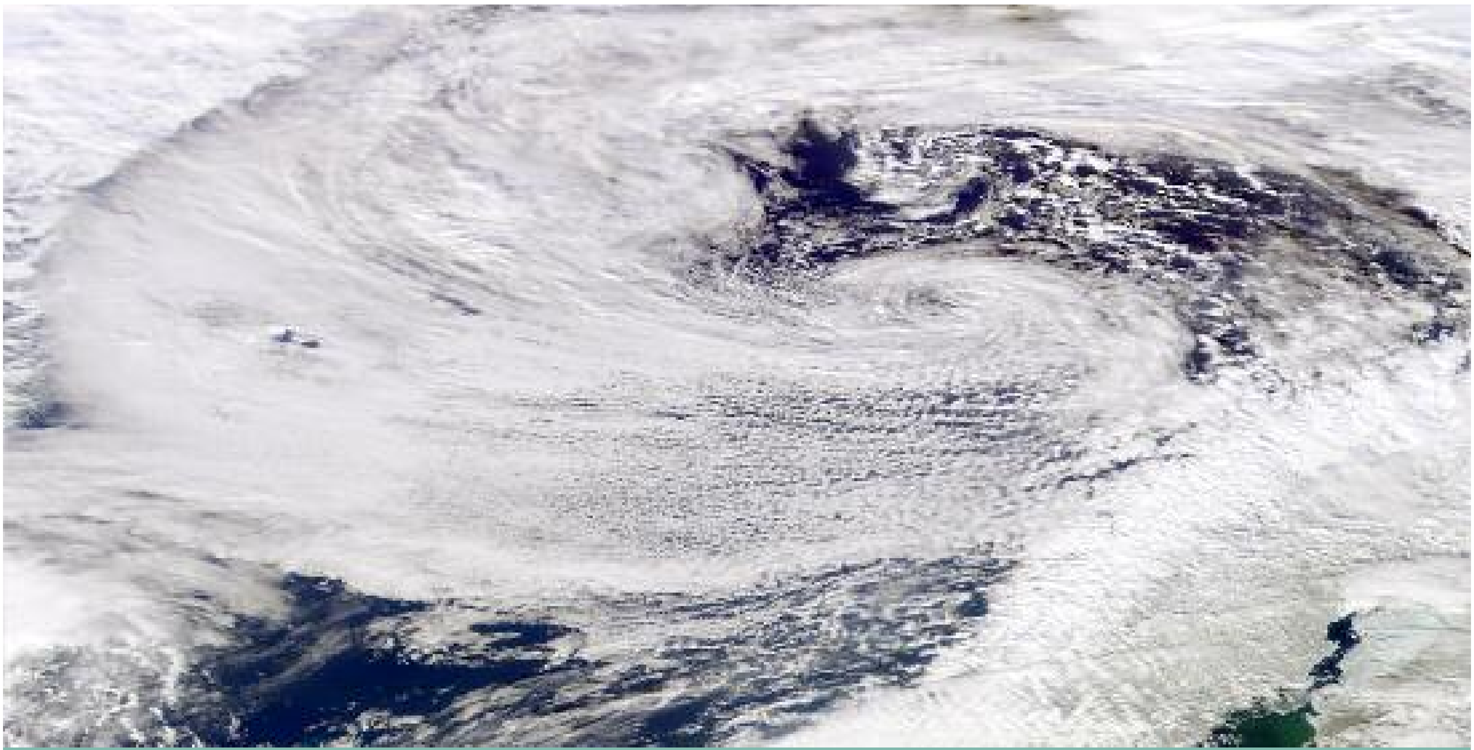

roadmap for europe

TOWARDS A SUSTAINABLE AND INDEPENDENT ENERGY SUPPLY

GREENPEACE

report The Energy [R]evolution for the EU 28

partners

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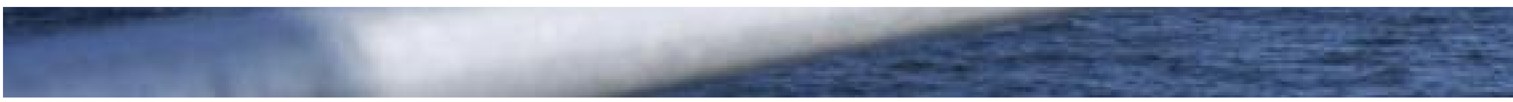

image OFFSHORE WINDFARM, MIDDELGRUNDEN, COPENHAGEN, DENMARK.

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

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introduction

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

This report, which includes the 4th edition of Greenpeace's EU Energy [R]evolution scenario[1], comes at a time of profound changes and challenges in the European energy market. The conflict in Ukraine has once again sparked a discussion about Europe's dependence on fossil and nuclear fuel imports and its need to reduce this dependence to ensure future energy security. The EU depends on Russian gas piped through Ukraine for about 10% of its overall needs, with some Eastern countries being much more exposed.

In March 2013, the threat of possible gas supply disruptions led EU leaders to ask the European Commission to draw up a plan to reduce Europe's energy dependence. The Commission released this plan on 28 May.

This energy security debate comes at the same time as discussions on the future direction of European climate and energy policies. The focus is on which targets the EU should set for 2030 to follow up its three targets for 2020 on carbon reductions, renewable energy and energy efficiency. In January 2014, the Commission tabled a proposal including two targets for 2030, a domestic 40% reduction in carbon emissions (compared to 1990 levels) and a 27% share of renewable energy in the EU's overall energy consumption.

The two discussions on energy security and 2030 targets are inextricably linked. While not every measure to enhance the EU's energy security will also advance its climate and energy agenda, a set of ambitious 2030 targets will drastically reduce the need for energy imports, thereby strengthening the EU's security of supply. EU leaders are expected to reach crucial decisions on both these discussions in October this year.

Against this background, this report compares the impact on energy imports of two approaches to 2030 climate and energy targets. The first approach is based on the Commission's proposal for a 40% cut in carbon emissions and a 27% renewable energy share by 2030, without any specific target for energy savings.[2] The second scenario reflects the demands by Greenpeace and other environmental organisations for a set of three targets, including a 55% cut in EU carbon emissions (compared to 1990), a renewable energy share of 45% and a reduction in primary energy consumption of 40% (compared to 2005).

Chapter 1 provides an analysis of global conventional fossil fuel production. It highlights the declining trend of this production with a particular focus on the EU's own fossil fuel production. Chapter 2 presents two scenarios based on the Commission proposal for 2030 targets (COM scenario) and Greenpeace's demands for such targets (Energy [R]evolution scenario). A third chapter provides an overview of fossil fuel import requirements of the two energy scenarios. Finally, Chapter 4 recommends a number of EU policy measures that would be needed to achieve the changes set out under the Greenpeace Energy [R]evolution scenario.

references

1 THE FIRST EDITION OF THE EU E[R] REPORT WAS PUBLISHED IN 2005. FURTHER EDITIONS FOLLOWED IN 2010 AND 2012.

2 AT THE TIME OF WRITING (JUNE 2014) THE COMMISSION HAS YET TO PROPOSE A FIRM TARGET ON 2030 ENERGY SAVINGS.

executive summary

image PIPELINES IN RUSSIA.

The consequences of the Ukraine crisis have once again highlighted Europe's vulnerability to energy import disruptions. There is a risk that, as in 2006 and 2009, gas imports from Russia through Ukraine could drop or dry up completely. These imports represent over 10% of Europe's gas supply.

However, Europe's reliance on Russian gas is part of a wider problem of import dependency. The EU spends about €400 billion buying over half of its energy (53%) from abroad.[1] At the same time, the use of imported fossil fuels leads to large amounts of CO_2 emissions which cause climate change.

The debate about energy security comes at a time when Europe is discussing what energy policies to set for beyond 2020. In January, the Commission tabled a proposal for 2030 climate and energy targets. In May, it also released a proposal for a European energy security strategy. EU leaders are expected to take a final decision on both issues – 2030 targets and energy security – at an EU summit in October.

This report compares the impact on EU energy imports of two approaches to 2030 climate and energy targets. This first approach is based on the Commission's proposal for a 40% cut in domestic EU carbon emissions (compared to 1990) and a 27% renewable energy share, without any specific target for energy savings. The second approach reflects demands by Greenpeace and other environmental organisations for a set of three targets including carbon emission cuts of at least 55% (compared to 1990), a renewable energy share of 45% and a reduction in primary energy consumption of 40% (compared to 2005).

The report shows that, based on the Commission's proposed 2030 targets, even if the European Union exploits all of its own conventional gas, oil and hard coal, it would still have to import a total of 29,000 petajoules (PJ) per year in fossil fuels by 2030.

Specifically, it would need to import about 255 billion cubic metres (m^3) of gas, 2.8 billion barrels (bbl) of oil and 81 million tonnes of hard coal. Overall, this would result in a limited reduction in EU energy imports compared to today's levels.

reference
3 HTTP://EC.EUROPA.EU/ENERGY/DOC/20140528_ENERGY_SECURITY_COMMUNICATION.PDF

By contrast, if EU leaders backed more ambitious 2030 targets, overall fossil fuel import requirements would be 45% lower than under the Commission proposal. Specifically, annual imports of about 90 billion m^3 of gas and 1.3 million bbl of oil could be avoided by 2030, while no imports of hard coal would be needed at all. Compared to the Commission proposal, this represents an extra 35% cut in gas imports and a 45% cut in oil imports by 2030. By 2020, gas imports could already be 12% lower, while oil and coal imports would be 19% and 42% lower respectively.

The Energy [R]evolution pathway would also result in much higher carbon emission cuts by 2030 compared to the Commission proposal. The investments required in the power sector would be very similar to those under the Commission's proposal. The Commission's impact assessment accompanying its 2030 proposal also shows that higher targets would lead to better health and more jobs for EU citizens.

EU leaders should therefore place much greater emphasis on energy savings and renewable energy in order to reduce Europe's dependence on fossil fuel imports and to enhance its energy security. A stringent set of policy targets for 2030 would deliver on both objectives – reducing the risk of energy supply shortages and reducing the risk posed by global climate change.

key results high efficiency energy [r]evolution pathway

- **Energy demand by sector:** Under the COM scenario, total primary energy demand in EU28 decreases by -20% from the current 72,300 PJ/a to 57,841 PJ/a in 2050. The energy demand in 2030 in the Energy [R]evolution scenario decreases by 40% compared to current consumption and it is expected by 2050 to reach 37,900 PJ/a.

- **Primary energy consumption**: Compared to the COM scenario, overall energy related primary energy demand under the Energy [R]evolution scenario will be reduced by around 40% in 2030. Around 48% of the remaining demand will be covered by renewable energy sources (including non-energy use).The Energy [R]evolution version reduces coal and oil significantly faster than the EC. This is made possible mainly by the replacement of coal power plants with renewables and a faster introduction of very efficient electric vehicles in the transport sector to replace oil combustion engines. This leads to an overall renewable primary energy share of 48% in 2030 and 92% in 2050. Nuclear energy is phased out just after 2030.

- **Power sector:** -Under the Energy [R]evolution scenario, electricity demand in the industry as well as in the residential and service sectors is expected to decrease after 2015. Because of the growing shares of electric vehicles, heat pumps and hydrogen generation however, electricity demand increases to 2,519 TWh in 2030 and 2,673 TWh/a in 2050, 27% below the COM case.

  - The development of the electricity supply market is characterised by a dynamically growing renewable energy market. This will compensate for the phasing out of nuclear energy and reduce the number of fossil fuel-fired power plants required for grid stabilization. By 2050, 95% of the electricity produced in EU28 will come from renewable energy sources. 'New' renewables – mainly wind, solar thermal energy and PV – will contribute 76% of electricity generation. The Energy [R]evolution scenario projects an immediate market development with high annual growth rates achieving a renewable electricity share of 44% across Europe already by 2020 and 75% by 2030. The installed capacity of renewables will reach 907 GW in 2030 and 1,211 GW by 2050.

- **Heating sector:** -Efficiency gains in the heat supply sector are larger than in the electricity sector. Under the Energy [R]evolution scenario, final demand for heat supply can even be reduced significantly. Compared to the COM scenario, consumption equivalent to 4,060 PJ/a is avoided through efficiency measures by 2050

  Renewables currently provide 15% of EU28's energy demand for heat supply, mainly from biomass. The lack of district heating networks is a severe structural barrier to the large scale utilization of geothermal and solar thermal energy. In the Energy [R]evolution scenario, renewables provide 47% of EU28's total heat demand in 2030 and 91% in 2050.

- **Future costs of electricity generation**: The Energy [R]evolution scenario slightly increases the generation costs of electricity generation in EU28 compared to the COM scenario. This difference will be less than 0.7 €cents/kWh up to 2020, however. Because of the lower CO_2 intensity of electricity generation, electricity generation costs will become economically favorable under the Energy [R]evolution scenario and by 2050 costs will be 2.5 €cents/kWh below those in the COM version. Under the COM scenario, the unchecked growth in demand, an increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's €324 billion per year to €355 billion in 2030 and more than €461 billion by 2050.

- **Future investments:** Until 2030 It would require about €1,754 billion in investment for the Energy [R]evolution scenario to become reality (including investments for replacement after the economic lifetime of the plants) - approximately €195 billion or €12 billion annually more than in the COM scenario (€1558 billion). The average annual investment in the power sector under the Energy [R]evolution scenario between today and 2050 would be approximately €84 billion.

- **Fuel costs savings:** The fuel cost savings in the Energy [R]evolution scenario reach a total of €1,192 billion up to 2050, or €29.8 billion per year. The total fuel cost savings based on the assumed energy price path therefore would cover the total additional investments several times over compared to the COM scenario.

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.

- **Transport**: In the transport sector, it is assumed under the Energy [R]evolution scenario that an energy demand reduction of about 6,000 PJ/a can be achieved by 2050, saving 49% compared to the COM scenario. Energy demand will therefore decrease between 2009 and 2050 by 54% to 6,200 PJ/a. In 2030, electricity will provide 12% of the transport sector's total energy demand in the Energy [R]evolution, while in 2050 the share will be 50%.
- **Development of CO_2 emissions**: While energy related CO_2 emissions in EU28 will decrease by 40% in the COM scenario, under the Energy [R]evolution scenario they will decrease by over 60% by 2030. It is important to note, that the original Commission scenario has a reduction target of 40% greenhouse gas (GHG), while the COM case calculates only energy related CO_2 emissions. Annual per capita emissions will drop from 7.2 tonne to 2.7 tonne in 2030 and 0.3 tonne in 2050. 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 in vehicles will reduce emissions in the transport sector. With a share of 18% of CO_2 emissions in 2030, the power sector will drop below transport and other sectors as the largest sources of emissions. By 2050, EU28's CO_2 emissions are 4% of 1990 levels.

fossil fuel resource analysis

GAS

OIL: QUALITATIVE ANALYSIS OF TRENDS AND PROJECTIONS

ANALYSIS OF COAL SUPPLY

URANIUM RESOURCES' - EU'S 97% DEPENDENCY ON URANIUM IMPORTS

CURRENT SUPPLY AND DEMAND IN EUROPE

image THE SCANDINAVIAN COUNTRIES, NORWAY AND SWEDEN, AND FINLAND TO THE NORTH OF THE SEA ARE STILL BLANKETED IN SNOW. FROM THE LEFT, THE COUNTRIES LINING THE BALTIC ON THE SOUTH ARE DENMARK, GERMANY, POLAND, RUSSIA (KALININGRAD), LITHUANIA, LATVIA, ESTONIA, AND RUSSIA. BELARUS FORMS THE LOWER RIGHT CORNER OF THE IMAGE.

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

Burning fossil fuels emits large amounts of CO_2 which is proven to cause climate change the science was indisputably laid out in the Fifth Assessment Report by the Intergovernmental Panel on Climate Change (IPCC)[4], which concluded that there is 95 percent certainty that human activity -- such as the burning of fossil fuels -- is the primary cause of climate change.

However, added to the worry with regards to the environment is also security of supply. Renewable energies – with the exception of bioenergy – have the fundamental advantage that they do not need any fuels which releases the EU from relying on imports from outside of its borders. Thus, one of the main drivers for the expansion of renewable energy markets should be security of supply. Currently the EU still relies for the majority of its energy needs on fossil fuel despite the dwindling local reserves and unreliable international markets that fluctuate dependent on economic and geopolitical externalities.

To better understand the current fossil fuel supplies the EU can tap into, this chapter takes an in depth view of the current fossil fuel landscape. It is based on a global fossil fuel resource analysis of Ludwig Bölkow System Analysis (LBST) for Greenpeace International which estimated the global conventional oil, gas and coal resources based on production capacities of existing oil- and gas wells and coal mines, current infrastructure as well as the investment plans known by the end of 2011. It assessed the remaining fossil fuel resources between 2012 and 2050 excluding any new deep sea and Arctic oil exploration, oil shale and tar sand mining.

The assessment is based on past and projected production volumes. The research distinguishes between resources, reserves and production dynamics:

- Resources very often have a large speculative element which has no correlation to possible production volumes. Resource estimates are by no means usable in the sense that these resources exist, or even when they exist that they have the possibility of becoming economically interesting for production one day. Nobody in a company or institute can be made responsible for a resource message which decades later turns out to be extremely unrealistic.
- Reserves have a closer correlation to potential future production volumes. However, the quality of reserve estimates still differs. It is by no means ensures that these reserves will be produced.
- The most important measure is production volumes. The dynamics between production from declining producing fields and still untouched but discovered new fields determines whether the net balance at a regional and global level will decline or rise. Despite the recent enthusiasm about rising gas resources it is a matter of fact that about half of present world gas production comes from regions where peak production happened: Europe, North America and Russia.

1.1 gas

1.1.1 qualitative analysis of trends and projections

All large gas producers in **Europe** except Norway are already in decline. Even Norway seems to be very close to peak production. It is agreed by almost all observers including IEA and Eurogas – the European gas producers association – that gas production in Europe will considerably decline by 2030 and 2035.

Conventional natural gas production peaked in the US in parallel to oil production around 1970. The development of tight gas formations – which very often are not distinguished from conventional production as the transition is smooth – helped to soften the decline. In 2010, gas production from tight gas had a share of about 30% on overall gas production. A further 10% is contributed by gas production from coal beds (CBM). However a regional analysis of coal bed methane (CBM) reservoirs and coal beds shows that peak has already been reached in the largest and most promising regions, for instance in Wyoming.

Some believe that shale gas will be a game changer. Indeed, US production from gas shale increased from below 1% in around 2000 to about 10% in 2010 This steep rise in production is taken as base for extrapolation to other shales in the USA and also in other countries around the world.

The natural gas production in **Russia** peaked in 1989 when production from the three largest fields Urengoy, Medvezhe and Yamburg peaked with a combined output of more than 90% of Russian gas production. In the meantime the decline has been stopped and reversed by the expensive development of already known fields, after the disintegration of the Soviet empire attracted new investments. However, the remaining new fields are further away from markets in geographically more challenging regions, requiring higher specific investments and longer lead times due to the short Arctic summers.

Presently, Russia faces serious challenges due to the steady decline of base production, the development of expensive new fields, a rising domestic demand and increased demand from Asia as well as Europe.

In face of these developments the industry enthusiasm for unconventional gas resources points towards serious problems with existing production infrastructure. The necessary huge investments in the development of unconventional gas resources must be interpreted as confirmation that gas production will become much more expensive than in the past – despite what is being claimed publicly.

Our scepticism with regards to shale gas resources is based on various issues:

First of all the production methods are harmful to the environment, requiring huge amounts of water, chemicals and disposal opportunities for wastewater. The fast development in the USA was only possible as the production was exempted from environmental rules (The US-EIA was excluded from monitoring and punishing violations by the Clean Energy Act in Amendment 1007, where these activities were explicitly excluded from the SWDA from 1974 and amendments).

reference
4 HTTPS://WWW.IPCC.CH/REPORT/AR5/WG1/

Still unclear:

- How will the current production volumes develop over time from existing wells as projections show that production can significantly decrease after only a very short timeframe?
- Can the USA production experiences of large quantities of shale gas actually be replicated in other regions – is this transferable to other countries?

Shale gas wells show a typical production profile with a short production period followed by a steep decline of 5 – 10% per month. The regional aggregation of individual well profiles shows that production can initially increase rapidly, with the addition of new wells. But very soon the decline of the individual wells takes the lead – new wells must be added faster and faster just to compensate for the decline. However economics has it that first developments start in the most rich areas which promise highest profits. As soon as these are developed the new well additions are smaller in production volume and lower in total output. Initally technological learning can compensate for this deficit. But as soon as the development speed of new pits decelerates so does the total output. This decline in output has already begun in the Antrim Shale (Michigan), the Barnett Shale (Texas), the Fayetteville Shale (Texas/Arkansas) and even the Haynesville shale.

The worldwide resource estimates assume huge recovery rates of around 25% of the estimated gas in place. However, the present developments in the US indicate that only 5%-10% of the gas in place may eventually be produced. But another restriction comes from the huge water requirements and the different geographic structure of these shale regions. For instance, it is very unlikely that in China, South Africa or Australia huge amounts of water (in the order of ten million litres per well and a total of several hundred thousand wells) will be allowed to be contaminated with toxic chemicals while these areas experience water scarcity already today. In addition these shales are very often far away from consumers and distribution networks while the pure economics prohibits their development; or too close to densely populated areas which immediately has the risk of strong opposition, as seen in New York, South Africa, the UK, the Netherlands, France, Germany, Austria and Bulgaria.

Finally it is often stated that by far the largest undeveloped conventional gas reserves are in Iran and in Qatar. Their development and liquefaction will result in ample supply for decades. But a closer analysis shows even here huge question marks arise. Most importantly is the often ignored fact that the huge reserves of both countries almost completely depend on one offshore field in the Arab gulf crossing the border between the two countries. The southern part in Qatar is called the North Field; the northern part in Iran is called South Pars. The size of this 6,000 km^2 field as the world's largest gas field was determined in the 1970s after its discovery by only a few exploration wells. Some years ago gas companies drilled a dry hole in an area which caste huge doubts on the reserve estimate which are still used today.

1.1.2 identification of potential regional shortfalls and bottlenecks

The gas sector is very different to the oil sector as regional markets developed where consumer and producer regions were connected by pipelines. Only a few percent of world gas production is transported in liquefied form to intercontinental destinations.

Mature areas with long lasting relations are the USA with connections to Canada and Mexico, Europe with connections to North Africa and Russia, and predominantly China. Korea and Japan are completely isolated. Their import needs are completely satisfied by LNG. Based on these structures, regional bottlenecks and inequalities between different markets are more likely to occur than with oil.

The USA is by far the largest consumer in North America and already receives imports from Canada to satisfy its needs. Based on experienced shortfalls in the early 2000s and expected rising requirements many new LNG import facilities have been planned, some of them already realized. Total US-regasification-capacitiy rose from 20 billion Nm^3/year in the year 2000 to 160 billion Nm^3/year in 2010. However three developments inverted the situation making USA for some time an exporter of LNG at very low level (~1 billion Nm^3/yr).

With regards to Europe, we believe that the decline of domestic production will set the frame for rising import needs. According to LBST, 200-300 billion cubic-meters per year [m^3/yr] must be imported additionally until 2030 in order to match an even flat demand. Shale gas developments inside Europe will only have a marginal influence on these developments. Probably also Russia will not be able to supply these quantities. Moreover, LBST believes that Russian exports to Europe will stay static and start to decline around 2020-2025. This judgement is based on the expected development:

- That Russia will struggle in increasing its gas production due to severe development problems of remaining on- and offshore fields in Yamal, Kara Sea and Barent Sea. According to our understanding it is by no means guaranteed that production will stay level until 2020-2030,
- That Russian domestic demand will rise in the future in parallel to its economic development which is based on rising profits from oil exports,
- That new consumers in Asia will be able to compete for higher prices. For instance gas pipelines from Turkmenistan – via Russia already an important gas exporter to Europe – will be much fast and cheaper build to China.

Indonesia, one of the most important LNG suppliers will also see strengthening supply problems in parallel to its declining oil production. Around 2003 Indonesia switched from an oil net exporter to a net importer. In parallel to its development the need for domestic gas supply will rise.

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.

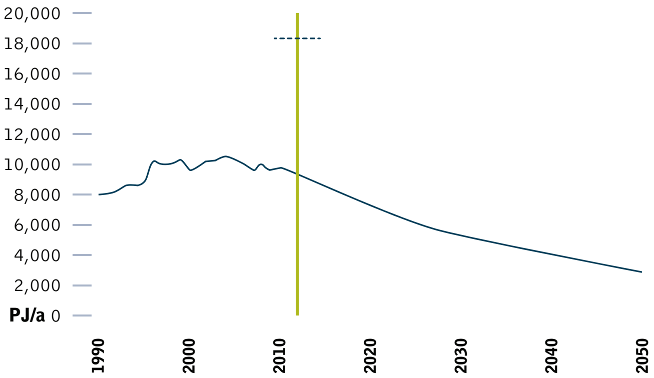
1.1.3 analysis of regional oversupply risks towards 2020

Probably the most gas rich regions over the next two decades will be Australia and Qatar. Their potential to increase production and exports will depend on their ability to ramp up liquefaction plants and export terminals.

1.1.4 gas production in the EU between 1990 and 2010 and a projection until 2050

Based on the analysis the European production development shown in Figure 1.1 (see below) has been calculated. We can see that the EU's own production can satisfy less than half of its current needs. It is worth noting that the EU's real production volumes are even lower because imported gas is in many cases cheaper than domestic production.

figure 1.1: gas-production 1990-2010 and projection until 2050 for europe



GAS-PRODUCTION 1990-2010 AND PROJECTION UNTIL 2050 FOR EUROPE

EU GAS DEMAND 2013

1.2 oil

1.2.1 qualitative analysis of trends and projections

According to the Ludwig Bölkow System Analysis (LBST), it is very likely that world oil production has been at peak since 2005 as conventional oil production started to decline since then. Only the inclusion of heavy oil and tars production in Canada and of natural gas liquids (NGL) production from various countries helped to keep total production since 2005 constant. Oil production from tight oil supplies in the US played a minor role, though it helped to invert the US oil production decline into a rise for a few years. However, due to the nature of these oil sources, we believe that the impact will be limited to a few years.

Further inclusion of so called refinery gains or processing gains (volume and energy gains during the refining process by hydration of hydrocarbons with hydrogen predominantly produced from natural gas) and of biofuels (predominantly from Brazil, USA, Europe and Indonesia) helped to still increase total production of "all liquids" according to statistics from the US Energy Information Administration (EIA) or International Energy Agency (IEA).

LBST sees a plausible scenario in an annual decline of world oil production of between 2-3%. This would result in roughly 50% decline of world oil availability in 2030 with corresponding consequences.

1.2.2 identification of potential regional short falls and bottlenecks

The world can be split into oil importing and oil exporting countries. Oil importing countries are vulnerable to supply deficits with serious impact on the country's infrastructure, almost all forms of transport and – partly as a result – to the economy. Regions with adequately established urban quarters will see advantages over those regions where the daily consumption pattern highly depends on individual motorized transport. Therefore short distances between daily destinations and well established public transport modes will help to soften the impact of oil scarcity considerably. This holds even more for the transport and distribution of produced goods. Regions where the GDP depends by a large share on the production of goods which strongly depend on oil availability (e.g. inefficient large cars) and on large goods with low volume specific prices will encounter larger problems than others.

For instance, economic powerful islands like Japan or South Korea, but also countries like USA which are used to low almost tax exempted gasoline prices, might be hit strongest.

1.2.3 analysis of regional oversupply risks towards 2020

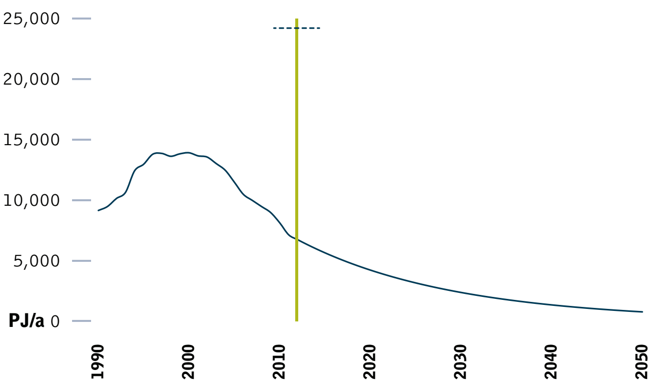
The above described situation will be mirrored by oil exporting countries which at a first glance will not have problems with rising oil prices – even when the export volumes decline. Predominantly this includes the Middle East Opec countries and Russia. However, oversupply risks cannot be identified even in exporting countries, except when the demand shrinks faster than the production capacities due to a recession.

It seems likely that the downturn of world oil production will be characterised by oil price fluctuations induced by variable economic prosperity whenever declining production volumes set a ceiling for economic growth as long as this growth induces a rising oil demand.

1.2.4 oil production in the EU between 1990 and 2010 and a projection until 2050

Based on the analysis the European production development shown has been calculated. The figure 1.2 (see below) shows the remaining production capacities and the additional production capacities assuming all new projects planned for 2012 till 2020 will go ahead. Even with new projects, the amount of remaining conventional oil is very limited and therefore a transition towards a low oil demand pattern is essential.

figure 1.2: oil-production 1990-2010 and projection until 2050 for europe



1.3 hard coal

1.3.1 qualitative analysis of trends and projections

Compared to hydrocarbons, coal reserves and resources seem to be ample. However some aspects create serious doubts on this view:

- World Coal reserves have been downgraded over the last decades several times and have in reality declined by some 50% since 1987;
- The static Reserve-to-Production ratio, which often is seen as a measure for sufficient reserves declined from 450 years in 1987 to less than 120 years in 2010;
- Reserve reporting practice casts doubts on the relevance and reliability of these numbers;
- Only about 10% of world coal consumption is imported from abroad;
- The USA, China and India which together are home to more than 50% of global coal reserves are among the largest consumers. China switched from a coal exporting country to the world's largest coal importer with almost 200 million tonnes in 2011.

Based on this analysis it can be expected that further rising coal production probably will come to an end within the next one to two decades, based on geological restrictions and not assuming voluntary restrictions based on climate change politics.

Lignite, which is also referred to as brown coal, should be considered separately. It has not been included in the LBST analysis. Due to its low energy and large water content it doesn't play a role in export markets. But in Germany, for example, lignite has been playing an important role in recent years. The shutdown of German nuclear power plants in Germany was counteracted by rising share of renewable electricity production in combination with rising contribution from lignite. It could be expected that these trends continue when European gas production declines and imported gas quantities are too small to allow gas power plants to play the role of a bridging technology to compensate for strong power fluctuations, according to LBST.

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

1.3.2 identification of potential regional shortfalls and bottlenecks

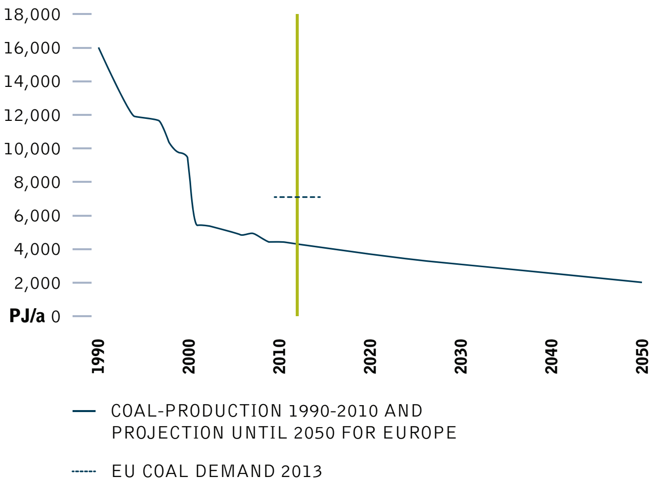
Probably the most stressed coal supply/demand patterns are in Asia, predominantly China and India. Both see a steeply rising demand while the domestic supply cannot keep pace, requiring ever larger imports.

Some arguments point on missing internal infrastructure in China to transport domestic coal to the consumer sites. It was easier to import coal by ship from abroad to the energy intense industrial sites in Eastern China along the coast line. However it seems that coal production in China more relies increasingly on three provinces: Inner Mongolia, Shanxi and Shaanxi.

Future Chinese import needs will determine whether other Asian coal importers will run into trouble to satisfy their needs of large coal imports which predominantly come from Indonesia (steam coal), Australia (largest exporter of metallurgic coal and second largest exporter of steam coal), South Africa (which more and more directs its exports from Europe to Asia), Colombia (which in 2011 for the first time exported coal to India) and Eastern CIS countries.

South Africa already faces coal supply risks and bottlenecks. Most experts assign this to transport and infrastructure developments. However, it also seems that declining coal supply quality forced utilities to run their power plants with lower efficiencies as the energetic throughput of the coal was not in line with the plant layout.

figure 1.3: coal-production 1990-2010 and projection until 2050 for europe



1.3.3 coal production in the EU between 1990 and 2010 and a projection until 2050

Based on the LBST analysis the European production development shown in Figure 1.3 (see below) has been calculated. As opposed to the global resource, the EU's economic hard coal resources are in decline and during the last decade coal has become an import fuel. Even in traditional coal mining areas such as Poland, the resource is in decline.

1.4 uranium

Under the Euratom Treaty, a common nuclear market was created. Euratom established the European Supply Agency (ESA) with the mandate to ensure the security of supply of nuclear fuels to nuclear utilities in the EU. The Euratom Treaty requires the ESA to be a party to supply contracts. The ESA also monitors all uranium transactions. This common market marks a formal distinction with the fossil fuel markets.

One of ESA's monitoring functions is to publish an annual report which gives an overview of the origins of the uranium used in the EU. Its publication from 2012 shows that the EU depends on 97.3% on imports with 82% of these coming from only five countries.[5] In those countries, uranium mining has had a disruptive impact on local communities and the environment.

In 2009, Greenpeace conducted scientific research in the area of Arlit in Niger,[6] exposing the environmental pollution and radioactive contamination created by the Uranium mining. In the streets of the local village of Akokan radiation dose rate levels were found to be up to almost 500 times higher than normal background levels. A person spending less than one hour a day at that location would be exposed to more than the maximum allowable annual dose.

Niger has the lowest human development index on the planet. This is in sharp contrast with the profits generated by the French state-owned company Areva in Niger over the last 40 years through its environmentally destructive uranium mining. Areva's activities have also fueled local unrest and conflicts with the Tuareg population, thereby also threatening the supply from the area.

Uranium mining is also threatening local communities in countries such as Canada or Australia, especially endangering the health of indigenous peoples.

references

5 HTTP://EC.EUROPA.EU/EURATOM/AR/LAST.PDF
6 HTTP://WWW.GREENPEACE.ORG/INTERNATIONAL/EN/NEWS/BLOGS/NUCLEAR-REACTION/LEFT-IN-THE-DUST-AREVAS-URANIUM-MINING-IN-NIG/BLOG/11734/

1.5 current supply and demand in europe

The recent 'European Energy Security Strategy' published by the European Commission in May 2014 outlines the EU's fossil fuel production and the state of energy security for all member states.[7]

1.5.1 EU primary energy production

According to the report, the EU's primary energy production decreased by almost a fifth between 1995 and 2012. In this period natural gas production dropped by 30%, production of crude oil and petroleum went down by 56% and of solid fuels (including coal) by 40%. On the other hand renewable energy production registered a remarkable growth – 9% in two years between 2010-2012 – and has reached a 22% share of primary energy production.

The Netherlands and the UK are the largest producers of natural gas in the EU and in 2012 respectively accounted for 43% and 26% of gas production in the EU; the third and fourth producers – Germany and Romania – have a 7% and 6.5% share of natural gas production in the EU. The UK is the largest producer of crude oil in the EU with a 61% share in 2012; Denmark is the second largest producer with a 14% share.

1.5.2 imports and energy deficit of the EU

Despite the growth in renewable energy production, the EU has been importing growing amounts of energy to compensate for declining domestic production and meet demand that until 2006 was steadily growing. Overall EU import dependency has increased, mostly driven by growth in import dependency of natural gas (+6 p.p in the period 1995-2012) and crude oil (+3 p.p. in the same period).

The EU relies on 53% of imports for its energy use. Energy import dependency is most pronounced in relation to crude oil (almost 90%) and natural gas (66%), and less pronounced in relation to coal (42%) and nuclear fuel (40%). The EU spends more than €1 billion per day (around €400 billion in 2013) on energy imports.

Since import dependency is a function of net imports and total demand any drop in production would result in an increase in imports. If this drop in production is faster than the decrease in demand, this would result in increasing import dependency against falling demand. While import dependency points to the relative share of imports in demand (in %), the net imports – showing the total energy deficit - denotes the absolute volumes of energy that the European economy needs to import (in energy terms), that is the difference between total demand and total production. Since the peak in 2006-2008, the net imports have decreased – largely driven by fall and shift of consumption; still net imports in 2012 were at 25% above its 1995 levels.

1.5.3 great differences among member states

The aggregated EU-level numbers hide a great deal of differences between Member States. In Member States with indigenous energy production, the share of production to total demand has decreased – in the case of the UK by half from its peak, in the case of Denmark and Poland by 30-40% and in the case of the Netherlands by more than 15%. Estonia is the only Member State that has seen a stable and significant increase in the share of domestic production in total energy demand against a stable growth in demand. As a result, the net imports of most Member States have increased. Nowhere is this more visible than in the UK, which had an energy surplus until 2003 and a steeply growing deficit ever since. France, Spain and Italy have all seen energy deficits peak in 2005 and go down ever since, likely driven by a combination of weak demand and increased renewables share. The deficit of the largest energy consumers in the EU – Germany – has unsurprisingly been the largest in energy terms and since its peak in 2001 has shown fluctuations in both directions, without a stable trend.

reference

7 COMMUNICATION FROM THE COMMISSION TO THE COUNCIL AND THE EUROPEAN PARLIAMENT EUROPEAN ENERGY SECURITY STRATEGY COM(2014) 330 FINAL); BRUSSELS/BELGIUM 28TH MAY 2014 HTTP://EC.EUROPA.EU/ENERGY/DOC/20140528_ENERGY_SECURITY_COMMUNICATION.PDF

energy [r]evolution: the EU energy independence pathway for europe

ASSUMPTIONS AND METHODOLOGY

KEY RESULTS OF THE ENERGY [R]EVOLUTION ENERGY INDEPENDENCE PATHWAY

"almost half of europe's energy supply could come from renewables by 2030"

image PROMINENT IN THE CENTER OF THE IMAGE ARE THE CURVING, DARK GREEN CARPATHIAN MOUNTAINS, WHICH START IN THE CZECH REPUBLIC AND CURVE TOWARD THE SOUTHEAST INTO ROMANIA. IN CENTRAL ROMANIA, THE CARPATHIANS RUN INTO THE EASTERN END OF THE TRANSYLVANIAN ALPS, WHICH RUN HORIZONTALLY ACROSS THE COUNTRY TO THE SERBIAN BORDER.

Moving from principles to action for ensuring energy supply that achieves all environmental, economic and security objectives requires a long-term perspective. Energy infrastructure takes time to build up; new energy technologies take time to develop. Policy shifts often also need many years to take effect. Any analysis that seeks to tackle energy and environmental issues therefore needs to look ahead at least several decades. The energy scenarios described in the following chapter outline how this can be achieved.

Scenarios help to describe possible development paths, to give decision-makers a broad overview and indicate how far they can shape the future energy system. Two scenarios are used here to demonstrate two possible pathways for a future energy supply system:

- A Commission scenario (COM) reflecting the recent proposal by the European Commission for a 2030 climate and energy framework;
- An updated high efficiency Energy [R]evolution scenario (E[R]) reflecting Greenpeace's demands for a 2030 climate and energy targets, including steep cuts in energy-related carbon emissions to achieve a 95% reduction by 2050, as well as a complete phase-out of nuclear power.

2.1 assumptions and methodology

The scenarios in this report were commissioned by Greenpeace from the Systems Analysis group of the Institute of Technical Thermodynamics, part of the German Aerospace Center (DLR). The supply scenarios were calculated using the MESAP/PlaNet simulation model adopted in the previous Energy [R]evolution studies.[8] The future development pathway for car technologies is based on a special report produced in 2012 by the Institute of Vehicle Concepts, DLR for Greenpeace International.

2.1.1 assumptions for the commission scenario (COM) used as a reference scenario

This scenario was calculated on the basis of data published by the European Commission in the Impact Assessment accompanying its Communication on 2030 climate and energy targets.[9]
It broadly reflects the Commission's "GHG40" scenario within that Impact Assessment, which presents the numbers underlying the Commission's 2030 proposal.

The most important assumptions were drawn from the PRIMES scenario model and adjusted to the MESAP/PlaNet model which is used for the calculation of the Energy [R]evolution scenarios. The results of the MESAP model in terms of energy mix, energy demand developments and CO_2 reduction pathways are similar to the GHG40 scenario but – due to the different modeling approach – not entirely identical.[10] However, they are the closest-possible representation of the Commission's GHG40 scenario. Especially the sector specific results can differ from GHG40. In this publication this scenario – which is used as a reference case of the Energy [R]evolution – is called "COM".

2.1.2 assumptions for the energy [r]evolution scenario

This latest edition of the Greenpeace Energy [R]evolution scenario for the EU includes significant efforts to fully exploit the large potential for energy efficiency, using currently available best practice technology. At the same time, all cost-effective renewable energy sources are used for heat and electricity generation as well as the production of biofuels.[11]

In the transport sector, energy demand decreases due to a change in driving patterns and a rapid uptake of efficient combustion vehicles and increasing use of electric and plug-in hybrid vehicles after 2025. The use of biofuels for private vehicles follows the latest scientific reports that indicate that biofuels might have higher a greenhouse emission footprint than fossil fuels.

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

references

8 'ENERGY [R]EVOLUTION: A SUSTAINABLE WORLD ENERGY OUTLOOK', GREENPEACE INTERNATIONAL, 2007 AND 2008.
9 HTTP://EUR-LEX.EUROPA.EU/LEGAL-CONTENT/EN/TXT/PDF/?URI=CELEX:52014SC0015&FROM=EN
10 UNDER GHG40, THE EU'S PRIMARY ENERGY CONSUMPTION (WITHOUT NON-ENERGY USES) IN 2030 IS 1413 MTOE, THE SHARE OF RENEWABLE ENERGY IN FINAL ENERGY CONSUMPTION IS 24.8%. UNDER COM, PRIMARY ENERGY CONSUMPTION IS 1436 MTOE, THE SHARE OF RENEWABLE ENERGY IS 26.5%.
11 A LOWER RATE OF ENERGY SAVINGS WOULD OBVIOUSLY REQUIRE LARGER PRODUCTION OF RENEWABLE ENERGY IN ORDER FOR THE EU TO CONTRIBUTE ITS FAIR SHARE OF GLOBAL EMISSION REDUCTIONS. SEE THE ANNEX FOR A SCENARIO BASED ON HIGHER ENERGY DEMAND AND THEREFORE A HIGHER EXPANSION OF RENEWABLE TECHNOLOGIES.

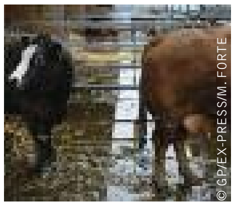


image COWS FROM A FARM WITH A BIOGAS PLANT IN ITTIGEN BERN, SWITZERLAND. THE FARMER PETER WYSS PRODUCES ON HIS FARM WITH A BIOGAS PLANT, GREEN ELECTRICITY WITH DUNG FROM COWS, LIQUID MANURE AND WASTE FROM FOOD PRODUCTION.

In all sectors, the latest market development projections of the renewable energy industry[12] have been taken into account. The fast introduction of electric vehicles, combined with the implementation of smart grids and fast expansion of super grids allows a high share of fluctuating renewable power generation (photovoltaic and wind) to be employed.

The efficiency pathway of this latest Energy [R]evolution scenario is based on research from the Fraunhofer Institute for Systems and Innovation Research (Fraunhofer ISI) published in 2013.[13] According to the study, the EU has a 41% cost-effective end-use energy savings potential for 2030. By tapping this potential, the EU would, by 2030, reap the wide-ranging economic, social and financial benefits of energy savings, including:

- Reducing greenhouse gas (GHG) emissions by between 49-61% compared to 1990 levels, enabling the EU to step up its fight against climate change and to keep on track for its 2050 climate change target of a GHG reduction of 80-95% compared to 1990 levels.
- Boosting its competitiveness through lower energy costs, increased industrial efficiency and a stronger demand for domestic products and services. Households and industry would receive net benefits of €240 billion annually by 2030 and of about €500 billion by 2050 in lower energy bills.

The study concludes that a 'GHG target' only approach to 2030 would fail to stimulate additional energy savings and neglect an important opportunity to curb energy waste and excessive spending on energy imports.

Compared to the EU27 Energy [R]evolution scenario published in 2012, higher assumptions for energy savings imply a lower expansion of renewable energy but achieve a higher level of CO_2 emission reductions.

population development Future population development is an important factor in energy scenario building because population size affects the size and composition of energy demand, directly and through its impact on economic growth and development.

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

Prospects for GDP growth have decreased considerably since the previous study, due to the financial crisis at the beginning of 2009, although underlying growth trends continue much the same. GDP growth of the EU has been down scaled from 1.8% between 2010 and 2050 to 1.1%. GDP projections are based on the PRIMES model for the EU 28 and assume a growth by around 0.6% between 2010 and 2020 and 1.2% between 2020 and 2035.

table 2.1: population development in the EU 28 2010 - 2050 (IN MILLIONS)

	2010	2015	2020	2025	2030	2040	**2050**
EU 28	505	511	515	518	520	519	**515**

source UNEP WORLD POPULATION PROSPECT 2010.

table 2.2: GDP development projections in the EU 28 2010 - 2050

	2010-2020	2020-2035	2035-2050	**2010-2050**
EU 28	0.6%	1.2%	1.2%	**1.1%**

source IEA WORLD ENERGY OUTLOOK 2011.

references
12 SEE EREC, RE-THINKING 2050, GWEC, EPIA ET AL.
13 HTTP://ENERGYCOALITION.EU/SITES/DEFAULT/FILES/FRAUNHOFER%20ISI_REFERENCETARGETSYSTEMREPORT.PDF

2.1.3 oil and gas price projections

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

Since the first Energy [R]evolution study was published in 2007, the actual price of oil has moved over €83/bbl for the first time, and in July 2008 reached a record high of more than €116/bbl. Although oil prices fell back to €83/bbl in September 2008 and around €66/bbl in April 2010, prices increased to more than €91/bbl in early 2012. Thus, the projections in the IEA Current Policies scenario might still be considered too conservative. Taking into account the growing global demand for oil we have assumed a price development path for fossil fuels slightly higher than the IEA WEO 2011 "Current Policies" case extrapolated forward to 2050 (see Table 2.3).

table 2.3: development projections for fossil fuel and biomass prices in € 2010

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

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

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

A detailed list of assumed investment costs for power generation as well as operation and maintenance costs can be found in previous energy scenarios.[14]

The Energy [R]evolution by no means claims to predict the future; it simply describes a potential development pathway out of the broad range of possible 'futures'. It is designed to indicate the efforts and actions required to achieve ambitious objectives and to illustrate the options Europe has at hand to change its energy supply system into one that is truly sustainable. The political change necessary to achieve the Energy [R]evolution is not part of this analysis.

reference
14 HTTP://WWW.ENERGYBLUEPRINT.INFO/FILEADMIN/MEDIA/DOCUMENTS/2013/0113_GPI_E_R__POLAND_07_LR.PDF

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

2.2 key results of the energy [r]evolution EU energy independence pathway

2.2.1 EU28: energy demand by sector

The future development pathways for Europe's energy demand are shown in Figure 2.1 for the COM and the Energy [R]evolution scenario with the advanced energy efficiency pathway. Under the COM scenario, total primary energy demand in EU28 decreases by -20% from the current 72,300 PJ/a to 57,841 PJ/a in 2050. The energy demand in 2030 in the Energy [R]evolution scenario decreases by 40% compared to current consumption and it is expected by 2050 to reach 37,900 PJ/a.

Under the Energy [R]evolution scenario, electricity demand in the industry as well as in the residential and service sectors is expected to decrease after 2015 (see Figure 2.2). Because of the growing shares of electric vehicles, heat pumps and hydrogen generation however, electricity demand increases to 2,519 TWh in 2030 and 2,673 TWh/a in 2050, 27% below the COM case. Efficiency gains in the heat supply sector are larger than in the electricity sector. Under the Energy [R]evolution scenario, final demand for heat supply can even be reduced significantly (see Figure 2.3). Compared to the COM scenario, consumption equivalent to 4,060 PJ/a is avoided through efficiency measures by 2050. As a result of energy-related renovation of the existing stock of residential buildings, as well as the introduction of low energy standards and 'passive houses' for new buildings, enjoyment of the same comfort and energy services will be accompanied by a much lower future energy demand.

figure 2.1: development of total final energy demand by sector in the energy [r]evolution scenario (high efficiency)

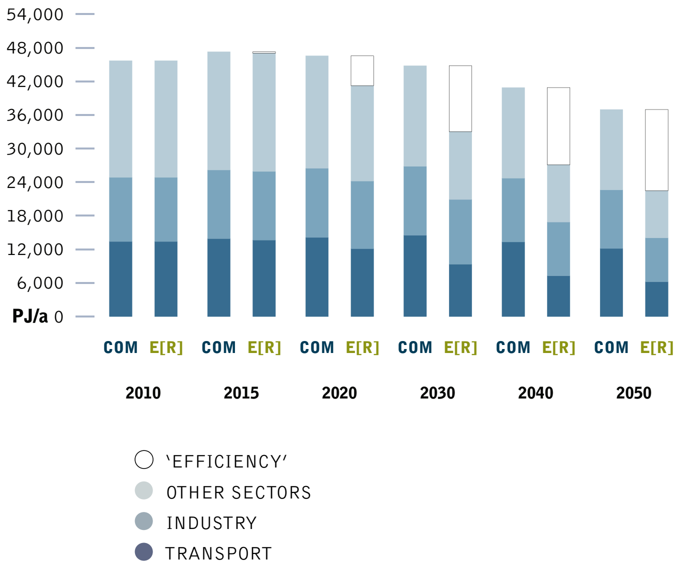


figure 2.2: development of electricity demand by sector in the energy [r]evolution scenario (high efficiency)

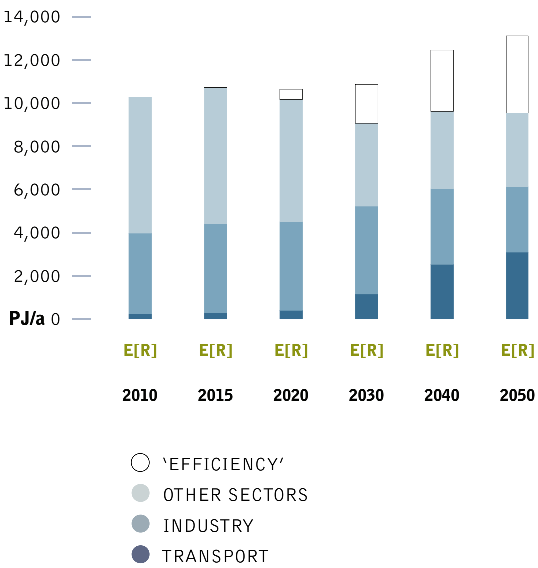
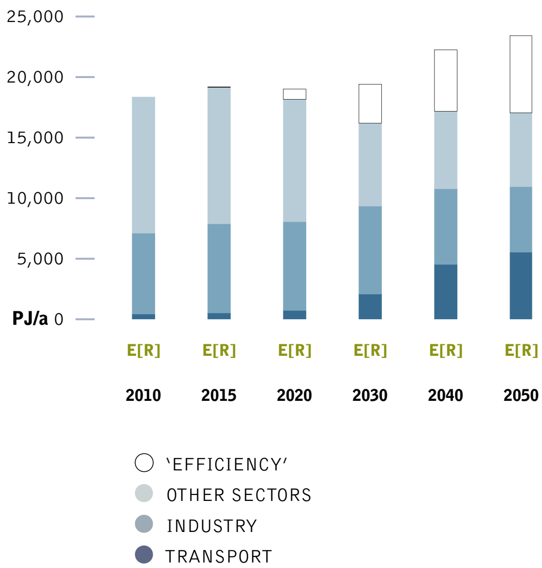


figure 2.3: development of heat demand by sector in the energy [r]evolution scenario (high efficiency)



2.2.2 EU28: electricity generation

The development of the electricity supply market is characterized by a dynamically growing renewable energy market. This will compensate for the phasing out of nuclear energy and reduce the number of fossil fuel-fired power plants required for grid stabilisation. By 2050, 95% of the electricity produced in EU28 will come from renewable energy sources. 'New' renewables – mainly wind, solar thermal energy and PV – will contribute 76% of electricity generation. The Energy [R]evolution scenario projects an immediate market development with high annual growth rates achieving a renewable electricity share of 44% across Europe already by 2020 and 75% by 2030. The installed capacity of renewables will reach 907 GW in 2030 and 1211 GW by 2050.

Table 2.4 shows the comparative evolution of the different renewable technologies in EU28 over time. Up to 2020 hydro and wind will remain the main contributors of the growing market share. After 2020, the continuing growth of wind will be complemented by electricity from biomass, photovoltaic and solar thermal (CSP) energy. The Energy [R]evolution scenario will lead to a high share of fluctuating power generation sources (photovoltaic, wind and ocean) of 58% by 2030, therefore the expansion of smart grids, demand side management (DSM) and storage capacity e.g. from the increased share of electric vehicles will be used for a better grid integration and power generation management.

The import of reliably available solar thermal power from Middle East and North Africa of around 400 TWh/a by 2050 will contribute significantly to the supply and the load balancing in the European energy system.

table 2.4: renewable electricity generation capacity under the COM scenario and the energy [r]evolution scenario (high efficiency) IN GW

		2010	2020	2030	2040	2050
Hydro	COM	147	156	170	178	186
	E[R]	147	152	152	153	154
Biomass	COM	23	29	41	49	63
	E[R]	23	36	56	61	59
Wind	COM	83	188	383	454	519
	E[R]	83	270	477	546	569
Geothermal	COM	1	2	2	3	4
	E[R]	1	6	19	38	42
PV	COM	23	130	171	216	303
	E[R]	23	170	277	336	406
CSP	COM	0	2	4	5	6
	E[R]	0	7	22	54	68
Ocean energy	COM	0	0	2	7	12
	E[R]	0	3	10	28	32
Total	**COM**	**277**	**507**	**772**	**912**	**1,093**
	E[R]	**277**	**607**	**907**	**1,103**	**1,211**

figure 2.4: electricity generation structure under the COM and the energy [r]evolution scenario (high efficiency)

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

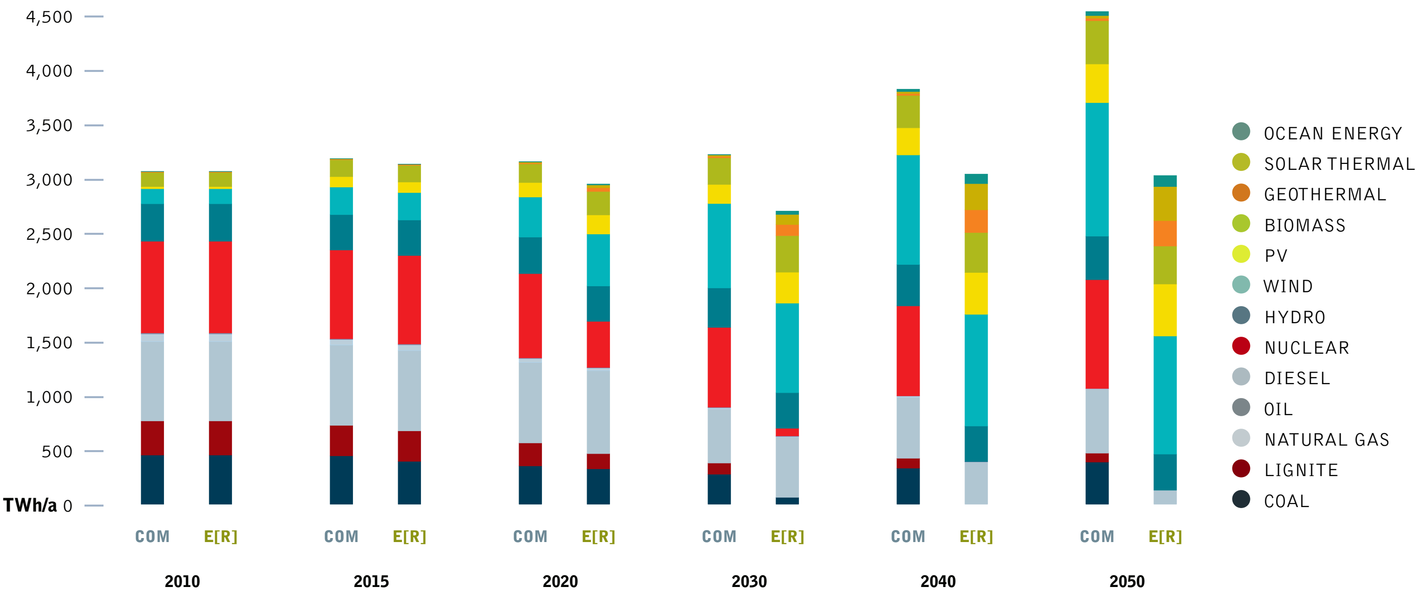


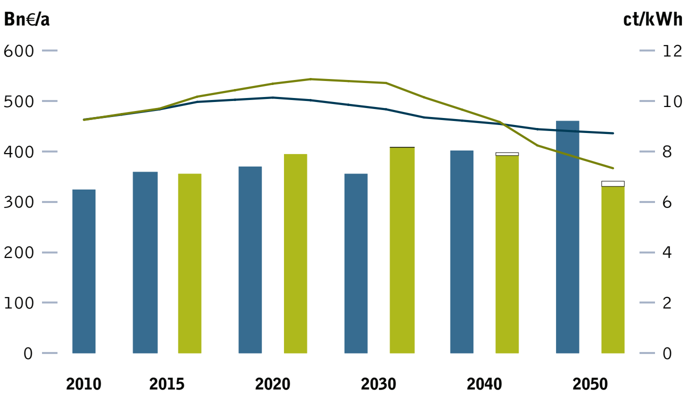
image AERIAL VIEW OF THE WORLD'S LARGEST OFFSHORE WINDPARK IN THE NORTH SEA HORNS REV IN ESBJERG, DENMARK.

2.2.3 EU28: future costs of electricity generation

Figure 2.5 shows that the introduction of renewable technologies under the Energy [R]evolution scenario slightly increases the generation costs of electricity generation in EU28 compared to the COM scenario. This difference will be less than 0.7 €cents/kWh up to 2020. Because of the lower CO_2 intensity of electricity generation, electricity generation costs will become economically favorable under the Energy [R]evolution scenario and by 2050 costs will be 2.5 €cents/kWh below those in the COM version.

Under the COM scenario, an increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's €324 billion per year to €355 billion in 2030 and more than €461 billion by 2050. Figure 2.5 shows that the Energy [R]evolution scenario not only complies with EU28's CO_2 reduction targets but also helps to stabilize energy costs. Increasing energy efficiency and shifting energy supply to renewables leads to long term costs for electricity supply that are 33% lower than in the COM scenario, although costs for efficiency measures of up to 3 €ct/kWh are taken into account.

figure 2.5: development of total electricity supply costs & of specific electricity generation costs



2.2.4 EU28: future investments

Up until 2030 an investment of €1,754 billion would be required to make the Energy [R]evolution scenario a reality in the power sector (including investments for replacement after the economic lifetime of power plants) - approximately €195 billion or €12 billion annually more than in the COM scenario (€1,558 billion).

Under the COM version, the levels of investment in conventional power plants add up to almost 30% while some 70% would be invested in renewable energy and cogeneration (CHP) until 2050. Under the Energy [R]evolution scenario, the EU28 would shift almost 95% of the entire investment towards renewables and cogeneration. Until 2030, the fossil fuel share of power sector investment would be focused mainly on CHP plants.

The total investment would increase until 2050 to of €3,369 billion under the Energy [R]evolution scenario compared to €3,243 billion under the COM scenario. The average annual investment in the power sector would be similar under both scenarios - €84 billion under the Energy [R]evolution scenario and €81 billion under the COM scenario.

Because renewable energy has no fuel costs, however, the fuel cost savings in the Energy [R]evolution scenario compared to the COM case reach a total of €1,192 billion up to 2050, or €29.8 billion per year, see also Chapter 3.3.

2.2.5 EU28: heat supply

Renewables currently provide 15% of EU28's energy demand for heat supply, the main contribution coming from the use of biomass. The lack of district heating networks is a severe structural barrier to the large scale utilisation of geothermal and solar thermal energy. In the Energy [R]evolution scenario, renewables provide 47% of EU28's total heat demand in 2030 and 91% in 2050.

- Energy efficiency measures can decrease the current total demand for heat supply by at least 20%, in spite of growing population and economic activities and improving living standards.
- For direct heating, solar collectors, biomass/biogas as well as geothermal energy are increasingly substituting for fossil fuel-fired systems.
- The introduction of strict efficiency measures e.g. via strict building standards and ambitious support programs for renewable heating systems are needed to achieve economies of scale within the next 5 to 10 years.

Table 2.5 shows the development of the different renewable technologies for heating in EU28 over time. Up to 2020 biomass will remain the main contributor of the growing market share. After 2020, the continuing growth of solar collectors and a growing share of geothermal heat pumps will reduce the dependence on fossil fuels.

table 2.5: projection of renewable heating capacity under the COM and the energy [r]evolution scenario (high efficiency)

		2010	2020	2030	2040	2050
Biomass	COM	2,978	3,315	3,979	4,563	4,924
	E[R]	2,978	3,369	3,396	3,142	2,912
Solar collectors	COM	62	101	207	468	898
	E[R]	62	850	2,665	4,291	5,430
Geothermal	COM	62	130	317	280	418
	E[R]	62	994	2,754	4,512	5,695
Hydrogen	COM	0	0	0	0	0
	E[R]	0	0	2	81	493
Total	**COM**	**3,102**	**3,545**	**4,503**	**5,311**	**6,239**
	E[R]	**3,102**	**5,212**	**8,818**	**12,025**	**14,530**

figure 2.6: development of total final energy demand by sector under the COM and the energy [r]evolution scenario (high efficiency)

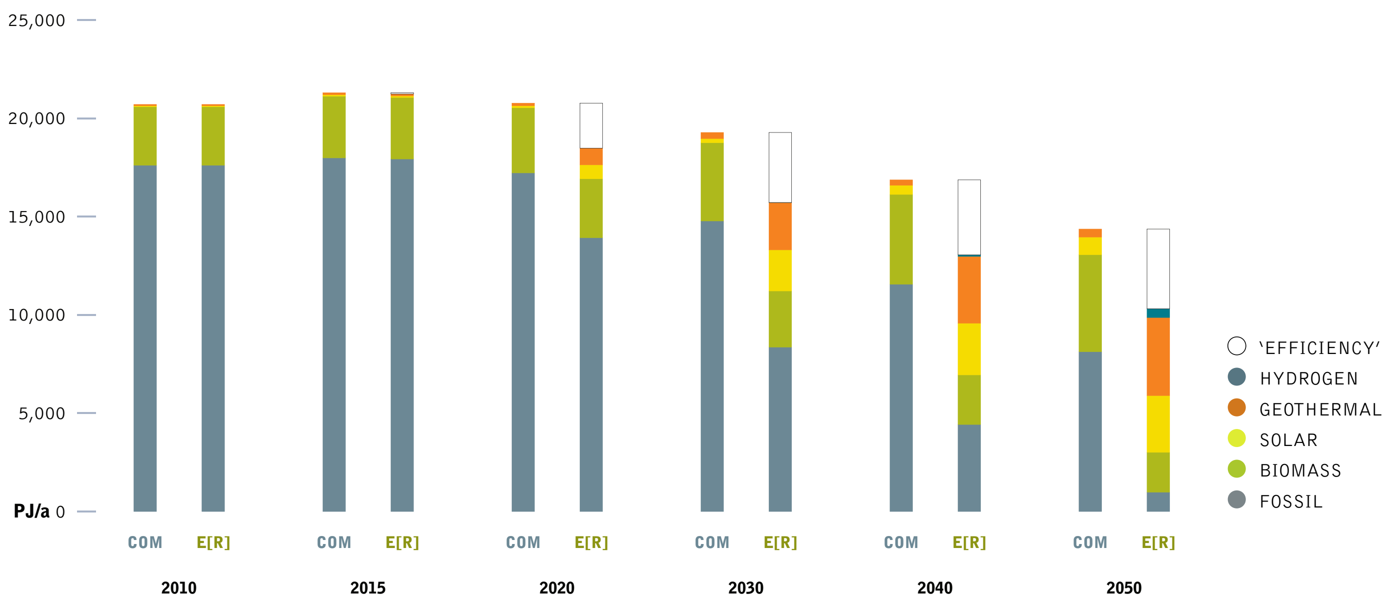


image ANDASOL 1 SOLAR POWER STATION IS EUROPE'S FIRST COMMERCIAL PARABOLIC TROUGH SOLAR POWER PLANT. IT WILL SUPPLY UP TO 200,000 PEOPLE WITH CLIMATE-FRIENDLY ELECTRICITY AND SAVE ABOUT 149,000 TONNES OF CARBON DIOXIDE PER YEAR COMPARED WITH A MODERN COAL POWER PLANT.

2.2.6 EU28: transport

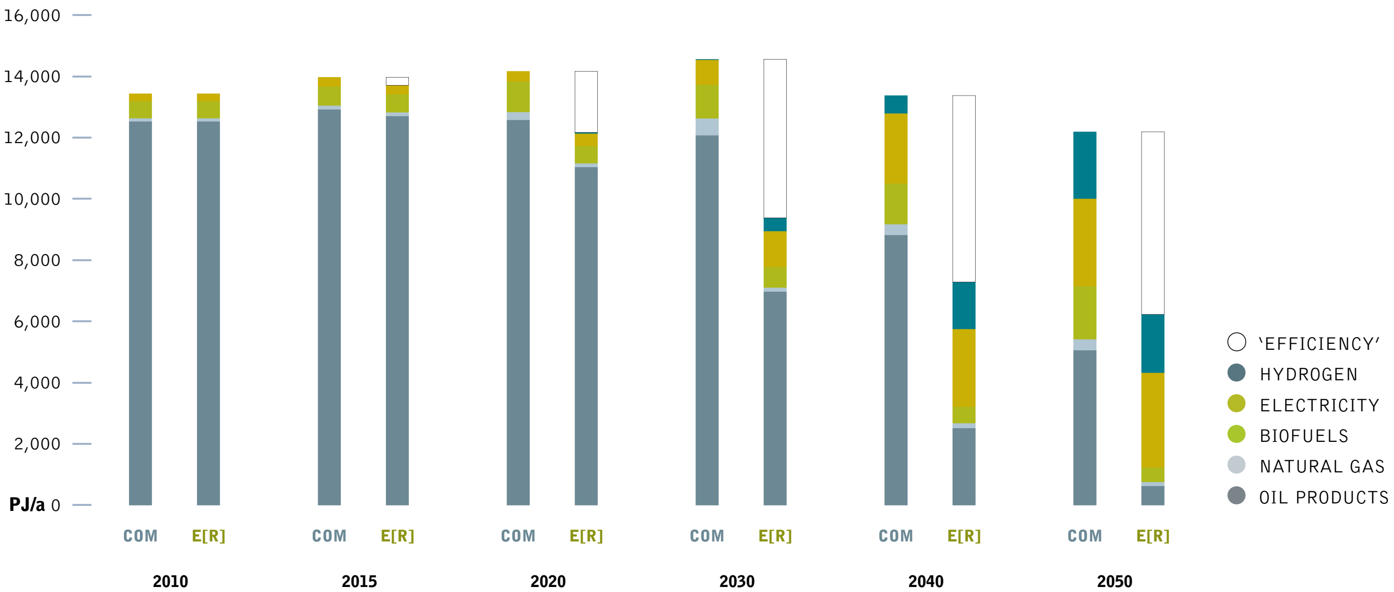
In the transport sector, it is assumed under the Energy [R]evolution scenario that an energy demand reduction of about 6,000 PJ/a can be achieved by 2050, a saving of 49% compared to the COM scenario. Energy demand will therefore decrease between 2009 and 2050 by 54% to 6,200 PJ/a. This reduction can be achieved by the introduction of highly efficient vehicles, by shifting the transport of goods from road to rail and by changes in mobility-related behavior patterns. Implementing a mix of increased public transport as attractive alternatives to individual cars, the car stock is growing slower and annual person kilometers are lower than in the COM scenario.

A shift towards smaller cars triggered by economic incentives together with a significant shift in propulsion technology towards electrified power trains and the reduction of vehicle kilometers travelled lead to significant energy savings. In 2030, electricity will provide 12% of the transport sector's total energy demand in the Energy [R]evolution, while in 2050 the share will be about 50%.

table 2.6: projection of transport energy demand by mode in the COM and the energy [r]evolution scenario (high efficiency)

		2010	2020	2030	2040	2050
Rail	COM	366	397	422	401	378
	E[R]	366	408	451	549	632
Road	COM	12,494	13,000	13,217	12,061	10,926
	E[R]	12,494	11,039	8,246	6,131	5,067
Domestic aviation	COM	279	432	552	574	577
	E[R]	279	408	403	364	326
Domestic navigation	COM	249	276	298	274	250
	E[R]	249	255	234	212	189
Total	**COM**	**13,388**	**14,105**	**14,490**	**13,310**	**12,131**
	E[R]	**13,388**	**12,110**	**9,333**	**7,255**	**6,214**

figure 2.7: development of total transport energy demand by fuel under the COM and the energy [r]evolution scenario (high efficiency)



2.2.7 EU28: primary energy consumption

Taking into account the assumptions discussed above, the resulting primary energy consumption under the Energy [R]evolution scenario is shown in Figure 2.8. Compared to the COM scenario, overall primary energy demand will be reduced by around 40% in 2030. Around 48% of the remaining demand will be covered by renewable energy sources (including non-energy use).

The Energy [R]evolution version reduces coal and oil significantly faster than the EC. This is made possible mainly by the replacement of coal power plants with renewables and a faster introduction of very efficient electric vehicles in the transport sector to replace oil combustion engines. This leads to an overall renewable primary energy share of 48% in 2030 and 92% in 2050. Nuclear energy is phased out just after 2030.

2.2.8 EU28: development of CO_2 emissions

Overall CO_2 emissions in EU28 will decrease by 40% until 2030 in the COM scenario (compared to 1990). Under the Energy [R]evolution scenario emissions will decrease by over 60% over the same period. Annual per capita emissions will drop from 7.2 tonne to 2.7 tonne in 2030 and 0.3 tonne in 2050. In spite of the phasing out of nuclear energy and increasing power demand, CO_2 emissions will decrease in the electricity sector. In the long run efficiency gains and the increased use of renewable electricity in vehicles will reduce emissions in the transport sector. With a share of 18% of CO_2 emissions in 2030, the power sector will drop below transport and other sectors as the largest sources of emissions. By 2050, EU28's CO_2 emissions are 4% of 1990 levels.

figure 2.9: development of CO_2 emissions by sector under the energy [r]evolution scenario (high efficiency)

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

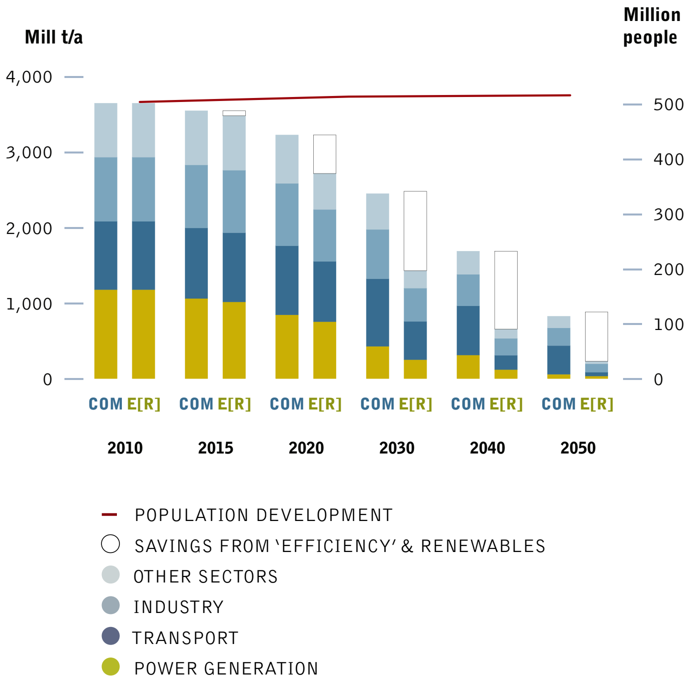
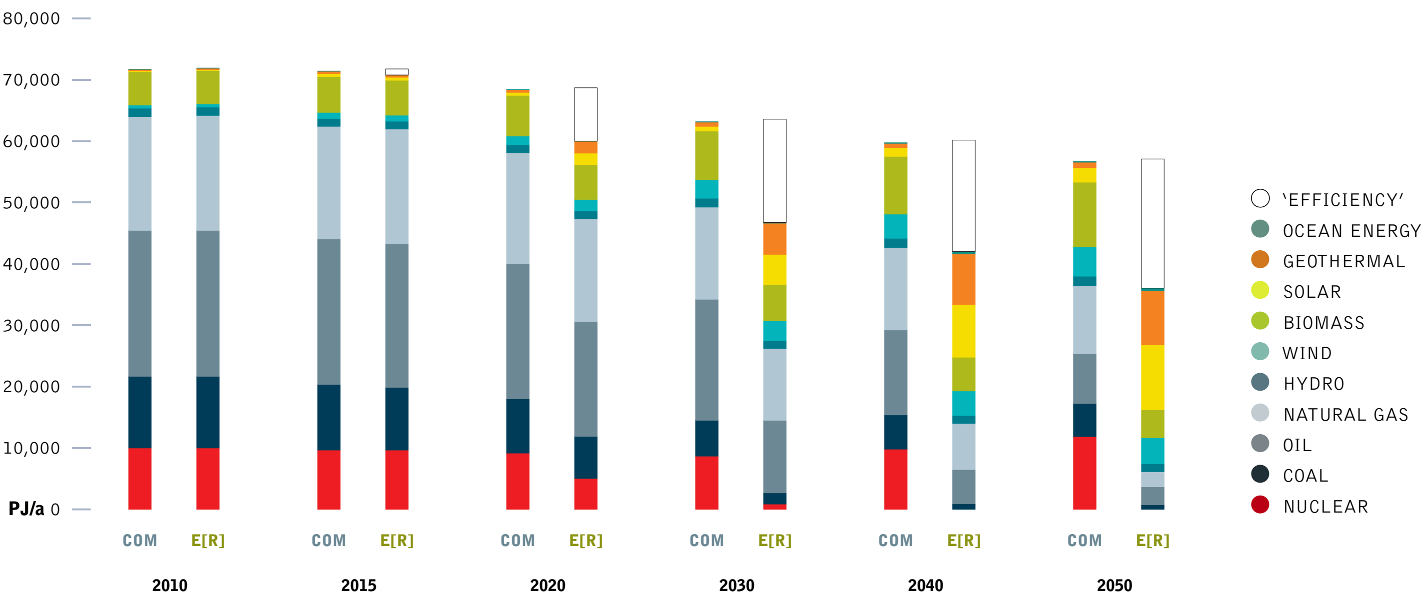


figure 2.8: development of total primary energy demand by sector under the COM and the energy [r]evolution scenario (high efficiency)



fossil fuel requirements for the EU

FOSSIL FUEL BALANCE: SCENARIO COMPARISON

FOSSIL FUEL BALANCES BY FUEL

FOSSIL FUEL COSTS VERSUS INVESTMENT IN NEW RENEWABLE POWER TECHNOLOGIES

image HEAVY RAINS IN CENTRAL EUROPE LED TO SOME OF THE WORST FLOODING THE REGION HAS SEEN IN OVER 100 YEARS. THE FLOODS KILLED OVER 100 PEOPLE IN GERMANY, RUSSIA, AUSTRIA, HUNGARY AND THE CZECH REPUBLIC AND LED TO AS MUCH AS $20 BILLION IN DAMAGE.

This section provides an overview of the fossil fuel requirement of the two different energy roadmaps previously outlined – the Commission roadmap and the Energy [R]evolution for EU 28 which assumes an advanced energy efficiency program. The demand projections are based on the results of Chapter 2.

The analysis does not include a detailed analysis of biomass imports. Broadly, the use of biomass is much lower under the Energy [R]evolution scenario than under the COM scenario, and so the amount of imports will be smaller too.

Similarly, no detailed assessment has been made of the EU's projected uranium consumption or imports. Under the COM scenario, the use of nuclear energy continues and even increases slightly by 2050 compared to the current situation. Under the Energy [R]evolution scenario the last reactor will be closed down between 2030 and 2035. Uranium imports will therefore be minimal by 2030, and non-existent by 2050.

3.1 fossil fuel balance: scenario comparison

The fossil fuel balances by scenario compare fuel demand with the fossil fuel resources available within the EU. The resource assessment is based on extensive research from Ludwig Bölkow Systemtechnik (LBST) for Greenpeace International in 2012 presented in the first section of this report.

The "Import Requirements" compare the theoretically available EU resources with the fuel demand. It does not reflect the actual situation of the fossil fuel markets - due to price differences of oil, gas and coal inside and outside the EU, not the entire local resource will be used. Import requirements are presented as a percentage showing the difference between the theoretically available resources within the EU and the overall demand, indicating the share which is needed from outside the EU.

Under the COM scenario the EU would retain a very high dependency on importing all three fossil fuels. With around 90% of oil and 64% of gas import dependency by 2030, the EU will only marginally change the current dependency on imports. In reality, the level of imports is likely to be even higher since not all available EU resources will be used.

In comparison, the Energy [R]evolution pathway will reduce the amount of imported oil, gas and coal already by 2020. In 2030, the EU would need to import 1,287 million barrels of oil and 90 billion m^3 gas less gas – per year. Coal imports have been entirely phased-out avoiding over the need of sourcing an extra 80 million tonne per year.

Table 3.2 on the following page, shows that the annual additional cost for fossil fuels of the COM scenario compared to the Energy [R]evolution pathway add up to €57 billion in 2020 and €180 billion in 2030.

table 3.1: overview of fuel demand under COM and the energy [r]evolution

	EUROPEAN FOSSIL FUEL RESOURCES WITH CURRENT PRODUCTION CAPACITIES			OIL			GAS			COAL		
COM	OIL	GAS	COAL	**Demand**	**Import requirement**	**Import requirement**	**Demand**	**Import requirement**	**Import requirement**	**Demand**	**Import requirement**	**Import requirement**
YEAR	MILLION BARREL	BILLION M^3	MILLION TONNE	MILLION BARREL	MILLION BARREL	%	BILLION M^3	BILLION M^3	%	MILLION TONNE	MILLION TONNE	%
2015	922	223	173	3,877	2,550	66%	485	225	46%	333	142	42%
2020	689	192	157	3,610	2,921	81%	477	286	60%	288	131	46%
2030	387	141	128	3,231	2,844	88%	396	255	64%	209	81	39%
2040	219	104	105	2,266	2,047	90%	355	251	71%	205	100	49%
2050	125	77	85	1,331	1,206	91%	292	215	74%	201	116	57%
E[R]												
2015	922	223	173	3,836	2,508	65%	483	223	46%	311	119	38%
2020	689	192	157	3,061	2,372	77%	442	250	57%	233	76	33%
2030	387	141	128	1,944	1,557	80%	306	165	54%	79	NON	NON
2040	219	104	105	915	696	76%	196	92	47%	39	NON	NON
2050	125	77	85	476	351	74%	64	NON	NON	33	NON	NON

image GEOTHERMAL ACTIVITY NEAR HOLSSELSNALAR CLOSE TO REYKJAVIK, ICELAND.

table 3.2: overview of additional fuel demand COM vs energy [r]evolution

	OIL			GAS			COAL			
	Additional annual demand	Assumed costs	Total costs	Additional annual demand	Assumed costs	Total costs	Additional annual demand	Assumed costs	Total costs	Total fuel costs savings
YEAR	MILLION BARREL	EURO/ BARREL	MILLION EURO	BILLION M^3	EURO/ BILLION M^3	MILLION EURO	MILLION TONNE	EURO/ TONNE	MILLION EURO	MILLION EURO
2015	41	93	3,854	1.31	266,000	0.35	22	105	2,333	6,187
2020	548	93	51,000	36	341,000	12	55	115	6,362	57,375
2030	1,287	126	162,190	90	456,000	41	131	141	18,430	180,661
2040	1,351	126	170,182	158	570,000	90	165	165	27,306	197,579
2050	855	126	107,787	227	760,000	173	168	170	28,587	136,547

3.2 fossil fuel balances by fuel

In order to provide a better overview, this section shows the development pathways described above by fuel and puts them in the context of both scenarios.

3.2.1 oil

In both scenarios it will not be possible to phase out overall oil imports within the next 35 years. However the Energy [R]evolution scenario will halve the demand for oil by 2030 thus the overall purchased oil from outside the EU will be reduced accordingly. To replace this oil, the money will be spent energy efficiency technologies and renewable electricity which increasingly supplies also the transport sector.

3.2.2 gas

The Energy [R]evolution pathway uses gas as a bridging fuel to complement the increasing share of renewables during the phase-out of nuclear, lignite and coal over the next two decades. However, by 2030 the overall import volume will be reduced 30% to today's level. The COM scenario has a significantly higher gas import requirement than the Energy [R]evolution.

figure 3.1: oil: EU import requirements versus oil demand: COM and energy [r]evolution

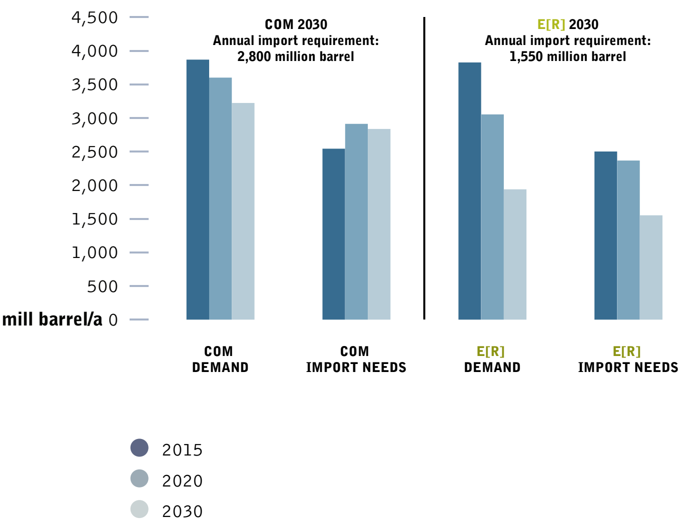
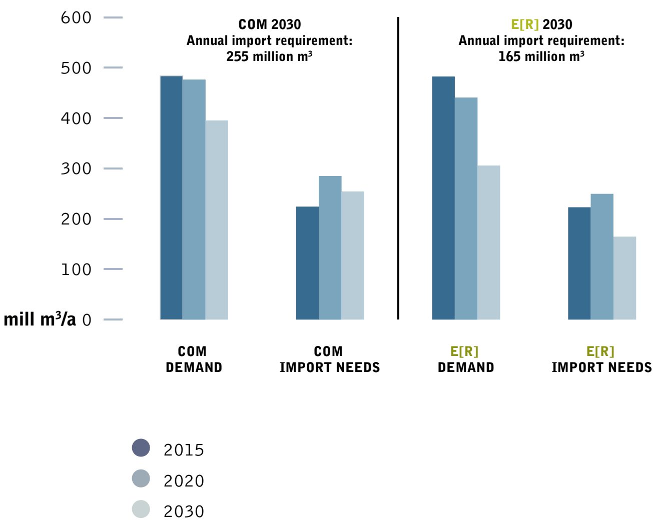


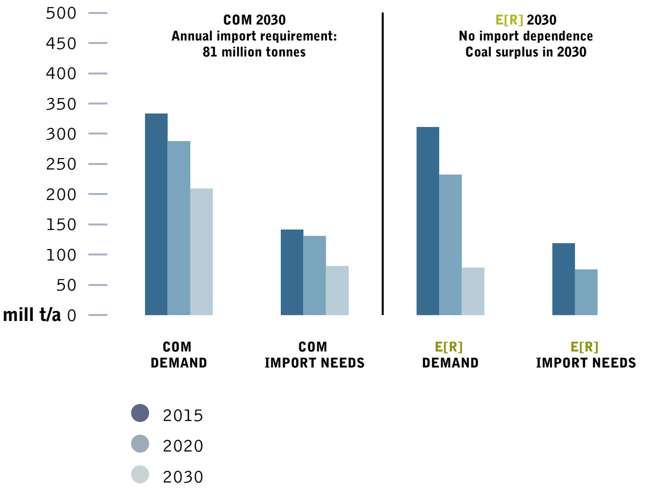
figure 3.2: gas: EU import requirements versus gas demand: COM and energy [r]evolution



3.2.3 coal

While the COM pathway will keep the EU dependent on coal imports, the Energy [R]evolution leads to a surplus of EU coal. Leaving coal in the ground will both benefit the climate and the investments saved in coal mining can be used for renewable energy which in turn creates sustainable jobs for future generations.

figure 3.3: coal: EU import requirements versus coal demand: COM and energy [r]evolution



Under the COM scenario, overall import requirement of the three fuels amount to 31,700 PJ by 2020 and 28,900 PJ by 2030, and still over 18,200 PJ by 2050. Under the Energy [R]evolution scenario this is only 25,700, 14,600 and 460 PJ. The comparison shows that the EU can reduce overall fuel imports by 19% already by 2020, by 45% by 2030 and 88% by 2050.

3.3 fossil fuel costs versus investment in new renewable power technologies

As part of the Energy [R]evolution scenario development, we conducted a detailed cost analysis for the power sector. An analysis of the efficiency measures in the power, heating and transport sectors has not been carried out.

Due the high average age of the European power plant fleet, the investment requirements in new power generation capacity – mainly to replace existing power plants – high even in the reference case. The Energy [R]evolution and the COM scenario are both on the same order of magnitude at around €84 billion respectively €81 billion per year between 2011 and 2050. However the COM case foresees investments of €28 billion in conventional fossil fuel power plants – which increase Europe's maintain on fossil fuel imports. As opposed to the Energy [R]evolution which channels over 90% of the investments into renewable energy technologies while the remaining money is spend on gas power plants either for dispatching or for districting heating CHP plants.

table 3.3: investments in new power plants under the energy [r]evolution and COM scenarios

COM		2011-2020	2021-2030	2031-2040	2041-2050	2011-2050	2011-2050 AVERAGE PER YEAR
Conventional (fossil & nuclear)	MILL. €	**268,938**	**271,506**	**352,817**	**239,498**	**1,132,759**	**28,319**
Renewables	MILL. €	**498,778**	**519,748**	**505,008**	**586,379**	**2,109,912**	**52,748**
Biomass	MILL. €	38,304	63,823	31,786	55,181	189,094	4,727
Hydro	MILL. €	82,492	100,214	86,852	84,759	354,317	8,858
Wind	MILL. €	179,439	274,831	230,787	320,114	1,005,171	25,129
PV power plant	MILL. €	174,303	63,676	134,453	101,384	473,816	11,845
Geothermal	MILL. €	9,394	6,616	5,178	4,558	25,747	644
Solar thermal power plants	MILL. €	13,692	7,483	8,194	12,269	41,638	1,041
Ocean energy	MILL. €	1,152	3,105	7,757	8,113	20,128	503
Total	MILL. €					**3,242,671**	**81,067**
Energy [R]evolution							
Conventional (fossil & nuclear)	MILL. €	**181,901**	**52,430**	**62,464**	**0**	**296,794**	**7,420**
Renewables	MILL. €	**745,218**	**775,113**	**854,199**	**697,509**	**3,072,039**	**76,801**
Biomass	MILL. €	67,881	94,909	62,027	53,989	278,807	6,970
Hydro	MILL. €	71,277	64,168	67,497	66,389	269,331	6,733
Wind	MILL. €	281,703	295,566	260,062	220,219	1,057,549	26,439
PV power plant	MILL. €	225,916	137,145	180,726	140,219	684,006	17,100
Geothermal	MILL. €	50,007	98,558	120,388	102,386	371,340	9,283
Solar thermal power plants	MILL. €	40,268	69,979	134,349	99,214	343,810	8,595
Ocean energy	MILL. €	8,166	14,788	29,149	15,093	67,196	1,680
Total	MILL. €					**3,368,833**	**84,221**

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

Over the entire scenario period until 2050 the overall fuel cost savings accumulate to €1,192 billion or €29.8 billion per year which can be used to compensate the additional investment requirements in new generation capacity of €3.2 billion. Additional investments in energy efficiency measure are required.

table 3.4: investments and fuel cost savings under the COM and the energy [r]evolution scenarios

COM		2011-2020	2021-2030	2031-2040	2041-2050	2011-2050	2011-2050 AVERAGE PER YEAR
Conventional (fossil & nuclear)	BILL. €	-87	-219	-290	-239	-836	-20.9
Renewables	BILL. €	246	255	349	111	962	24.1
Total	BILL. €	**159**	**36**	**59**	**-128**	**126**	**3.2**
Energy [R]evolution							
Fuel oil	BILL. €	7.1	18.7	24.1	21.1	71	1.8
Gas	BILL. €	-8.8	-56.7	115.1	602.2	652	16.3
Hard coal	BILL. €	12.7	69.3	149.2	199.4	431	10.8
Lignite	BILL. €	2.1	12.2	12.4	12.1	39	1.0
Total	BILL. €	**13.1**	**43.5**	**300.8**	**834.9**	**1,192**	**29.8**

EU policy recommendations

4

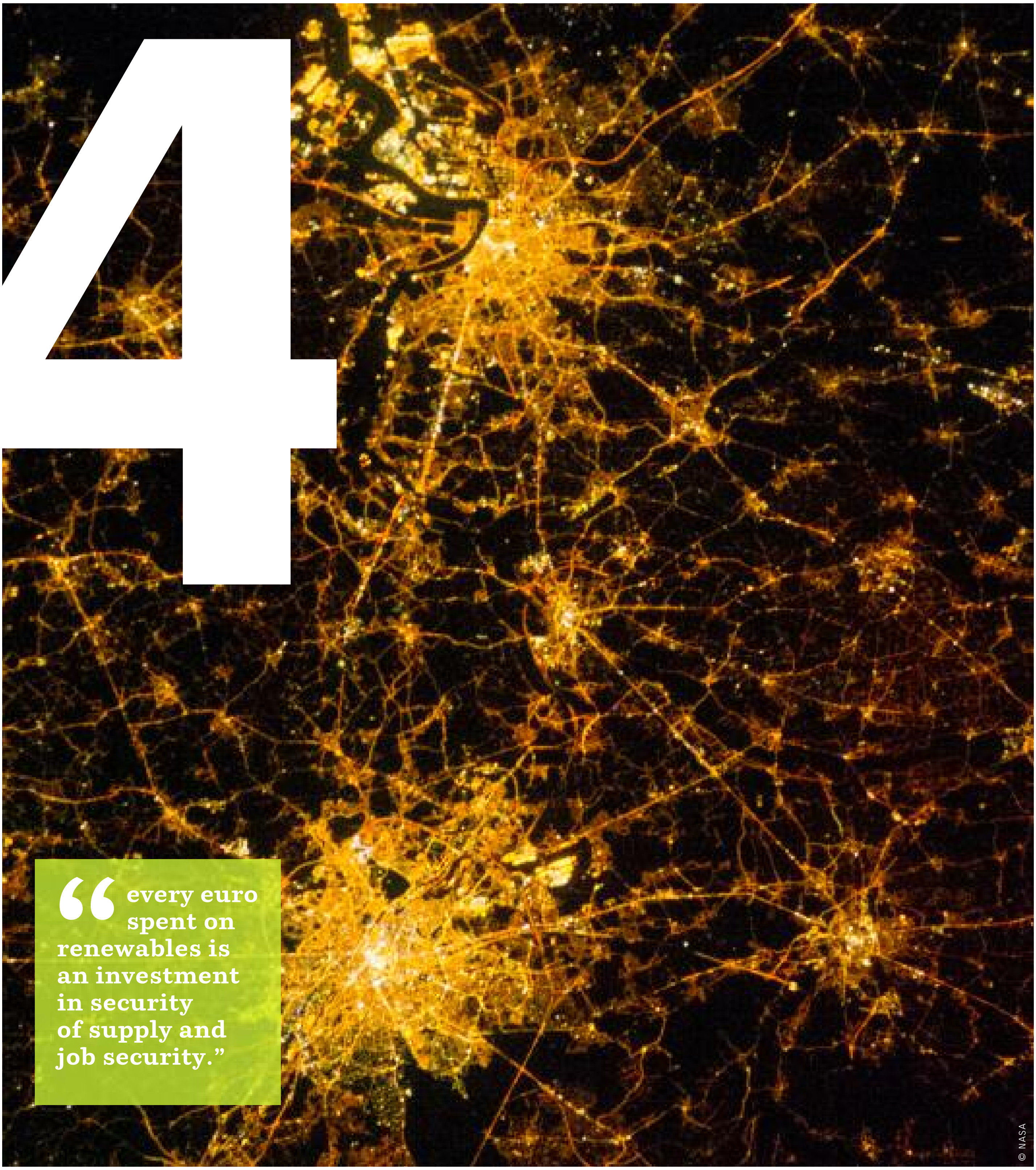


image NIGHT PHOTOGRAPH OF TWO OF BELGIUM'S MAJOR METROPOLITAN AREAS. ANTWERP IS A MAJOR EUROPEAN PORT LOCATED ON THE SCHELDT RIVER, AND BRUSSELS, THE CAPITAL AND LARGEST CITY IN BELGIUM, AND ALSO THE DE FACTO HEADQUARTERS OF THE EUROPEAN UNION. BRILLIANT POINTS OF LIGHT ARE THE CITY CENTER AND THE BRUSSELS NATIONAL AIRPORT. DEVELOPED ROADWAYS APPEAR AS STRAIGHTER, BRIGHTER LINES RADIATING FROM THE TWO CITIES.

The Energy [R]evolution EU Energy Independence Pathway demonstrates that ambitious 2030 energy and climate targets will – unlike the European Commission's proposals – deliver a substantial reduction in energy imports, making EU countries less vulnerable to external supply disruptions. It shows that environmental and climate protection and a reduction of energy import dependence do not have to be contradictory but can be mutually reinforcing.

Therefore the EU should make the following key decisions:

Agree and implement ambitious 2030 energy and climate targets

EU heads of state and government should adopt a 2030 Energy and Climate Package that contains binding targets for renewables – 45% - and energy savings of 40% (compared to 2005) - along with an ambitious target for emission reductions within the EU of at least 55% (compared to 1990). As the next step, EU institutions should put in place effective laws to guarantee its successful implementation. Such a framework will not only bolster the EU's energy independence, it will also deliver significant climate, employment and health benefits.

This can be achieved by the following measures:

1. **Strictly implement & strengthen existing EU energy efficiency legislation**
   Recognising the economic and environmental benefits of energy savings, EU member states have already agreed to save 20% energy by 2020, compared to business-as-usual. They have adopted an Energy Efficiency Directive (EED) and submitted National Energy Efficiency Action Plans, including 2020 indicative national targets. Nonetheless, the 2020 target is likely to be missed.

   The Commission should therefore make sure that EU countries which presented deficient action plans improve these. It should also start infringement procedures against those EU countries whose plans clearly fail to comply with key requirements under the EED as well as the Energy Performance of Buildings Directive (EPBD).

   In addition, the Commission should strengthen the Energy Labelling and Ecodesign laws to ensure greater energy savings. This should include more dynamic standards that also move beyond products towards system-wide energy savings.

2. **Set-up an EU Energy Security Fund for buildings renovation**
   The buildings sector alone is responsible for about 40% of the EU's energy consumption. EU action should therefore prioritize the refurbishment and improved insulation of existing building envelopes and replacement of inefficient heating systems. However, access to finance represents a major obstacle.

   Therefore, EU member states should task the European Investment Bank (EIB), in collaboration with national investment banks, to create an Energy Security Fund to support development, financing and delivery of plans for improving the energy performance of buildings. The focus should be on those countries that are particularly vulnerable to energy supply disruptions and have the greatest potential for efficiency improvements.

3. **Eliminate subsidies for fossil and nuclear energy technologies**
   Many EU countries still give generous subsidies and other support to coal, nuclear and shale gas technologies. Spain, Germany, Poland and Romania subsidise their coal sectors, while Italy and Ireland operate capacity payments for natural gas plants. Nuclear subsidies – even after half a century of commercial operation – exist in many countries, ranging from liability-related subsidies to public support for nuclear waste management and decommissioning. This is despite the unanimous call by all EU heads of state and government in May 2013 for a phase out of environmentally or economically harmful subsidies, including fossil fuel ones.

   EU governments should, without further delay, phase out any subsidies (including export credit financing) for fossil and nuclear energy technologies. In most cases, such subsidies exist to support fuel imports from third countries, which run counter to the EU's energy security objective.

4. **Improve electricity grid connections between EU countries**
   The Energy [R]evolution EU Energy Independence Pathway shows that the development of renewable energy is one of the main drivers for reducing dependency on energy imports. In order to promote renewable energy, additional grid connections are needed both within and between EU member states, and existing connections must be modernized. Priority should be given to those electricity interconnections that have a direct impact on the integration of renewable energy sources.

5. **Plan infrastructure projects using the rights assumptions**
   The Energy [R]evolution EU Energy Independence Pathway shows that the combination of ambitious energy efficiency and renewable energy measures will significantly reduce the need for energy imports.

   EU member states should take into account the reduced fossil fuel consumption when planning any new pipelines or electricity lines in order to prevent a costly "over-engineering" of the energy system and the creation of stranded assets.

glossary & appendix

GLOSSARY OF COMMONLY USED TERMS AND ABBREVIATIONS

DEFINITION OF SECTORS

EU 28: SCENARIO RESULTS DATA

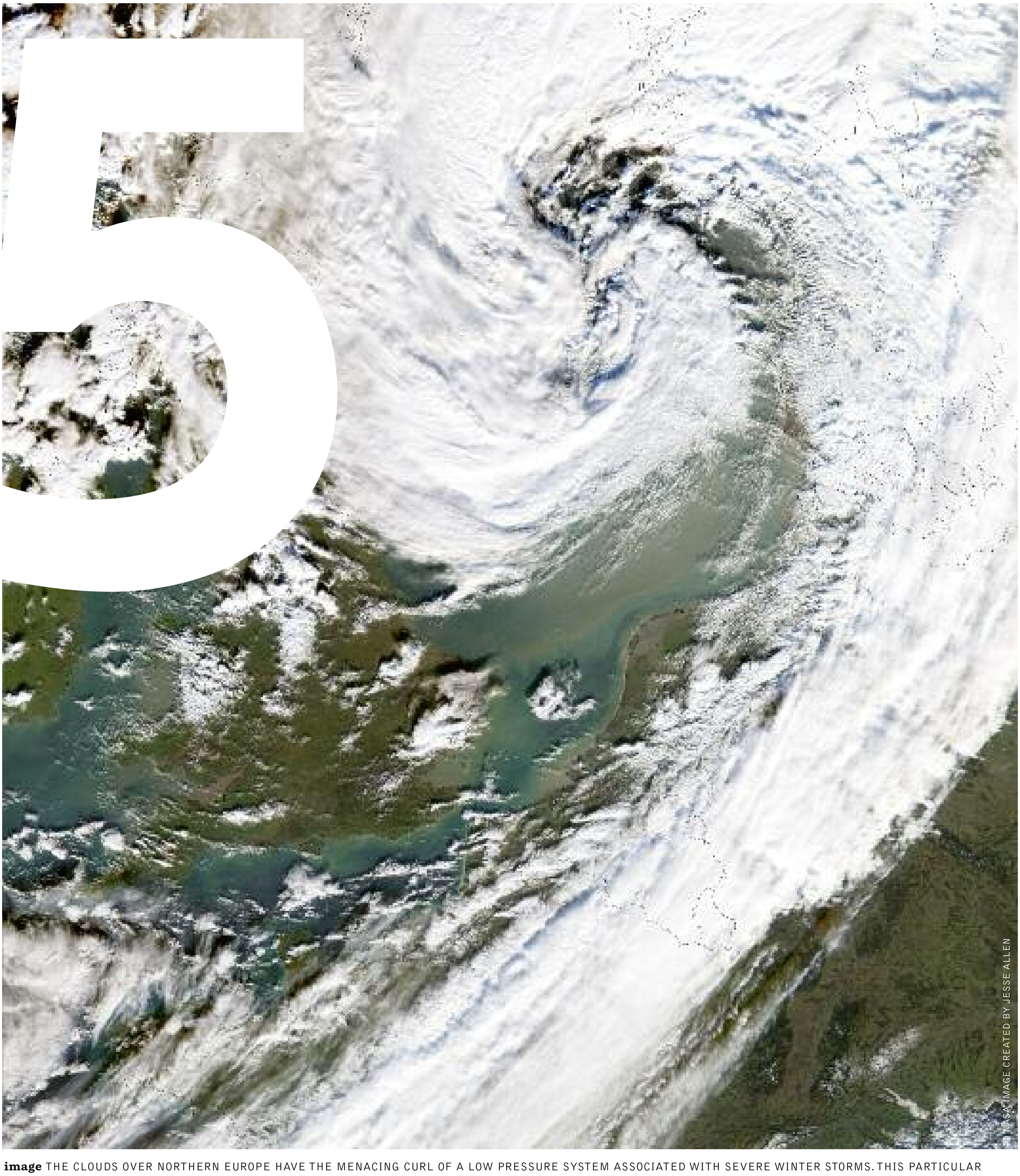


image THE CLOUDS OVER NORTHERN EUROPE HAVE THE MENACING CURL OF A LOW PRESSURE SYSTEM ASSOCIATED WITH SEVERE WINTER STORMS. THIS PARTICULAR STORM LASHED THE UNITED KINGDOM, SCANDINAVIA, NORTHERN GERMANY, AND RUSSIA WITH HURRICANE-FORCE WINDS AND INTENSE RAINS. THE STORM BROUGHT SEVERE FLOODS TO NORTHERN ENGLAND AND SCOTLAND, SUBMERSING THE ENGLISH TOWN OF CARLISLE ENTIRELY. ACROSS NORTHERN EUROPE, TRAIN SERVICES WERE HALTED AND ELECTRICITY FLICKERED OUT UNDER THE ONSLAUGHT OF WINDS THAT GUSTED UP TO 180 KILOMETERS PER HOUR (112 MPH).

10.1 glossary of commonly used terms and abbreviations

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

J Joule, a measure of energy:
kJ (Kilojoule) = 1,000 Joules
MJ (Megajoule) = 1 million Joules
GJ (Gigajoule) = 1 billion Joules
PJ (Petajoule) = 10^{15} Joules
EJ (Exajoule) = 10^{18} Joules

W Watt, measure of electrical capacity:
kW (Kilowatt) = 1,000 watts
MW (Megawatt) = 1 million watts
GW (Gigawatt) = 1 billion watts
TW (Terawatt) = 1^{12} watts

kWh Kilowatt-hour, measure of electrical output:
kWh (Kilowatt-hour) = 1,000 watt-hours
TWh (Terawatt-hour) = 10^{12} watt-hours

t Tonnes, measure of weight:
t = 1 tonne
Gt = 1 billion tonnes

table 10.1: conversion factors - fossil fuels

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

table 10.2: conversion factors - different energy units

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

10.2 definition of sectors

The definition of different sectors follows the sectorial break down of the IEA World Energy Outlook series.

All definitions below are from the IEA Key World Energy Statistics.

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

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

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

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

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

EU 28: scenario results data

image WESTERN EUROPE, FROM SOUTHERN ENGLAND IN THE NORTH TO SPAIN IN THE SOUTH AND FROM FRANCE IN THE WEST TO AUSTRIA IN THE EAST, BEGINNING TO SHOW SIGNS OF SPRING

EU 28: COM scenario

table 10.3: EU 28: electricity generation

TWh/a	2010	2015	2020	2030	2040	2050
Power plants	**2,644**	**2,770**	**2,736**	**2,806**	**3,437**	**4,194**
Coal	347	330	227	157	224	290
Lignite	248	217	147	36	28	23
Gas	458	463	463	190	236	245
Oil	38	27	20	3	3	1
Diesel	10	7	6	5	1	0
Nuclear	917	887	843	798	900	1,089
Biomass	74	93	100	152	203	299
Hydro	375	354	364	396	414	433
Wind	149	274	401	844	1,096	1,336
of which wind offshore	0	28	43	115	270	460
PV	23	106	145	191	270	388
Geothermal	6	9	10	15	18	21
Solar thermal power plants	0	2	8	14	20	27
Ocean energy	1	1	2	7	23	41
Combined heat & power plants	**682**	**686**	**688**	**693**	**714**	**734**
Coal	145	154	156	144	137	132
Lignite	93	88	83	75	72	67
Gas	337	340	342	351	374	395
Oil	39	29	20	10	9	4
Biomass	69	75	87	113	122	134
Geothermal	0	0	0	0	1	2
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	488	490	492	496	516	536
Autoproducers	195	196	196	197	198	198
Total generation	**3,326**	**3,456**	**3,424**	**3,499**	**4,151**	**4,928**
Fossil	1,714	1,656	1,464	970	1,083	1,157
Coal	492	484	383	300	360	422
Lignite	340	305	230	111	100	90
Gas	795	803	805	540	610	640
Oil	77	56	40	13	12	5
Diesel	10	7	6	5	1	0
Nuclear	917	887	843	798	900	1,089
Hydrogen	0	0	0	0	0	0
Renewables	**695**	**914**	**1,117**	**1,731**	**2,167**	**2,682**
Hydro	375	354	364	396	414	433
Wind	149	274	401	844	1,096	1,336
of which wind offshore	0	28	43	115	270	460
PV	23	106	145	191	270	388
Biomass	142	168	188	265	325	433
Geothermal	6	9	10	15	19	23
Solar thermal	0	2	8	14	20	27
Ocean energy	1	1	2	7	23	41
Distribution losses	195	183	176	176	170	167
Own consumption electricity	287	286	287	299	303	311
Electricity for hydrogen production	0	0	0	5	220	809
Final energy consumption (electricity)	**2,852**	**2,981**	**2,954**	**3,018**	**3,457**	**3,640**
Fluctuating RES (PV, Wind, Ocean)	173	381	548	1,042	1,389	1,765
Share of fluctuating RES	5.2%	11.0%	16.0%	29.8%	33.5%	35.8%
RES share (domestic generation)	**20.9%**	**26.4%**	**32.6%**	**49.5%**	**52.2%**	**54.4%**

table 10.4: EU 28: heat supply

PJ/a	2010	2015	2020	2030	2040	2050
District heating	**696**	**797**	**965**	**1,239**	**1,352**	**1,566**
Fossil fuels	529	615	745	948	933	940
Biomass	164	179	217	278	365	470
Solar collectors	0	0	0	6	27	78
Geothermal	3	3	3	6	27	78
Heat from CHP	**1,943**	**1,899**	**1,912**	**2,072**	**2,335**	**2,499**
Fossil fuels	1,619	1,618	1,612	1,724	1,952	2,091
Biomass	324	281	300	348	375	392
Geothermal	0	0	0	0	8	17
Hydrogen	0	0	0	0	0	0
Direct heating[1]	**18,069**	**18,612**	**17,898**	**15,975**	**13,188**	**10,312**
Fossil fuels	15,459	15,750	14,873	12,111	8,680	5,107
Biomass	2,489	2,688	2,798	3,352	3,823	4,062
Solar collectors	62	80	101	201	441	819
Geothermal[2]	59	95	126	311	245	323
Total heat supply[1]	**20,708**	**21,308**	**20,775**	**19,286**	**16,875**	**14,376**
Fossil fuels	17,607	17,983	17,230	14,783	11,565	8,137
Biomass	2,978	3,148	3,315	3,979	4,563	4,924
Solar collectors	62	80	101	207	468	898
Geothermal	62	97	130	317	280	418
Hydrogen	0	0	0	0	0	0
RES share (including RES electricity)	**15.0%**	**15.6%**	**17.1%**	**23.3%**	**31.5%**	**43.4%**

1) cooling. 2) cooling heat pumps.

table 10.5: EU 28: CO_2 emissions

MILL t/a	2010	2015	2020	2030	2040	2050
Condensation power plants	**792**	**730**	**555**	**203**	**164**	**32**
Coal	298	285	197	110	94	23
Lignite	272	238	162	26	12	2
Gas	186	182	176	61	55	7
Oil	29	21	17	3	3	0
Diesel	7	5	4	3	0	0
Combined heat & power production	**472**	**387**	**338**	**259**	**170**	**31**
Coal	151	153	127	94	61	12
Lignite	121	80	63	48	28	5
Gas	162	134	135	111	78	14
Oil	38	20	13	6	3	1
CO_2 emissions power generation (incl. CHP public)	**1,264**	**1,117**	**893**	**462**	**333**	**63**
Coal	449	438	324	204	154	35
Lignite	393	318	225	74	40	7
Gas	348	316	311	172	133	20
Oil & diesel	74	45	34	12	7	1
CO_2 emissions by sector	**3,650**	**3,552**	**3,230**	**2,453**	**1,689**	**826**
% of 1990 emissions	88.9%	86.5%	78.7%	59.8%	41.1%	20.1%
Industry[1]	480	471	461	348	204	96
Other sectors[1]	715	721	643	477	307	155
Transport	906	934	917	897	651	381
Power generation[2]	1,180	1,063	844	427	312	57
Other conversion[3]	370	363	364	304	215	137
Population (Mill.)	505	511	515	520	519	515
CO_2 emissions per capita (t/capita)	**7.2**	**7.0**	**6.3**	**4.7**	**3.3**	**1.6**

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

table 10.6: EU 28: installed capacity

GW	2010	2015	2020	2030	2040	2050
Power plants	**707**	**826**	**862**	**1,013**	**1,167**	**1,391**
Coal	99	94	65	61	66	83
Lignite	34	29	20	5	3	3
Gas	127	129	132	70	74	79
Oil	33	28	24	4	4	1
Diesel	5	3	3	2	0	0
Nuclear	143	134	124	116	127	153
Biomass	12	15	15	23	30	43
Hydro	147	154	156	170	178	186
Wind	83	137	188	383	454	519
of which wind offshore	0	9	13	36	73	121
PV	23	100	130	171	216	303
Geothermal	1	1	2	2	3	3
Solar thermal power plants	0	1	2	4	5	6
Ocean energy	0	0	0	2	7	12
Combined heat & power production	**181**	**182**	**178**	**167**	**165**	**159**
Coal	40	41	38	34	31	29
Lignite	13	12	11	10	9	9
Gas	84	90	97	97	98	97
Oil	32	26	19	8	7	3
Biomass	11	12	13	17	19	20
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	121	121	121	116	116	113
Autoproducers	59	61	57	51	49	46
Total generation	**888**	**1,008**	**1,040**	**1,179**	**1,332**	**1,550**
Fossil	468	454	409	291	294	304
Coal	139	136	103	95	97	112
Lignite	47	42	31	14	13	12
Gas	212	219	229	167	172	176
Oil	65	54	43	12	11	4
Diesel	5	3	3	2	0	0
Nuclear	143	134	124	116	127	153
Hydrogen	0	0	0	0	0	0
Renewables	**277**	**419**	**507**	**772**	**912**	**1,093**
Hydro	147	154	156	170	178	186
Wind	83	137	188	383	454	519
of which wind offshore	0	9	13	36	73	121
PV	23	100	130	171	216	303
Biomass	23	26	29	41	49	63
Geothermal	1	1	2	2	3	4
Solar thermal	0	1	2	4	5	6
Ocean energy	0	0	0	2	7	12
Fluctuating RES (PV, Wind, Ocean)	106	237	319	555	677	834
Share of fluctuating RES	11.9%	23.5%	30.6%	47.1%	50.8%	53.8%
RES share (domestic generation)	**31.2%**	**41.6%**	**48.8%**	**65.5%**	**68.4%**	**70.5%**

table 10.7: EU 28: primary energy demand

PJ/a	2010	2015	2020	2030	2040	2050
Total	**71,887**	**71,580**	**68,834**	**63,677**	**60,243**	**57,196**
Fossil	**54,161**	**52,888**	**49,054**	**40,672**	**32,946**	**24,624**
Hard coal	7,971	7,680	6,629	4,823	4,717	4,631
Lignite	3,757	3,055	2,196	1,016	877	762
Natural gas	18,610	18,423	18,137	15,059	13,484	11,083
Crude oil	23,823	23,730	22,091	19,773	13,867	8,148
Nuclear	**10,006**	**9,680**	**9,204**	**8,711**	**9,825**	**11,888**
Renewables	**7,720**	**9,012**	**10,576**	**14,294**	**17,472**	**20,683**
Hydro	1,349	1,276	1,309	1,426	1,491	1,561
Wind	537	987	1,444	3,039	3,946	4,810
Solar	145	496	761	1,137	1,785	2,761
Biomass	5,439	5,871	6,603	7,948	9,462	10,550
Geothermal/ambient heat	248	379	453	721	704	852
Ocean energy	2	4	5	24	85	149
RES share	**10.5%**	**12.3%**	**14.9%**	**21.6%**	**28.1%**	**35.2%**

table 10.8: EU 28: final energy demand

PJ/a	2010	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**50,288**	**51,747**	**50,751**	**48,498**	**44,125**	**39,878**
Total (energy use)	**45,823**	**47,413**	**46,684**	**44,924**	**41,007**	**37,090**
Transport	**13,434**	**13,970**	**14,165**	**14,555**	**13,373**	**12,190**
Oil products	12,533	12,925	12,578	12,079	8,823	5,056
Natural gas	104	124	260	550	351	358
Biofuels	558	627	1,000	1,100	1,325	1,737
Electricity	240	294	328	813	2,294	2,854
RES electricity	50	78	107	402	1,198	1,553
Hydrogen	0	0	0	13	579	2,185
RES share Transport	**4.5%**	5.0%	**7.8%**	**10.4%**	**21.1%**	**36.7%**
Industry	**11,488**	**12,278**	**12,403**	**12,354**	**11,420**	**10,486**
Electricity	3,738	4,120	4,201	4,363	4,453	4,542
RES electricity	782	1,089	1,370	2,159	2,325	2,472
District heat	654	683	693	777	823	911
RES district heat	123	118	125	150	178	231
Coal	790	1,012	981	587	262	63
Oil products	1,443	1,442	1,349	1,202	690	94
Gas	3,845	3,850	3,955	3,968	3,432	2,812
Solar	0	0	0	13	105	323
Biomass and waste	1,017	1,171	1,224	1,436	1,614	1,666
Geothermal/ambient heat	0	0	0	9	42	76
Hydrogen	0	0	0	0	0	0
RES share Industry	**16.7%**	**19.4%**	**21.9%**	**30.5%**	**37.3%**	**45.5%**
Other Sectors	**20,901**	**21,165**	**20,115**	**18,015**	**16,214**	**14,414**
Electricity	6,288	6,316	6,106	5,687	5,697	5,709
RES electricity	1,315	1,670	1,992	2,814	2,975	3,107
District heat	1,580	1,599	1,742	2,026	2,312	2,568
RES district heat	290	266	293	358	467	613
Coal	587	623	535	328	136	30
Oil products	3,286	3,206	2,540	1,855	752	266
Gas	7,309	7,461	7,118	5,425	4,197	2,311
Solar	62	80	100	188	336	497
Biomass and waste	1,749	1,816	1,885	2,289	2,634	2,848
Geothermal/ambient heat	40	65	88	216	149	185
RES share Other Sectors	**16.5%**	**18.4%**	**21.7%**	**32.6%**	**40.5%**	**50.3%**
Total RES	**5,985**	**6,980**	**8,186**	**11,140**	**13,651**	**16,497**
RES share	**13.1%**	**14.7%**	**17.5%**	**24.8%**	**33.3%**	**44.5%**
Non energy use	**4,464**	**4,334**	**4,067**	**3,573**	**3,118**	**2,788**
Oil	3,840	3,727	3,453	2,957	2,513	2,206
Gas	572	555	562	565	554	533
Coal	52	51	52	52	51	49

EU 28: energy [r]evolution (high renewables) scenario

table 10.9: EU 28: electricity generation

TWh/a	2010	2015	2020	2030	2040	2050
Power plants	**2,644**	**2,716**	**2,639**	**2,728**	**3,230**	**3,404**
Coal	347	275	239	33	0	0
Lignite	248	217	163	0	0	0
Gas	458	463	429	299	258	25
Oil	38	27	11	4	0	0
Diesel	10	7	5	3	1	0
Nuclear	917	887	461	78	0	0
Biomass	74	93	84	66	62	59
Hydro	375	354	354	363	376	387
Wind	149	274	579	1,189	1,433	1,510
of which wind offshore	0	28	133	430	583	614
PV	23	106	238	414	567	729
Geothermal	6	9	22	74	110	136
Solar thermal power plants	0	2	45	141	297	406
Ocean energy	1	1	10	63	125	153
Combined heat & power plants	**682**	**686**	**760**	**815**	**800**	**730**
Coal	145	154	146	53	0	0
Lignite	93	88	21	0	0	0
Gas	337	340	411	419	310	106
Oil	39	29	15	0	0	0
Biomass	69	75	151	264	323	394
Geothermal	0	0	16	79	162	204
Hydrogen	0	0	0	0	6	26
CHP by producer						
Main activity producers	488	490	530	560	525	480
Autoproducers	195	196	230	255	275	250
Total generation	**3,326**	**3,401**	**3,399**	**3,543**	**4,030**	**4,134**
Fossil	1,714	1,601	1,440	811	569	131
Coal	492	429	385	86	0	0
Lignite	340	305	184	0	0	0
Gas	795	803	840	718	568	131
Oil	77	56	26	4	0	0
Diesel	10	7	5	3	1	0
Nuclear	917	887	461	78	0	0
Hydrogen	0	0	0	0	6	26
Renewables	**695**	**914**	**1,498**	**2,653**	**3,455**	**3,978**
Hydro	375	354	354	363	376	387
Wind	149	274	579	1,189	1,433	1,510
of which wind offshore	0	28	133	430	583	614
PV	23	106	238	414	567	729
Biomass	142	168	235	330	385	453
Geothermal	6	9	38	153	272	340
Solar thermal	0	2	45	141	297	406
Ocean energy	1	1	10	63	125	153
Distribution losses	195	183	205	208	203	201
Own consumption electricity	287	286	250	217	173	139
Electricity for hydrogen production	0	0	14	155	617	903
Final energy consumption (electricity)	**2,852**	**2,979**	**2,984**	**3,094**	**3,333**	**3,385**
Fluctuating RES (PV, Wind, Ocean)	173	381	827	1,666	2,125	2,392
Share of fluctuating RES	5.2%	11.2%	24.3%	47.0%	52.7%	57.8%
RES share (domestic generation)	**20.9%**	**26.9%**	**44.1%**	**74.9%**	**85.7%**	**96.2%**
'Efficiency' savings (compared to Com.)	**0**	**0**	**-9**	**16**	**200**	**349**

table 10.10: EU 28: heat supply

PJ/a	2010	2015	2020	2030	2040	2050
District heating	**696**	**725**	**1,288**	**1,878**	**2,292**	**2,655**
Fossil fuels	529	560	721	610	289	106
Biomass	164	163	335	479	481	451
Solar collectors	0	0	155	498	1,077	1,540
Geothermal	3	2	77	291	445	558
Heat from CHP	**1,943**	**1,899**	**2,322**	**2,896**	**3,362**	**3,353**
Fossil fuels	1,619	1,618	1,622	1,344	880	296
Biomass	324	281	557	842	1,011	1,149
Geothermal	0	0	143	708	1,454	1,829
Hydrogen	0	0	0	2	18	79
Direct heating[1)]	**18,069**	**18,612**	**17,291**	**15,242**	**12,555**	**9,994**
Fossil fuels	15,459	15,750	13,345	9,244	5,016	1,069
Biomass	2,489	2,688	2,477	2,075	1,650	1,312
Solar collectors	62	80	696	2,168	3,213	3,890
Geothermal[2)]	59	95	774	1,755	2,613	3,309
Hydrogen		0	0	0	63	414
Total heat supply[1)]	**20,708**	**21,236**	**20,900**	**20,016**	**18,210**	**16,002**
Fossil fuels	17,607	17,928	15,688	11,198	6,185	1,472
Biomass	2,978	3,132	3,369	3,396	3,142	2,912
Solar collectors	62	80	850	2,665	4,291	5,430
Geothermal	62	97	994	2,754	4,512	5,695
Hydrogen	0	0	0	2	81	493
RES share (including RES electricity)	**15.0%**	**15.6%**	**24.9%**	**44.1%**	**66.0%**	**90.7%**
'Efficiency' savings (compared to Com.)	**0**	**71**	**-125**	**-730**	**-1,334**	**-1,626**

1) cooling. 2) cooling heat pumps.

table 10.11: EU 28: CO_2 emissions

MILL t/a	2010	2015	2020	2030	2040	2050
Condensation power plants	**792**	**683**	**561**	**146**	**97**	**9**
Coal	298	238	207	27	0	0
Lignite	272	238	178	0	0	0
Gas	186	182	163	112	96	9
Oil	29	21	9	5	0	0
Diesel	7	5	3	2	0	0
Combined heat & power production	**472**	**389**	**307**	**205**	**115**	**37**
Coal	151	153	119	41	0	0
Lignite	121	82	16	0	0	0
Gas	162	134	162	164	115	37
Oil	38	20	10	0	0	0
CO_2 emissions power generation (incl. CHP public)	**1,264**	**1,072**	**869**	**351**	**212**	**46**
Coal	449	391	326	68	0	0
Lignite	393	320	195	0	0	0
Gas	348	316	326	276	212	46
Oil & diesel	74	45	22	7	0	0
CO_2 emissions by sector	**3,650**	**3,483**	**2,924**	**1,707**	**840**	**209**
% of 1990 emissions	88.9%	85%	71%	42%	20%	5%
Industry[1)]	480	473	389	268	147	27
Other sectors[1)]	715	721	582	379	210	65
Transport	906	918	798	520	189	51
Power generation[2)]	1,180	1,015	818	309	176	31
Other conversion[3)]	370	356	337	231	118	35
Population (Mill.)	505	511	515	520	519	515
CO_2 emissions per capita (t/capita)	**7.2**	**6.8**	**5.7**	**3.3**	**1.6**	**0.4**
'Efficiency' savings (compared to Com.)	**0**	**69**	**305**	**746**	**848**	**617**

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

table 10.12: EU 28: installed capacity

GW	2010	2015	2020	2030	2040	2050
Power plants	**707**	**815**	**944**	**1,222**	**1,371**	**1,497**
Coal	99	79	68	11	0	0
Lignite	34	29	22	0	0	0
Gas	127	128	116	100	81	36
Oil	33	34	13	5	0	0
Diesel	5	3	2	1	0	0
Nuclear	143	134	68	11	0	0
Biomass	12	15	13	10	9	11
Hydro	147	154	152	156	161	166
Wind	83	137	259	496	550	569
of which wind offshore	0	9	42	134	157	162
PV	23	100	213	370	454	570
Geothermal	1	1	4	12	17	21
Solar thermal power plants	0	1	11	31	62	81
Ocean energy	0	0	3	18	36	44
Combined heat & power production	**181**	**180**	**193**	**182**	**163**	**133**
Coal	40	40	36	13	0	0
Lignite	13	12	3	0	0	0
Gas	84	90	114	115	85	33
Oil	32	26	15	0	0	0
Biomass	11	12	23	41	50	60
Geothermal	0	0	3	13	27	34
Hydrogen	0	0	0	0	1	5
CHP by producer						
Main activity producers	121	120	129	122	104	86
Autoproducers	59	61	65	60	59	47
Total generation	**888**	**996**	**1,138**	**1,403**	**1,533**	**1,630**
Fossil	468	442	389	246	166	69
Coal	139	119	104	24	0	0
Lignite	47	42	25	0	0	0
Gas	212	217	230	216	165	69
Oil	65	61	28	5	0	0
Diesel	5	3	2	1	0	0
Nuclear	143	134	68	11	0	0
Hydrogen	0	0	0	0	1	5
Renewables	**277**	**419**	**681**	**1,146**	**1,366**	**1,556**
Hydro	147	154	152	156	161	166
Wind	83	137	259	496	550	569
of which wind offshore	0	9	42	134	157	162
PV	23	100	213	370	454	570
Biomass	23	26	36	51	59	71
Geothermal	1	1	6	25	45	56
Solar thermal	0	1	11	31	62	81
Ocean energy	0	0	3	18	36	44
Fluctuating RES (PV, Wind, Ocean)	106	237	475	883	1,039	1,182
Share of fluctuating RES	11.9%	23.8%	41.8%	63.0%	67.8%	72.5%
RES share (domestic generation)	**31.2%**	**42.1%**	**59.8%**	**81.7%**	**89.1%**	**95.5%**

table 10.13: EU 28: primary energy demand

PJ/a	2010	2015	2020	2030	2040	2050
Total	**71,887**	**70,615**	**64,291**	**56,566**	**52,236**	**47,459**
Fossil	**54,161**	**52,085**	**45,170**	**29,677**	**16,946**	**6,733**
Hard coal	7,971	7,168	5,744	1,890	908	760
Lignite	3,757	3,067	1,843	11	0	0
Natural gas	18,610	18,373	18,423	15,258	10,263	3,038
Crude oil	23,823	23,476	19,160	12,518	5,775	2,936
Nuclear	**10,006**	**9,680**	**5,033**	**851**	**0**	**0**
Renewables	**7,720**	**8,851**	**14,089**	**26,038**	**35,290**	**40,726**
Hydro	1,349	1,276	1,273	1,308	1,354	1,395
Wind	537	987	2,085	4,281	5,161	5,435
Solar	145	496	2,484	6,590	11,458	15,063
Biomass	5,439	5,710	6,158	6,708	6,355	6,044
Geothermal/ambient heat	248	378	2,052	6,923	10,511	12,239
Ocean energy	2	4	36	227	450	551
RES share	**10.5%**	**12.1%**	**22.1%**	**46.3%**	**68.0%**	**86.1%**
'Efficiency' savings (compared to Com.)	**0**	**434**	**4,680**	**7,237**	**7,515**	**8,538**

table 10.14: EU 28: final energy demand

PJ/a	2010	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**50,288**	**51,483**	**48,683**	**43,511**	**38,240**	**33,933**
Total (energy use)	**45,823**	**47,149**	**44,455**	**39,591**	**34,531**	**30,482**
Transport	**13,434**	**13,707**	**12,165**	**9,378**	**7,285**	**6,229**
Oil products	12,533	12,705	11,035	7,157	2,519	624
Natural gas	104	123	123	132	159	132
Biofuels	558	590	568	554	535	475
Electricity	240	288	404	1,141	2,539	3,094
RES electricity	50	77	178	855	2,177	2,976
Hydrogen	0	0	34	395	1,533	1,905
RES share Transport	**4.5%**	**4.9%**	**6.3%**	**18.2%**	**55.3%**	**84.8%**
Industry	**11,488**	**12,278**	**12,131**	**11,310**	**10,066**	**8,930**
Electricity	3,738	4,120	4,117	3,872	3,675	3,486
RES electricity	782	1,107	1,815	2,900	3,151	3,354
District heat	654	683	1,167	1,585	1,984	2,245
RES district heat	123	117	409	938	1,576	2,098
Coal	790	1,012	629	115	40	14
Oil products	1,443	1,442	903	416	131	22
Gas	3,845	3,850	3,873	3,387	1,836	220
Solar	0	0	177	561	957	1,137
Biomass and waste	1,017	1,171	1,131	973	779	575
Geothermal/ambient heat	0	0	134	401	599	800
Hydrogen	0	0	0	0	65	431
RES share Industry	**16.7%**	**19.5%**	**30.2%**	**51.0%**	**70.7%**	**93.8%**
Other Sectors	**20,901**	**21,165**	**20,159**	**18,903**	**17,180**	**15,323**
Electricity	6,288	6,316	6,222	6,119	5,757	5,508
RES electricity	1,315	1,697	2,742	4,583	4,936	5,299
District heat	1,580	1,599	2,037	2,711	3,208	3,335
RES district heat	290	263	723	1,630	2,593	3,138
Coal	587	623	345	73	0	0
Oil products	3,286	3,205	2,106	1,123	375	39
Gas	7,309	7,461	6,894	5,051	3,172	1,052
Solar	62	80	519	1,607	2,256	2,753
Biomass and waste	1,749	1,816	1,621	1,333	1,054	882
Geothermal/ambient heat	40	65	416	885	1,358	1,753
RES share Other Sectors	**16.5%**	**18.5%**	**29.9%**	**53.1%**	**71.0%**	**90.2%**
Total RES	**5,985**	**6,982**	**10,448**	**17,515**	**23,341**	**27,488**
RES share	**13.1%**	**14.8%**	**23.5%**	**44.2%**	**67.6%**	**90.2%**
Non energy use	**4,464**	**4,334**	**4,229**	**3,919**	**3,710**	**3,451**
Oil	3,840	3,727	3,453	2,957	2,513	2,206
Gas	572	555	582	590	603	623
Coal	52	51	194	372	594	621

EU 28: energy [r]evolution (high efficiency) scenario

table 10.15: EU 28: electricity generation

TWh/a	2010	2015	2020	2030	2040	2050
Power plants	**2,644**	**2,716**	**2,443**	**2,137**	**2,526**	**2,628**
Coal	347	275	207	30	0	0
Lignite	248	217	133	0	0	0
Gas	458	463	419	234	165	22
Oil	38	27	11	4	0	0
Diesel	10	7	5	3	1	0
Nuclear	917	887	461	78	0	0
Biomass	74	93	84	66	40	32
Hydro	375	354	354	355	357	360
Wind	149	274	520	896	1,116	1,180
of which wind offshore	0	28	122	340	428	456
PV	23	106	190	310	420	520
Geothermal	6	9	22	26	70	62
Solar thermal power plants	0	2	28	100	260	340
Ocean energy	1	1	10	34	98	112
Combined heat & power plants	**682**	**686**	**760**	**795**	**782**	**683**
Coal	145	154	146	38	0	0
Lignite	93	88	21	0	0	0
Gas	337	340	411	373	260	119
Oil	39	29	15	0	0	0
Biomass	69	75	151	298	358	348
Geothermal	0	0	16	86	158	193
Hydrogen	0	0	0	0	5	23
CHP by producer						
Main activity producers	488	490	530	540	515	460
Autoproducers	195	196	230	255	267	223
Total generation	**3,326**	**3,401**	**3,203**	**2,932**	**3,308**	**3,311**
Fossil	1,714	1,601	1,368	682	426	141
Coal	492	429	353	68	0	0
Lignite	340	305	154	0	0	0
Gas	795	803	830	607	425	141
Oil	77	56	26	4	0	0
Diesel	10	7	5	3	1	0
Nuclear	917	887	461	78	0	0
Hydrogen	0	0	0	0	5	23
Renewables	**695**	**914**	**1,374**	**2,171**	**2,877**	**3,147**
Hydro	375	354	354	355	357	360
Wind	149	274	520	896	1,116	1,180
of which wind offshore	0	28	122	340	428	456
PV	23	106	190	310	420	520
Biomass	142	168	235	364	398	380
Geothermal	6	9	38	112	228	255
Solar thermal	0	2	28	100	260	340
Ocean energy	1	1	10	34	98	112
Distribution losses	195	183	189	184	167	148
Own consumption electricity	287	286	231	191	143	103
Electricity for hydrogen production	0	0	14	169	616	881
Final energy consumption (electricity)	**2,852**	**2,979**	**2,823**	**2,519**	**2,677**	**2,673**
Fluctuating RES (PV, Wind, Ocean)	173	381	720	1,240	1,634	1,812
Share of fluctuating RES	5.2%	11.2%	22.5%	42.3%	49.4%	54.7%
RES share (domestic generation)	**20.9%**	**26.9%**	**42.9%**	**74.1%**	**87.0%**	**95.0%**
'Efficiency' savings (compared to Com.)	**0**	**0**	**152**	**597**	**855**	**1,059**

table 10.16: EU 28: heat supply

PJ/a	2010	2015	2020	2030	2040	2050
District heating	**696**	**725**	**871**	**902**	**854**	**830**
Fossil fuels	529	560	488	293	108	33
Biomass	164	163	226	230	179	141
Solar collectors	0	0	104	239	401	481
Geothermal	3	2	52	140	166	174
Heat from CHP	**1,943**	**1,899**	**2,322**	**2,874**	**3,269**	**3,159**
Fossil fuels	1,619	1,618	1,622	1,137	700	341
Biomass	324	281	557	960	1,127	1,013
Geothermal	0	0	143	776	1,424	1,734
Hydrogen	0	0	0	2	17	71
Direct heating[1)]	**18,069**	**18,612**	**15,298**	**11,943**	**8,876**	**5,956**
Fossil fuels	15,459	15,750	11,819	6,936	3,617	620
Biomass	2,489	2,688	2,212	1,666	1,223	863
Solar collectors	62	80	602	1,848	2,229	2,410
Geothermal[2)]	59	95	665	1,492	1,807	2,063
Hydrogen	0	0	0	0	60	367
Total heat supply[1)]	**20,708**	**21,236**	**18,490**	**15,719**	**13,059**	**10,312**
Fossil fuels	17,607	17,928	13,929	8,367	4,425	995
Biomass	2,978	3,132	2,995	2,856	2,530	2,018
Solar collectors	62	80	706	2,087	2,631	2,891
Geothermal	62	97	860	2,408	3,397	3,971
Hydrogen	0	0	0	2	77	439
RES share (including RES electricity)	**15.0%**	**15.6%**	**24.7%**	**46.8%**	**66.0%**	**90.1%**
'Efficiency' savings (compared to Com.)	**0**	**71**	**2,285**	**3,567**	**3,816**	**4,064**

1) cooling. 2) cooling heat pumps.

table 10.17: EU 28: CO_2 emissions

MILL t/a	2010	2015	2020	2030	2040	2050
Condensation power plants	**792**	**683**	**497**	**119**	**62**	**8**
Coal	298	238	180	25	0	0
Lignite	272	238	145	0	0	0
Gas	186	182	159	88	61	8
Oil	29	21	9	5	0	0
Diesel	7	5	3	2	0	0
Combined heat & power production	**472**	**389**	**307**	**172**	**93**	**42**
Coal	151	153	119	29	0	0
Lignite	121	82	16	0	0	0
Gas	162	134	162	143	93	42
Oil	38	20	10	0	0	0
CO_2 emissions power generation (incl. CHP public)	**1,264**	**1,072**	**804**	**292**	**155**	**50**
Coal	449	391	298	54	0	0
Lignite	393	320	162	0	0	0
Gas	348	316	322	230	154	50
Oil & diesel	74	45	22	7	0	0
CO_2 emissions by sector	**3,650**	**3,483**	**2,718**	**1,400**	**657**	**171**
% of 1990 emissions	88.9%	85%	66%	34%	16%	4%
Industry[1)]	480	473	389	268	142	27
Other sectors[1)]	715	721	477	232	124	33
Transport	906	918	799	507	189	51
Power generation[2)]	1,180	1,015	754	251	120	34
Other conversion[3)]	370	356	300	174	83	25
Population (Mill.)	505	511	515	520	519	515
CO_2 emissions per capita (t/capita)	**7.2**	**6.8**	**5.3**	**2.7**	**1.3**	**0.3**
'Efficiency' savings (compared to Com.)	**0**	**69**	**511**	**1,053**	**1,032**	**655**

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

table 10.18: EU 28: installed capacity

GW	2010	2015	2020	2030	2040	2050
Power plants	**707**	**815**	**854**	**953**	**1,073**	**1,156**
Coal	99	79	59	10	0	0
Lignite	34	29	18	0	0	0
Gas	127	128	113	78	51	31
Oil	33	34	13	5	0	0
Diesel	5	3	2	1	0	0
Nuclear	143	134	68	11	0	0
Biomass	12	15	13	10	6	6
Hydro	147	154	152	152	153	154
Wind	83	137	232	371	433	449
of which wind offshore	0	9	38	106	116	120
PV	23	100	170	277	336	406
Geothermal	1	1	4	4	11	10
Solar thermal power plants	0	1	7	22	54	68
Ocean energy	0	0	3	10	28	32
Combined heat & power production	**181**	**180**	**193**	**172**	**154**	**128**
Coal	40	40	36	9	0	0
Lignite	13	12	3	0	0	0
Gas	84	90	114	103	71	38
Oil	32	26	15	0	0	0
Biomass	11	12	23	46	55	53
Geothermal	0	0	3	14	27	32
Hydrogen	0	0	0	0	1	5
CHP by producer						
Main activity producers	121	120	129	113	96	85
Autoproducers	59	61	65	59	58	43
Total generation	**888**	**996**	**1,048**	**1,124**	**1,227**	**1,284**
Fossil	468	442	373	206	123	69
Coal	139	119	95	19	0	0
Lignite	47	42	21	0	0	0
Gas	212	217	227	181	122	69
Oil	65	61	28	5	0	0
Diesel	5	3	2	1	0	0
Nuclear	143	134	68	11	0	0
Hydrogen	0	0	0	0	1	5
Renewables	**277**	**419**	**607**	**907**	**1,103**	**1,211**
Hydro	147	154	152	152	153	154
Wind	83	137	232	371	433	449
of which wind offshore	0	9	38	106	116	120
PV	23	100	170	277	336	406
Biomass	23	26	36	56	61	59
Geothermal	1	1	6	19	38	42
Solar thermal	0	1	7	22	54	68
Ocean energy	0	0.3	3	10	28	32
Fluctuating RES (PV, Wind, Ocean)	106	237	405	658	797	887
Share of fluctuating RES	11.9%	23.8%	38.7%	58.5%	65.0%	69.1%
RES share (domestic generation)	**31.2%**	**42.1%**	**57.9%**	**80.6%**	**89.9%**	**94.3%**

table 10.19: EU 28: primary energy demand

PJ/a	2010	2015	2020	2030	2040	2050
Total	**71,887**	**70,615**	**60,125**	**46,815**	**42,068**	**36,095**
Fossil	**54,161**	**52,085**	**42,402**	**25,359**	**13,970**	**6,117**
Hard coal	7,971	7,168	5,355	1,813	906	758
Lignite	3,757	3,067	1,527	5	0	0
Natural gas	18,610	18,373	16,785	11,645	7,463	2,446
Crude oil	23,823	23,476	18,735	11,895	5,601	2,913
Nuclear	**10,006**	**9,680**	**5,033**	**851**	**0**	**0**
Renewables	**7,720**	**8,851**	**12,691**	**20,605**	**28,098**	**29,978**
Hydro	1,349	1,276	1,273	1,278	1,285	1,296
Wind	537	987	1,872	3,226	4,018	4,249
Solar	145	496	1,873	4,929	8,631	10,632
Biomass	5,439	5,710	5,709	5,952	5,531	4,546
Geothermal/ambient heat	248	378	1,927	5,096	8,281	8,852
Ocean energy	2	4	36	122	353	403
RES share	**10.5%**	**12.1%**	**21.3%**	**44.4%**	**67.3%**	**83.6%**
'Efficiency' savings (compared to Com.)	**0**	**434**	**8,846**	**16,988**	**17,683**	**19,903**

table 10.20: EU 28: final energy demand

PJ/a	2010	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**50,288**	**51,483**	**45,581**	**37,039**	**30,877**	**25,980**
Total (energy use)	**45,823**	**47,149**	**41,352**	**33,120**	**27,167**	**22,530**
Transport	**13,434**	**13,707**	**12,165**	**9,378**	**7,285**	**6,229**
Oil products	12,533	12,705	11,039	6,971	2,519	624
Natural gas	104	123	123	132	159	132
Biofuels	558	590	565	684	535	475
Electricity	240	288	404	1,163	2,539	3,094
RES electricity	50	77	173	862	2,208	2,940
Hydrogen	0	0	34	429	1,533	1,905
RES share Transport	**4.5%**	**4.9%**	**6.2%**	**19.9%**	**56.0%**	**83.9%**
Industry	**11,488**	**12,278**	**12,114**	**11,577**	**9,633**	**7,866**
Electricity	3,738	4,120	4,100	4,061	3,495	3,029
RES electricity	782	1,107	1,759	3,008	3,040	2,879
District heat	654	683	1,167	1,626	1,916	1,998
RES district heat	123	117	396	1,013	1,544	1,810
Coal	790	1,012	629	194	38	12
Oil products	1,443	1,442	903	418	125	20
Gas	3,845	3,850	3,873	3,261	1,759	195
Solar	0	0	177	634	917	1,009
Biomass and waste	1,017	1,171	1,131	979	746	510
Geothermal/ambient heat	0	0	134	403	574	710
Hydrogen	0	0	0	0	63	383
RES share Industry	**16.7%**	**19.5%**	**29.7%**	**52.2%**	**71.4%**	**92.6%**
Other Sectors	**20,901**	**21,165**	**17,073**	**12,164**	**10,249**	**8,434**
Electricity	6,288	6,316	5,660	3,840	3,576	3,412
RES electricity	1,315	1,697	2,428	2,844	3,110	3,243
District heat	1,580	1,599	1,674	1,792	1,893	1,726
RES district heat	290	263	571	1,135	1,566	1,580
Coal	587	623	282	67	0	0
Oil products	3,286	3,205	1,724	735	218	20
Gas	7,309	7,461	5,642	2,951	1,846	536
Solar	62	80	425	1,214	1,313	1,400
Biomass and waste	1,749	1,816	1,327	872	613	449
Geothermal/ambient heat	40	65	341	695	790	891
RES share Other Sectors	**16.5%**	**18.5%**	**29.8%**	**55.6%**	**72.1%**	**89.7%**
Total RES	**5,985**	**6,982**	**9,439**	**14,660**	**18,343**	**20,073**
RES share	**13.1%**	**14.8%**	**22.8%**	**44.3%**	**67.5%**	**89.1%**
Non energy use	**4,464**	**4,334**	**4,229**	**3,919**	**3,710**	**3,451**
Oil	3,840	3,727	3,453	2,957	2,513	2,206
Gas	572	555	582	590	603	623
Coal	52	51	194	372	594	621

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