energy [r]evolution

A SUSTAINABLE EU 27 ENERGY OUTLOOK

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report regional energy scenario

foreword

Of all the sectors of a modern economic system, the one that appears to be getting the maximum attention currently is the energy sector. While the recent increase in oil prices certainly requires some temporary measures to tide over the problem of increasing costs of oil consumption particularly for oil importing countries, there are several reasons why the focus must now shift towards longer term solutions. First and foremost, of course, are the growing uncertainties related to oil imports both in respect of quantities and prices, but there are several other factors that require a totally new approach to planning energy supply and consumption in the future. Perhaps, the most crucial of these considerations is the threat of global climate change which has been caused overwhelmingly in recent decades by human actions that have resulted in the build up of greenhouse gases (GHGs) in the Earth's atmosphere.

> **"will we look into the eyes of our children and confess**
>
> that we had the **opportunity,**
> but lacked the **courage?**
> that we had the **technology,**
> but lacked the **vision?"**

contents

image CHECKING THE SOLAR PANELS ON TOP OF THE GREENPEACE POSITIVE ENERGY TRUCK IN BRAZIL.
cover image A TEST WIND MILL BUILT BY THE GERMAN COMPANY NORDEX IN THE ROSTOCK HARBOUR.

Impacts of climate change are diverse and serious, and unless the emissions of GHGs are effectively mitigated these would threaten to become far more serious over time. There is now, therefore, a renewed interest in renewable sources of energy, because by creating and using low carbon substitutes to fossil fuels, we may be able to reduce emissions of GHGs significantly while at the same time ensuring economic growth and development and the enhancement of human welfare across the world. As it happens, there are major disparities in the levels of consumption of energy across the world, with some countries using large quantities per capita and others being deprived of any sources of modern energy forms. Solutions in the future would, therefore, also have to come to grips with the reality of lack of access to modern forms of energy for hundreds of millions of people. For instance, there are 1.6 billion people in the world who have no access to electricity. Households, in which these people reside, therefore, lack a single electric bulb for lighting purposes, and whatever substitutes they use provide inadequate lighting and environmental pollution, since these include inefficient lighting devices using various types of oil or the burning of candles.

Future policies can be guided by the consideration of different scenarios that can be linked to specific developments. This publication advocates the need for something in the nature of an energy revolution. This is a view that is now shared by several people across the world, and it is also expected that energy plans would be based on a clear assessment of specific scenarios related to clearly identified policy initiatives and technological developments. This edition of Energy [R]evolution Scenarios provides a detailed analysis of the energy efficiency potential and choices in the transport sector. The material presented in this publication provides a useful basis for considering specific policies and developments that would be of value not only to the world but for different countries as they attempt to meet the global challenge confronting them. The work carried out in the following pages is comprehensive and rigorous, and even those who may not agree with the analysis presented would, perhaps, benefit from a deep study of the underlying assumptions that are linked with specific energy scenarios for the future.

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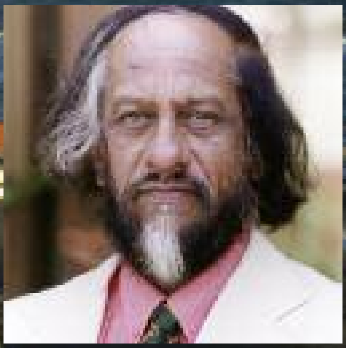
OCTOBER 2008



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Greenpeace International

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introduction

"NOW IS THE TIME TO COMMIT TO A TRULY SECURE AND SUSTAINABLE ENERGY FUTURE – A FUTURE BUILT ON CLEAN TECHNOLOGIES, ECONOMIC DEVELOPMENT AND THE CREATION OF MILLIONS OF NEW JOBS."


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image WORKERS EXAMINE PARABOLIC TROUGH COLLECTORS IN THE PS10 CONCENTRATING SOLAR TOWER PLANT IN SEVILLA, SPAIN. EACH PARABOLIC TROUGH HAS A LENGTH OF 150 METERS AND CONCENTRATES SOLAR RADIATION INTO A HEAT-ABSORBING PIPE INSIDE WHICH A HEAT-BEARING FLUID FLOWS. THE HEATED FLUID IS THEN USED TO HEAT STEAM IN A STANDARD TURBINE GENERATOR.

Humankind is at a critical crossroads. Since the industrial revolution, the planet has warmed by 0.74°C, a distortion of the climate system caused by human activities such as the burning of carbon-intensive fossil fuels[1]. The impacts we are witnessing are occurring far sooner than had been predicted. Droughts in many parts of the world, the near-total loss of the Arctic ice-cap and an additional 150,000 deaths per year[2] indicate that we are already experiencing dangerous climate change.

The challenge humanity faces now is to avoid "runaway" climate change. Climate scientists warn that if we warm the atmosphere by more than 2°C from pre-industrial levels, we invite catastrophic climate change and trigger processes that result in even more emissions being released, taking global warming beyond our control. The warming we have already experienced, plus an additional degree expected due to the "lag" effect of greenhouse gases already in the atmosphere, takes us to the brink. If we pass this threshold, the economic, social, political, cultural and environmental impacts will be catastrophic.

In presenting the greatest threat the planet faces, climate change also presents an opportunity. We can avert runaway climate change and at the same time revolutionise the way we harness and use the resources available to us. We can create a sustainable society, using technologies and behaviours that are low-carbon intensive. However, we do not have much time and the transition must begin immediately.

Action is required on all fronts. Internationally, it is critical that parties to the Kyoto Protocol reach an agreement that ensures global emissions fall substantially by the year 2020. Domestically, there is much Europe can do to take a leading role in the climate debate, as well as get ahead of the game as the world moves to a low-carbon future. Currently, Europe is still one of the worst greenhouse-polluting countries in the world on a per-capita basis. Renewable energy is forced to compete on an uneven playing field, as the lion's share of political and financial support is enjoyed by the powerful fossil fuel industry. However, this can and must be turned around. Europe is fortunate to have some of the best renewable energy resources in the world and, with the political will, could become a renewable energy leader. It is also well placed to become much more energy efficient and reduce costs of energy as well as emissions. By setting strong targets to reduce greenhouse pollution domestically and taking the lead on climate change,

> “Europe is fortunate enough to have some of the best renewable energy resources in the world and, with the political will, could become a renewable energy leader.”


© GP/NICK COBBING

image ICEBERG MELTING ON GREENLAND’S COAST.

Europe could steer international negotiations towards a binding agreement that ensures global greenhouse gases fall to levels that avoid runaway climate change.

energy [r]evolution scenario: europe

This scenario is based on the global energy scenario produced by Greenpeace International, which demonstrates how energy related global CO_2 emissions can be at least halved by 2050. The Europen scenario provides an exciting, ambitious and necessary blueprint for how emission reductions can be made in the energy and transport sectors and how Europe’s energy can be sustainably managed up to the middle of this century.

our renewable energy future

This report demonstrates that renewable energy is mature, ready and can be deployed on a large scale. Decades of technological progress have seen renewable energy technologies such as wind, solar photovoltaic, geothermal power plants and solar thermal collectors move steadily into the mainstream. They will play a vital role in providing secure, reliable and zero-emission energy in the future.

The global market for renewable energy is booming internationally; installed capacity of wind grew by 27% globally[3] in 2007 while solar photovoltaics grew by 50%[4]. As renewable energy is scaled up, we can begin turning off polluting coal-fired power plants, starting with the oldest and dirtiest. Decisions made today by governments and power utilities will determine the energy supply in decades to come and coal-fired power plants are incompatible with an energy mix that helps us avoid runaway climate change. An energy revolution that drives down emissions could be a result of today’s political action.

the forgotten solution: energy efficiency

The Europen Energy [R]evolution Scenario takes advantage of the enormous potential for Europe to become more energy efficient. Energy efficiency offers some of the simplest, easiest and most cost effective measures for reducing both greenhouse gas emissions and cost to end-users.

Market based measures that reduce emissions will result in the cost of fossil fuels increasing. Removal of government subsidies, emissions trading and carbon taxes will all result in the cost of fossil fuels increasing, perhaps to a level that truly reflects the damage they cause. As fossil fuels are phased out, it will be necessary to protect those most vulnerable to energy price increases. Energy efficiency presents opportunities for people to be protected from the costs of rising energy prices.

keeping it fair

The Energy [R]evolution Scenario: Europe describes a major restructuring of energy and transport markets. An integral part of the inevitable transition from fossil fuels to renewable energy will be ensuring that total negative social and economic impacts are kept to a minimum and the opportunities for new employment, investment and innovation are maximized.

The transition away from fossil fuels opens up new opportunities in skills development and sharing, manufacturing and infrastructure development. Early planning will help ensure that a skilled workforce is ready to deliver the low-carbon future. Moving to a renewable energy-based society can be done smoothly and justly.

on the front foot

Avoiding runaway climate change will require the most far-reaching structural reforms carried out by human society. Business as usual is simply not an option. Furthermore, there can be no half measures, or falling short of the required emission reductions. The risk of passing the threshold of runaway climate change is not one that humankind can afford to take. The Energy [R]evolution Scenario demonstrates that making the necessary transformation in how we use energy is achievable, and provides a wealth of opportunities to stimulate economic growth and ensure social security.

We call on political leaders to turn the Energy [R]evolution Scenario into reality and to begin the inevitable transition from fossil-fuels to renewable energy now, delivering immediate reductions in emissions, minimising economic and social disruption and maximising opportunities for the European economy to prosper from the transition.

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CLIMATE & ENERGY UNIT
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DECEMBER 2008

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GREENPEACE EUROPEAN UNIT

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executive summary

"TOWARDS A SUSTAINABLE ENERGY SUPPLY SYSTEM."

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

energy [r]evolution: a sustainable pathway to a clean energy future for EU 27

The Energy [R]evolution Scenario reduces carbon dioxide emissions from the EU energy sector by some 30% below 1990 levels by 2020 and roughly 80% by 2050. This, in concert with additional greenhouse gas savings in other sectors, is necessary to keep the increase in global temperature as much below +2°C as possible.

A second objective of the energy [r]evolution is the global phasing out of nuclear energy. To achieve these targets, the scenario is characterised by significant efforts to fully exploit the large potential for energy efficiency. At the same time, all cost-effective renewable energy sources are accessed for both heat and electricity generation.

Today, renewable energy sources account for 7% of the European 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 14.3%. The contribution of renewables to primary energy demand for heat supply is around 10%. About 80% of the European primary energy supply today still comes from fossil fuels.

The Energy [R]evolution Scenario describes a development pathway which turns the present situation into a sustainable energy supply for the EU-27:

- Exploitation of the existing large energy efficiency potentials will reduce primary energy demand from the current 77,260 PJ/a (2005) to 49,749 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 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 limit the further expansion of combined heat and power generation.
- The electricity sector will continue to be the forerunner of renewable energy sources (RES) utilisation. By 2050, 88% of the electricity will be produced from renewable energy sources. A capacity of 1,070 GW will produce 2,900 TWh/a RES electricity in 2050.

image A WELDER WORKING AT VESTAS WIND TURBINE FACTORY, CAMPELLTOWN, SCOTLAND.

- In the heat supply sector, the contribution of renewables will continue to grow, reaching more than 56% in 2050. In particular, biomass, solar collectors and geothermal energy will substitute conventional systems for direct heating and cooling.
- Before sustainable bio fuels are introduced in the transport sector, the existing large efficiency potentials have to be exploited. As biomass is mainly bound in stationary applications, the production of bio fuels is limited by the availability of biomass. Electric vehicles will play an increasingly important role from 2020 onwards.
- By 2050, 56.4% of the primary energy demand will be covered by 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_2 emissions

While energy-related CO_2 emissions in EU-27 will increase by 20% under the Reference Scenario until 2050 and are thus far removed from a sustainable development path, under the Energy [R]evolution Scenario CO_2 emissions will decrease from 3,900 Mill. t in 2005 to 979 Mill. t in 2050. Annual per capita emissions will drop from 7.9 t/capita to 2 t/capita. In spite of the phasing out of nuclear energy and a slightly increasing electricity demand CO_2 emissions will decrease in the electricity sector enormously. Efficiency gains and the increased use renewable electricity for vehicles and some limited sustainable bio fuels will reduce CO_2 emissions in the transport sector by over 70%. The transport sector will take over the role as one of the largest sources of CO_2 emissions in EU-27, with a share of 30% of total CO_2 emissions in 2050.

According to latest scientific findings, further emissions reductions may be necessary. These would require the further development of currently less developed renewable energy sources, such as ocean energy, and further efficiency measures. This will require further research and development funding, as well as bold political measures. At the same time, lifestyle and behaviour changes could become increasingly important.

To complement these savings in the energy sector, further reductions of carbon dioxide and other greenhouse gas emissions have to be achieved through the phase-out of fluorinated gases, a strict stop on deforestation and the increase of the natural carbon sequestration potential by forests and soils, for example by the regeneration of forests and sustainable farming practices.

costs

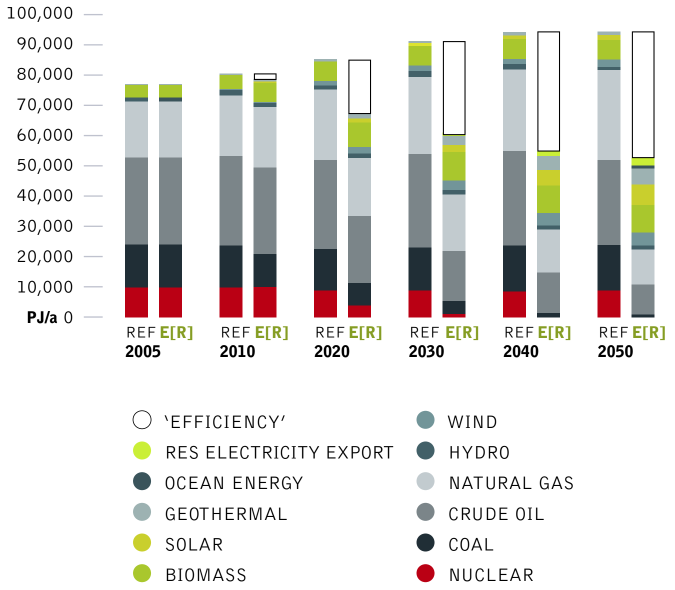
The introduction of renewable technologies under the Energy [R]evolution Scenario slightly increases the costs of electricity generation compared to the Reference Scenario. This difference will be less than 0.5 cents/kWh up to 2020. Because of the lower CO_2 intensity of electricity generation, by 2020 electricity generation costs will become economically favourable under the Energy Revolution Scenario, and by 2050 generation costs will be more than 2.4 cents/kWh below those in the Reference Scenario. Under the Reference Scenario, the unchecked growth in demand, the increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's €330 billion per year to more than €730 billion in 2050. The inclusion of the costs of CO_2 emissions further emphasises the long-term economic benefits of the Energy [R]evolution Scenario.

to make the energy [r]evolution real and to avoid dangerous climate change, Greenpeace demand for the energy sector that the following policies and actions are implemented:

1. Set effective emission reduction targets in line with the 2°Celsius global warming limit.
2. Phase out all subsidies and other support measures for inefficient plants, appliances, vehicles and buildings, as well as for fossil fuel use and nuclear power installations.
3. Secure an effective emissions trading system that makes polluters pay.
4. Set stringent and ever-improving efficiency standards.
5. Implement legally binding targets and stable support for renewable energy.
6. Remove barriers to renewable energy development and reform the electricity market.
7. Develop marketing, training and awareness-raising for renewable energy and energy efficiency technologies.
8. Support innovation in energy efficiency, low-carbon vehicles, renewable energy.

figure 0.1: EU 27: development of primary energy consumption under the two scenarios

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



the energy [r]evolution

1

> “clearly, tackling the causes and effects of climate change will require fundamental change.”
>
> **JOSÉ MANUEL BARROSO**
> PRESIDENT OF THE EUROPEAN COMMISSION

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

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

key principles

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

1. **respect natural limits – phase out fossil fuels by the end of this century** We must learn to respect natural limits. There is only so much carbon that the atmosphere can absorb. Each year we emit over 25 billion tonnes of CO_2; we are literally filling up the sky. Geological resources of coal could provide several hundred years of fuel, but we cannot burn them and keep within safe limits. Oil and coal development must be ended.

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

2. **equity and fairness** It is imperative to have a fair distribution of benefits and costs within societies. At one extreme, a third of the world’s population has no access to electricity, whilst the most industrialised countries consume much more than their fair share.

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

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

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

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

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

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

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

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

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

image ICE AND WATER IN THE NORTH POLE. GREENPEACE EXPLORERS, LONNIE DUPRE AND ERIC LARSEN MAKE HISTORY AS THEY BECOME THE FIRST-EVER TO COMPLETE A TREK TO THE NORTH POLE IN SUMMER. THE DUO UNDERTAKE THE EXPEDITION TO BRING ATTENTION TO THE PLIGHT OF THE POLAR BEAR WHICH SCIENTISTS CLAIM COULD BE EXTINCT AS EARLY AS 2050 DUE TO THE EFFECTS OF GLOBAL WARMING.

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from principles to practice

In 2005, renewable energy sources accounted for 13% of the world's primary energy demand. Biomass, which is mostly used for heating, is the main renewable energy source. The share of renewable energy in electricity generation was 18%. The contribution of renewables to primary energy demand for heat supply was around 24%. About 80% of primary energy supply today still comes from fossil fuels, and 6% from nuclear power[5].

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

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

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

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

a development pathway

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

step 1: energy efficiency The Energy [R]evolution is aimed at the ambitious exploitation of the potential for energy efficiency. It focuses on current best practice and technologies which will become available in the future, assuming continuous innovation. The energy savings are fairly equally distributed over the three sectors – industry, transport and domestic/business. Intelligent use, not abstinence, is the basic philosophy for future energy conservation.

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

A dramatic reduction in primary energy demand compared to the IEA's "Reference Scenario" (see Chapter 6) – but with the same GDP and population development - is a crucial prerequisite for achieving a significant share of renewable energy sources in the overall energy supply system, compensating for the phasing out of nuclear energy and reducing the consumption of fossil fuels.

step 2: structural changes

decentralised energy and large scale renewables In order to achieve higher fuel efficiencies and reduce distribution losses, the Energy [R]evolution Scenario makes extensive use of Decentralised Energy (DE). This is energy generated at or near the point of use.

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

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

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

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

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[5] 'ENERGY BALANCE OF NON-OECD COUNTRIES' AND 'ENERGY BALANCE OF OECD COUNTRIES', IEA, 2007

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

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

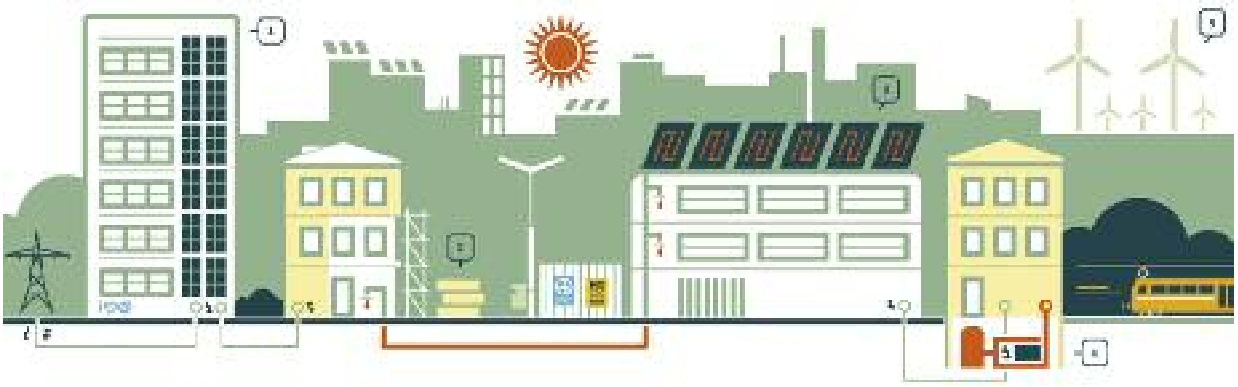
transport Before new technologies such as hybrid or electric cars or new fuels such as bio fuels can play a substantial role in the transport sector, the existing large efficiency potentials have to be exploited. In this study, biomass is primarily committed to stationary applications; the use of bio fuels for transport is limited by the availability of sustainably grown biomass[6]. Electric vehicles will therefore play an even more important role in improving energy efficiency in transport and substituting for fossil fuels.

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

figure 1.1: **a decentralised energy future**

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

city



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

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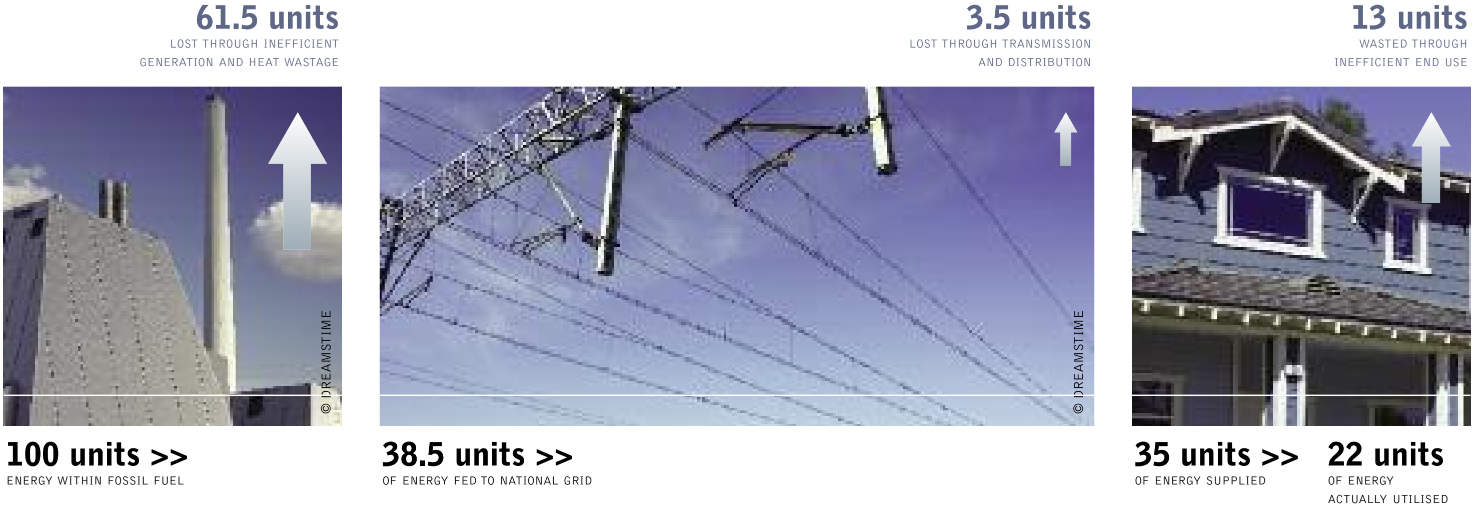
references

[6] SEE CHAPTER 13

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

figure 1.2: centralised energy infrastructures waste more than two thirds of their energy



optimised integration of renewable energy

Modification of the energy system will be necessary to accommodate the significantly higher shares of renewable energy expected under the Energy [R]evolution Scenario. This is not unlike what happened in the 1970s and 1980s, when most of the centralised power plants now operating were constructed in OECD countries. New high voltage power lines were built, night storage heaters marketed and large electric-powered hot water boilers installed in order to sell the electricity produced by nuclear and coal-fired plants at night.

Several OECD countries have demonstrated that it is possible to smoothly integrate a large proportion of decentralised energy, including variable sources such as wind. A good example is Denmark, which has the highest percentage of combined heat and power generation and wind power in Europe. With strong political support, 50% of electricity and 80% of district heat is now supplied by cogeneration plants. The contribution of wind power has reached more than 18% of Danish electricity demand. At certain times, electricity generation from cogeneration and wind turbines even exceeds demand. The load compensation required for grid stability in Denmark is managed both through regulating the capacity of the few large power stations and through import and export to neighbouring countries. A three tier tariff system enables balancing of power generation from the decentralised power plants with electricity consumption on a daily basis.

It is important to optimise the energy system as a whole through intelligent management by both producers and consumers, by an appropriate mix of power stations and through new systems for storing electricity.

appropriate power station mix: The power supply in OECD countries is mostly generated by coal and – in some cases – nuclear power stations, which are difficult to regulate. Modern gas power stations, by contrast, are not only highly efficient but easier and faster to regulate and thus better able to compensate for fluctuating loads. Coal and nuclear power stations have lower fuel and operating costs but comparably high investment costs. They must therefore run round-the-clock as 'base load' in order to earn back their investment. Gas power stations have lower investment costs and are profitable even at low output, making them better suited to balancing out the variations in supply from renewable energy sources.

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

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

generation management: Renewable electricity generation systems can also be involved in load optimisation. Wind farms, for example, can be temporarily switched off when too much power is available on the network.

energy storage: Another method of balancing out electricity supply and demand is through intermediate storage. This storage can be decentralised, for example by the use of batteries, or centralised. So far, pumped storage hydro power stations have been the main method of storing large amounts of electric power. In a pumped storage system, energy from power generation is stored in a lake and then allowed to flow back when required, driving turbines and generating electricity. 280 such pumped storage plants exist worldwide. They already provide an important contribution to security of supply, but their operation could be better adjusted to the requirements of a future renewable energy system.

In the long term, other storage solutions are beginning to emerge. One promising solution besides the use of hydrogen is the use of compressed air. In these systems, electricity is used to compress air into deep salt domes 600 metres underground and at pressures of up to 70 bar. At peak times, when electricity demand is high, the air is allowed to flow back out of the cavern and drive a turbine. Although this system, known as CAES (Compressed Air Energy Storage) currently still requires fossil fuel auxiliary power, a so-called "adiabatic" plant is being developed which does not. To achieve this, the heat from the compressed air is intermediately stored in a giant heat store. Such a power station can achieve a storage efficiency of 70%.

The **forecasting** of renewable electricity generation is also continually improving. Regulating supply is particularly expensive when it has to be found at short notice. However, prediction techniques for wind power generation have become considerably more accurate in recent years and are still being improved. The demand for balancing supply will therefore decrease in the future.

the "virtual power station" [7]

The rapid development of information technologies is helping to pave the way for a decentralised energy supply based on cogeneration plants, renewable energy systems and conventional power stations. Manufacturers of small cogeneration plants already offer internet interfaces which enable remote control of the system. It is now possible for individual householders to control their electricity and heat usage so that expensive electricity drawn from the grid can be minimised – and the electricity demand profile is smoothed. This is part of the trend towards the 'smart house' where its mini cogeneration plant becomes an energy management centre. We can go one step further than this with a 'virtual power station'. Virtual does not mean that the power station does not produce real electricity. It refers to the fact that there is no large, spatially located power station with turbines and generators. The hub of the virtual power station is a control unit which processes data from many decentralised power stations, compares them with predictions of power demand, generation and weather conditions, retrieves the available power market prices and then intelligently optimises the overall power station activity. Some public utilities already use such systems, integrating cogeneration plants, wind farms, photovoltaic systems and other power plants. The virtual power station can also link consumers into the management process.

> **"it is important to optimise the energy system as a whole through intelligent management by both producers and consumers..."**

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references

[7] 'RENEWABLE ENERGIES - INNOVATIONS FOR THE FUTURE', GERMAN MINISTRY FOR THE ENVIRONMENT, NATURE CONSERVATION AND NUCLEAR SAFETY (BMU), 2006

© PAUL LANGROCK/ZENIT/GP

image TEST WINDMILL N90 2500, BUILT BY THE GERMAN COMPANY NORDEX, IN THE HARBOUR OF ROSTOCK. THIS WINDMILL PRODUCES 2,5 MEGA WATT AND IS TESTED UNDER OFFSHORE CONDITIONS. TWO TECHNICIANS WORKING INSIDE THE TURBINE.

future power grids

The **power grid network** must also change in order to realise decentralised structures with a high share of renewable energy. Today's grids are designed to transport power from a few centralised power stations out to the passive consumers. A future system must enable an active integration of consumers and decentralised power generators and thus realise real time two-way power and information flows. Large power stations will feed electricity into the high voltage grid but small decentralised systems such as solar, cogeneration and wind plants will deliver their power into the low or medium voltage grid. In order to transport electricity from renewable generation such as offshore wind farms in remote areas (see box), a limited number of new high voltage transmission lines will need to be constructed. These power lines will also be available for cross-border power trade. Within the Energy [R]evolution Scenario, the share of variable renewable energy sources is expected to reach about 10% of total electricity generation by 2020 and about 35% by 2050.

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case 1: a north sea electricity grid

A new Greenpeace report shows how a regionally integrated approach to the large-scale development of offshore wind in the North Sea could deliver reliable clean energy for millions of homes. The 'North Sea Electricity Grid [R]evolution' report (September 2008) calls for the creation of an offshore network to enable the smooth flow of electricity generated from renewable energy sources into the power systems of seven different countries - the United Kingdom, France, Germany, Belgium, The Netherlands, Denmark and Norway – at the same time enabling significant emissions savings. The cost of developing the grid is expected to be between €15 and €20 billion. This investment would not only allow the broad integration of renewable energy but also unlock unprecedented power trading opportunities and cost efficiency.
In a recent example, a new 600 kilometre-long power line between Norway and the Netherlands cost €600 million to build, but is already generating a daily cross-border trade valued at €800,000.

The grid would enable the efficient integration of renewable energy into the power system across the whole North Sea region. By aggregating power generation from wind farms spread across the whole area, periods of very low or very high power flows would be reduced to a negligible amount. A dip in wind power generation in one area would be 'balanced' by higher production in another area, even hundreds of kilometres away. Over a year, an installed offshore wind power capacity of 68.4 GW in the North Sea would be able to generate an estimated 247 TWh of electricity.

An offshore grid in the North Sea would also allow, for example, the import of electricity from hydro power generation in Norway to the British and UCTE (Central European) network. This could replace thermal baseload plants and increase flexibility within a portfolio. In addition, increased liquidity and trading facilities on the European power markets will allow for a more efficient portfolio management. The value of such an offshore therefore lies in its contribution to increased security of supply, its function in aggregating the dispatch of power from offshore wind farms and its role as a facilitator for power exchange and trade between regions and power systems.

"a future system must enable an active integration of consumers and decentralised power generators..."

figure 1.3: **offshore grid topology proposal and offshore wind power installed capacity scenario**

Wind energy is booming in the EU. In 2007 alone, no less than 8550MW of wind turbines were installed in the EU, which is 40% of all newly-installed capacity. By 2020–2030, offshore wind energy in the North Sea could grow to 68,000MW and supply 13% of all current electricity production of seven North Sea countries. In order to integrate the electricity from the offshore wind farms, an offshore grid will be required. Greenpeace demands that the governments of these seven countries and the European Commission cooperate to make this happen.

INSTALLED AND PLANNED CAPACITY

[MW]

	[MW]	[TWh]
BELGIUM	3,850	13.1
DENMARK	1,580	5.6
FRANCE	1,000	3.4
GERMANY	26,420	97.5
UNITED KINGDOM	22,240	80.8
NETHERLANDS	12,040	41.7
NORWAY	1,290	4.9
TOTAL	**68,420**	**247**

LEGEND

- - **GRID:** PROPOSED OR DISCUSSED IN THE PUBLIC DOMAIN

— **GRID:** IN OPERATION OR PLANNING

☐ **PRINCIPLE HVDC SUBSTATIONS**

● **WIND FARMS:** INSTALLED PLANNED CAPACITY < 1000 MW

● **WIND FARMS:** INSTALLED PLANNED CAPACITY > 1000 MW

* MAP IS INDICATIVE. NO ENVIRONMENTAL IMPACT ASSESSMENT OF LOCATIONS AND SITING OF WINDFARMS AND CABLES HAS BEEN DONE.

image OFFSHORE WINDFARM, MIDDELGRUNDEN, COPENHAGEN, DENMARK.

image CONSTRUCTION OF WIND TURBINES.

rural electrification[8]

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

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

The Millennium Development Goal of halving global poverty by 2015 will not be reached without adequate energy to increase production, income and education, create jobs and reduce the daily grind involved in having to just survive. Halving hunger will not come about without energy for more productive growing, harvesting, processing and marketing of food.

Improving health and reducing death rates will not happen without energy for the refrigeration needed for clinics, hospitals and vaccination campaigns. The world's greatest child killer, acute respiratory infection, will not be tackled without dealing with smoke from cooking fires in the home. Children will not study at night without light in their homes. Clean water will not be pumped or treated without energy.

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

the role of sustainable, clean renewable energy

Achieving the dramatic emissions cuts needed to avoid climate change - at least 30% by 2020 and more than 80% by 2050 - will require a massive uptake of renewable energy. The targets for renewable energy must be greatly expanded in industrialised countries both to substitute for fossil fuel and nuclear generation and to create the necessary economies of scale necessary for global expansion. Within the Energy [R]evolution Scenario we assume that modern renewable energy sources, such as solar collectors, solar cookers and modern forms of bio energy, will replace inefficient, traditional biomass use.

references

[8] 'SUSTAINABLE ENERGY FOR POVERTY REDUCTION: AN ACTION PLAN', IT POWER/GREENPEACE INTERNATIONAL, 2002

scenario principles in a nutshell

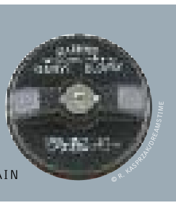
- Smart consumption, generation and distribution
- Energy production moves closer to the consumer
- Maximum use of locally available, environmentally friendly fuels

image THE PS10 CONCENTRATING SOLAR TOWER PLANT USES 624 LARGE MOVABLE MIRRORS CALLED HELIOSTATS. THE MIRRORS CONCENTRATE THE SUN'S RAYS TO THE TOP OF A 115 METER (377 FOOT) HIGH TOWER WHERE A SOLAR RECEIVER AND A STEAM TURBINE ARE LOCATED. THE TURBINE DRIVES A GENERATOR, PRODUCING ELECTRICITY, SEVILLA, SPAIN.

energy resources & security of supply

2

> **"the price of oil, the greenhouse gas emissions produced by oil and the exhaustion of fossil resources in the long term have turned renewable energies into the sole alternative to substitute the traditional energy sources."**
>
> **JOSÉ LUIS RODRÍGUEZ ZAPATERO**
> PRESIDENT OF THE GOVERNMENT OF SPAIN



The issue of security of supply is now at the top of the energy policy agenda. Concern is focused both on price security and the security of physical supply. At present around 80% of global energy demand is met by fossil fuels. The unrelenting increase in energy demand is matched by the finite nature of these sources. The regional distribution of oil and gas resources, on the other hand, does not match the distribution of demand. Some countries have to rely almost entirely on fossil fuel imports. The maps on the following pages provide an overview of the availability of different fuels and their regional distribution. Information in this chapter is based partly on the report 'Plugging the Gap'[9].

oil

Oil is the lifeblood of the modern global economy, as the effects of the supply disruptions of the 1970s made clear. It is the number one source of energy, providing 36% of the world's needs and the fuel employed almost exclusively for essential uses such as transportation. However, a passionate debate has developed over the ability of supply to meet increasing consumption, a debate obscured by poor information and stirred by recent soaring prices.

the reserves chaos

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

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

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

gas

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

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

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references

[9] 'PLUGGING THE GAP - A SURVEY OF WORLD FUEL RESOURCES AND THEIR IMPACT ON THE DEVELOPMENT OF WIND ENERGY', GLOBAL WIND ENERGY COUNCIL/RENEWABLE ENERGY SYSTEMS, 2006

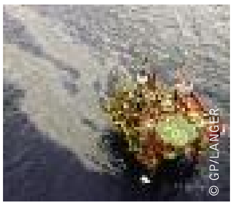


image PLATFORM/OIL RIG DUNLIN IN THE NORTH SEA SHOWING OIL POLLUTION.

image HIGH MARNHAM COAL-FIRED POWER STATION ON THE RIVER TRENT IN NOTTINGHAMSHIRE, UK.

coal

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

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

nuclear

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

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

A joint report by the OECD Nuclear Energy Agency[10] and the International Atomic Energy Agency estimates that all existing nuclear power plants will have used up their nuclear fuel, employing current technology, within less than 70 years. Given the range of scenarios for the worldwide development of nuclear power, it is likely that uranium supplies will be exhausted sometime between 2026 and 2070. This forecast includes the use of mixed oxide fuel (MOX), a mixture of uranium and plutonium.

references
10 'URANIUM 2003: RESOURCES, PRODUCTION AND DEMAND'

table 2.1: overview of fossil fuel reserves and resources

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

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

source SEE TABLE [a] INCLUDING GAS HYDRATES

renewable energy

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

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

definition of types of energy resource potential[11]

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

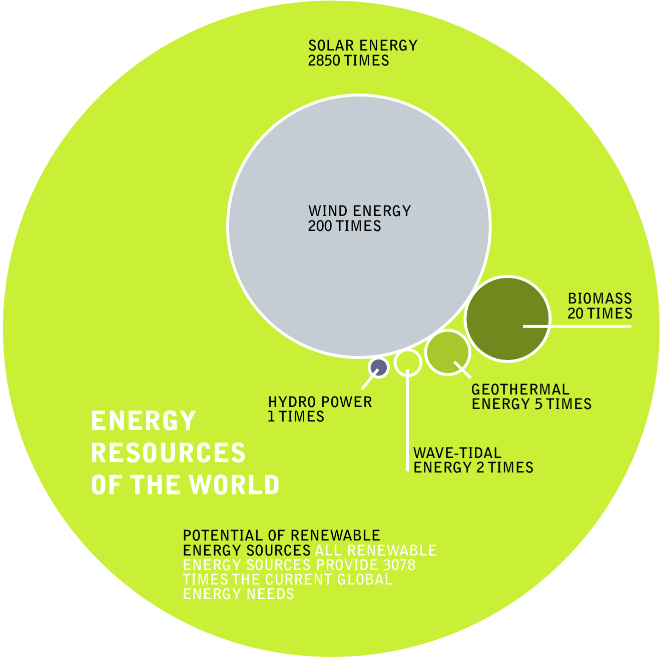
conversion potential This is derived from the annual efficiency of the respective conversion technology. It is therefore not a strictly defined value, since the efficiency of a particular technology depends on technological progress.

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

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

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

figure 2.1: **energy resources of the world**



source WBGU

table 2.2: **technically accessible today**

THE AMOUNT OF ENERGY THAT CAN BE ACCESSED WITH CURRENT TECHNOLOGIES SUPPLIES A TOTAL OF 5.9 TIMES THE GLOBAL DEMAND FOR ENERGY

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

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references
11 WBGU (GERMAN ADVISORY COUNCIL ON GLOBAL CHANGE)'

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

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

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© LANGROCK/ZENIT/GP

renewable energy potential by region and technology

Based on the report 'Renewable Energy Potentials' from REN 21, a global policy network[12], we can provide a more detailed overview of renewable energy prospects by world region and technology. The table below focuses on large economies, which consume 80% of the world's primary energy and produce a similar share of the world's greenhouse gas emissions.

Solar photovoltaic (PV) technology can be harnessed almost everywhere, and its technical potential is estimated at over 1,500 EJ/year, closely followed by concentrating solar thermal power (CSP). These two cannot simply be added together, however, because they would require much of the same land resources. The onshore wind potential is equally vast, with almost 400 EJ/year available beyond the order of magnitude of future electricity consumption. The estimate for offshore wind potential (22 EJ/year) is cautious, as only wind intensive areas on ocean shelf areas, with a relatively shallow water depth, and outside shipping lines and protected areas, are included. The various ocean or marine energy potentials also reach a similar magnitude, most of it from ocean waves. Cautious estimates reach a figure of around 50 EJ/year. The estimates for hydro and geothermal resources are well established, each having a technical potential of around 50 EJ/year. Those figures should be seen in the context of a current global energy demand of around 500 EJ.

In terms of heating and cooling, apart from using biomass, there is the option of using direct geothermal energy. The potential is extremely large and could cover 20 times the current world energy demand for heat. The potential for solar heating, including passive solar building design, is virtually limitless. However, heat is costly to transport and one should only consider geothermal heat and solar water heating potentials which are sufficiently close to the point of consumption. Passive solar technology, which contributes enormously to the provision of heating services, is not considered as a (renewable energy) supply source in this analysis but as an efficiency factor to be taken into account in the demand forecasts.

table 2.3: technical renewable energy potential by region

EXCL. BIO ENERGY

	SOLAR CSP	SOLAR PV	HYDRO POWER	WIND ON-SHORE	WIND OFF-SHORE	OCEAN POWER	GEO-THERMAL ELECTRIC	GEO-THERMAL DIRECT USES	SOLAR WATER HEATING	TOTAL
	ELECTRICITY [EJ/YEAR]							HEATING [EJ/YEAR]		
OECD North America	21	72	4	156	2	68	5	626	23	976
Latin America	59	131	13	40	5	32	11	836	12	1,139
OECD Europe	1	13	2	16	5	20	2	203	23	284
Non OCED Europe & Transition Economies	25	120	5	67	4	27	6	667	6	926
Africa & Middle East	679	863	9	33	1	19	5	1,217	12	2,838
East & South Asia	22	254	14	10	3	103	12	1,080	45	1,543
Oceania	187	239	1	57	3	51	4	328	2	872
World	**992**	**1,693**	**47**	**379**	**22**	**321**	**45**	**4,955**	**123**	**8,578**

source REN21

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references

[12] 'RENEWABLE ENERGY POTENTIALS: OPPORTUNITIES FOR THE RAPID DEPLOYMENT OF RENEWABLE ENERGY IN LARGE ENERGY ECONOMIES', REN 21, 2007

the global potential for sustainable biomass

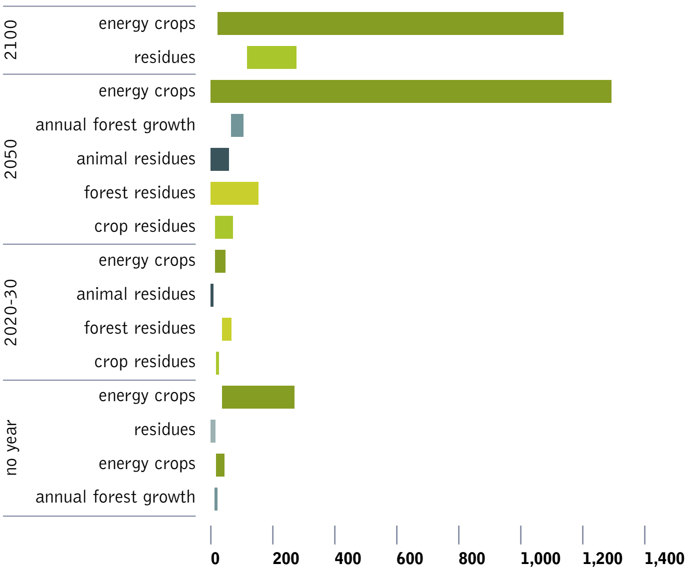
As part of background research for the Energy [R]evolution Scenario, Greenpeace commissioned the German Biomass Research Centre, the former Institute for Energy and Environment, to investigate the worldwide potential for energy crops in different scenarios up to 2050. In addition, information has been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

assessment of biomass potential studies

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

Data from 18 studies has been examined, with a concentration on those studies which report the potential for biomass residues. Among these there were ten comprehensive assessments with more or less detailed documentation of the methodology. The majority focus on the long-term potential for 2050 and 2100. Little information is available for 2020 and 2030. Most of the studies were published within the last ten years. Figure 2.2 shows the variations in potential by biomass type from the different studies.

figure 2.2: ranges of potentials for different resource categories



source GERMAN BIOMASS RESEARCH CENTRE (DBFZ)

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

figure 2.3: bio energy potential analysis from different authors

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

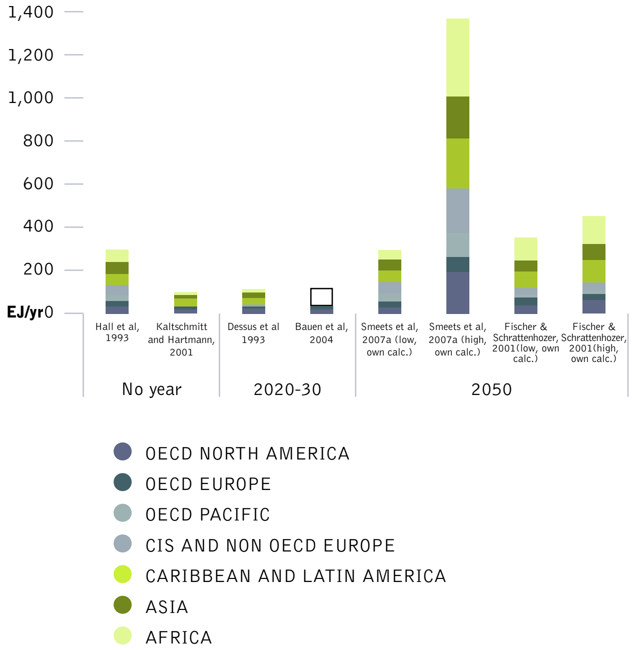


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image THE BIOENERGY VILLAGE OF JUEHNDE WHICH WAS THE FIRST COMMUNITY IN GERMANY TO PRODUCE ALL ITS ENERGY NEEDED FOR HEATING AND ELECTRICITY, WITH CO_2 NEUTRAL BIOMASS.

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

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potential of energy crops

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

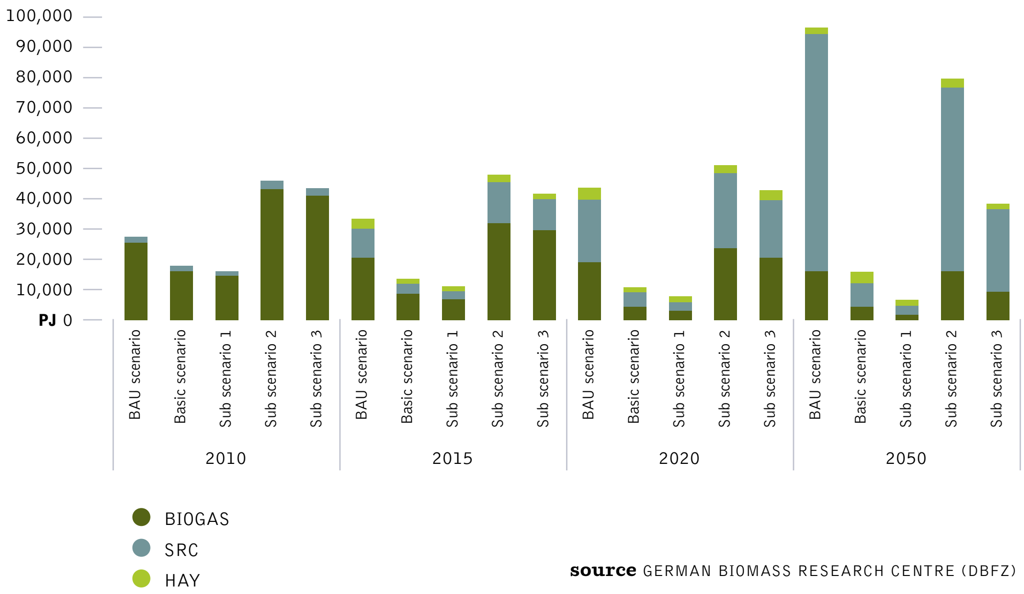
- Business as usual (BAU) scenario: Present agricultural activity continues for the foreseeable future
- Basic scenario: No forest clearing; reduced use of fallow areas for agriculture
- Sub-scenario 1: Basic scenario plus expanded ecological protection areas and reduced crop yields
- Sub-scenario 2: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

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

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

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

figure 2.4: world wide energy crop potentials in different scenarios



source GERMAN BIOMASS RESEARCH CENTRE (DBFZ)

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

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

scenarios for a future energy supply

3

> **"our climate change commitments and the insecurity of future and current fossil fuel supplies require us to make a quantum change in our energy policy."**
>
> **EAMON RYAN**
> MINISTER OF COMMUNICATIONS, ENERGY AND NATURAL RESOURCES, IRELAND

1. fossil fuel and biomass price projections

The recent dramatic increase in global oil prices has resulted in much higher forward price projections for fossil fuels. Under the 2004 'high oil and gas price' scenario from the European Commission, for example, an oil price of just $34 per barrel was assumed in 2030. More recent projections of oil prices in 2030 range from the IEA's $\$_{2006}$62/bbl ($\$_{2005}$60/bbl) (WEO 2007) up to $\$_{2006}$119/bbl ($\$_{2005}$115/bbl) in the 'high price' scenario of the US Energy Information Administration's Annual Energy Outlook 2008.

Since the last Energy [R]evolution study was published, however, the price of oil has moved over $100/bbl for the first time (at the end of 2007), and in July 2008 reached a record high of more than $140/bbl. Although oil prices fell back to $100/bbl in September 2008, the above projections might still be considered too conservative. Considering the growing global demand for oil and gas we have assumed a price development path for fossil fuels in which the price of oil reaches $120/bbl by 2030 and $140/bbl in 2050.

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

2. cost of CO_2 emissions

Assuming that a CO_2 emissions trading system is established in all world regions in the long term, the cost of CO_2 allowances needs to be included in the calculation of electricity generation costs. Projections of emissions costs are even more uncertain than energy prices, and available studies span a broad range of future CO_2 cost estimates. As in the previous Energy [R]evolution study we assume CO_2 costs of €8/tCO_2 in 2010, rising to €40/tCO_2 in 2050. Additional CO_2 costs are applied in Kyoto Protocol Non-Annex B (developing) countries only after 2020.

table 3.2: assumptions on fuel price development

	2005	2006	2007	2010	2015	2020	2030	2040	2050
Crude oil import prices in €2005 per barrel	42	48	57						
IEA WEO 2007 ETP 2008				46	44		48		50
US EIA 2008 'Reference'				57		46	54		
US EIA 2008 'High Price'				61		79	92		
Energy [R]evolution 2008				80	84	88	96	104	112
Gas import prices in €2005 per GJ	2000	2005	2006						
IEA WEO 2007/ ETP 2008									
US imports	3.7		5.9	6.0	6.0		6.4		6.5
European imports	2.7		6.0	5.4	5.4		6.0		6.1
Japan imports	4.5		5.7	6.0	6.0		6.4		6.5
Energy [R]evolution 2008									
US imports		4.5		9.2	10.1	11.7	14.7	17.5	19.6
European imports		4.6		8.0	9.1	10.6	13.7	16.4	18.3
Asia imports		4.5		9.2	10.0	11.7	14.6	17.5	19.6
Hard coal import prices in €2005 per tonne	2000	2005	2006						
IEA WEO 2007/ ETP 2008	30		49	43	44		47	0	47
Energy [R]evolution 2008				114	133	155	200	248	286
Biomass (solid) prices in €2005 per GJ	2005								
Energy [R]evolution 2008									
OECD Europe	6.0			6.3	6.8	7.5	8.2	8.4	8.6
OECD Pacific, NA	2.4			2.6	2.8	3.0	3.4	3.7	4.1
Other regions	2.0			2.2	2.5	2.8	3.2	3.7	3.9

image GROUP OF YOUNG PEOPLE TOUCHING SOLAR PANELS IN BRAZIL.

table 3.3: assumptions on CO_2 emissions cost development

(€/tCO_2)

COUNTRIES	2010	2020	2030	2040	2050
Kyoto Annex B countries	8	15.9	23.9	31.9	**39.8**
Non-Annex B countries		15.9	23.9	31.9	**39.8**

3. power plant investment costs

fossil fuel technologies and carbon capture and storage (CCS)

While the fossil fuel power technologies in use today for coal, gas, lignite and oil are established and at an advanced stage of market development, further cost reduction potentials are assumed. The potential for cost reductions is limited, however, and will be achieved mainly through an increase in efficiency, bringing down investment costs[13].

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

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

Cost estimates for CCS vary considerably, depending on factors such as power station configuration, technology, fuel costs, size of project and location. One thing is certain, however, CCS is expensive. It requires significant funds to construct the power stations and the necessary infrastructure to transport and store carbon. The IPCC assesses costs at €12-60 per ton of captured CO_2[14], while a recent US Department of Energy report found installing carbon capture systems to most modern plants resulted in a near doubling of costs[15]. These costs are estimated to increase the price of electricity in a range from 21-91%[16].

Pipeline networks will also need to be constructed to move CO_2 to storage sites. This is likely to require a considerable outlay of capital[17]. Costs will vary depending on a number of factors, including pipeline length, diameter and manufacture from corrosion-resistant steel, as well as the volume of CO_2 to be transported. Pipelines built near population centres or on difficult terrain, such as marshy or rocky ground, are more expensive[18].

The IPCC estimates a cost range for pipelines of €1-6/ton of CO_2 transported. A United States Congressional Research Services report calculated capital costs for an 11 mile pipeline in the Midwestern region of the US at approximately €5 million. The same report estimates that a dedicated interstate pipeline network in North Carolina would cost upwards of €4 billion due to the limited geological sequestration potential in that part of the country[19]. Storage and subsequent monitoring and verification costs are estimated by the IPCC to range from €0.4-6/tCO_2 injected and €0.1-0.2/tCO_2 injected, respectively. The overall cost of CCS could therefore serve as a major barrier to its deployment[20].

For the above reasons, CCS power plants are not included in our financial analysis. Table 3.4 summarises our assumptions on the technical and economic parameters of future fossil-fuelled power plant technologies. In spite of growing raw material prices, we assume that further technical innovation will result in a moderate reduction of future investment costs as well as improved power plant efficiencies. These improvements are, however, outweighed by the expected increase in fossil fuel prices, resulting in a significant rise in electricity generation costs.

table 3.4: development of efficiency and investment costs for selected power plant technologies

		2005	2010	2020	2030	2040	2050
Coal-fired condensing power plant	Efficiency (%)	45	46	48	50	52	**53**
	Investment costs (€/kW)	1,052	980	948	924	900	**876**
	Electricity generation costs including CO_2 emission costs (€cents/kWh)	5.3	7.2	8.6	10.0	11.3	**12.5**
	CO_2 emissions [a] (g/kWh)	744	728	697	670	644	**632**
Lignite-fired condensing power plant	Efficiency (%)	41	43	44	44.5	45	**45**
	Investment costs (€/kW)	1,251	1,147	1,100	1,076	1,052	**1,028**
	Electricity generation costs including CO_2 emission costs (€cents/kWh)	4.7	5.2	6.0	6.7	7.4	**8.2**
	CO_2 emissions [a] (g/kWh)	975	929	908	898	888	**888**
Natural gas combined cycle	Efficiency (%)	57	59	61	62	63	**64**
	Investment costs (€/kW)	550	538	514	486	462	**438**
	Electricity generation costs including CO_2 emission costs (€cents/kWh)	6.0	8.4	10.1	12.2	13.9	**15.1**
	CO_2 emissions [a] (g/kWh)	354	342	330	325	320	**315**

source DLR, 2008 [a] CO_2 EMISSIONS REFER TO POWER STATION OUTPUTS ONLY; LIFE-CYCLE EMISSIONS ARE NOT CONSIDERED.

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4. cost projections for renewable energy technologies

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

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

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

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

Assumptions on future costs for renewable electricity technologies in the Energy [R]evolution Scenario are derived from a review of learning curve studies, for example by Lena Neij and others[21], from the analysis of recent technology foresight and road mapping studies, including the European Commission funded NEEDS (New Energy Externalities Developments for Sustainability)[22] project or the IEA Energy Technology Perspectives 2008, and a discussion with experts from the renewable energy industry.

> **"large cost reductions can be achieved through technical advances, manufacturing improvements and large-scale production."**

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[22] WWW.NEEDS-PROJECT.ORG

image TRANSPORT POLLUTION.

photovoltaics (pv)

The worldwide photovoltaics (PV) market has been growing at over 35% per annum in recent years and the contribution it can make to electricity generation is starting to become significant. Development work is focused on improving existing modules and system components by increasing their energy efficiency and reducing material usage. Technologies like PV thin film (using alternative semiconductor materials) or dye sensitive solar cells are developing quickly and present a huge potential for cost reduction. The mature technology crystalline silicon, with a proven lifetime of 30 years, is continually increasing its cell and module efficiency (by 0.5% annually), whereas the cell thickness is rapidly decreasing (from 230 to 180 microns over the last five years). Commercial module efficiency varies from 14 to 21% depending on silicon quality and fabrication process.

The learning factor for PV modules has been fairly constant over the last 30 years, with a cost reduction of 20% each time the installed capacity doubles, indicating a high rate of technical learning. Assuming a globally installed capacity of 1,600 GW by between 2030 and 2040, and with an electricity output of 2,600 TWh, we can expect that generation costs of around 5-10 cents/kWh (depending on the region) will be achieved. During the following five to ten years, PV will become competitive with retail electricity prices in many parts of the world and competitive with fossil fuel costs by 2050. The importance of photovoltaics comes from its decentralised/centralised character, its flexibility for use in an urban environment and huge potential for cost reduction.

concentrating solar power (csp)

Solar thermal 'concentrating' power stations (CSP) can only use direct sunlight and are therefore dependent on high irradiation locations. North Africa, for example, has a technical potential which far exceeds local demand. The various solar thermal technologies (parabolic trough, power towers and parabolic dish concentrators) offer good prospects for further development and cost reductions. Because of their more simple design, 'Fresnel' collectors are considered as an option for additional cost reduction. The efficiency of central receiver systems can be increased by producing compressed air at a temperature of up to 1,000°C, which is then used to run a combined gas and steam turbine.

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

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

table 3.5: photovoltaics (pv)

	2005	2010	2020	2030	2040	**2050**
Global installed capacity (GW)	5.2	21	269	921	1,799	**2,911**
Investment costs (€/kW)	5,259	2,996	1,323	1,020	908	**861**
Operation & maintenance costs (€/kWa)	53	30	13	10	9	**8**

table 3.6: concentrating solar power (csp)

	2005	2010	2020	2030	2040	**2050**
Global installed capacity (GW)	0.53	5	83	199	468	**801**
Investment costs (€/kW)	6,000	5,052	4,175	3,530	3,474	**3,442**
Operation & maintenance costs (€/kWa)	239	199	167	143	127	**124**

wind power

Within a short period of time, the dynamic development of wind power has resulted in the establishment of a flourishing global market. The world's largest wind turbines, several of which have been installed in Germany, have a capacity of 6 MW. While favourable policy incentives have made Europe the main driver for the global wind market, in 2007 more than half of the annual market was outside Europe. This trend is likely to continue. The boom in demand for wind power technology has nonetheless led to supply constraints. As a consequence, the cost of new systems has stagnated or even increased. Because of the continuous expansion of production capacities, the industry expects to resolve the bottlenecks in the supply chain over the next few years. Taking into account market development projections, learning curve analysis and industry expectations, we assume that investment costs for wind turbines will reduce by 30% for onshore and 50% for offshore installations up to 2050.

biomass

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

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

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

table 3.7: wind power

	2005	2010	2020	2030	2040	**2050**
Installed capacity (on+offshore)	59	164	893	1,622	2,220	**2,733**
Wind onshore						
Global installed capacity (GW)	59	162	866	1,508	1,887	**2,186**
Investment costs (€/kW)	1,203	1,092	940	884	869	**869**
O&M costs (€/kWa)	46	41	36	34	33	**33**
Wind offshore						
Global installed capacity (GW)	0,3	1,6	27	114	333	**547**
Investment costs (€/kW)	2,996	2,773	2,072	1,753	1,586	**1,506**
O&M costs (€/kWa)	132	122	91	77	70	**66**

table 3.8: biomass

	2005	2010	2020	2030	2040	**2050**
Biomass (electricity only)						
Global installed capacity (GW)	21	35	56	65	81	**99**
Investment costs (€/kW)	2,422	2,191	2,016	1,968	1,944	**1,924**
O&M costs (€/kWa)	146	132	121	118	117	**116**
Biomass (CHP)						
Global installed capacity (GW)	32	60	177	275	411	**521**
Investment costs (€/kW)	4,598	3,960	3,076	2,693	2,478	**2,351**
O&M costs (€/kWa)	322	277	216	188	174	**165**

image THE PS10 SOLAR TOWER PLANT AT SAN LUCAR LA MAYOR OUTSIDE SEVILLE, SPAIN, APRIL 29, 2008.

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geothermal

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

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

- for conventional geothermal power, from 6 €cents/kWh to about 2 €cents/kWh.
- for EGS, despite the presently high figures (about 16 €cents/kWh), electricity production costs - depending on the payments for heat supply - are expected to come down to around 4 €cents/kWh in the long term.

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

ocean energy

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

The cost of energy from initial tidal and wave energy farms has been estimated to be in the range of 12-44 €cents/kWh, and for initial tidal stream farms in the range of 9-18 €cents/kWh. Generation costs of 8-20 €cents/kWh are expected by 2020. Key areas for development will include concept design, optimisation of the device configuration, reduction of capital costs by exploring the use of alternative structural materials, economies of scale and learning from operation. According to the latest research findings, the learning factor is estimated to be 10-15% for offshore wave and 5-10% for tidal stream. In the medium term, ocean energy has the potential to become one of the most competitive and cost effective forms of generation. In the next few years a dynamic market penetration is expected, following a similar curve to wind energy.

Because of the early development stage any future cost estimates for ocean energy systems are uncertain, and no learning curve data is available. Present cost estimates are based on analysis from the European NEEDS project[23].

table 3.9: geothermal

	2005	2010	2020	2030	2040	**2050**
Geothermal (electricity only)						
Global installed capacity (GW)	8.7	12	33	71	120	**152**
Investment costs (€/kW)	13,896	11,984	9,211	8,088	7,562	**7,155**
O&M costs (€/kWa)	514	444	341	299	280	**265**
Geothermal (CHP)						
Global installed capacity (GW)	0.24	1.7	13	38	82	**124**
Investment costs (€/kW)	13,944	10,398	7,578	6,335	5,522	**5,028**
O&M costs (€/kWa)	516	385	280	234	204	**186**

table 3.10: ocean energy

	2005	2010	2020	2030	2040	**2050**
Global installed capacity (GW)	0.27	0.9	17	44	98	**194**
Investment costs (€/kW)	7,203	4,120	2,319	1,785	1,490	**1,331**
Operation & maintenance costs (€/kWa)	287	165	93	71	60	**53**

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[23] WWW.NEEDS-PROJECT.ORG

hydro power

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

table 3.11: hydro

	2005	2010	2020	2030	2040	**2050**
Global installed capacity (GW)	878	978	1,178	1,300	1,443	**1,565**
Investment costs (€/kW)	2,199	2,295	2,446	2,550	2,645	**2,725**
Operation & maintenance costs (€/kWa)	88	92	98	102	106	**109**

summary of renewable energy cost development

Figure 3.3 summarises the cost trends for renewable energy technologies as derived from the respective learning curves. It should be emphasised that the expected cost reduction is basically not a function of time, but of cumulative capacity, so dynamic market development is required. Most of the technologies will be able to reduce their specific investment costs to between 30% and 70% of current levels by 2020, and to between 20% and 60% once they have achieved full development (after 2040).

Reduced investment costs for renewable energy technologies lead directly to reduced heat and electricity generation costs, as shown in Figure 3.4. Generation costs today are around 8 to 25 €cents/kWh (10-25 $cents/kWh) for the most important technologies, with the exception of photovoltaics. In the long term, costs are expected to converge at around 4 to 10 €cents/kWh (5-12 $cents/kWh). These estimates depend on site-specific conditions such as the local wind regime or solar irradiation, the availability of biomass at reasonable prices or the credit granted for heat supply in the case of combined heat and power generation.

figure 3.3: future development of investment costs

(NORMALISED TO CURRENT COST LEVELS) FOR RENEWABLE ENERGY TECHNOLOGIES

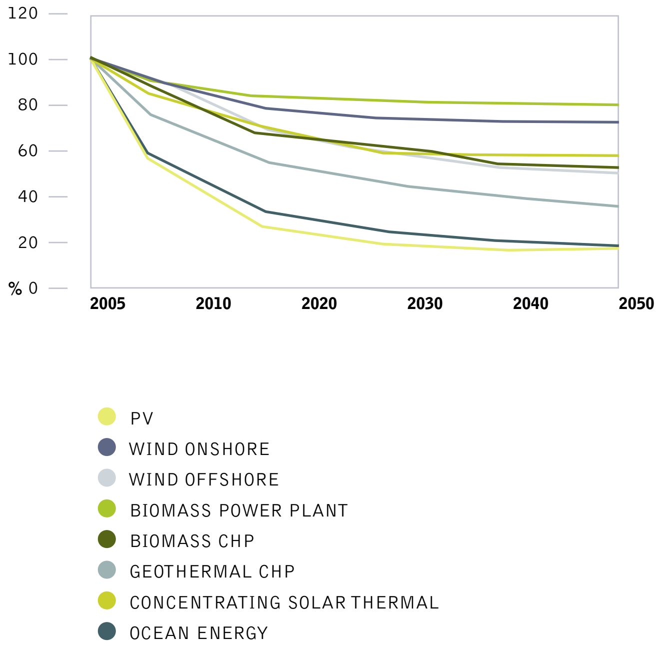
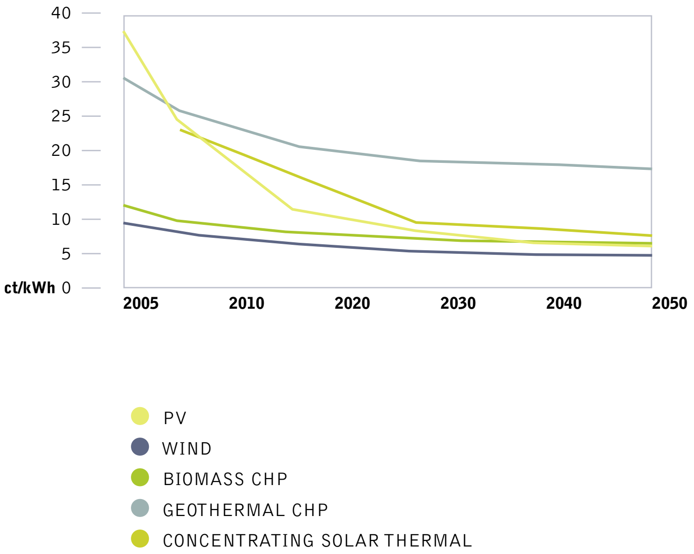


figure 3.4: expected development of electricity generation costs from fossil fuel and renewable options

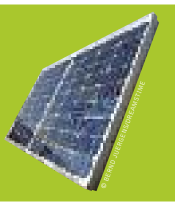
EXAMPLE FOR OECD NORTH AMERICA



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

4

> **“this is an interesting vision, which should be possible to implement if there is sufficient political will behind it.”**
>
> **MARTIN BURSIK,**
> GOVERNMENT VICE-CHAIRMAN AND ENVIRONMENT MINISTER OF THE CZECH REPUBLIC
> ON THE FIRST EDITION OF THE ENERGY [R]EVOLUTION SCENARIO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1. population development

One important underlying factor in energy scenario building is future population development. Population growth affects the size and composition of energy demand, directly and through its impact on economic growth and development. World Energy Outlook 2007 uses the United Nations Development Programme (UNDP) projections for population development. For this study the most recent population projections from UNDP up to 2050 are applied[24].

The world’s population is expected to grow by 0.77% on average over the period 2005 to 2050, from 6.5 billion people in 2005 to more than 9.1 billion in 2050. Population growth will slow over the projection period, from 1.2% during 2005-2010 to 0.4% during 2040-2050. However, the updated projections show an increase in population of almost 300 million compared to the previous edition. This will further increase the demand for energy. The population of the developing regions will continue to grow most rapidly. The Transition Economies will face a continuous decline, followed after a short while by the OECD Pacific countries. OECD Europe and OECD North America are expected to maintain their population, with a peak in around 2020/2030 and a slight decline afterwards. The share of the population living in today’s Non-OECD countries will increase from the current 82% to 86% in 2050. China’s contribution to world population will drop from 20% today to 15% in 2050. Africa will remain the region with the highest growth rate, leading to a share of 21% of world population in 2050.

Satisfying the energy needs of a growing population in the developing regions of the world in an environmentally friendly manner is a key challenge for achieving a global sustainable energy supply.

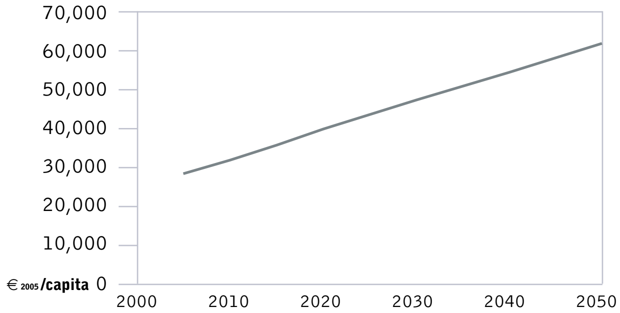
2. economic growth

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

Although PPP assessments are still relatively imprecise compared to statistics based on national income and product trade and national price indexes, they are considered to provide a better basis for global scenario development.[25] Thus all data on economic development in WEO 2007 refers to purchasing power adjusted GDP. However, as WEO 2007 only covers the time period up to 2030, the projections for 2030-2050 are based on our own estimates.

Prospects for GDP growth have increased considerably compared to the previous study, whilst underlying growth trends continue much the same. GDP growth in all regions is expected to slow gradually over the coming decades. World GDP is assumed to grow on average by 3.6% per year over the period 2005-2030, compared to 3.3% from 1971 to 2002, and on average by 3.3% per year over the entire modelling period. China and India are expected to grow faster than other regions, followed by the Developing Asia countries, Africa and the Transition Economies. The Chinese economy will slow as it becomes more mature, but will nonetheless become the largest in the world in PPP terms early in the 2020s. GDP in EU-27 and OECD Pacific is assumed to grow by around 2% per year over the projection period, while economic growth in OECD North America is expected to be slightly higher. The OECD share of global PPP-adjusted GDP will decrease from 55% in 2005 to 29% in 2050.

figure 4.1: EU 27: GDP per capita projection



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references

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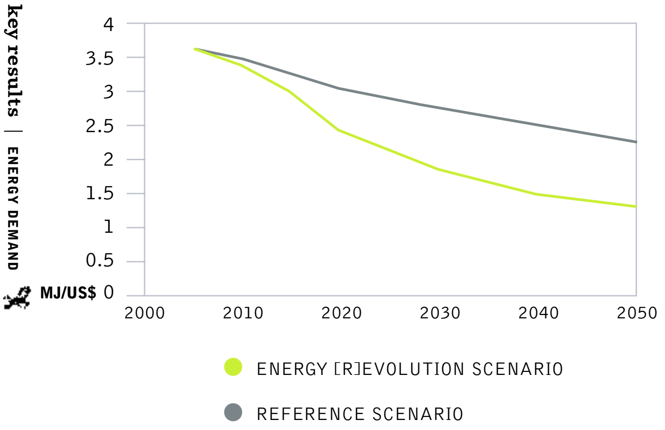
25 NORDHAUS, W, ‘ALTERNATIVE MEASURES OF OUTPUT IN GLOBAL ECONOMIC-ENVIRONMENTAL MODELS: PURCHASING POWER PARITY OR MARKET EXCHANGE RATES?’, REPORT PREPARED FOR IPCC EXPERT MEETING ON EMISSION SCENARIOS, US-EPA WASHINGTON DC, JANUARY 12-14, 2005

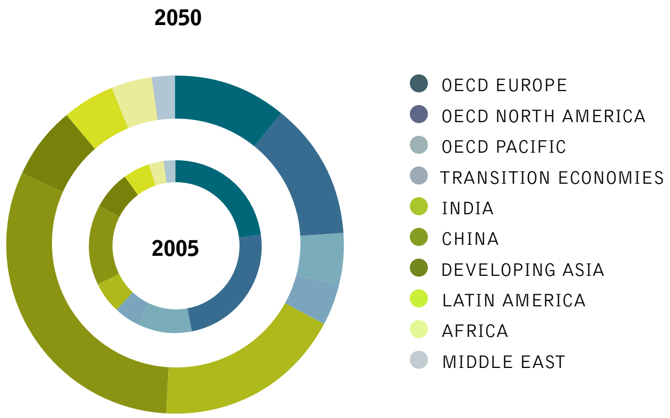
figure 4.2: EU27: projection of energy intensity by demand sector under the reference and energy [r]evolution scenarios



EU 27: energy demand by sector

Combining the projections on population development, GDP growth and energy intensity results in future development pathways for Europe's energy demand. These are shown in Figure 4.4 for both the Reference and the Energy Revolution Scenarios. Under the Reference Scenario, total energy demand increase by more than 20% the current 77,260 PJ/a to 94,600 PJ/a in 2050. In the Energy Revolution Scenario, the energy demand decreases by 35% compared to current consumption and is expected by 2050 to reaching 49,749 PJ/a.

figure 4.3: development of world GDP$_{PPP}$ by regions



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.

figure 4.4: EU 27: projection of total final energy demand by sector for the two scenarios

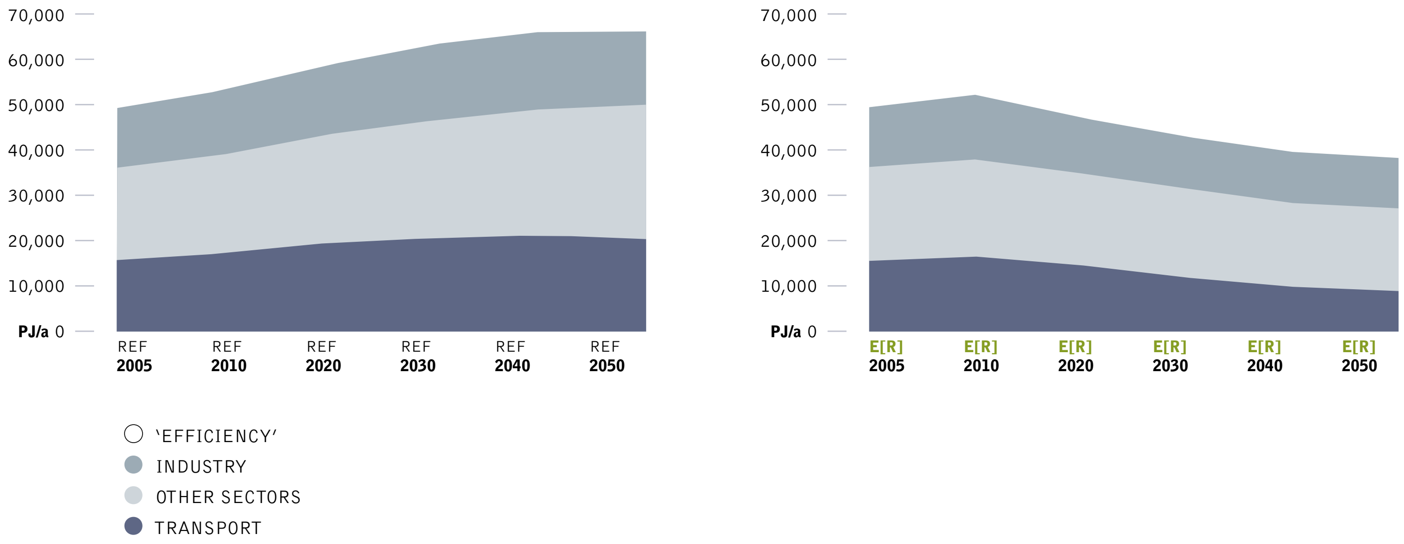


image image OFFSHORE WINDFARM, MIDDELGRUNDEN, COPENHAGEN, DENMARK.

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

© LANGROCK/ZENIT/GP

Under the Energy Revolution Scenario, electricity demand is expected to decrease disproportionately, with households and services the main source of reduced consumption. With the exploitation of efficiency measures, but with an increase use of electric vehicles, an increase can not be avoided, leading to electricity demand of around 3543 TWh in the year 2050. Compared to the Reference Scenario, efficiency measures avoid the generation of about 1351 TWh. This reduction in energy demand can be achieved in particular by introducing highly efficient electronic devices using the best available technology in all demand sectors. Employment of solar architecture in both residential and commercial buildings will help to curb the growing demand for active air-conditioning.

Efficiency gains in the heat supply sector are even larger. Under the Energy Revolution Scenario, final demand for heat supply can even be reduced (see Figure 4.6). Compared to the Reference Scenario, consumption equivalent to 7420 PJ/a is avoided through efficiency gains by 2050. As a result of energy-related renovation of the existing stock of residential buildings, as well as the introduction of low energy standards and 'passive houses' for new buildings, enjoyment of the same comfort and energy services will be accompanied by a much lower future energy demand.

In the transport sector, it is assumed under the Energy Revolution Scenario that energy demand will decrease by almost half to 8,700 PJ/a by 2050, saving 67% compared to the Reference Scenario. This reduction can be achieved by the introduction of highly efficient vehicles, by shifting the transport of goods from road to rail and by changes in mobility-related behaviour patterns.

figure 4.5: EU 27: development of electricity demand by sector

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO; OTHER SECTORS = SERVICES, HOUSEHOLDS)

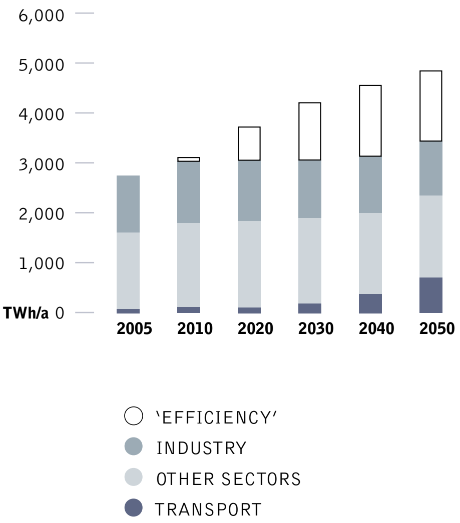
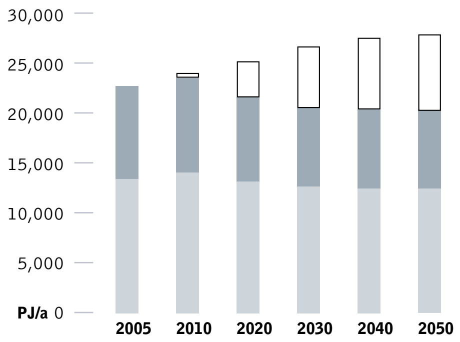


figure 4.6: EU 27: development of heat demand by sector

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



EU 27: electricity generation

The development of the electricity supply sector is characterised by a dynamically growing renewable energy market and an increasing share of renewable electricity. This will compensate for the phasing out of nuclear energy and reduce the number of fossil fuel-fired power plants required for grid stabilisation. By 2050, 88% of the electricity produced in the EU will come from renewable energy sources. 'New' renewables – mainly wind, solar thermal energy and PV – will contribute 75% of electricity generation. The following strategy paves the way for a future renewable energy supply:

- The phasing out of nuclear energy and rising electricity demand will be met initially by bringing into operation new highly efficient gas-fired combined-cycle power plants, plus an increasing capacity of wind turbines and biomass. In the long term, wind will be the most important single source of electricity generation.
- Solar energy, hydro and biomass will make substantial contributions to electricity generation. In particular, as non-fluctuating renewable energy sources, hydro and solar thermal, combined with efficient heat storage, are important elements in the overall generation mix.
- The installed capacity of renewable energy technologies will grow from the current 168 GW to 1,070 GW in 2050. Increasing renewable capacity by a factor of six within the next 42 years requires political support and well-designed policy instruments, however. There will be a considerable demand for investment in new production capacity over the next 20 years. As investment cycles in the power sector are long, decisions on restructuring the world's energy supply system need to be taken now.

To achieve an economically attractive growth in renewable energy sources, a balanced and timely mobilisation of all technologies is of great importance. This mobilisation depends on technical potentials, cost reduction and technological maturity. Figure 4.8 shows the comparative evolution of the different renewable technologies over time. Up to 2020, hydro-power and wind will remain the main contributors to the growing market share. After 2020, the continuing growth of wind will be complemented by electricity from biomass, photovoltaic and solar thermal (CSP) energy.

None of these numbers describe a maximum feasibility, but a possible balanced approach. With the right policy development, the solar industry believes that a much further uptake could happen. This is particularly true for concentrated solar power (CSP) which could unfold to 30GW already by 2020 and more than 120GW in 2050. The photovoltaic industry believes in a possible electricity generation capacity of 350GW by 2020 in Europe alone, assuming the necessary policy changes.

table 4.1: EU 27: projection of renewable electricity generation capacity under the energy [r]evolution scenario

IN GW

	2005	2010	2020	2030	2040	2050
Hydro	109	114	123	128	132	137
Wind	34	83	213	264	331	357
PV	1	10	94	204	300	370
Biomass	21.4	38.5	66.3	91.6	102.8	110
Geothermal	1	2	5	13	27	38
Solarthermal	0	1	9	17	27	31
Ocean energy	0	0	2	6	16	26
Total	**168**	**249**	**511**	**723**	**936**	**1,069**

figure 4.7: EU 27: development of electricity generation structure under the two scenarios

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

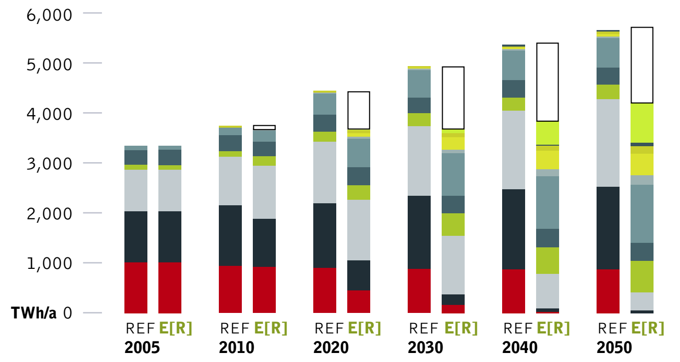


figure 4.8: EU 27: growth of renewable electricity generation capacity under the energy [r]evolution scenario

BY INDIVIDUAL SOURCE

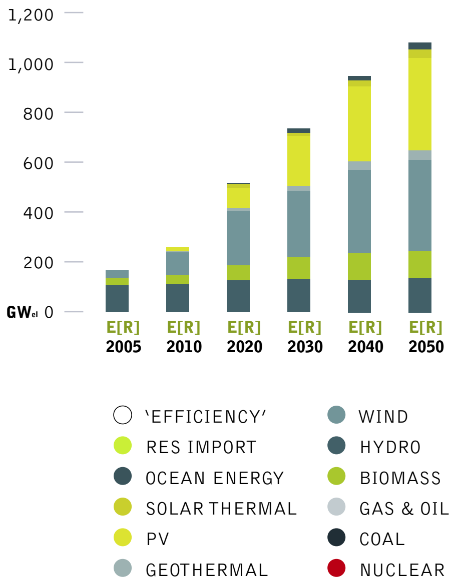


image 100 KW PV GENERATING PLANT NEAR BELLINZONA-LOCARNO RAILWAY LINE. GORDOLA, SWITZERLAND.

image THE POWER OF THE OCEAN.


© GP/MARTIN BOND


© JOANNE/DREAMSTIME

EU 27: future costs of electricity generation

Figure 4.9 shows that the introduction of renewable technologies under the Energy [R]evolution Scenario slightly increases the costs of electricity generation compared to the Reference Scenario. This difference will be less than 0.5 cents/kWh up to 2020. Note that any increase in fossil fuel prices beyond the projection given in Table 3.2 will reduce the gap between the two scenarios. Because of the lower CO_2 intensity of electricity generation, by 2020 electricity generation costs will become economically favourable under the Energy Revolution Scenario, and by 2050 generation costs will be more than 2.4 cents/kWh below those in the Reference Scenario.

Due to growing demand, we face a significant increase in society's expenditure on electricity supply. Under the Reference Scenario, the unchecked growth in demand, the increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's €330 billion per year to more than €730 bn in 2050. Figure 4.10 shows that the Energy [R]evolution Scenario not only complies with EU-27 CO_2 reduction targets but also helps to stabilise energy costs and relieve the economic pressure on society. Increasing energy efficiency and shifting energy supply to renewables leads to long term costs for electricity supply that are one third lower than in the Reference Scenario. It becomes clear that pursuing stringent environmental targets in the energy sector also pays off in terms of economics.

figure 4.9: EU 27: development of specific electricity generation costs under the two scenarios

(CO_2 EMISSION COSTS IMPOSED FROM 2010, WITH AN INCREASE FROM 15 $/T$_{CO_2}$ IN 2010 TO 50 $/T$_{CO_2}$ IN 2050)

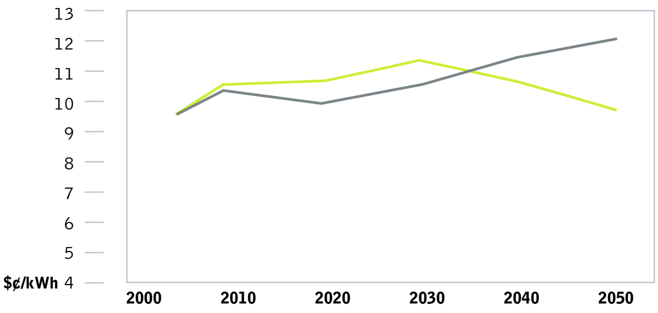
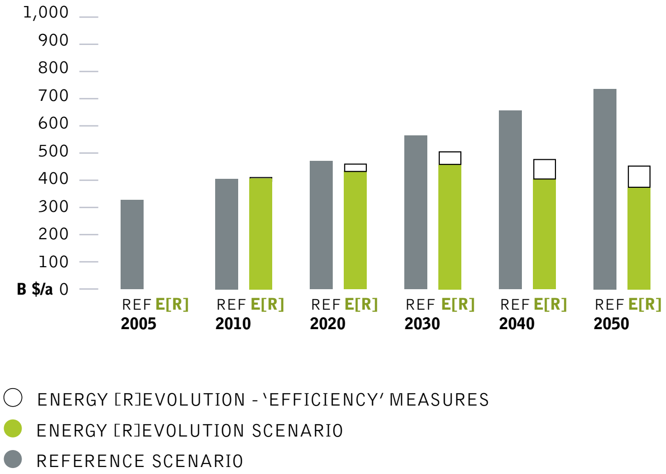


figure 4.10: EU 27: development of total electricity supply costs



EU 27: heat and cooling supply

Development of renewables in the heat supply sector raises different issues. Today, renewables provide 10% of Europe's primary energy demand for heat supply, the main contribution coming from the use of biomass. The lack of district heating networks is a severe structural barrier to the large scale utilisation of geothermal and solar thermal energy. Past experience shows that it is easier to implement effective support instruments in the grid-connected electricity sector than in the heat market, with its multitude of different actors. Dedicated support instruments are required to ensure a dynamic development.

In the Energy [R]evolution scenario, renewables provide 56% of EU-27's total heating and cooling demand in 2050.

- Energy efficiency measures can decrease the current demand for heat supply by 10%, in spite of improving living standards.
- For direct heating, solar collectors, biomass/biogas as well as geothermal energy are increasingly substituting for fossil fuel-fired systems.
- A shift from coal and oil to natural gas in the remaining conventional applications will lead to a further reduction of CO_2 emissions.

EU 27: transport

In the transport sector, it is assumed under the Energy Revolution Scenario that energy demand will decrease by almost half to 8,700 PJ/a by 2050, saving 57% compared to the Reference Scenario. This reduction can be achieved by the introduction of highly efficient vehicles, by shifting the transport of goods from road to rail and by changes in mobility-related behaviour patterns. Implementing attractive alternatives to individual cars, the car stock is growing slower than in the reference scenario, to reach 235 million cars in 2050. A shift towards smaller cars triggered by economic incentives together with a significant shift in propulsion technology towards electrified power trains and a reduction of vehicle kilometres travelled by 0.25% per year leads to a 60% final energy savings.

figure 4.11: EU 27: development of heat supply structure under the two scenarios

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

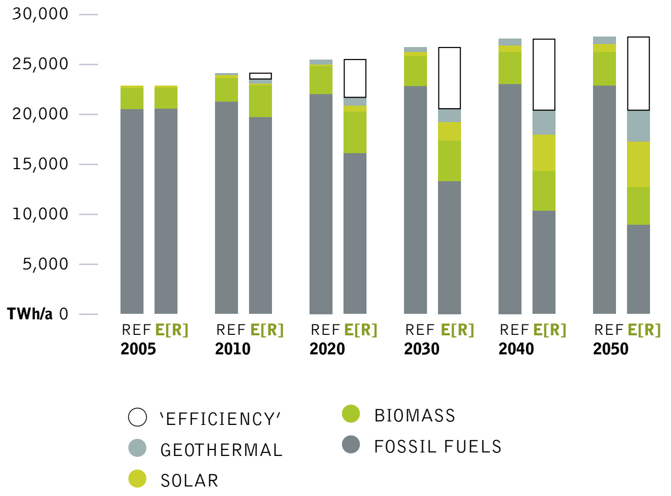


figure 4.12: EU 27: transport under the two scenarios

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

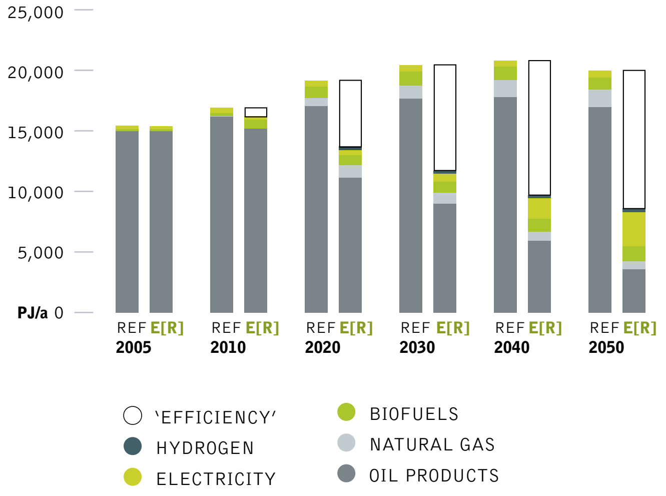


image PLANT NEAR REYKJAVIK WHERE ENERGY IS PRODUCED FROM THE GEOTHERMAL ACTIVITY.

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

EU 27: development of CO_2 emissions

Whilst Europe's emissions of CO_2 will increase by almost 20% under the Reference Scenario, under the Energy Revolution Scenario they will decrease by 75% from 3,900 million tons in 2005 to 979 million tons in 2050. Annual per capita emissions will drop from 7.9 t to 2.0 t. In spite of the phasing out of nuclear energy and increasing demand, CO_2 emissions will decrease in the electricity sector. In the long run efficiency gains and the increased use of renewable electricity and sustainable bio fuels in vehicles will even reduce CO_2 emissions in the transport sector. With a share of 11% of total CO_2 in 2050, the power sector will drop below transport as the largest source of emissions.

EU 27: primary energy consumption

Taking into account the assumptions discussed above, the resulting primary energy consumption under the Energy Revolution Scenario is shown in Figure 4.14. Compared to the Reference Scenario, overall energy demand will be reduced by almost 53% in 2050. Around 56% of the remaining demand will be 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 as energy suppliers.

figure 4.13: EU 27: development of CO_2 emissions by sector under the energy [r]evolution scenario

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

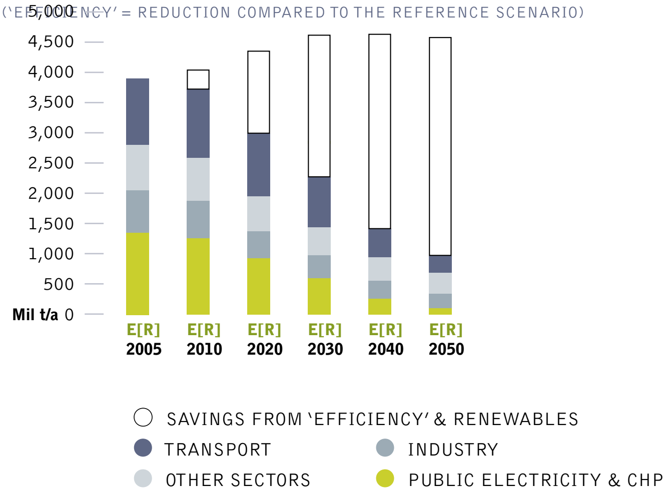
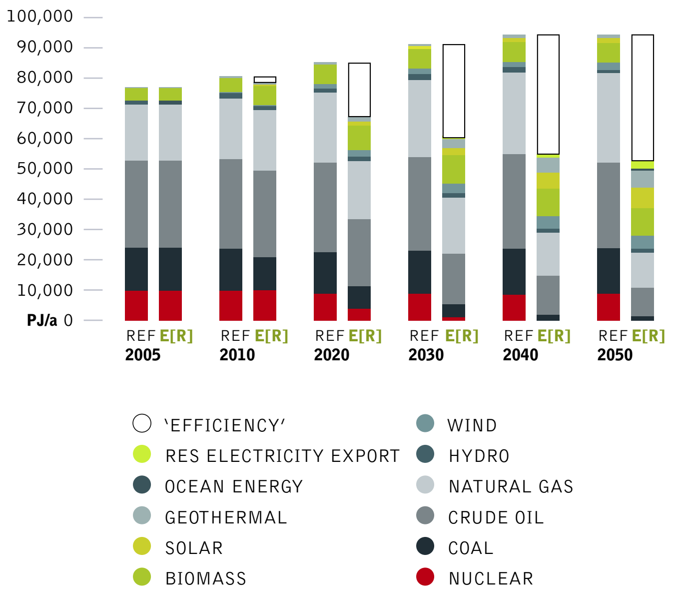


figure 4.14: EU 27: development of primary energy consumption under the two scenarios

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



EU 27: investment in new power plants

The overall level of investment required in new power plants up to 2030 will be in the region of €1.4 to 1.8 trillion. The main driver for investment in new generation capacity in Europe will be the ageing power plant units.

Power producers will make their technology choices within the next five to ten years based on national energy policies, in particular market liberalisation, renewable energy and CO_2 reduction targets. The EU emissions trading scheme will have an important influence on whether the majority of investment goes into fossil fuel power plants or renewable energy and co-generation. The investment volume required to realise the Energy [R]evolution scenario is €1.79 trillion, approximately 25% higher than in the Reference Scenario, which will require €1.42 trillion. While the levels of investment in renewable energy, fossil fuels and nuclear power plants are almost equal under the Reference Scenario, at about €500 billion each up to 2030, the Energy [R]evolution scenario shifts about 60% of investment towards renewable energy. The fossil fuel share of power sector investment is focused mainly on combined heat and power, and efficient gas-fired power plants.

The average annual investment required in the power sector under the Energy [R]evolution scenario between 2005 and 2030 is approximately €72 billion. Most investment in new renewable power generation will go towards wind power, followed by solar photovoltaics.

figure 4.16: change in cumulative power plant investment in the energy [r]evolution scenario

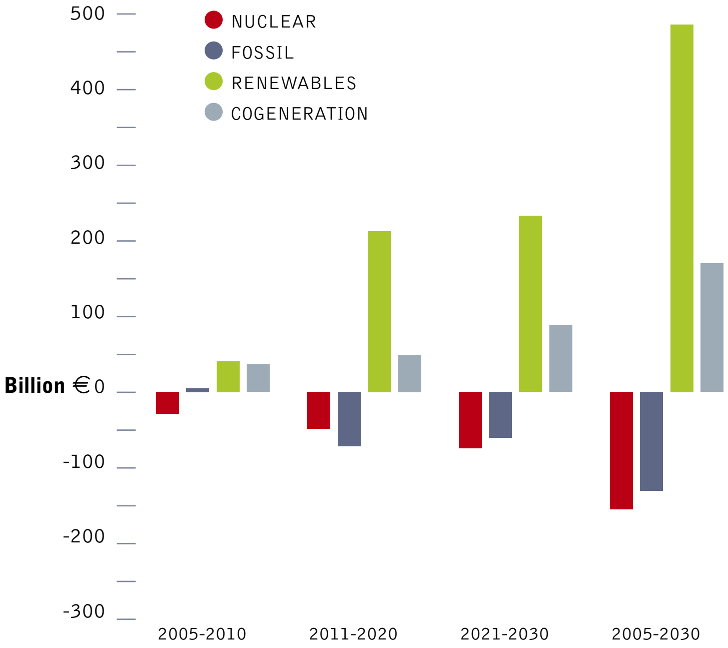
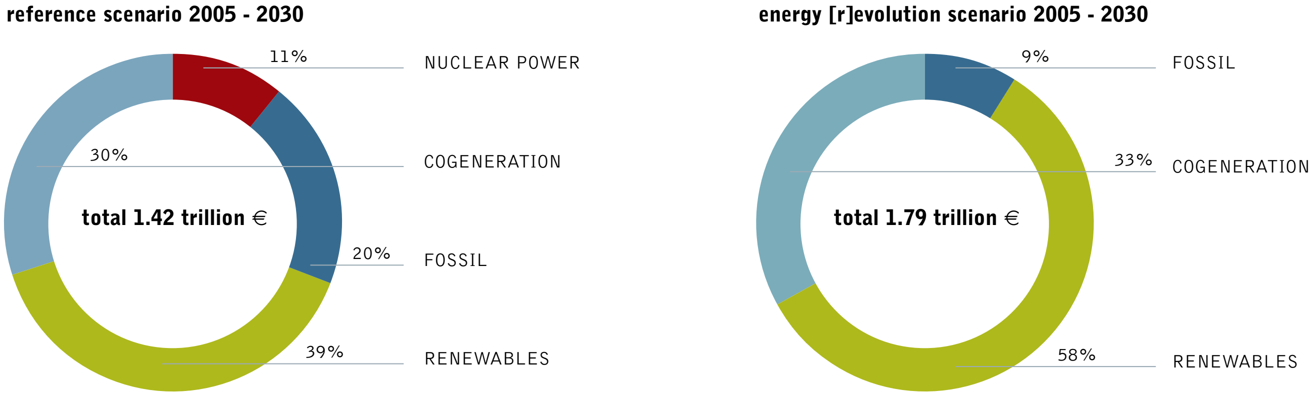


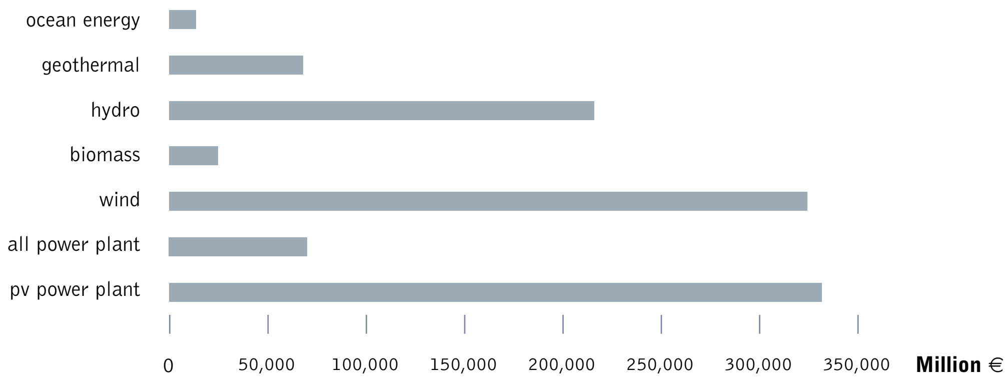
figure 4.15: change in cumulative power plant investment under the energy [r]evolution scenario share of investment


reference scenario 2005 - 2030

energy [r]evolution scenario 2005 - 2030

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

figure 4.17: renewable energy investments in the energy [r]evolution 2005-2030



renewable power generation investment

Under the Reference Scenario, investment in renewable electricity generation will be €556 billion. This compares to €1044 billion in the Energy [R]evolution scenario. How investment is divided between the different renewable power generation technologies depends on their level of technical development. Technologies such as wind power, which in many regions with good wind resources is already cost competitive , will take a larger investment volume and a bigger market share. The market volume attributed to different technologies also depends on local resources and policy frameworks within EU member states. Figure 4.17 provides an overview of the investment required for each technology.

For solar photovoltaics, the main market will remain in Germany and Spain for some years to come, but should soon expand across other EU member states. Because solar photovoltaic energy is a highly modular and decentralised technology which can be used almost everywhere, its market will eventually be spread across the entire EU.

Concentrated solar power systems, on the other hand, can only be operated in the most southern regions of the EU. The main investment in this technology will therefore take place in Spain, France, Italy and Greece.

The main development of the wind industry will take place in northern Europe, Spain and Portugal. Offshore wind technology will take a larger share from around 2015 onwards. The main offshore wind development will take place around the North Sea region.

Bio energy power plants will be distributed across the whole of Europe, as there is potential almost everywhere for biomass and/or biogas (cogeneration) power plants.

fossil fuel power generation investment

Under the Reference Scenario, the main market expansion for new fossil fuel power plants will be in gas power plants, followed by coal power plants, which will have a volume of €123 billion and €107 billion respectively. In the Energy [R]evolution scenario, the overall investment in fossil fuel power stations up to 2030 will be €160 billion, significantly lower than the Reference Scenario's €291 billion.

The largest investments in coal power plants from European utilities will take place in Germany. While in the Reference Scenario the current growth trend (2000–2010) will continue until 2030, the Energy [R]evolution scenario assumes that in the second and third decades (2011-2030) growth slows down significantly.

The total cost for fossil fuels in the Reference Scenario between 2005 and 2030 amounts to €5.6 trillion, compared to €3.8 trillion in the Energy [R]evolution scenario. This means that fuel costs in the Energy [R]evolution scenario would already be about 32% lower by 2030 and 83% lower by 2050. Although the investment in gas-fired power stations and cogeneration plants remains relatively highin both scenarios, the financial support for oil and coal for electricity generation in the Energy [R]evolution scenario is more than 70% below the Reference Scenario.

fuel cost savings with renewables

Because renewable energy has no fuel costs, the total fuel cost saving in the Energy [R]evolution scenario is €1.7 trillion, or €70 billion per year. A comparison between extra fuel costs associated with the Reference Scenario and the extra investment costs of the Energy [R]evolution scenarios shows that the average annual additional fuel costs in the Reference Scenario are about four and a half times higher than the additional investment requirements in the Energy [R]evolution. In fact, the additional costs for coal fuel from today until the year 2030 would be as high as €1.7 trillion. This would cover the entire investment in renewable and cogeneration capacity required to implement the Energy [R]evolution scenario. These renewable energy sources will produce electricity without any further fuel costs beyond 2030, while the costs for coal and gas will continue to be a burden on national economies.

table 4.2: fuel and investment costs in the reference and the energy [r]evolution scenario

INVESTMENT COST	EURO	2005-2010	2011-2020	2021-2030	2005-2030	2005-2030 AVERAGE PER YEAR
REFERENCE SCENARIO						
Total Nuclear	billion € 2005	31	51	74	155	6
Total Fossil	billion € 2005	104	103	84	291	12
Total Renewables	billion € 2005	125	255	176	556	22
Total Cogeneration	billion € 2005	129	189	101	420	17
Total	billion € 2005	390	598	434	1,422	57
E[R] SCENARIO						
Total Fossil	billion € 2005	108	31	21	160	6
Total Renewables	billion € 2005	166	469	410	1,044	42
Total Cogeneration	billion € 2005	166	236	188	590	24
Total	billion € 2005	439	736	619	1,794	72
DIFFERENCE E[R] VERSUS REF						
Total Fossil & Nuclear	billion € 2005	-28	-122	-136	-286	-11
Total Cogeneration	billion € 2005	40	214	234	488	20
Total Renewables	billion € 2005	37	47	87	170	7
Total	billion € 2005	50	138	185	372	15
FUEL COSTS						
REFERENCE SCENARIO						
Total Fuel Oil	billion €/a	109	161	102	371	15
Total Gas	billion €/a	221	670	1,068	1,959	78
Total Coal	billion €/a	465	1,200	1,487	3,153	126
Total Lignite	billion €/a	24	39	44	107	4
Total Fossil Fuels	billion €/a	819	2,070	2,701	5,591	224
E[R] SCENARIO						
Total Fuel Oil	billion €/a	105	128	44	277	11
Total Gas	billion €/a	234	718	1,032	1,984	79
Total Coal	billion €/a	399	751	355	1,506	60
Total Lignite	billion €/a	23	29	15	68	3
Total Fossil Fuels	billion €/a	762	1,625	1,447	3,834	153
SAVINGS REF VERSUS E[R]						
Fuel Oil	billion €/a	3	33	58	94	4
Gas	billion €/a	-13	-47	36	-24	-1
Coal	billion €/a	66	449	1,132	1,647	66
Lignite	billion €/a	1	10	28	39	2
Total Fossil Fuel Savings	billion €/a	57	445	1,245	1,756	70

climate & energy policy

5

“we need to take the scientific research seriously.
the time we have left to respond is getting shorter every day.”

HANS-GERT PÖTTERING
PRESIDENT OF THE EUROPEAN PARLIAMENT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climate policy

The Intergovernmental Panel on Climate Change (IPCC) projects global temperature increases over the next hundred years of up to 5.8°C, depending on action taken to mitigate greenhouse gas emissions. This is much faster than anything experienced in human history and does not include the very strong likelihood of "positive feedbacks" being triggered, which result in additional greenhouse gases emitted and enhanced warming.

We are already experiencing impacts of climate change. From the Inuit in the far north to residents of low-lying atolls and river delta regions, people are already struggling with climate impacts. Millions of people are threatened with an increased risk of hunger, malaria, flooding and water shortages. Never before has humanity been forced to grapple with such an immense environmental crisis.

Impacts of small to moderate warming include:

- Sea level rise due to melting glaciers and the thermal expansion of the oceans as global temperature increases.
- Massive releases of greenhouse gases from melting permafrost and dying forests, which exacerbate global warming.
- A high risk of more extreme weather events such as heat waves, droughts and floods. Already, the global incidence of drought has doubled over the past 30 years and regions such as South-Eastern Europe have been gripped by drought since the turn of the century.
- Natural systems, including glaciers, coral reefs, mangroves, alpine ecosystems, boreal forests, tropical forests, prairie wetlands and native grasslands are severely threatened.
- Increased risk of species extinction and biodiversity loss.

The greatest impacts will be on poorer countries in sub-Saharan Africa, South Asia, Southeast Asia, Andean South America, as well as small islands least able to protect themselves from increasing droughts, rising sea levels, the spread of disease and decline in agricultural production. However, Europe is the most vulnerable of all developed countries to climate change. Europe has a unique environmental sensitivity to climate change and an economy that is largely dependant on a healthy environment.

If immediate political action to stop climate change does not occur and overall temperatures rise to more than 2°C beyond pre-industrial levels, the damage will become catastrophic. Warming from greenhouse gas emissions may trigger the irreversible meltdown of the Greenland ice sheet, adding up to seven metres of sea level rise. New evidence also shows that the rate of ice discharge from parts of the Antarctic mean it is also at risk of meltdown. Slowing, shifting or shutting down of the Atlantic Gulf Stream current will have dramatic effects in Europe and disrupt the global ocean circulation system. Large releases of methane from melting permafrost and from the oceans will lead to rapid increases of the gas in the atmosphere and consequent warming. There is clearly an imperative to reduce emissions as much and as quickly as possible.

The goal of climate policy should be to keep the global mean temperature rise to as far below 2°C above pre-industrial levels as possible. Given that we are already committed to 1.8°C increases above pre-industrial levels, the goal of climate policy should be ensuring emissions peaking as soon as possible and substantially reduced by the year 2020.

the kyoto protocol

Recognising these threats, the signatories to the 1992 UN Framework Convention on Climate Change agreed the Kyoto Protocol in 1997. The Protocol finally entered into force in early 2005 and its 165 member countries meet twice annually to negotiate further refinement and development of the agreement. Only one major industrialised nation, the United States, has not ratified Kyoto. The Kyoto Protocol commits industrialised countries to reduce their greenhouse gas emissions by 5.2% from their 1990 level by the target period of 2008-2012. This has in turn resulted in the adoption of a series of regional and national reduction targets. In the European Union, for instance, the commitment is to an overall reduction of 8%. In order to reach this target, the EU has also agreed a target to increase its proportion of renewable energy from 6% to 12% by 2010.

At present, the Kyoto countries are negotiating the second phase of the agreement, covering the period from 2013-2017. Greenpeace is calling for the commitments under the Kyoto protocol to be in line with at least 30% emissions reductions in industrialised countries by 2020. Only with these cuts do we stand a reasonable chance of meeting the 2°C target. The Kyoto Protocol’s architecture relies fundamentally on legally binding emissions reduction obligations. To achieve these targets, carbon is turned into a commodity which can be traded. The aim is to encourage the most economically efficient emissions reductions, in turn leveraging the necessary investment in clean technology from the private sector to drive a revolution in energy supply.

Negotiators are running out of time, however. Signatory countries agreed a negotiating ‘mandate’, known as the Bali Action Plan, in December 2007, but they must complete these negotiations with a final agreement on the second Kyoto commitment period by the end of 2009 at the absolute latest. Forward-thinking nations can move ahead of the game by implementing strong domestic targets now, building the industry and skills bases that will deliver the transition to a low-carbon society, and thereby provide a strong platform from which to negotiate the second commitment period.

european energy policy

Europe has often claimed to be a leader on climate change, and the EU institutions have committed to keeping global temperature rise below the dangerous 2°Celsius level. To drive the energy revolution that is required in this fight against global warming, the EU must lead by example through a shift towards a clean and sustainable energy system. The energy [r]evolution demonstrates that this is entirely feasible. Its realisation would not only deliver the substantial emission reductions required, but it would also contribute to sustainable economic growth, high quality jobs, technology development, global competitiveness and industrial and research leadership. But European decision-makers need to make it happen and it needs to happen fast.

At present, a wide range of energy-market failures still discourage the significant investments in renewable energy and energy efficiency that are needed to lead Europe on a sustainable energy pathway. An ambitious approach is required to remove these barriers so as to increase energy efficiency and conservation and to replace fossil fuels with clean and abundant renewable energy sources.

The European Union and its Member States should **demonstrate commitment** to a clean energy future, should **regulate** the energy market to create the conditions for a sustainable energy system, both on the supply and on the demand side, and **stimulate** governments, businesses, industries and citizens to opt for energy efficiency and renewable energy.

Greenpeace proposes eight measures that the European Union should take to realisez the energy [r]evolution.

1. Set effective emission reduction targets in line with the 2°Celsius global warming limit
2. Phase out all subsidies and other support measures for inefficient plants, appliances, vehicles and buildings, as well as for fossil fuel use and nuclear power installations
3. Secure an effective emissions trading system that makes polluters pay
4. Set stringent and ever-improving efficiency standards
5. Implement legally binding targets and stable support for renewable energy
6. Remove barriers to renewable energy development and reform the electricity market
7. Develop marketing, training and awareness-raising for renewable energy and energy efficiency technologies
8. Support innovation in energy efficiency, low-carbon vehicles, renewable energy

eight political steps for the energy [r]evolution

1. **set effective emission reduction targets in line with the 2°Celsius global warming limit** The European Union has already committed to the objective of keeping global mean temperature increase below 2°, compared to pre-industrial levels. Above this level, damage to ecosystems and disruption of the climate system would increase dramatically. The time window to keep within this limit is short. Emissions have to peak by 2015 and go down swiftly. Until 2020, the European Union will have to reduce its domestic greenhouse gas emissions by at least 30% compared to 1990 levels. EU leaders should commit to these reductions, while working for an ambitious international agreement on the second commitment period (2013-2017) of the Kyoto Protocol.

   At the same time, the European Union will have to provide substantial additional finance to help developing countries mitigate climate change with clean energy technologies and other climate protection measures.

2. **phase out all subsidies and other support measures for inefficient plants, appliances, vehicles and buildings, as well as for fossil fuel use and nuclear power installations** In August 2008, the UN Environmental Programme reported that each year globally around €240 billion or 0.7 per cent of global GDP is being spent on energy subsidies. The lion's share is being used to artificially lower the real price of fossil fuels or nuclear energy. These subsidies make energy efficiency less attractive, keep renewable energy out of the market place and prop up non-competitive and non-efficient technologies and fuels. Eliminating these fuel subsidies, according to UNEP, would also reduce greenhouse gas emissions by as much as six per cent a year while contributing 0.1 per cent to global GDP. Many of these seemingly well-intentioned subsidies rarely make economic sense and rarely address poverty, given that many of these price support systems benefit the wealthier sections of society rather than those on low incomes. In recent years, several countries have even increased research and development funding for fossil technologies, in the hope to promote carbon capture and storage technology. Spending money on carbon capture and storage is diverting urgent funding away from renewable energy solutions for the climate crisis. Even assuming that at some stage carbon capture becomes technically feasible, commercially viable, capable of long-term storage and environmentally safe, it would still only have a limited impact on emission reductions and would come at a high cost. Redressing these subsidies for fossil and nuclear energy sources and redirecting these considerable financial flows towards investments in energy efficiency and renewable energy would bring consistency to government policies and would allow the inclusion of social and environmental costs in prices.


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image OFF SHORE WINDFARM, MIDDELGRUNDEN, COPENHAGEN, DENMARK.

image A MELT POOL NEAR SERMALIK FJORD, EAST GREENLAND, MADE BY THE HELHEIM GLACIER WHICH HAS RECEDED AND MELTED AWAY. THE LINES IN THE EARTH BANK ARE SCULPTED BY THE MOVEMENT OF THE GLACIER'S RETREAT.

In addition, fossil and nuclear energy currently benefit from a range of indirect subsidies, given that the market is not incorporating the external costs of these fuels: the real cost of energy production by conventional energy sources would include expenses borne by society, such as those related to health impacts and local and regional environmental degradation ranging from mercury pollution to acid rain – as well as global climate-related impacts. Hidden costs also include the waiving of nuclear accident insurance given that this is too expensive to be covered by the nuclear operators. These external costs should be factored into energy pricing to move the energy sector towards a truly level playing field. The European Union and its national and regional governments should therefore strictly apply the 'polluter-pays principle'. One element of creating fairer competition is to adopt polluter-pays taxation for dirty energy sources, and to exclude renewable energy from environment-related taxation.

3. **secure an effective emissions trading system that makes polluters pay** To integrate the climate-related impacts of energy generation into its price, the European Union has chosen its emissions trading system (ETS), capping total greenhouse gas emissions from large point sources and allowing the participants in the system to trade allowances between each other. However, so far the EU ETS has failed to adequately reflect the costs of different fossil fuel-based technologies. It is vitally important that the failings of the system are removed. The ETS should define caps in line with the 2°C threshold, requiring a reduction of total domestic EU emissions by at least 30% by 2020 compared with 1990 levels. These domestic reductions must not be offset by investments outside the EU (by purchasing external credits); instead high-quality external credits should only be additional to an adequate level of domestic reductions.

To provide the right market signals and the economic incentives for the transition of our energy system along the whole production and consumption chain, all allowances under the Emissions Trading System should be auctioned rather than being given out for free. Auctioning reduces the total cost of European climate action because it is the most economically efficient allocation methodology, eliminating windfall profits from free allowances. It reinforces the incentive to reduce emissions and to invest in and develop clean and efficient technologies. Revenues from auctioning allowances should be invested in climate-friendly renewable energy and energy efficiency projects in the EU and to support mitigation and adaptation in developing countries.

4. **set stringent and ever-improving efficiency standards** Determined policies to improve energy efficiency are vital to set Europe on a clean energy pathway. It is imperative that the European Union and its Member States legally commit to their declaredvoluntary objective of reducing energy waste by 20% by 2020.

According to the European Commission's research, 20% energy savings compared to business as usual could save more than €60 billion every year (up to €1000 per household per year), while reducing CO_2 emissions by 780 million tons a year by 2020[26]. The European Union should commit to stringent and mandatory efficiency standards for all energy appliances and phase out the most inefficient appliances, such as incandescent lighting or stand-by technologies. These standards should improve over time and adapt to technological innovation.

Strict building codes should define maximum levels for the annual energy consumption and ensure compliance and performance levels for major envelope and equipment components in both new and existing buildings. The European Union should strictly regulate the efficiency of passenger cars and other transport vehicles, exacting emissions reductions through downsizing, design and technology improvements.

> **"never before has humanity been forced to grapple with such an immense environmental crisis."**
>
> **GREENPEACE INTERNATIONAL**
> CLIMATE CAMPAIGN

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references

[26] EUROPEAN COMMISSION GREEN PAPER "ENERGY EFFICIENCY – DOING MORE WITH LESS", COM(2005) 265 FINAL, JUNE 22, 2005.

5. **implement legally binding targets and stable support for renewable energy** EU leaders have already adopted a binding target of 20% for the share of renewable energy in total energy use by 2020, which is an important element for securing investor confidence. This target, as well as its breakdown into national renewable energy targets, should be supported by binding interim targets, as well as sector-specific targets for renewable energy in electricity, heating & cooling and transport.

In order to secure the realisation of the 20% target, European governments should implement effective support policies to compensate for market failures and to help maturing renewable energy technologies to achieve their full economic potential. Introducing support policies is a practical political solution to acknowledge that. Also, support policies for renewable energy help these technologies to become competitive with respect to fossil and nuclear energy sources which have been able to mature after decades of state subsidies and protectionist, monopolistic market structures.

In the **electricity sector**, two types of incentives can be identified as the main instruments to promote the deployment of renewable electricity. These are fixed price systems, where the government defines the electricity price paid to the producer and lets the market determine the quantity (so-called feed-in systems and premium systems), and renewable quota systems or tradable green certificate (TGC) systems, where the government dictates the quantity of renewable electricity an electricity company has to provide and leaves it to the market to determine the price. Both systems create a protected market against a background of subsidised, depreciated conventional generators whose external environmental costs are not accounted for. Their aim is to provide incentives for technology improvements and cost reductions, leading to cheaper renewables that can compete with conventional sources in the future.

Experience shows that fixed price systems, if designed well, have been the most successful and cost effective instruments to promote the broad uptake of renewable power technologies.

Possible instruments for the support of renewable energy in **heating and cooling** include a building obligation, which establishes that a certain share of heating or cooling of new and existing buildings has to come from renewable energy sources. This policy has, for example, been successfully implemented in Spain. To secure the uptake of renewable energy in heating & cooling, which has long been neglected in Europe, this model should be applied across the European Union.

Investment subsidies and tax credits are among the additional instruments available to support renewable energy in heating & cooling, as well as in electricity and transport. Apart from the general support instruments chosen, it is the detailed design of the mechanisms, in combination with other measures, that determines their success.

6. **remove barriers to renewable energy development and reform the electricity market** Substantial reforms of the energy sector are necessary to integrate new renewable energy technologies on a larger scale. Complex licensing procedures and bureaucratic hurdles constitute one of the most difficult obstacles faced by renewable energy producers in many countries. The European Union and its governments should propose detailed procedural guidelines to strengthen existing legislation and secure simple and transparent authorisation and licensing procedures, including tight time-limits. At the same time, favourable access conditions to infrastructure, electricity grids, district heating networks and gas networks should be defined to reduce bottlenecks. This includes priority connection, priority access and priority dispatch of electricity from renewable energy sources.

But more fundamental changes of the energy market are required. After decades of state-subsidies to conventional energy sources, the entire network system, transmission and congestion management practices and technical requirements have been developed so as to suit centralised nuclear and fossil production structures. Variable and decentralised renewable energy technologies now to have break into these historically developed market conditions.

As an important step to facilitate the reform of the energy market, especially in the electricity sector, all European governments should secure the full ownership unbundling of transmission network operation from production and supply activities. This is the only effective way to provide fair market access and overcome existing discriminatory practices against new market entrants, such as renewable energy producers. These practices currently include extensive administrative requirements and other delaying tactics for grid access, excessive costs of grid connection and unjustified operational charges, partial transmission practices or discriminatory grid codes.

A European energy regulator should be established. Both the European and national regulators should be sufficiently powerful so as to foster the development of a flexible and interconnected European market and to secure fair market conditions. Effective rules should be put in place to overcome the historically developed centralised network structures, to secure grid connection for renewable energy installations, as well as the necessary network extension for the integration of small-scale and large-scale renewable energy production. These should also introduce smart meters for households to facilitate an active demand-side management. Network development costs for new installations, such as offshore wind farms, should be paid by grid system operators.

Furthermore, the EU and national governments should promote the development of combined heat and power generation. District heating networks are a precondition for the efficient use of several renewable, as well as fossil, energy sources. Targeted policies and financial incentives should encourage investments in combined heat and power generation and the development of district heating networks.

image COMPACT FLUORESCENT LAMP LIGHT BULB.

image WASHING MACHINE.

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7. develop marketing, training and awareness-raising for renewable energy and energy efficiency technologies

Regulatory measures to support energy efficiency and renewable energy should be complemented with market transformation policies to promote the manufacture and purchase of clean and energy-efficient products and services so as to induce lasting structural and behavioural changes.

European governments should oblige planners and architects to always consider renewable energy technologies, district heating networks and efficient energy management in the planning, construction and renovation of industrial and residential areas. General education and training programmes for architects, builders, installers and suppliers of heating, cooling and electricity equipment should include technical schooling on renewable energy and energy efficiency options and measures.

At the same time, the energy consumption of buildings should be made available in "energy passes" to house owners, as well as tenants. The European Union should develop strategies and programmes to promote the education of architects, engineers and other professionals in the building sector as well as end-users about energy efficiency opportunities in new and existing buildings. As part of this strategy, governments should invest in the further development of energy intermediaries and energy audit programmes in order to assist professionals and consumers in identifying opportunities for improving and upgrading the energy efficiency of their buildings, as well as the use of renewable energy technologies for heat or electricity generation.

Given that investment costs are often a barrier for implementing clean measures, in particular for retrofitting and investing in renewable energy options, governments should provide subsidies, financial incentives and other fiscal measures such as tax reduction schemes, investment subsidies and preferential loans.

Similarly, effective efficiency labelling requirements for electrical appliances should inform consumers of a product's relative or absolute performance and energy operating costs. These labels can also serve as bases for implementing rebates, tax incentives or preferential public procurement programmes.

Finally, improved disclosure should also be applied to the electricity supply. Power suppliers should state visibly on the bill, as well as in advertising campaigns, their electricity mix and its environmental impact.

8. support innovation in energy efficiency, low-carbon vehicles, renewable energy Innovation will play an important role in making the energy [r]evolution more attractive. Direct public support is often necessary to speed up the deployment of radically new technologies. The European Union, national governments, as well as public finance institutions should prioritise investments in research and development for more efficient appliances and building techniques, new forms of insulation, new types of renewable energy production such as tidal and wave power as well as in low-emitting transport options, such as the development of better batteries for plug-in electric cars, freight transport management programmes and "tele working". There are several means to support innovation. The most important type of policies are those instruments that reduce the costs of research and development: tax incentives, staff subsidies or project grants. These can be accompanied by additional policies that do not increase the financial resources of a research project by providing a risk insurance. But direct research and development support can only be part of a coherent set of policies that are conducive to clean innovation in the energy market.

glossary & appendix

6

> **"the sooner we act, the more effective and cost efficient efforts at controlling climate change will be."**
>
> **PROFESSOR JACQUELINE MCGLADE**
> EXECUTIVE DIRECTOR OF THE EUROPEAN ENVIRONMENT AGENCY

glossary of commonly used terms and abbreviations

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

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

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

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

conversion factors - fossil fuels

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

conversion factors - different energy units

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

definition of sectors

The definition of different sectors is analog to the sectorial break down of the IEA World Energy Outlook series.

All definitions below are from the IEA Key World Energy Statistics

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

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

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

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

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

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image NEXT EXIT 'SUNSHINE', CANADA.

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image THE PS10 CONCENTRATING SOLAR TOWER PLANT IN SEVILLA, SPAIN, USES 624 LARGE MOVABLE MIRRORS CALLED HELIOSTATS. THE MIRRORS CONCENTRATE THE SUN'S RAYS TO THE TOP OF A 115 METER (377 FOOT) HIGH TOWER WHERE A SOLAR RECEIVER AND A STEAM TURBINE ARE LOCATED. THE TURBINE DRIVES A GENERATOR, PRODUCING ELECTRICITY.

appendix: EU 27 reference scenario

table 6.1: EU 27: electricity generation

TWh/a	2005	2010	2020	2030	2040	2050
Power plants	**2,620**	**2,932**	**3,538**	**3,977**	**4,318**	**4,583**
Coal	407	578	682	844	1,022	1,102
Lignite	323	325	322	297	254	231
Gas	394	476	756	910	1,075	1,252
Oil	85	82	54	36	21	5
Diesel	4	2	1	0	0	0
Nuclear	998	950	865	860	850	850
Biomass	29	38	55	79	81	80
Hydro	304	322	335	349	352	355
Wind	70	145	423	530	567	590
PV	1	6	24	40	51	57
Geothermal	5	6	11	14	17	19
Solar thermal power plants	0	3	8	12	19	27
Ocean energy	1	1	2	5	9	15
Combined heat & power production	**651**	**723**	**813**	**878**	**923**	**954**
Coal	148	168	173	195	204	213
Lignite	95	95	94	92	89	85
Gas	302	340	396	420	439	449
Oil	50	53	40	29	26	21
Biomass	56	66	109	140	164	185
Geothermal	0	1	2	2	2	2
CHP by producer						
Main acitivity producers	469	521	586	633	665	688
Autoproducers	182	202	227	245	258	266
Total generation	**3,271**	**3,655**	**4,351**	**4,855**	**5,241**	**5,537**
Fossil	1,807	2,118	2,517	2,824	3,129	3,358
Coal	555	745	854	1,039	1,225	1,315
Lignite	418	420	416	389	343	316
Gas	696	816	1,152	1,330	1,514	1,701
Oil	135	135	94	65	47	26
Diesel	4	2	1	0	0	0
Nuclear	998	950	865	860	850	850
Renewables	**466**	**586**	**969**	**1,171**	**1,262**	**1,329**
Hydro	304	322	335	349	352	355
Wind	70.5	144.8	423	530	567	590
PV	1.5	5.5	24	40	51	57
Biomass	84.4	103.5	164	219	245	265
Geothermal	5.4	7.0	13	16	19	21
Solar thermal	0	3.2	8	12	19	27
Ocean energy	0.5	0.5	2	5	9	15
Import	324	330	325	323	322	321
Import RES	61	72	96	102	102	100
Export	313	313	313	313	313	313
Distribution losses	221	234	252	260	265	267
Own consumption electricity	307	332	365	381	383	385
Electricity for hydrogen production	0	0	0	0	0	0
Final energy consumption (electricity)	**2,754**	**3,105**	**3,746**	**4,223**	**4,602**	**4,894**
Fluctuating RES (PV, Wind, Ocean)	73	151	449	575	627	662
Share of fluctuating RES	2.2%	4.1%	10.3%	11.8%	12.0%	12.0%
RES share	**14.3%**	**16.0%**	**22.3%**	**24.1%**	**24.1%**	**24.0%**

table 6.2: EU 27: heat supply

PJ/A	2005	2010	2020	2030	2040	2050
District heating plants	**1,067**	**953**	**871**	**571**	**771**	**840**
Fossil fuels	840	748	682	446	602	655
Biomass	224	200	183	120	162	176
Solar collectors	0	0	0	0	0	1
Geothermal	3	5	6	5	7	8
Heat from CHP	**2,376**	**2,659**	**3,342**	**3,788**	**3,652**	**3,627**
Fossil fuels	2131	2,343	2,834	3,263	3,163	3,119
Biomass	245	304	494	510	473	492
Geothermal	0	12	14	15	16	16
Direct heating[1]	**19,373**	**20,428**	**21,166**	**22,370**	**23,150**	**23,400**
Fossil fuels	17,628	18,254	18,463	19,082	19,292	18,995
Biomass	1,687	1,967	2,125	2,315	2,457	2,690
Solar collectors	29	105	301	553	833	972
Geothermal	29	103	277	419	569	743
Total heat supply[1]	**22,815**	**24,040**	**25,380**	**26,729**	**27,573**	**27,867**
Fossil fuels	20,599	21,345	21,980	22,792	23,057	22,768
Biomass	2,156	2,471	2,802	2,945	3,092	3,358
Solar collectors	29	105	301	554	833	973
Geothermal	32	120	297	438	591	767
RES share (including RES electricity)	**9.7%**	**11.2%**	**13.4%**	**14.7%**	**16.4%**	**18.3%**

[1] heat from electricity (direct and from electric heat pumps) not included; covered in the model under 'electric appliances'

table 6.3: EU 27: CO_2 emissions

MILL t/a	2005	2010	2020	2030	2040	2050
Condensation power plants	**912**	**1,047**	**1,121**	**1,237**	**1,344**	**1,384**
Coal	349.1	476.5	518.6	628.0	735.6	768.9
Lignite	338.3	330	306.4	279.2	236.0	205.1
Gas	155.6	179.1	258.3	305.8	358.2	407.1
Oil	64.8	59.9	36.5	23.7	13.8	3.3
Diesel	3.7	1.9	0.9	0.3	0	0
Combined heat & power production	**526**	**417**	**399**	**503**	**518**	**521**
Coal	161	153	128	173	185	195
Lignite	117	40	59	99	98	93
Gas	153	164	187	212	219	221
Oil	95	59	25	18	15	12
CO_2 emissions electricity & steam generation	**1,438**	**1,464**	**1,519**	**1,740**	**1,862**	**1,905**
Coal	510	629	646	801	921	964
Lignite	455	370	365	378	334	298
Gas	308	344	445	518	577	628
Oil & diesel	164	121	63	42	29	15
CO_2 emissions by sector	**3,895**	**4,046**	**4,187**	**4,467**	**4,642**	**4,587**
% of 1990 emissions	96%	100%	103%	110%	115%	113%
Industry	691	675	662	650	644	572
Other sectors	761	778	766	778	790	810
Transport	1089	1188	1286	1354	1379	1321
Electricity & steam generation	1,281	1,341	1,416	1,646	1,778	1,828
District heating	72	63	57	38	51	56
Population (Mill.)	490	495	498	496	489	479
CO_2 emissions per capita (t/capita)	**7.9**	**8.2**	**8.4**	**9.0**	**9.5**	**9.6**

table 6.4: EU 27: installed capacity

GW	2005	2010	2020	2030	2040	2050
Power plants	**666**	**757**	**878**	**896**	**917**	**948**
Coal	79	109	120	130	157	170
Lignite	50	50	48	44	37	33
Gas	181	211	236	228	215	228
Oil	68	66	45	33	21	6
Diesel	4	2	1	0	0	0
Nuclear	134	127	115	115	113	121
Biomass	4.6	5.9	8.3	11.5	11.2	10.7
Hydro	109	113	117	122	123	124
Wind	34.4	65.3	159.5	169.9	181.7	189.1
PV	1.5	5.2	20.9	34.8	44.3	49.6
Geothermal	1.0	1.0	2.0	2.6	3.1	3.5
Solar thermal power plants	0	1.2	2.7	3.7	5.4	6.8
Ocean energy	0.3	0.2	1.0	2.4	4.3	7.2
Combined heat & power production	**248**	**272**	**308**	**304**	**316**	**325**
Coal	62	71	73	75	80	85
Lignite	50	50	42	28	27	26
Gas	90	106	146	157	166	172
Oil	29	26	18	12	10	6
Biomass	17	19	29	32	33	35
Geothermal	0	0	0	0	0	0
CHP by producer						
Main activity producers	203	225	257	252	263	272
Autoproducers	46	47	51	53	52	53
Total generation	**914**	**1,029**	**1,185**	**1,200**	**1,232**	**1,273**
Fossil	612	691	730	707	713	725
Coal	141	179	194	205	237	255
Lignite	100	100	90	72	64	59
Gas	270	318	383	385	381	400
Oil	97	92	63	45	31	12
Diesel	4	2	1	0	0	0
Nuclear	**134**	**127**	**115**	**115**	**113**	**121**
Renewables	168	211	340	379	407	426
Hydro	109	113	117	122	123	124
Wind	34	65	160	170	182	189
PV	1	5	21	35	44	50
Biomass	21.4	25.0	36.9	43.0	44.1	45.7
Geothermal	1	1	2	3	3	4
Solar thermal	0	1	3	4	5	7
Ocean energy	0	0	1	2	4	7
Fluctuating RES (PV, Wind, Ocean)	**36.2**	**70.8**	**181.3**	**207.1**	**230.4**	**245.9**
Share of fluctuating RES	4.0%	6.9%	15.3%	17.3%	18.7%	19.3%
RES share	**18.4%**	**20.5%**	**28.7%**	**31.6%**	**33.0%**	**33.5%**

table 6.5: EU 27: primary energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total	**77,260**	**80,688**	**85,792**	**91,505**	**94,623**	**94,608**
Fossil	**61,028**	**63,747**	**66,658**	**70,936**	**73,448**	**72,890**
Hard coal	9,125	10,171	9,756	10,695	12,182	12,290
Lignite	4,102	3,336	3,288	3,408	3,010	2,688
Natural gas	18,754	20,166	23,184	26,064	27,731	29,176
Crude oil	29,047	30,074	30,430	30,770	30,524	28,736
Nuclear	**10,886**	**10,365**	**9,438**	**9,383**	**9,274**	**9,274**
Renewables	**5,346**	**6,575**	**9,696**	**11,186**	**11,900**	**12,443**
Hydro	1,094	1,159	1,206	1,256	1,267	1,278
Wind	254	521	1,523	1,908	2,041	2,124
Solar	34	136	416	741	1,085	1,275
Biomass	3,736	4,536	6,100	6,664	6,709	6,777
Geothermal	226	222	451	616	797	988
Ocean Energy	2	2	7	18	32	54
RES share	**7.0%**	**8.2%**	**11.4%**	**12.3%**	**12.7%**	**13.3%**

table 6.6: EU 27: final energy demand

PJ/a	2005	2010	2020	2030	2040	2050
Total (incl. non-energy use)	**54,289**	**58,827**	**64,967**	**69,719**	**72,617**	**73,008**
Total (energy use)	**49,559**	**53,699**	**59,293**	**63,620**	**66,260**	**66,610**
Transport	**15,521**	**17,153**	**19,452**	**20,743**	**21,157**	**20,274**
Oil products	15,100	16,429	17,414	18,009	18,122	17,251
Natural gas	21	77	556	1,009	1,298	1,386
Biofuels	132	301	1,025	1,205	1,193	1,109
Electricity	268	346	457	519	544	527
RES electricity	38	56	102	125	131	127
Hydrogen	0	0	0	0	0	0
RES share Transport	**1.1%**	**2.1%**	**5.8%**	**6.4%**	**6.3%**	**6.1%**
Industry	**13,328**	**14,393**	**15,710**	**16,685**	**16,968**	**16,460**
Electricity	4,059	4,520	5,337	5,785	6,047	6,174
RES electricity	579	725	1,188	1,396	1,456	1,482
District heat	464	529	793	991	1,094	1,131
RES disrict heat	151	182	294	312	333	359
Coal	1,346	1,288	1,164	746	1,097	767
Oil products	2,103	2,179	2,196	2,155	1,986	1,669
Gas	4,617	4,917	5,189	5,900	5,606	5,398
Solar	0	6	6	6	6	17
Biomass and waste	739	951	1,013	1,082	1,092	1,219
Geothermal	0	3	11	20	40	85
RES share Industry	**11.0%**	**13.0%**	**16.0%**	**16.9%**	**17.2%**	**19.2%**
Other Sectors	**20,709**	**22,152**	**24,132**	**26,192**	**28,135**	**29,877**
Electricity	5,589	6,314	7,693	8,898	9,975	10,916
RES electricity	797	1,013	1,713	2,147	2,402	2,621
District heat	1,857	1,975	2,141	2,190	2,232	2,258
RES disrict heat	284	302	363	305	295	303
Coal	472	491	229	149	10	18
Oil products	4,024	3,961	3,886	3,836	3,840	3,668
Gas	7,321	7,705	8,027	8,463	8,904	9,489
Solar	29	99	295	547	827	955
Biomass and waste	1,389	1,512	1,606	1,728	1,843	1,945
Geothermal	29	96	254	381	505	628
RES share Other Sectors	**12.2%**	**13.6%**	**17.5%**	**19.5%**	**20.9%**	**21.6%**
Total RES	**4,165**	**5,246**	**7,869**	**9,253**	**10,122**	**10,850**
RES share	**8.4%**	**9.8%**	**13.3%**	**14.5%**	**15.3%**	**16.3%**
Non energy use	**4,730**	**5,128**	**5,674**	**6,099**	**6,357**	**6,398**
Oil	4,047	4,387	4,854	5,218	5,438	5,474
Gas	636	690	763	820	855	860
Coal	47	51	57	61	64	64

appendix: EU 27 energy [r]evolution scenario

table 6.7: EU 27: electricity generation

TWh/a	2005	2010	2020	2030	2040	2050
Power plants	**2,620**	**2,838**	**2,679**	**2,600**	**2,419**	**2,466**
Coal	407	414	253	99	45	10
Lignite	323	324	187	76	15	0
Gas	394	523	653	645	296	148
Oil	85	81	34	12	0	0
Diesel	4	2	1	0	0	0
Nuclear	998	927	425	158	22	0
Biomass	29	38	55	79	81	81
Hydro	304	325	352	365	377	391
Wind	70	185	564	825	1,032	1,115
PV	1	11	108	235	345	425
Geothermal	5	6	17	39	79	116
Solar thermal power plants	0	2	26	54	93	125
Ocean energy	1	1	3	13	34	55
Combined heat & power production	**651**	**747**	**915**	**919**	**892**	**850**
Coal	148	159	134	8	0	0
Lignite	95	53	31	6	0	0
Gas	302	374	504	517	370	237
Oil	50	47	16	8	0	0
Biomass	56	110	220	353	459	529
Geothermal	0	4	9	27	64	84
CHP by producer						
Main acitivity producers	469	525	623	620	583	534
Autoproducers	182	222	292	299	309	316
Total generation	**3,271**	**3,585**	**3,594**	**3,519**	**3,311**	**3,316**
Fossil	1,807	1,977	1,814	1371	726	395
Coal	555	573	388	107	45	10
Lignite	418	377	218	82	15	0
Gas	696	897	1,157	1162	666	385
Oil	135	128	50	20	0	0
Diesel	4	2	1	0	0	0
Nuclear	998	927	425	158	22	0
Renewables	**466**	**681**	**1,355**	**1,991**	**2,563**	**2,921**
Hydro	304	325	352	365	377	391
Wind	70.5	185	564	825	1,032	1,115
PV	1.5	11	108	235	345	425
Biomass	84.4	148	275	432	540	610
Geothermal	5.4	10	26	66	143	200
Solar thermal	0	2	26	54	93	125
Ocean energy	0.5	1	3	13	34	55
Import	324	330	325	323	560	880
Import RES	61	79	124	194	549	876
Export	313	310	295	230	110	73
Distribution losses	221	230	209	193	186	197
Own consumption electricity	307	326	303	283	270	284
Electricity for hydrogen production	0	0	36	65	99	99
Final energy consumption (electricity)	**2,754**	**3,049**	**3,076**	**3,071**	**3,206**	**3,543**
Fluctuating RES (PV, Wind, Ocean)	73	197	675	1,073	1,411	1,595
Share of fluctuating RES	2.2%	5.5%	18.8%	30.5%	42.6%	48.1%
RES share	**14.3%**	**19.0%**	**37.7%**	**56.6%**	**77.4%**	**88.1%**
'Efficiency' savings (compared to Ref.)	**0**	**57**	**670**	**1,152**	**1,396**	**1,351**

table 6.8: EU 27: heat supply

PJ/A	2005	2010	2020	2030	2040	2050
District heating plants	**1,067**	**1,043**	**997**	**1,181**	**1,998**	**2,654**
Fossil fuels	840	762	583	461	240	0
Biomass	224	250	289	319	499	610
Solar collectors	0	21	70	272	919	1,566
Geothermal	3	9	55	130	340	478
Heat from CHP	**2,376**	**2,864**	**3,958**	**3,877**	**3,343**	**3,043**
Fossil fuels	2131	2,315	2,863	2,334	1,451	864
Biomass	245	517	1,010	1,297	1,318	1,424
Geothermal	0	32	85	246	574	756
Direct heating[1]	**19,373**	**19,711**	**16,824**	**15,560**	**15,109**	**14,746**
Fossil fuels	17,628	16,806	12,733	10,550	8,857	8,095
Biomass	1,687	2,469	2,896	2,559	2,161	1,778
Solar collectors	29	112	540	1,469	2,610	3,057
Geothermal	29	324	654	981	1,481	1,815
Total heat supply[1]	**22,815**	**23,618**	**21,778**	**20,618**	**20,450**	**20,444**
Fossil fuels	20,599	19,884	16,179	13,345	10,548	8,959
Biomass	2,156	3,236	4,195	4,175	3,978	3,813
Solar collectors	29	133	610	1,741	3,529	4,623
Geothermal	32	365	794	1,357	2,395	3,049
RES share (including RES electricity)	**9.7%**	**15.8%**	**25.7%**	**35.3%**	**48.4%**	**56.2%**
'Efficiency' savings (compared to Ref.)		**423**	**3,602**	**6,111**	**7,123**	**7,423**

[1] heat from electricity (direct and from electric heat pumps) not included; covered in the model under 'electric appliances'

table 6.9: EU 27: co₂ emissions

MILL t/a	2005	2010	2020	2030	2040	2050
Condensation power plants	**912**	**928**	**618**	**370**	**145**	**55**
Coal	349.1	341.0	192.7	73.4	32.4	6.9
Lignite	338.3	329.0	177.9	71.5	13.9	0
Gas	155.6	196.9	223.1	216.7	98.6	48.1
Oil	64.8	59.2	23.0	7.9	0	0
Diesel	3.7	1.9	0.9	0.3	0	0
Combined heat & power production	**526**	**401**	**367**	**279**	**180**	**109**
Coal	161	145	99	7	0	0
Lignite	117	22	19	7	0	0
Gas	153	181	238	261	180	109
Oil	95	53	11	5	0	0
CO_2 emissions electricity & steam generation	**1,438**	**1,329**	**985**	**649**	**325**	**164**
Coal	510	486	292	81	32	7
Lignite	455	351	197	78	14	0
Gas	308	378	461	477	278	158
Oil & diesel	164	114	34	13	0	0
CO_2 emissions by sector	**3,895**	**3,712**	**2,802**	**2,122**	**1,402**	**979**
% of 1990 emissions	96%	92%	69%	52%	35%	24%
Industry	691	612	451	370	277	230
Other sectors	761	723	575	461	384	345
Transport	1089	1104	859	695	469	294
Electricity & steam generation	1,281	1,210	871	562	257	111
District heating	72	63	46	34	16	0
Population (Mill.)	490	495	498	496	489	479
CO_2 emissions per capita (t/capita)	**7.9**	**7.5**	**5.6**	**4.3**	**2.9**	**2.0**

table 6.10: EU 27: installed capacity

GW	2005	2010	2020	2030	2040	2050
Power plants	**666**	**767**	**815**	**858**	**902**	**982**
Coal	79	78	45	15	7	2
Lignite	50	49	28	11	2	0
Gas	181	232	204	161	59	27
Oil	68	65	28	11	0	0
Diesel	4	2	1	0	0	0
Nuclear	134	124	57	21	3	0
Biomass	4.6	6	8	11	11	11
Hydro	109	114	123	128	132	137
Wind	34.4	83	213	264	331	357
PV	1.5	10	94	204	300	370
Geothermal	1.0	1.1	3.1	7.1	14.4	21.2
Solar thermal power plants	0	0.7	8.7	16.6	26.6	31.3
Ocean energy	0.3	0.3	1.6	6.3	16.3	26.4
Combined heat & power production	**248**	**269**	**322**	**287**	**236**	**194**
Coal	62	68	58	3	0	0
Lignite	50	28	14	2	0	0
Gas	90	116	183	192	131	78
Oil	29	23	7	4	0	0
Biomass	17	33	58	80	92	99
Geothermal	0	1	2	5	13	17
CHP by producer						
Main activity producers	203	217	257	223	174	131
Autoproducers	46	52	65	63	62	62
Total generation	**914**	**1,035**	**1,136**	**1,144**	**1,138**	**1,176**
Fossil	612	662	568	400	200	106
Coal	141	146	103	18	7	2
Lignite	100	77	42	13	2	0
Gas	270	348.6	386.7	353.7	190.5	104.8
Oil	97	88.4	35.8	14.4	0	0
Diesel	4	2	1	0	0	0
Nuclear	134	124.3	56.7	21.1	2.9	0
Renewables	**168**	**249**	**511**	**723**	**936**	**1,069**
Hydro	109	114	123	128	132	137
Wind	34	83	213	264	331	357
PV	1	10	94	204	300	370
Biomass	21.4	38.5	66.3	91.6	102.8	110
Geothermal	1	2	5	13	27	38
Solar thermal	0	1	9	17	27	31
Ocean energy	0	0	2	6	16	26
Fluctuating RES (PV, Wind, Ocean)	36.2	94.2	308.2	475.0	647.1	753.4
Share of fluctuating RES	4.0%	9.1%	27.1%	41.5%	56.9%	64.1%
RES share	**18.4%**	**24.0%**	**45.0%**	**63.2%**	**82.2%**	**91.0%**

table 6.11: EU 27: primary energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total	**77,260**	**78,725**	**66,736**	**59,977**	**53,381**	**49,749**
Fossil	**61,028**	**59,704**	**48,347**	**39,990**	**29,485**	**22,980**
Hard coal	9,125	7,985	5,445	3,056	1,757	1,173
Lignite	4,102	3,165	1,778	704	126	0
Natural gas	18,754	19,962	19,965	19,287	14,929	12,245
Crude oil	29,047	28,593	21,159	16,943	12,674	9,562
Nuclear	10,886	10,115	4,637	1,724	240	0
Renewables	**5,346**	**8,906**	**13,752**	**18,263**	**23,657**	**26,769**
Hydro	1,094	1,170	1,267	1,314	1,357	1,408
Wind	254	666	2,030	2,970	3,715	4,014
Solar	34	180	1,093	2,781	5,106	6,603
Biomass	3,736	6,381	8,201	8,861	8,929	8,797
Geothermal	226	507	1,149	2,290	4,427	5,749
Ocean Energy	2	2	12	47	122	198
RES share	**7.0%**	**11.4%**	**20.6%**	**30.6%**	**46.1%**	**56.4%**
'Efficiency' savings (compared to Ref.)	**0**	**1,923**	**18,780**	**30,921**	**39,625**	**41,898**

table 6.12: EU 27: final energy demand

PJ/a	2005	2010	2020	2030	2040	2050
Total (incl. non-energy use)	**54,289**	**57,253**	**52,212**	**49,033**	**46,130**	**44,622**
Total (energy use)	**49,559**	**52,128**	**46,552**	**42,956**	**39,805**	**38,264**
Transport	**15,521**	**16,315**	**13,581**	**11,773**	**9,781**	**8,695**
Oil products	15,100	15,261	11,218	9,016	5,934	3,511
Natural gas	21	73	909	804	732	708
Biofuels	132	652	898	1,045	1,165	1,248
Electricity	268	329	467	742	1,691	2,961
RES electricity	38	63	176	420	1,310	2,608
Hydrogen	0	0	89	166	259	267
RES share Transport	**1.1%**	**4.4%**	**8.2%**	**13.2%**	**27.3%**	**47.1%**
Industry	**13,328**	**14,090**	**12,402**	**11,575**	**11,230**	**11,124**
Electricity	4,059	4,492	4,439	4,163	3,978	3,979
RES electricity	579	853	1,673	2,355	3,080	3,505
District heat	464	516	757	889	1,006	1,119
RES disrict heat	151	113	240	416	729	1,008
Coal	1,346	850	874	1,040	539	329
Oil products	2,103	2,023	858	337	162	81
Gas	4,617	4,790	3,631	3,076	2,825	2,696
Solar	0	43	216	483	1,041	1,259
Biomass and waste	739	1,200	1,346	1,169	998	823
Geothermal	0	176	281	419	682	837
RES share Industry	**11.0%**	**16.9%**	**30.3%**	**41.8%**	**58.1%**	**66.8%**
Other Sectors	**20,709**	**21,724**	**20,570**	**19,608**	**18,794**	**18,444**
Electricity	5,589	6,155	6,167	6,151	5,872	5,815
RES electricity	797	1,169	2,323	3,479	4,546	5,122
District heat	1,857	2,215	2,592	2,711	2,898	3,116
RES disrict heat	272	483	821	1,268	2,099	2,807
Coal	472	319	120	61	0	0
Oil products	4,024	3,975	3,027	1,777	959	448
Gas	7,321	6,980	5,826	5,579	5,394	5,389
Solar	29	69	324	986	1,570	1,798
Biomass and waste	1,389	1,891	2,223	1,936	1,584	1,269
Geothermal	29	120	289	406	517	610
RES share Other Sectors	**12.1%**	**17.2%**	**29.1%**	**41.2%**	**54.9%**	**62.9%**
Total RES	**4,153**	**6,833**	**10,846**	**14,476**	**19,520**	**23,128**
RES share	**8.4%**	**13.1%**	**23.3%**	**33.7%**	**49.0%**	**60.4%**
Non energy use	**4,730**	**5,125**	**5,660**	**6,077**	**6,325**	**6,358**
Oil	4,047	4,385	4,842	5,199	5,411	5,439
Gas	636	689	761	817	851	855
Coal	47	51	57	61	63	64

GREENPEACE

Greenpeace is a global organisation that uses non-violent direct action to tackle the most crucial threats to our planet's biodiversity and environment. Greenpeace is a non-profit organisation, present in 40 countries across Europe, the Americas, Asia and the Pacific. It speaks for 2.8 million supporters worldwide, and inspires many millions more to take action every day. To maintain its independence, Greenpeace does not accept donations from governments or corporations but relies on contributions from individual supporters and foundation grants.

Greenpeace has been campaigning against environmental degradation since 1971 when a small boat of volunteers and journalists sailed into Amchitka, an area west of Alaska, where the US Government was conducting underground nuclear tests. This tradition of 'bearing witness' in a non-violent manner continues today, and ships are an important part of all its campaign work.

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image ICEBERGS CALVING FROM THE ILUISSAT GLACIER IN GREENLAND. MEASUREMENTS OF THE MELT LAKES ON THE GREENLAND ICE SHEET SHOW ITS VULNERABILITY TO WARMING TEMPERATURES.

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