



### iii conventional technologies

Similar to the renewable energy technologies, the conventional energy conversion technologies also offer a large portfolio of options for different fuels and applications. Based on a long history of technological development, advances in material science and process engineering still lead to improved system designs and increased efficiencies.

To give an indication of advances in conventional technologies, Table 42 summarises the development of costs and efficiencies for a set of key power technologies. While the improvements in the field of conventional technologies is less dramatic than in the dynamic field of new renewable energy technologies, the continuous increase in efficiency, in particular in the highly efficient natural-gas-fired combined-cycle power plants, is an important contribution for reducing CO<sub>2</sub> emissions from the power sector.

### fossil fuel technologies

In recent years, we have observed an increasing variability in fossil fuel prices, which makes cost projections more uncertain. The primary energy carrier prices given in Figure 5, which are used here as a basis for cost calculations, are slightly above the European Commission's recent projections of energy carrier prices. However, taking into account that oil prices are at the moment above 60 US\$/barrel (~ 9 €/GJ), this projection of energy prices might be considered as very conservative. Any increase in fossil fuel prices which is beyond the cost projection shown in Figure 4 further increases the competitiveness of renewable energy technologies compared to technologies that are based on the use of fossil fuels.

Thanks to the European CO<sub>2</sub>-emission trading scheme, it is now well accepted that CO<sub>2</sub> emissions bring an additional economic burden. To reflect these additional costs in the cost calculations, additional CO<sub>2</sub> costs are applied to each tonne of CO<sub>2</sub> emissions. Starting in 2010 with 15 €/tCO<sub>2</sub>, the CO<sub>2</sub> costs increases continuously to 50 €/tCO<sub>2</sub> in 2050, thus reflecting the increasing need for reducing greenhouse gas emissions, and the external costs related to climate change from CO<sub>2</sub> emissions.

In spite of growing fuel efficiency and reduced investment costs, the expected increase in fossil fuel prices results in a significant increase in electricity-generation costs, in particular from gas-fired power plants. Even without considering the CO<sub>2</sub> costs, in the long-term, electricity-generation costs from new fossil power plants are at least in the same order of magnitude as those from renewable energy technologies. Adding in the economic burden resulting from CO<sub>2</sub> emissions, the electricity-generation costs from fossil fuels becomes higher.

**FIGURE 5: ASSUMED EVOLUTION OF PRIMARY ENERGY CARRIER PRICES IN €<sub>2000</sub>/GJ**

	2000	2010	2020	2030	2050
Crude oil	5.3	4.8	5.6	6.7	8.9
Natural gas	2.8	4.1	5.0	6.3	8.6
Hard coal	1.4	1.9	2.1	2.3	2.8

Source: DLR, 2005

### summary – conventional technologies

**TABLE 2: DEVELOPMENT OF EFFICIENCY AND INVESTMENT COSTS FOR SELECTED POWER PLANT TECHNOLOGIES**

		2010	2020	2050	
Coal-fired condensing power plant	Efficiency (%)		40	46	48
	Investment costs (€/kW)		980	930	880
	Electricity generation costs (ct/kWh)				
	- without CO <sub>2</sub> costs		4.7	4.6	4.5
	- with CO <sub>2</sub> costs		5.9	7.0	8.0
	specific CO <sub>2</sub> emissions <sup>a)</sup> (g/kWh)		837	728	697
Lignite fired condensing power plant	Efficiency (%)		39	43	45
	Investment costs (€/kW)		1,150	1,080	1,030
	Electricity generation costs (ct/kWh)				
	- without CO <sub>2</sub> costs		4.1	4.1	4.2
	- with CO <sub>2</sub> costs		5.7	7.1	8.6
	specific CO <sub>2</sub> emissions <sup>a)</sup> (g/kWh)		1,024	929	888
Natural gas combined cycle	Efficiency (%)		58	60	61
	Investment costs (€/kW)		435	390	375
	Electricity generation costs (ct/kWh)				
	- without CO <sub>2</sub> costs		5.4	6.5	7.6
	- with CO <sub>2</sub> costs		6.0	7.6	9.3
	Specific CO <sub>2</sub> emissions <sup>a)</sup> (g/kWh)		348	336	325

<sup>a)</sup>refers to direct emissions only, life-cycle emissions are not considered here.

Source: DLR, 2005.

# ENERGY REVOLUTION: A SUSTAINABLE PATHWAY TO A CLEAN ENERGY FUTURE FOR EUROPE

## A EUROPEAN ENERGY SCENARIO FOR EU-25

### nuclear power plants<sup>2</sup>

**current commercial reactor types** At the start of 2005, there were 441 nuclear power reactors operating in 31 countries. The age, size and design type of all of these reactors vary considerably. The most prevalent design in operation is the *Pressurised Water Reactors (PWR)*, with 215 currently operating around the world. The PWR design was originally conceived to propel military submarines. Therefore, relative to other designs, these reactors are small but have a high-energy output. Consequently, the cooling water in the reactor's primary circuit is at a higher temperature and pressure than other comparable reactor designs. These factors can accelerate the corrosion of components; in particular, the steam generators have to be replaced frequently.

Of similar design and history to the PWR is the Russian *VVER* reactor. There are currently 53 such reactors deployed in seven countries in Eastern Europe in three main reactor designs. The oldest, VVER 440-230, has significant and serious design flaws and consequently the G8 and EU believe that, from an economical viewpoint, they cannot be brought up to an acceptable safety standard. The lack of a secondary containment system and adequate emergency core cooling system are of particular concern. The second generation of VVERs, the 440-213s, has introduced a more effective emergency core cooling system but does not deploy a full secondary containment system. A third VVER design, the 1000-320s, introduced further design changes but, despite this, the reactors are not considered as safe as contemporary PWRs. In fact, following unification of Germany, VVERs of all generations were closed or their construction abandoned. Both safety and economic considerations were given for these decisions, with safety concerns being more heavily weighted.

The second most prevalent reactor design is the *Boiling Water Reactor (BWR)* (there are 90 in operation around the world) which was developed from the PWR. The modifications were undertaken to increase the simplicity of the design and create higher thermal efficiency by using a single circuit and generating steam within the reactor core. However, this modification has failed to improve safety. The result is a reactor that still exhibits most of the hazardous features of the PWR, while introducing a number of new problems.

The next most prevalent reactor currently deployed is the *Pressurised Heavy Water Reactor*, of which there are 39 currently in operation in seven countries. The main design is the Canadian *CANDU* reactor which is fuelled by natural uranium and is heavy-water cooled and moderated.

The other design serialised in Russia was the *RBMK* reactor which is a graphite moderated boiling water reactor used at the Chernobyl station in Ukraine, the site of the world's worst civilian nuclear power accident in 1986. The reactor exhibits some of the same design problems as the *CANDU*, namely positive void coefficient and core instability, but has a series of additional problems that exacerbate the former – in particular, the large number of pressure tubes (1693 in the *RBMK 1000s*).

The United Kingdom has developed two designs from the plutonium production reactors: the *Magnox* – air-cooled, graphite-moderated natural uranium reactor – and, subsequently – the *Advanced Gas Reactor (AGR)*. *Magnox* reactors have very low power density and consequently large cores. In an attempt to overcome this perceived weakness, power density was increased by a factor of two in the *AGR*, but it is still low compared to light-water reactors. Carbon dioxide gas circulates in the primary circuit. Gas circulation is more complex in *AGRs* as the higher temperature requires a special gas flow through the graphite moderator. In both designs, the reactor core is located inside a large pressure vessel. The *Magnox* reactors with older steel pressure vessels have suffered from corrosion. These problems are aggravated by thermal ageing and material degradation caused by neutron-induced embrittlement.

**ageing:** There is general consensus that the extension of reactor life today is of the upmost importance for the nuclear industry. The International Energy Agency pointedly sums it up as follows:

**“If there are no changes in policy towards nuclear power, plant lifetime is the single most important determinant of nuclear electricity production in the coming decade.”**

Over the last two decades there has been a general trend worldwide against ordering new reactors. As a consequence, the average age of nuclear reactors around the world has increased year on year and is now 21. At the time of their construction, it was assumed that these reactors would not operate beyond 40 years. However, in order to maximise profits, lifetime extension offers an attractive proposition for nuclear operators.

**greenpeace position on a nuclear phase-out in Europe** Greenpeace calls for a nuclear phase out as soon as it is technically possible. The nuclear threat is increasing with the ageing of the reactors worldwide. Governments should increase their efforts to build up renewable energy capacities and increase energy efficiency. Nuclear power is blocking the solutions.

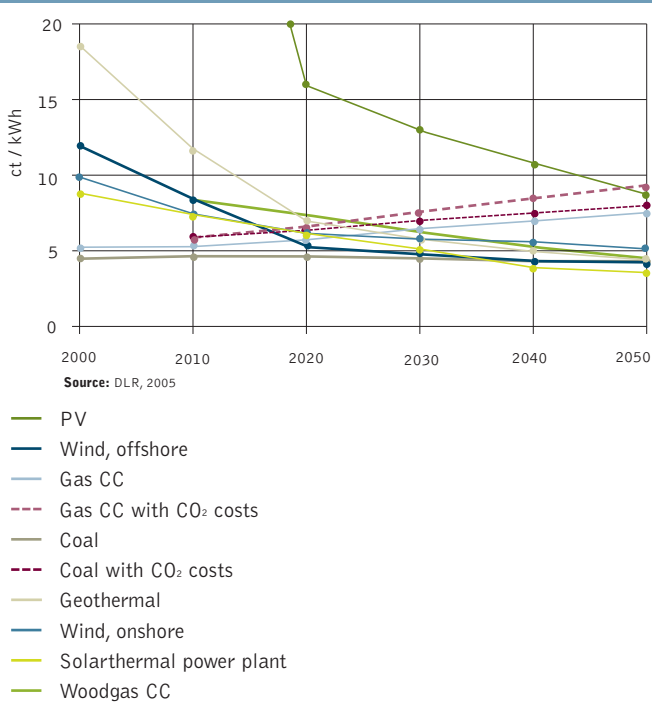
This scenario was calculated with a maximum lifetime for nuclear plants of 30 years. The period of 30 years serves exclusively as a basis for calculations, but does not indicate an acceptance of a 30 years lifetime of nuclear reactors by Greenpeace.

<sup>2</sup> | All information comes from Chapter 4.2. of the Greenpeace report “Nuclear Reactor Hazards - Ongoing Dangers of Operating Nuclear Technology in the 21st Century”, published in April 2005.



#### iv summary – conventional technology versus renewables

**FIGURE 6: EXPECTED DEVELOPMENT OF ELECTRICITY-GENERATION COSTS FROM FOSSIL AND RENEWABLE OPTIONS**



#### v energy efficiency – better with less

Energy efficiency often has multiple positive effects. For example, an efficient clothes washing machine or dishwasher uses less water. Efficiency also usually provides a higher level of comfort. For example, a well-insulated house will feel warmer in the winter, cooler in the summer and be healthier to live in. An efficient refrigerator will make less noise, have no frost inside, no condensation outside and will probably last longer. Efficient lighting will offer you more light where you need it. Efficiency is thus really: 'better with less'. Efficiency has an enormous potential. There are very simple steps you can take, such as putting additional insulation in your roof, using super-insulating glazing or buying a high-efficiency washing machine when the old one wears out. All of these examples will save both money and energy. But the biggest savings will not be found in such incremental steps. The real gains come from rethinking the whole concept, e.g. 'the whole house', 'the whole car' or even 'the whole transport system'. When you do this, surprisingly often energy needs can be cut back by four to ten times what is needed today. Take the example of a house: by insulating the whole outer shell (from roof to basement) properly, which requires an additional investment, the demand for heat will be so low that you can install a smaller and cheaper heating system – offsetting the cost of the extra insulation. The result is a house that only

needs one-third of the energy without being any more expensive to build. By insulating even further and installing a high-efficiency ventilation system, heating demand is reduced to one-tenth. It sounds amazing, but thousands of these super-efficient houses have been successfully built in Europe over the last ten years. This is no dream for the future, but part of everyday life for those thousands of families. Here is another example: imagine you are the manager of an office. Throughout the hot summer months, air-conditioning pumps cold air on your staff's shoulders to keep them productive. As this is fairly expensive, you could ask a clever engineer to improve the efficiency of the cooling pumps. But why not take a step back instead and look at the whole system. If we first improve the building to keep the sun from heating the office like an oven, then install more energy-efficient computers, copiers and lights (which save electricity and generate less heat), and then install passive cooling systems such as ventilation at night – you may well find that the air-conditioning system is no longer necessary. Then, of course, if the building had been properly planned and built, you would not have bought the air-conditioner.

#### electricity

There is a huge potential to save electricity in relatively short period of time. By simply switching off standby, and changing to energy-efficient light bulbs, etc., consumers would save electricity and money in every household. If all of the 185 million households within the EU-25 did this, several large power plants could be switched off almost immediately. The following table provides a brief overview of mid-term measures for household appliances:

**TABLE 3: ELECTRICITY CONSUMPTION SAVINGS AND TRENDS IN THE RESIDENTIAL SECTOR, EU-15**

	ELECTRICITY SAVINGS ACHIEVED IN THE PERIOD 1992-2003	CONSUMPTION IN 2003	CONSUMPTION IN 2010 (WITH CURRENT POLICIES)	CONSUMPTION IN 2010 (WITH AVAILABLE POTENTIAL TO 2010 (WITH ADDITIONAL POLICIES))
	[TWh/YEAR]	[TWh/YEAR]	[TWh/YEAR]	[TWh/YEAR]
Washing Machines	10-11	26	23	14
Refrigerators and Freezers	12-13	103	96	80
Electric ovens	-	17	17	15.5
Standby	1-2	44	66	46
Lighting	1-5	85	94	79
Dryers	-	13.8	15	12
DESWH <sup>3</sup>	-	67	66	64
Air-conditioners		5.8	8.4	6.9
Dishwashers	0.5	16.2	16.5	15.7
<b>Total</b>	<b>24.5-31.5</b>	<b>377.8</b>	<b>401.9</b>	<b>333.1</b>

source: Green Paper on energy efficiency, June 2005/EWai 2004, Kem 2004.

<sup>3</sup> Domestic Electric Storage Water Heaters (DESWH): the saving potential indicated is only related to the reduction of the thermal standby losses due to thicker insulation. Additional savings will come from control strategy (thermostat and timer). Larger electricity savings will be achieved by introducing solar thermal panels.

# ENERGY REVOLUTION: A SUSTAINABLE PATHWAY TO A CLEAN ENERGY FUTURE FOR EUROPE

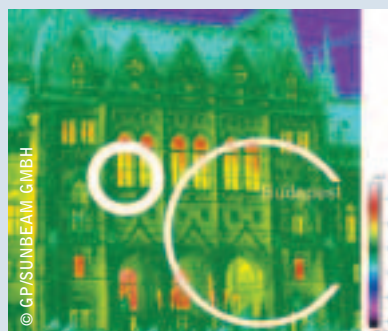
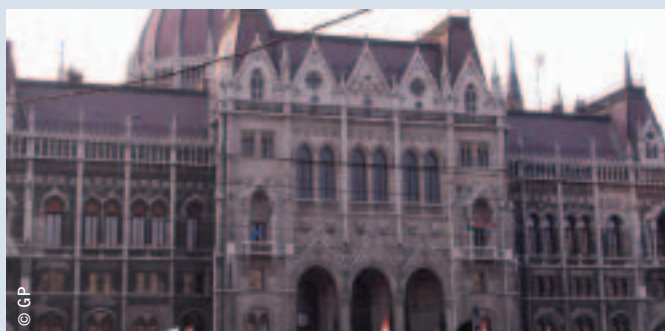
A EUROPEAN ENERGY SCENARIO FOR EU-25

## heating

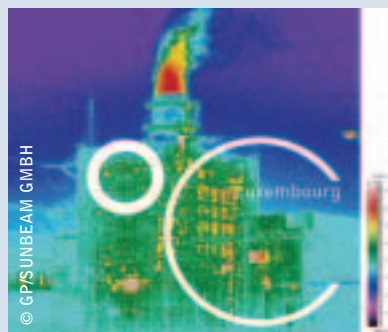
Insulation and thermal design can dramatically reduce heat loss and help stop climate change. Energy demand for heating in existing buildings can be reduced on average by 30-50%. In new buildings it can be reduced by 90-95%, using widely available and competitive technology and design\*.

Heat losses can be easily detected with thermographic photos (see example below).

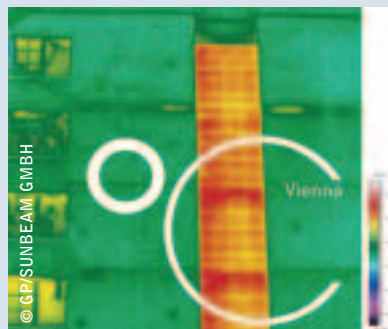
A thermographic camera shows details the eye cannot detect. Parts of the building that have a higher surface temperature than the rest appear in yellow and red. This means that in these areas heat is leaking through gaps and poor insulating materials, and valuable energy is being lost. This results both in damage to the environment due to a waste of energy resources, and to unnecessary costs for home owners and tenants. Typical weak points are window panes and frames and thin walls below windows, where radiators are commonly positioned and insulation should be optimal.



BUDAPEST, PARLIAMENT. THE YELLOW AREAS DEPICT STORED HEAT RATHER THAN HEAT LEAKS. HEAT ESCAPES THROUGH THE WINDOWS.



LUXEMBOURG TWINERG GAS POWER PLANT. THE PLUME OF WASTE GAS IS NORMALLY NOT VISIBLE. THE THERMOGRAM SHOWS THE WASTE OF ENERGY THROUGH THE CHIMNEY.



VIENNA AM SCHÖPFWERK RESIDENTIAL ESTATE. AS WELL AS LOSSES OF HEAT ENERGY THROUGH THE WINDOWS THERE ARE DIVERSE HEAT BRIDGES IN THE FABRIC OF THE BUILDING.

\*1 | Insulation for Sustainability (February 2002), published by XCO:- <http://www.xco-.com>

## II TWO SCENARIOS DESCRIBING THE FUTURE EUROPEAN ENERGY SUPPLY SYSTEM

Analysing the interdependencies between energy and climate change mitigation requires taking a long-term perspective. Energy infrastructure takes time to build up, and has a useful life lasting decades. New energy technologies take time to develop. The increasing concentration of greenhouse gases affects ecosystems and global climate over decades and centuries. Policy response often results in effects that can be appreciated only after considerable delay. Any analysis that seeks to tackle energy and environmental issues thus needs to look ahead at least to the next 50 years.

Scenarios are used to describe possible future development paths, to give decision-makers an overview of future perspectives, and to indicate how far they can shape the future energy system. Two different scenarios are used here to characterise the wide range of possible development paths for the future European energy supply system: a Reference Scenario, reflecting a continuation of current trends and policies into the future, and the Energy Revolution Scenario, which is designed to achieve a set of dedicated environmental policy targets:

- \* **the reference scenario:** The Reference Scenario is based on the European Commission's 'European Energy and Transport – Trends to 2030' [1] and 'European Energy and Transport – Scenarios on key drivers' [2] publications. This Scenario takes existing policies into account. Baseline assumptions include, for example, the modernisation of the EU economy and the completion of the internal electricity and gas markets, certain policies to support renewables and energy efficiency, as well as the nuclear phase-out decision in some Member States. The Reference Scenario does not include additional policies to reduce greenhouse gas emissions. As the European Commission's scenario only covers a time horizon up to 2030, it has been extended based on the extrapolation of key macroeconomic indicators. This Scenario provides a baseline reference for comparison with the Energy Revolution Scenario.
- \* **the energy revolution scenario:** The Energy Revolution Scenario is a normative scenario developed in a back-casting process. A key target is the reduction of European per capita CO<sub>2</sub> emissions down to a level of less than 3 tonnes of CO<sub>2</sub> per year by 2050, which is consistent with stabilising global CO<sub>2</sub> concentrations at a level below 450 ppm under a global CO<sub>2</sub> emission trading scheme. A second key objective is the phasing out of nuclear energy in all EU-25 Member States. To achieve these targets, the Energy Revolution Scenario is characterised by significant efforts towards fully exploiting the large energy efficiency potentials. As far as possible, all cost-effective renewable energy potentials are made accessible for heat and electricity generation as well as for the production of biofuels. General framing conditions referring to population development and GDP growth remain unchanged compared to the Reference Scenario.

The scenarios by no means claim to predict the future; they simply describe two potential development paths out of the broad range of possible 'futures'. The Energy Revolution Scenario is designed to indicate the efforts and actions required to achieve the ambitious objectives mentioned above, and to illustrate the options we have at hand to cope with the challenge of changing our energy supply system into a sustainable one.

### i development of energy demand in the EU-25 member states

The development of future energy demand is basically determined by the three key factors:

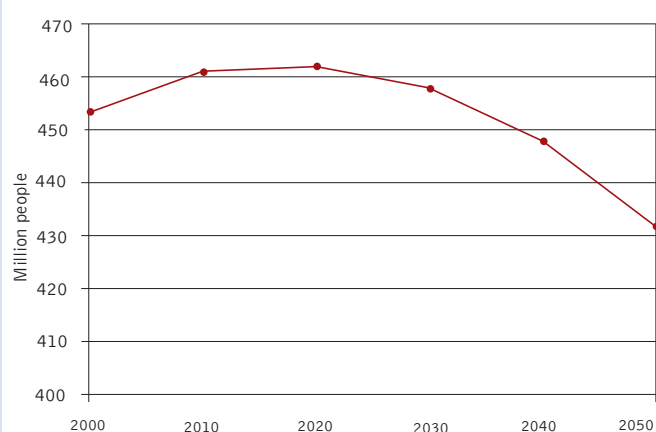
- \* Population development, i.e. the number of people consuming energy or using energy services;
- \* The development of economic activities, for which the Gross Domestic Product (GDP) is a commonly used indicator. In general, an increase in GDP goes along with an increase in energy demand.
- \* Energy intensity which is a measure of how much energy is required to produce, for example, a unit of GDP. Energy intensities can be reduced by exploiting the still large energy efficiency potentials.

*Both the Reference and the Energy Revolution Scenarios are based on the same projections of population development and of the development of economic activities. The future development of energy intensities, however, differ between the two, taking into account the efforts for increasing energy efficiency under the Energy Revolution Scenario.*

### projection of population development

Following both the European Commission's and United Nation's population development projections, the population in the EU-25 countries will continue to grow until it peaks around 2020 at a population of about 460 million people. After 2020, it is expected that the European population will start to decrease, so that in 2050 the EU-25 population will only be about 430 million. In the medium to long term, this reduction in population helps to reduce the pressure on energy resources and the environment.

FIGURE 7: POPULATION DEVELOPMENT PROJECTION IN THE EU-25 COUNTRIES

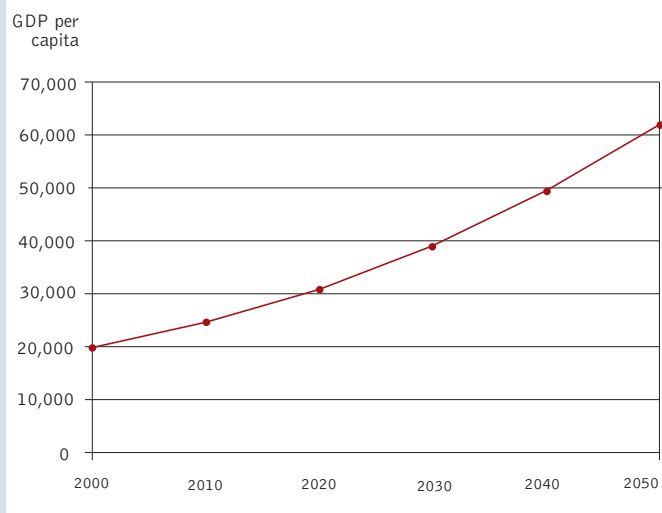


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**projection of GDP development** While we anticipate that the European population will shrink, people will continue to enjoy a further rise in living standards. The Gross Domestic Product, which is considered as an aggregated welfare indicator, is expected to grow in the EU-25 countries by 2.3% per year, leading to a tripling of today's GDP by 2050. The GDP growth is not evenly distributed across EU countries. While the French or German economy is expected to grow at or below 2% per year, the new Member States are currently experiencing much higher GDP growth rates. It is anticipated that GDP growth rates across European countries will converge by 2050, while per capita GDP will still show remarkable variations within the EU-25.

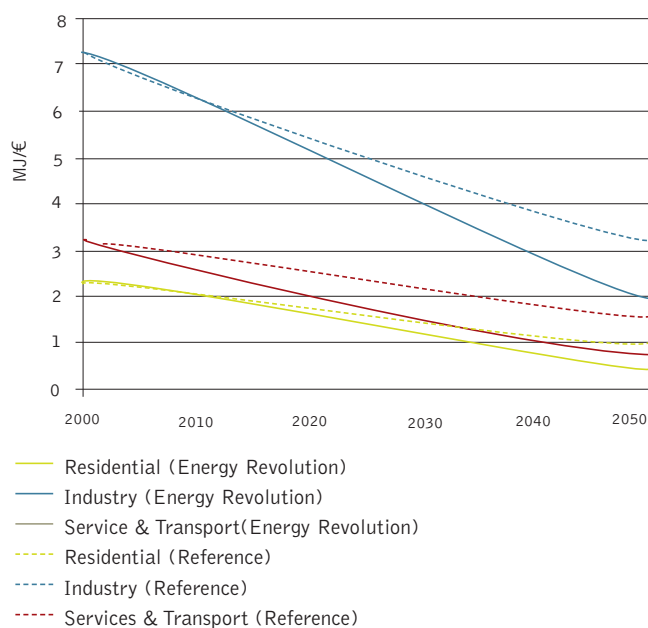
**FIGURE 8: PROJECTION OF AVERAGE GDP PER CAPITA DEVELOPMENT IN EU-25 COUNTRIES IN €<sub>2000</sub>/CAPITA**



### projection of energy intensities

In terms of pressure on the environment, the increase in economic activity and economic welfare will partly cancel out the effect of the decreasing population. But an increase in GDP does not necessarily result in an equivalent increase in energy demand, as there is still a large potential for exploiting energy efficiency measures. Even under the Reference Scenario, we assume that energy intensity will be reduced by about 1.5% per year, leading to a reduction of final energy demand per unit GDP by about 50% between 2000 and 2050. Under the Energy Revolution Scenario, it is assumed that due to active policy support the technical potential for efficiency measures is largely exploited, leading to a further significant reduction of energy intensities. Energy and electricity intensities are expected to converge across the EU-25 countries.

**FIGURE 9: PROJECTION OF ENERGY INTENSITIES BY DEMAND SECTOR UNDER THE REFERENCE AND ENERGY REVOLUTION SCENARIO**



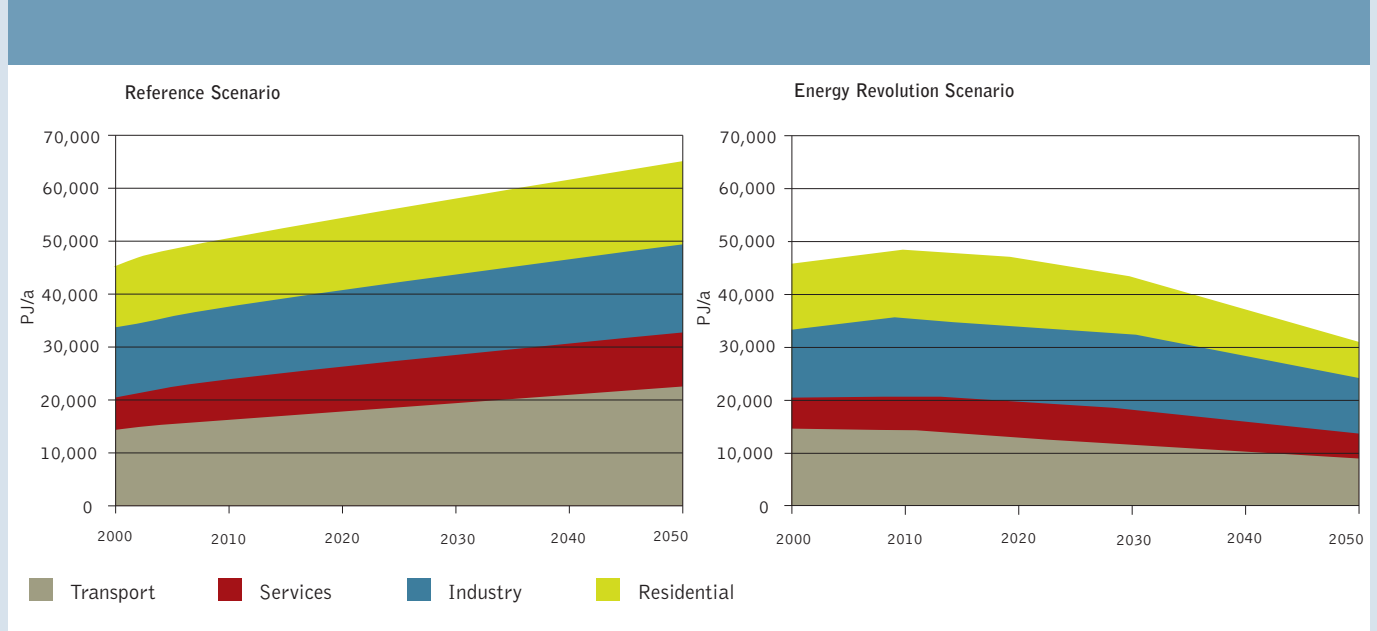


### development of total final energy demand in the EU-25 countries

Combining the projections on population development, GDP growth, and energy intensities results in future development pathways for final energy demand in the EU-25 countries, which are shown in Figure 10 for both the Reference and the Energy Revolution Scenarios. Under the Reference Scenario, the total final energy demand increases by more than 40% from the current 45,000 PJ/a to 65,000 PJ/a in 2050. In the Energy Revolution Scenario, we expect energy demand to peak in 2020, and then fall back to 31,100 PJ/a in 2050, which is about two-thirds of today's final energy demand, and half of the projected consumption under the Reference Scenario.

The accelerated increase of energy efficiency, which is a crucial prerequisite for achieving a sufficiently large share of renewable energy sources for our energy supply, is beneficial not only for the environment, but also from an economic point of view. Taking into account the full service life, in most cases the implementation of energy efficiency measures saves costs compared to the additional energy supply. The mobilisation of cost-effective energy saving potentials leads directly to the reduction of costs. A dedicated energy efficiency strategy thus also helps to compensate in part for the additional costs required during the market introduction phase of renewable energy sources. It will also help to insulate the economy from the effects of anticipated steep rises rapid fluctuations in energy prices.

FIGURE 10: PROJECTION OF TOTAL FINAL ENERGY DEMAND BY SECTOR IN EU-25 COUNTRIES FOR BOTH THE REFERENCE AND ENERGY REVOLUTION SCENARIOS



Under the Energy Revolution Scenario, the final electricity demand is expected to stabilise around 2030, with the industry sector being the main source for growing electricity consumption until then (Figure 11). Due to the exploitation of efficiency measures, after 2030 electricity consumption starts to decrease slowly in spite of continuous economic growth, leading to an electricity demand of less than 3,000 TWh/a in the year 2050. Compared to the Reference Scenario, efficiency measures avoid the generation of about 1,600 TWh/a in 2050. The continuous reduction in energy demand can be achieved in particular by using highly efficient electronic devices representing the best available technology in all demand sectors. The consideration of solar architecture in both residential and commercial buildings helps to curb the growing demand for active air-conditioning.

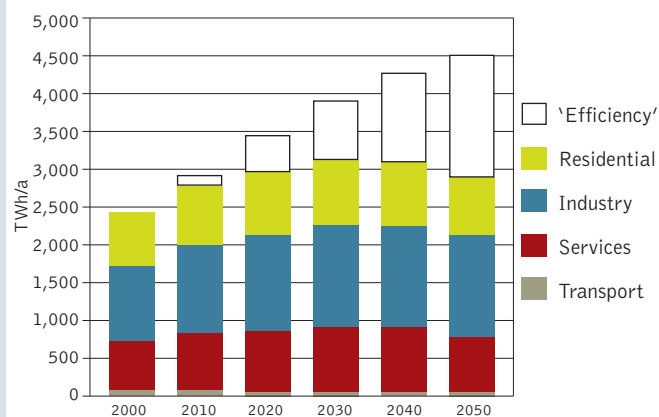
# ENERGY REVOLUTION: A SUSTAINABLE PATHWAY TO A CLEAN ENERGY FUTURE FOR EUROPE

## A EUROPEAN ENERGY SCENARIO FOR EU-25

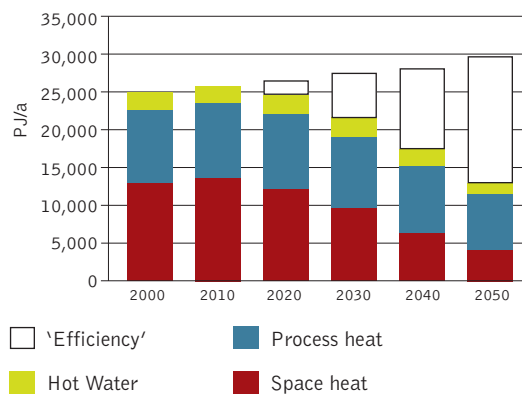
Efficiency gains in the heat supply sector are even larger. Under the Energy Revolution Scenario, the final energy demand for heat supply will be halved by 2050 (Figure 12). Compared to the Reference Scenario, which is characterised by putting less effort into the implementation of energy efficiency measures, in 2050 the consumption of 16,900 PJ/a is avoided through efficiency gains. Space heating is by far the largest contribution to this reduction. As the result of the energy-related renovation of the existing stock of residential buildings, as well as the introduction of low energy standards and 'passive houses' for new buildings, enjoying both the same comfort and energy services will accompany a much lower energy demand in the future.

The reduction of energy demand in industry, the residential and the tertiary sectors is complemented by significant efficiency gains in the transport sector, which is not analysed in detail in the present study. Under the Energy Revolution Scenario, it is assumed that the final energy demand for transportation in the EU-25 countries will be reduced from today's 14,100 PJ/a to 8,500 PJ/a in 2050. This reduction in energy demand can be achieved by the introduction of highly efficient vehicles, by shifting the transport of goods from road to rail, and by changes in mobility-related behaviour patterns.

**FIGURE 11: DEVELOPMENT OF FINAL ENERGY DEMAND FOR ELECTRICITY BY DEMAND SECTORS ('EFFICIENCY'=REDUCTION COMPARED TO REFERENCE SCENARIO)**



**FIGURE 12: DEVELOPMENT OF FINAL ENERGY DEMAND FOR HEAT SUPPLY ('EFFICIENCY'=REDUCTION COMPARED TO REFERENCE SCENARIO)**



### ii an alternative scenario for a sustainable energy supply in Europe: the Greenpeace energy revolution scenario

Today, renewable energy sources account for 6% of the EU-25 Member States' primary energy demand. Biomass, which is mainly used for heating, is the main renewable energy source. The share of renewable energies for electricity generation is 15%, with hydro power plants being the largest source. The contribution of renewables to primary energy demand from heat supply is around 9%. About 80% of the European primary energy supply today still comes from fossil fuels.

The Energy Revolution Scenario describes a development pathway which turns the present situation into a sustainable European energy supply:

- \* Exploitation of the existing large energy efficiency potentials will reduce primary energy demand from the current 72,000 PJ/a (2003) to 46,000 PJ/a in 2050. This dramatic reduction in primary energy demand is a crucial prerequisite for achieving a significant share of renewable energy sources in the overall energy supply system, for compensating the phasing out of nuclear energy, and for reducing the consumption of fossil fuels.
- \* The increased use of combined heat and power generation (CHP) increases the supply system's energy conversion efficiency. Fossil fuels for CHP are increasingly being substituted by biomass and geothermal energy. The availability of district heating networks is a key precondition for achieving a high share of decentralised CHP. In the long term, the decreasing demand for heat and the large potential for producing heat directly from renewable energy sources limits the further expansion of combined heat and power generation.
- \* The electricity sector will continue to be the forerunner of RES utilisation. By 2050, more than 70% of the electricity will be produced from renewable energy sources (including large hydro). A capacity of 720 GW will produce 1,920 TWh/a RES electricity in 2050.
- \* In the heat supply sector, the contribution of renewables will continue to grow, reaching more than 50% in 2050. In particular, biomass, solar collectors and geothermal energy will substitute conventional systems for direct heating and cooling.

- \* Before biofuels are introduced on a large scale in the transport sector, the existing large efficiency potentials have to be exploited. Because the use of biomass for CO<sub>2</sub> reduction in stationary applications is more cost effective, the use of biofuels is limited by the availability of biomass within the EU-25 countries.
- \* By 2050, nearly half of the primary energy demand will be covered by renewable energy sources.

### electricity generation

The development of the electricity supply sector is characterised by a dynamically growing RES market and a continuously increasing share of renewable energy sources, which compensates for the phasing out of nuclear energy and the reduction of fossil-fired condensing power plants to a minimum, as is required for grid stabilisation. By 2050, 70% of the electricity produced in the EU-25 Member States will come from renewable energy sources. 'New' renewables – excluding large hydro plants – will contribute to 55% of electricity generation. The following strategy paves the way for a future renewable energy supply:

- \* The phasing out of nuclear energy and an electricity demand which continues to increase until 2020 is compensated for in a first step by bringing into operation new highly efficient gas-fired combined-cycle power plants, plus the increasing capacity of wind turbines. The potential for onshore wind is expected to be limited to a capacity of around 160 GW. In the long term, offshore wind will be the most important single source of electricity generation.
- \* PV, biomass and geothermal will make substantial contributions to electricity production. In particular, as a non-fluctuating renewable energy source geothermal is an important element in the overall generation mix.
- \* Because of nature conservation aspects, the use of hydro power will be limited and will not grow very much compared to today's level. It is assumed that the largest additional potential can be exploited by modernising large run-of-river power plants.
- \* The import of electricity from renewable energy sources is of growing importance for achieving ambitious long-term CO<sub>2</sub>-reduction targets within the EU-25. North African countries offer a vast potential for producing electricity in concentrating solar thermal power plants, which not only helps Europe to increase the share of electricity from renewables, but also opens up new ways of economic and technical co-operation.
- \* The installed capacity of new renewable energy technologies (excluding large hydro) will increase from the current 40 GW to 580 GW in 2050. Increasing RES capacity by a factor of 15 within the next 45 years requires policy support and well-designed policy instruments. Because of an electricity demand which is still growing, and the age structure of the existing European power plant park there is a large demand for investment into new capacities over the next 20 years. As investment cycles in the power sector are long, decisions for restructuring the European electricity supply system need to be taken now.

To achieve an economically attractive growth in renewable energy sources, a balanced and timely mobilisation of all RES technologies is of great importance. This mobilisation depends on technical potentials, actual costs, cost-reduction potentials, and technological maturity. Figure 15 shows the complementary evolution of the different RES technologies over time. Until 2010, cost-effective hydro-power, biomass power plants and wind turbines will remain the main contributors to the growing market share of RES technologies. By 2020, the potential available for hydro power and onshore wind – which is determined, amongst others, by strong nature conservation aspects – will be nearly fully exploited. After 2020, the continually growing use of offshore wind will be complemented by electricity from photovoltaics, solar thermal power plants, and from geothermal energy.

FIGURE 13: DEVELOPMENT OF THE ELECTRICITY SUPPLY STRUCTURE UNDER THE REFERENCE SCENARIO

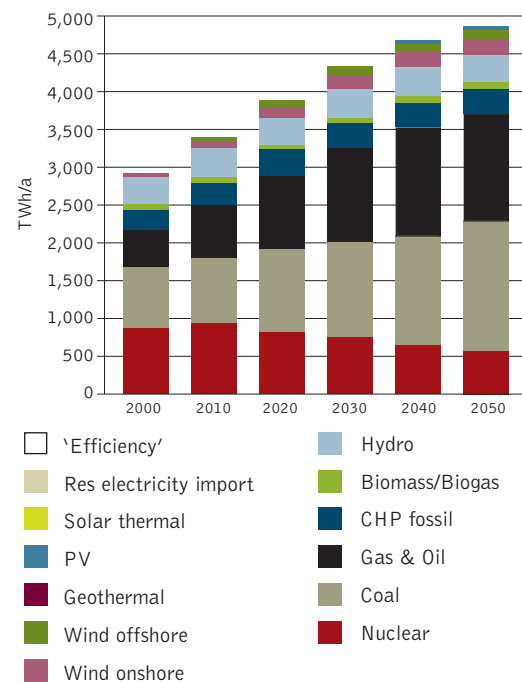
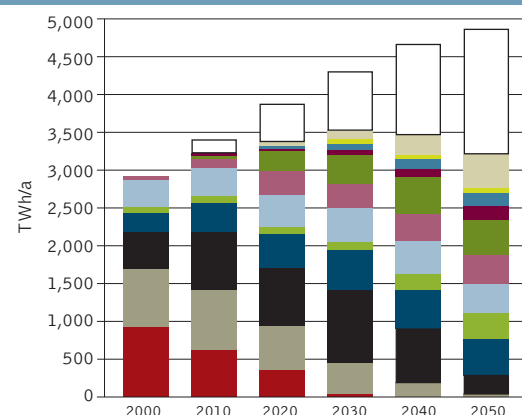


FIGURE 14: DEVELOPMENT OF THE ELECTRICITY SUPPLY STRUCTURE UNDER THE ENERGY REVOLUTION SCENARIO ('EFFICIENCY'= REDUCTION COMPARED TO THE REFERENCE SCENARIO)



# ENERGY REVOLUTION: A SUSTAINABLE PATHWAY TO A CLEAN ENERGY FUTURE FOR EUROPE

## A EUROPEAN ENERGY SCENARIO FOR EU-25

FIGURE 15: GROWTH OF RES ELECTRICITY GENERATION UNDER THE ENERGY REVOLUTION SCENARIO, BY INDIVIDUAL SOURCES

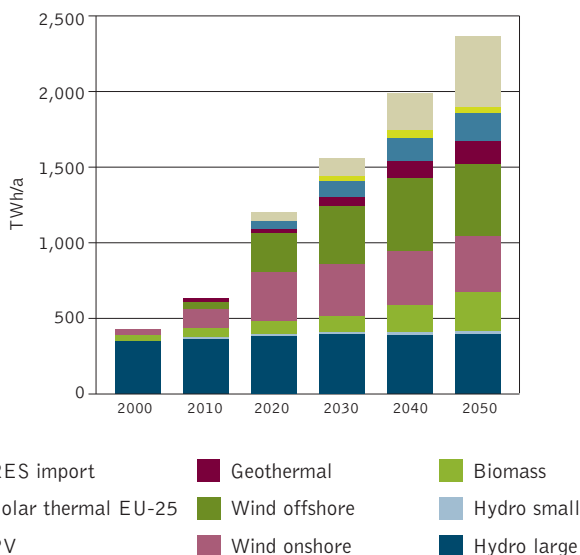


TABLE 4: PROJECTION OF RES CAPACITY FOR ELECTRICITY GENERATION UNDER THE ENERGY REVOLUTION SCENARIO, IN MW

YEAR	2000	2010	2020	2030	2050
Hydro	130,540	137,350	145,160	148,390	148,390
- small	3,410	4,010	5,020	5,380	5,380
- large	127,130	133,340	140,140	143,010	143,010
Wind	13,530	79,830	229,800	267,470	296,790
- onshore	13,240	69,740	159,910	162,790	163,640
- offshore	290	10,090	69,890	104,680	133,150
Photovoltaics	146	5,050	39,980	92,340	180,060
Biomass	15,760	17,390	20,600	23,370	51,590
Geothermal	620	2,500	6,000	11,960	28,490
Solar thermal	-	870	3,980	15,170	17,920
<b>Total</b>	<b>160,600</b>	<b>242,990</b>	<b>445,520</b>	<b>558,700</b>	<b>723,230</b>

### heat supply

The starting point for renewables in the heat supply sector is more difficult than in the power sector. Today, renewables provide less than 10% of primary energy demand for heat supply, the main contribution being biomass for small-scale individual heating systems. The availability of district heating networks is a severe structural barrier for large-scale utilisation of geothermal and solar thermal energy for heat supply. Past experience shows that it is easier to implement effective support instruments in the grid-bound electricity sector than in the heat market with its multitude of different actors. Dedicated support instruments are required to ensure a continuously dynamic development of renewables in the heat market.

- \* Energy efficiency measures can reduce the current primary energy demand for heat supply by about 50%.
- \* The increasing contribution of decentralised combined heat and power production in a shrinking heat market will lead to a CHP share of nearly 30% in 2050.
- \* Solar collectors, biomass/biogas as well as geothermal energy are increasingly substituting conventional fossil-fired heating systems.
- \* A shift from coal and oil to natural gas in the remaining conventional applications leads to a further reduction of CO<sub>2</sub> emissions.

FIGURE 16: DEVELOPMENT OF THE HEAT SUPPLY STRUCTURE UNDER THE REFERENCE SCENARIO

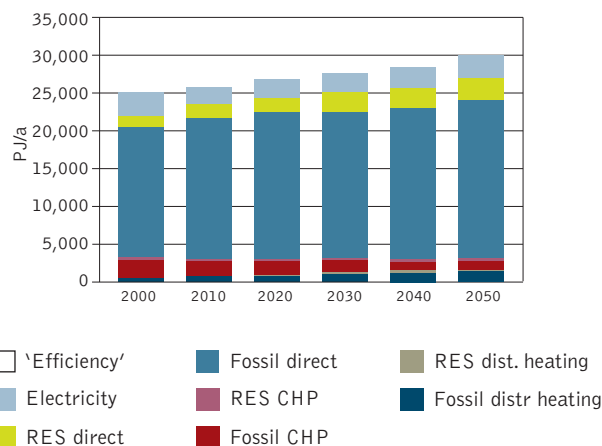
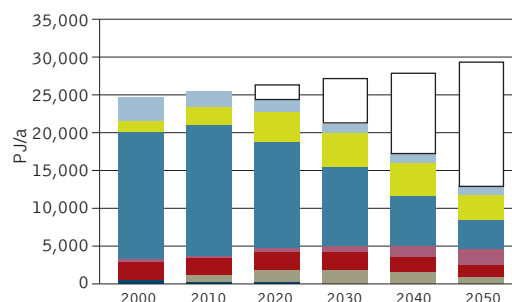


FIGURE 17: DEVELOPMENT OF PRIMARY HEAT SUPPLY STRUCTURE UNDER THE ENERGY REVOLUTION SCENARIO ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

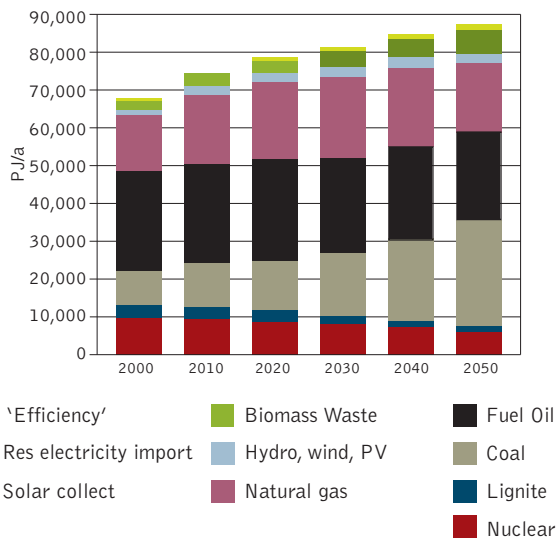




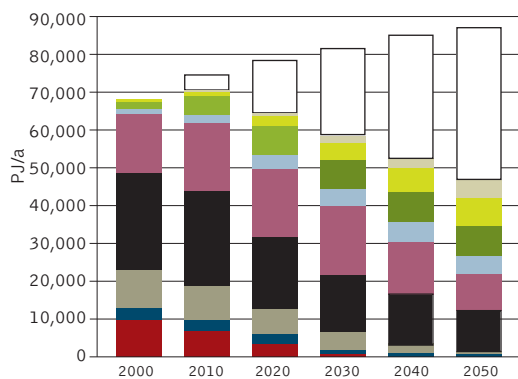
### primary energy consumption

Taking into account the assumptions discussed above, the resulting primary energy consumption in the EU-25 countries under the Energy Revolution Scenario is shown in Figure 19. Compared to the Reference Scenario, under the Energy Revolution Scenario the primary energy demand will be reduced by about 50% in 2050. Nearly half of the remaining primary energy demand is covered by renewable energy sources. Note that because of the 'efficiency method' used for the calculation of primary energy consumption, which postulates that the amount of electricity generation from hydro, wind, solar and geothermal energy equals the primary energy consumption, the share of renewables seems to be lower than their actual importance for providing energy carriers.

**FIGURE 18: DEVELOPMENT OF PRIMARY ENERGY CONSUMPTION UNDER THE REFERENCE SCENARIO**



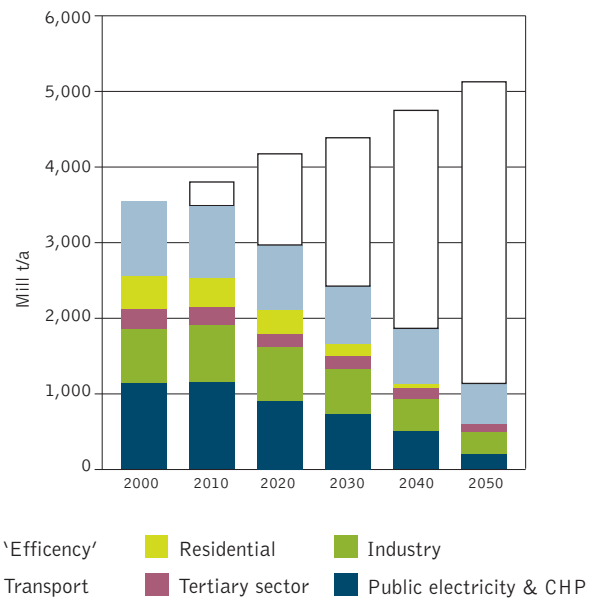
**FIGURE 19: DEVELOPMENT OF PRIMARY ENERGY CONSUMPTION UNDER THE ENERGY REVOLUTIONS SCENARIO ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)**



### development of CO<sub>2</sub>-emissions

While CO<sub>2</sub> emissions in the EU-25 Member States will increase under the Reference Scenario by nearly 50% until 2050 and are thus far removed from a sustainable development path, under the Energy Revolution Scenario CO<sub>2</sub> emissions will continue to decrease from 3,850 Mill. t in 2000 to 1,150 Mill. t in 2050. Annual per capita emissions will drop from 7.9 t/capita to 2.7 t/capita. While the phasing out of nuclear energy together with an increasing electricity demand will result in a very small increase of CO<sub>2</sub> emissions in the electricity sector until 2010, efficiency gains and the increased use of renewables for heating in the residential sector compensates for this, thus facilitating a continual decrease in total CO<sub>2</sub> emissions. While today the power sector is the largest source of CO<sub>2</sub> emissions in Europe, it will contribute to less than 20% of total CO<sub>2</sub> emissions in 2050.

**FIGURE 20: DEVELOPMENT OF CO<sub>2</sub> EMISSIONS IN THE EU 25 COUNTRIES BY SECTOR UNDER THE ENERGY REVOLUTION SCENARIO ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)**



# ENERGY REVOLUTION: A SUSTAINABLE PATHWAY TO A CLEAN ENERGY FUTURE FOR EUROPE

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### future costs of electricity generation

Figure 23 shows that the introduction of RES technologies under the Energy Revolution Scenario slightly increases the specific costs of electricity generation compared to the Reference Scenario<sup>5</sup>. This cost difference will be about 0.3 ct/kWh in 2020, increasing to 1 ct/kWh in 2050. Note that any increase in fossil energy prices beyond the price projection given in Figure 5 (page 19) is a further direct burden on fossil electricity generation, and thus reduces the cost-gap between the two scenarios.

When considering the costs of CO<sub>2</sub> emissions, the difference in specific electricity generation costs is reduced to less than a maximum of 0.2 ct/kWh. Because of the lower CO<sub>2</sub> intensity of electricity generation, by 2040 electricity generation costs will become economically favourable under the Energy Revolution Scenario, and in 2050 the specific generation costs will be 0.5 ct/kWh below the costs of the Reference Scenario.

Figure 6.5.22 shows that the slightly higher specific electricity generation costs under the Energy Revolution Scenario are to a large extent compensated for by the reduced demand for electricity. Assuming average costs of 4.5 ct/kWh for implementing energy efficiency measures, the additional cost for electricity supply under the Energy Revolution Scenario – excluding the costs of CO<sub>2</sub>-emissions – amount to a maximum of 6 billion €/a in 2020. These additional costs, which are society's investment into a future environmental benign, safe, and economic energy supply, will continue to decrease after 2020, and by 2050 the annual costs of electricity supply will be 10 billion €/a below the electricity supply costs in the Reference Scenario. Inclusion of the costs of CO<sub>2</sub> emissions further emphasises the long-term economic benefits of the Energy Revolution Scenario.

FIGURE 23: DEVELOPMENT OF TOTAL ELECTRICITY SUPPLY COSTS (WITHOUT CO<sub>2</sub> COSTS); REF = REFERENCE SCENARIO, ER = ENERGY REVOLUTION SCENARIO

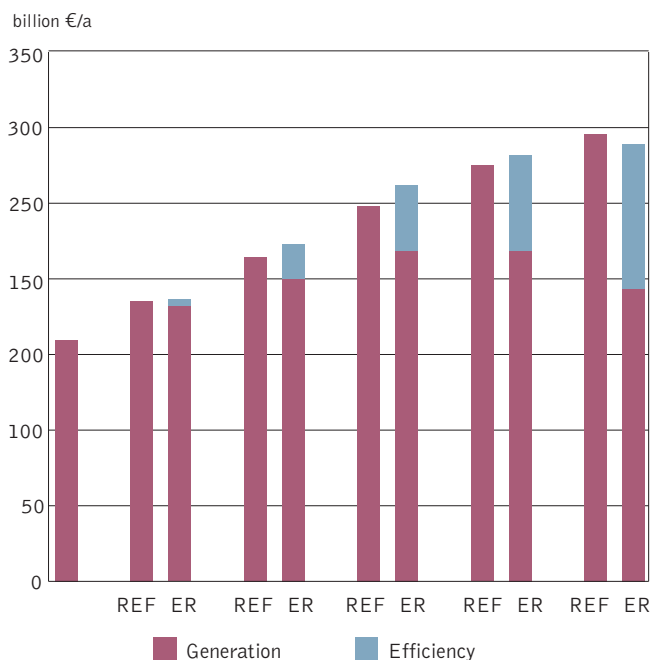
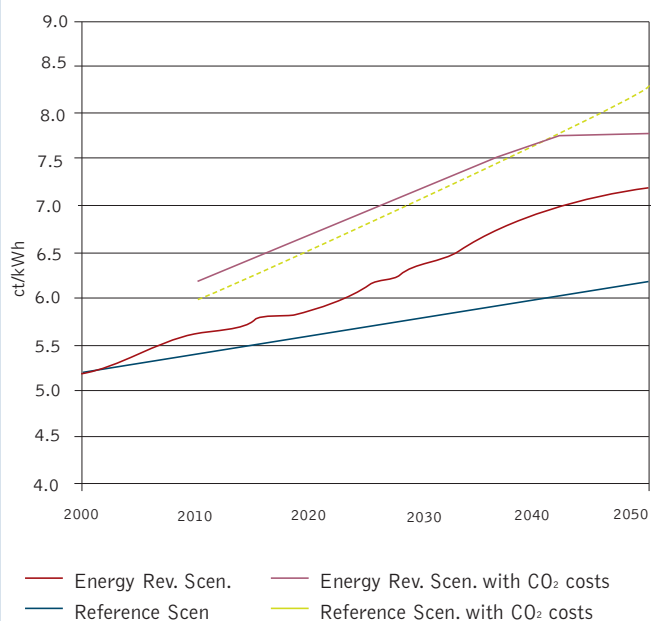


FIGURE 21: DEVELOPMENT OF SPECIFIC ELECTRICITY GENERATION COSTS UNDER THE TWO SCENARIOS (CO<sub>2</sub>-COSTS IMPOSED IN 2010 INCREASES FROM 15 €/T<sub>CO<sub>2</sub></sub> TO 50 €/T<sub>CO<sub>2</sub></sub> IN 2050)

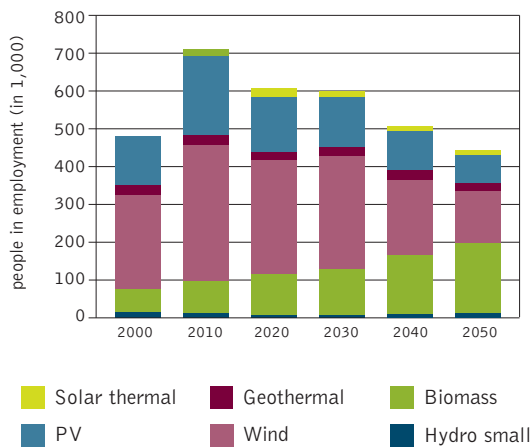


<sup>5</sup> Cost calculations assume electricity supply at the medium-voltage level. Average costs for transforming and distributing high-voltage electricity is assumed to be 1.2 ct/kWh.

### employment effects

The rapid growth of renewable energy technologies described under the Energy Revolution Scenario will lead to large investment into new technologies. This dynamic market growth results in a shift of employment opportunities from conventional energy-related industries like coal mining to new occupational fields in, for example, the wind and solar industry. The growing contribution of renewables is expected to provide about 700,000 jobs in the field of electricity generation from renewable energy sources in the coming years. This includes both 'direct' effects related to electricity generation and the production of investment goods, as well as 'indirect' effects covering the upstream production chain. The employment effects are estimated by using assumptions on import shares, labour productivity and their growth rates until 2050. Because of increasing labour productivity and growing import quotas, the total number of jobs related to electricity generation is expected to shrink. It is anticipated that in 2050, under the Energy Revolution Scenario, more than 90% of the jobs related to electricity generation will be linked to the process chains of RES technologies.

**FIGURE 24: PEOPLE IN EMPLOYMENT RESULTING FROM ELECTRICITY GENERATION FROM RENEWABLE ENERGY SOURCES UNDER THE ENERGY REVOLUTION SCENARIO**



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<http://www.oeko.de/dokum.php?setlan=1&vers=&id=236&PHPSESSID=e670f58f51a56a0131427275bcef44f> (in German)



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