



Trends and drivers of change in the EU energy sector: Scenarios

Introduction

Executive summary

General assumptions and basic drivers in the scenarios

The 'business as usual' scenario

The 'renaissance' scenario

The 'evolution' scenario

The 'revolution' scenario

Bibliography



Introduction

The energy sector in the EU25 employs more than one million people and generates a turnover reaching €535 billion a year, thereby contributing significantly to the European economy (Eurostat, 2007). Moreover, the energy sector is fundamental for most other sectors and hence can be defined as a key sector to economic growth and social and territorial cohesion. In fact, the development of the EU we see today has been closely interlinked with treaties and developments within the European energy sector, starting with the Coal and Steel Community in 1951 and the European Atomic Energy Community in 1957.

During the last decade, the European energy sector has experienced significant changes. Processes of liberalisation, technological progress and the growing concern over climate have restructured the sector at both market and company level. Still, challenges and changes seem to have only just begun. With an ever-increasing energy demand, an outdated energy infrastructure, strengthened environmental requirements and an increasing lack of skilled labour, the European energy sector today faces the most serious list of challenges ever. But great opportunities are also present if the sectoral challenges are met in the right way. The future development of the energy sector is, of course, highly dependent on a wide number of factors containing many uncertainties, of which the outcome of the ongoing debate on global warming is one of the most important and decisive.

This report explores four possible future scenarios of the European energy sector and their consequences for the structure and workings of the sector within the next 30 to 50 years. Special attention will be paid to issues such as changes in skills needs and labour demands, location patterns, R&D investments and the role of renewable and alternative energy sources.

The scenarios are based on a specific scenario-building technique focusing on drivers of change, which in spite of containing significant uncertainties, are highly decisive for the possible futures of the relevant sector. The methodology will be explained in greater detail in the following sections.

Further, the scenarios are part of the European Foundation for the Improvement of Living and Working Conditions' ongoing process of developing monitoring instruments to identify drivers of change in important European industries and business sectors.

Definitions and terminology

The energy sector in Europe is structured into three sub-sectors: electricity, gas and steam and hot water supply, each including branches of production or manufacturing, distribution and end (retail) sales. It is mainly the joint future of these three sub-sectors that will be described in the scenarios.

Under normal circumstances, oil is not directly relevant to the parts of the energy sector treated here, since it has almost been phased out of electricity, steam and hot water production. Nevertheless, oil prices may have a major indirect effect on the electricity sector. If oil prices continue to go up, electrical cars such as hybrid plug-in cars could, for example, become economically favourable compared to regular gasoline- or diesel-driven vehicles. This will result in a significant rise in demand for electricity as well as in the need for massive changes of the electricity infrastructure.

Methodology

Inspiration and data for the scenarios have been collected through comprehensive desk research and literature studies of existing energy outlooks and scenarios as well as general reports, statistics and relevant websites related to the energy sector.

Further, the scenarios are part of an in-depth study of trends and drivers of change in the European energy sector. The study also consists of a mapping report as well as a number of case studies of energy companies and clusters. To carry out the case studies and mapping report, a large group of energy experts and key people have been interviewed. Several of these were also asked questions on the future developments of the energy sector as well as what scenarios they found most plausible. The experts have not been presented with the four final scenarios described in this report, but their statements, comments and predictions have been used as inputs and inspiration in the scenario-building process.

The chosen experts represent different stakeholders within the energy sector, such as enterprises, labour and industry associations, cluster organisations and research centres. A complete list of the consulted experts can be found in the appendix of the mapping report.

What is a scenario?

According to Chambers English Dictionary (2006), a scenario is ‘an outline of future development which shows the operation of causes’. Scenarios typically describe the future of a sector or a specific business environment. They are not predictions, but explore the extremes which challenge the existing sector or business model. Scenarios should, however, be rooted in reliable data and identifiable trends which are extrapolated and organised. In this way, scenarios are statements of different possible future outcomes (Analysys.com, 2007; Infinitifutures.com, 2007).

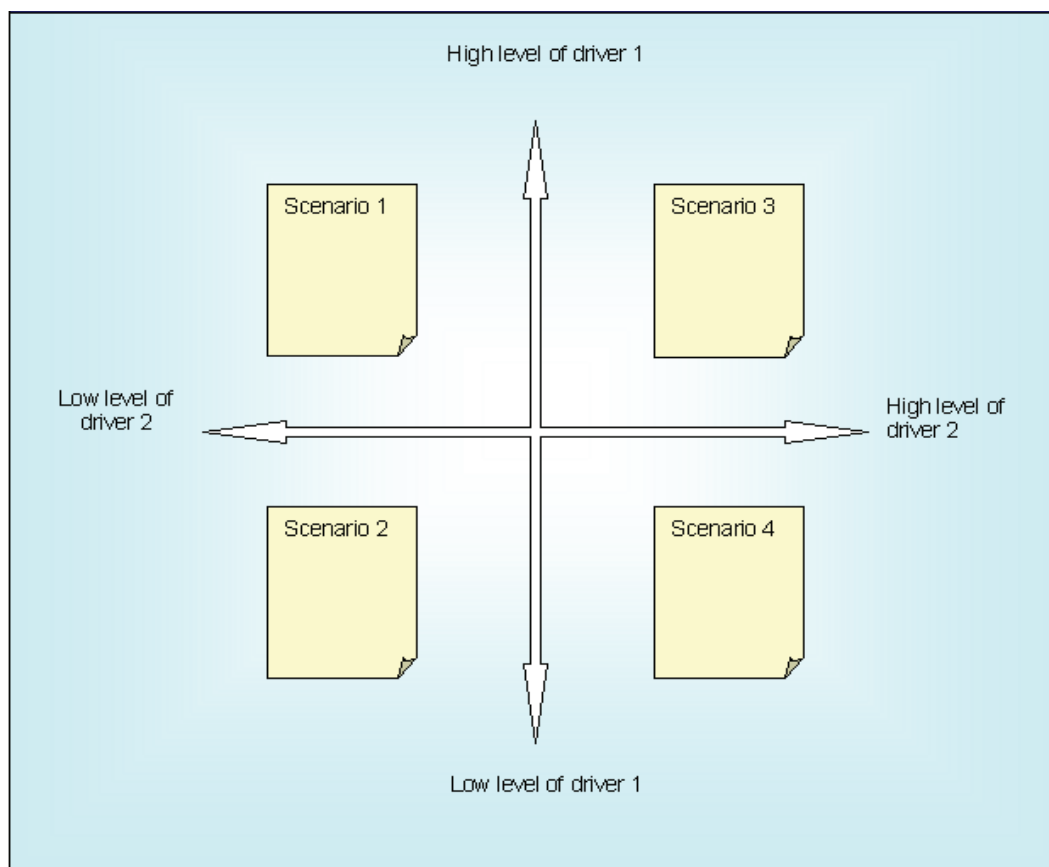
Hence, the aim of the scenarios presented in this report is not to submit a precise statistical forecast, but to present a number of possible futures for the energy sector as well as their impacts on the general structures and workings of the sector.

The scenario-building technique

The four scenarios are built on two major drivers of the future development of the energy sector, one being the extension and level of international agreements on climate and climate-friendly energy production and the other being the level of technological progress and breakthroughs related to energy and energy production.

The exact future of the energy sector depends on a huge number of different drivers. However, some of the drivers, such as the increase in energy demand, are so likely to happen that all scenarios should incorporate them as a basic assumption. There might be some uncertainties in the precise growth in demand, but these fluctuations will most likely be of minor importance to the overall development and structure of the energy sector. Other drivers, such as the level of international agreements on climate, still contain great uncertainties, and different developments of these drivers could result in widely different and sometimes divergent futures of the energy sector. Thus, these ‘uncertain’ drivers should be explored in order to identify different scenarios and possible developments and contribute to a better understanding, anticipation and management of industrial change at an early stage.

The scenario-building technique applied in the presented scenarios has therefore been to identify important sector drivers containing great uncertainties. Among these, the two drivers assessed to contain the biggest impact on the structure and general workings of the relevant sector have been selected, and the scenarios have been constructed by crossing the axes of the two drivers, as shown in Figure 1, thereby creating four different possible scenarios (gbn.com, 2007).

Figure 1: *The scenario-building technique*

Source: *Oxford Research, 2007*

For this study, the two selected main drivers are the extension and level of international agreements on climate and climate-friendly energy production and the level of technological progress and breakthroughs within energy and energy production.

For example, international agreements potentially impacting the energy sector will be whether China, the EU, India, Japan, Russia and the US agree on seriously reducing CO₂ emissions with exact amounts and deadlines. Also, the future workings of the CO₂ trading scheme will be of major importance to the development of the energy sector. One could also imagine future international agreements on the share of renewables in electricity production, electricity and biofuels in the transport sector and on how to subsidise climate-friendly energy production. At EU level, there already exist binding agreements on cutting down CO₂ emissions, but globally (within the UN system), it has so far not been possible to agree on the exact measures or timeline for the process. The level of future energy and climate-related agreements within the EU will probably depend on the extension and level of global agreements, thus making global/international agreements on climate a crucial factor.

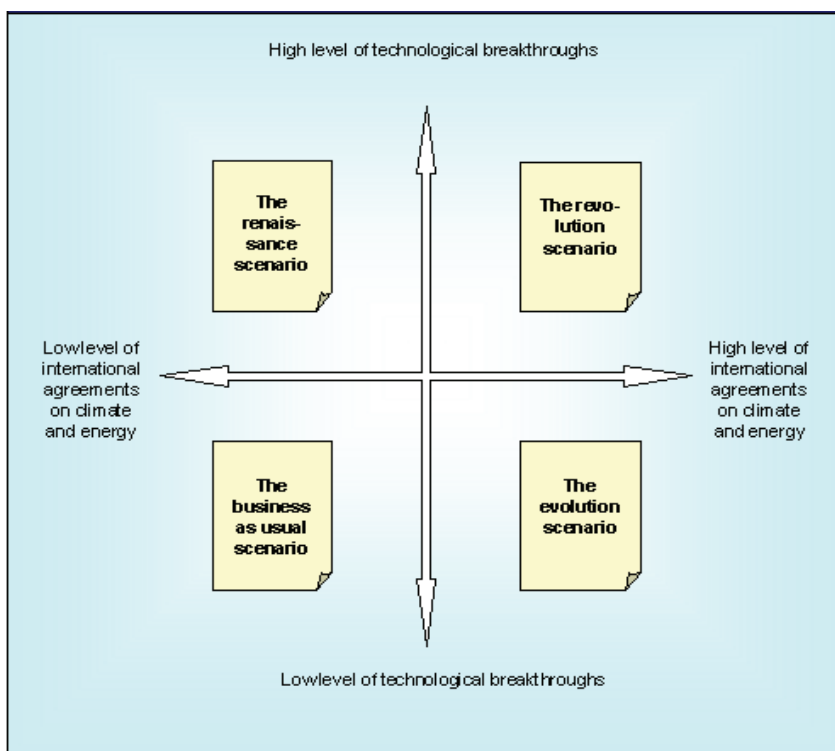
Important breakthroughs in energy-related technology that would change the energy sector could be the successful development of hydrogen and fuel cell technology, battery-driven cars at reasonable prices and CO₂ storage techniques. But breakthroughs could also come within more common renewable energy sources, such as solar and wave power, making them much more effective than today – a development which is needed if renewable energy is to be a real alternative to fossil fuels. The pace of technological progress can to some extent be controlled by putting resources into R&D activities, but even great amounts of money cannot secure major technological breakthroughs and it is therefore a

driver containing great uncertainties. As an example, much money has been put into developing hydrogen and fuel cell technology, but according to most experts, we are actually still far away from the technological breakthrough that would make the technology applicable in everyday life.

Applying these two drivers to the scenario-building techniques creates the following four different scenarios (see also Figure 2).

1. A scenario with a low level of international agreements and few important technological breakthroughs: the **'business as usual scenario'**.
2. A scenario with a low level of international agreements but still a considerable level of important technological breakthroughs: the **'renaissance scenario'**.
3. A scenario with a high level of international agreements but a relatively low level of technological breakthroughs: the **'evolution scenario'**.
4. A scenario with both a high level of international agreements and many technological breakthroughs: the **'revolution scenario'**.

Figure 2: *The four scenarios*



Source: *Oxford Research, 2007*

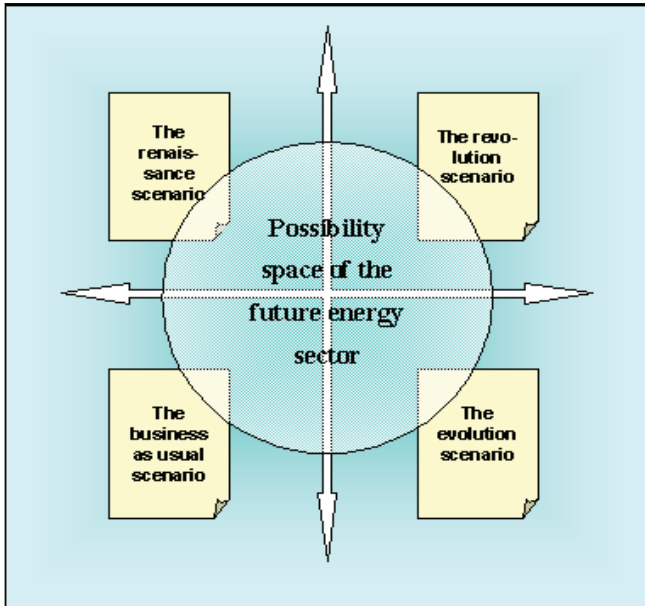
The future of the European energy sector

Until the 1970s, scenarios were mostly extrapolations of the past into the future. But with the growing speed of radical social changes, scenario methods have had to change, leaving more space for this greater uncertainty and pace of change (Cabinet Office, 2001).

The scenario technique used here takes radical social changes and uncertainties into account by presenting four 'extreme' situations of the future energy sector.

The four 'extremes', or radical situations, where drivers are taken to a maximum or minimum level, together create a 'possibility space', as illustrated in Figure 3.

Figure 3: *The future energy sector*



Source: *Oxford Research, 2007*

It is somewhere within this possibility space that the future of the European energy sector is likely to unfold (Cabinet Office, 2001).

Executive summary

This report presents four different scenarios, all representing possible but uncertain futures of the energy sector. Main drivers have been identified to be international agreements on climate and climate-friendly energy solutions, especially agreements on lowering CO₂ emissions, and the level of technological breakthroughs achieved within renewables and other alternative energy solutions. Different developments within these two main drivers create different possible sector futures. Though the scenario-building technique explores four 'extremes', it is possible to draw out some general learning perspectives from the different scenarios that are useful no matter what the actual future looks like.

One of the general learning perspectives from the four scenarios is that political action on reducing CO₂ emissions and increasing renewables' share of energy production will not only have a positive impact on the climate threat, but also on the development and dynamics of the energy sector.

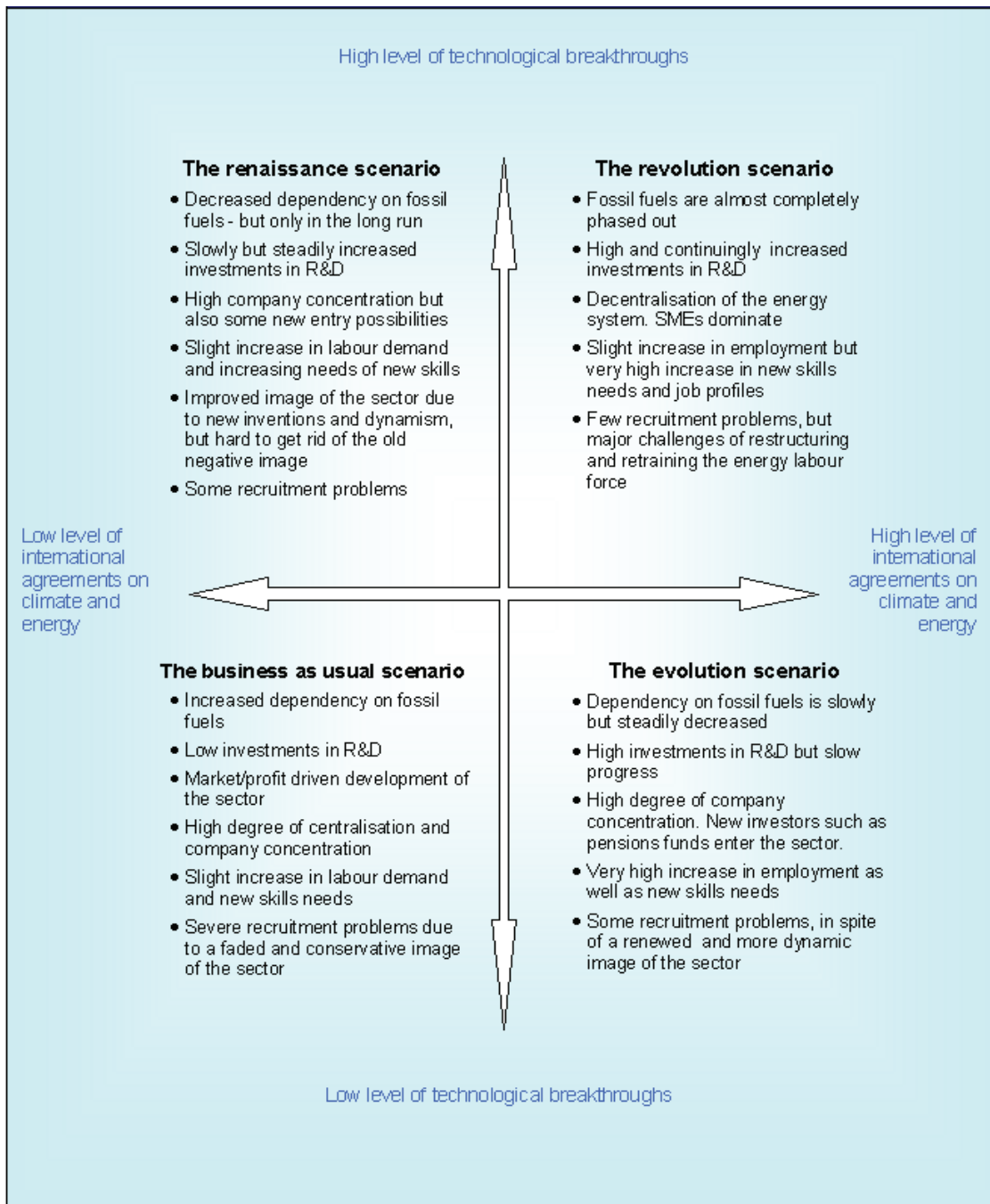
Political action is clearly needed and wanted, but the energy sector itself can still do much to ensure that the sector develops in an economically, socially and environmentally sustainable way. In the possible situation where international negotiation on lowering CO₂ emissions breaks down, the energy sector should keep investing in R&D and in turn into renewables and CO₂-neutral technologies. Though much more profitable in the short run, relying on fossil fuels will result in increased dependency on ever-scarcer resources, low investments in R&D in renewables and an energy sector lacking in skilled labour due to a fading image. The final outcome of this development could easily be a downward spiral with incalculable consequences for the energy sector itself as well as for the whole of society.

Another possible situation described in the scenarios is that technological breakthroughs cannot follow the pace of the required changes. This obviously makes it a good idea for the energy sector to increase investment as fast as possible in a diverse set of technologies, including different renewable sources and CO₂ storing techniques as well as energy efficiency solutions. In the long run, this will also lead to a more economically advantageous and sustainable development of the sector.

However, in different ways and to a different degree, getting the right skills and employees will be a major challenge in all of the scenarios. No matter what is done, the combination of an ageing workforce, increased energy demand and the inevitable task of extending and renewing Europe's energy infrastructure will present the energy sector with a serious challenge in getting the needed labour. However, the willingness to change and to invest much more in innovation, R&D and in making the transformation to renewable energy sources as the number one priority are key factors in all the scenarios to improving the sector's dusty image and thereby improving its ability to attract new and well-educated employees.

Figure 4 summarises the characteristics of each scenario.

Figure 4: Summary of scenarios



Source: Oxford Research, 2007

General assumptions and basic drivers in the scenarios

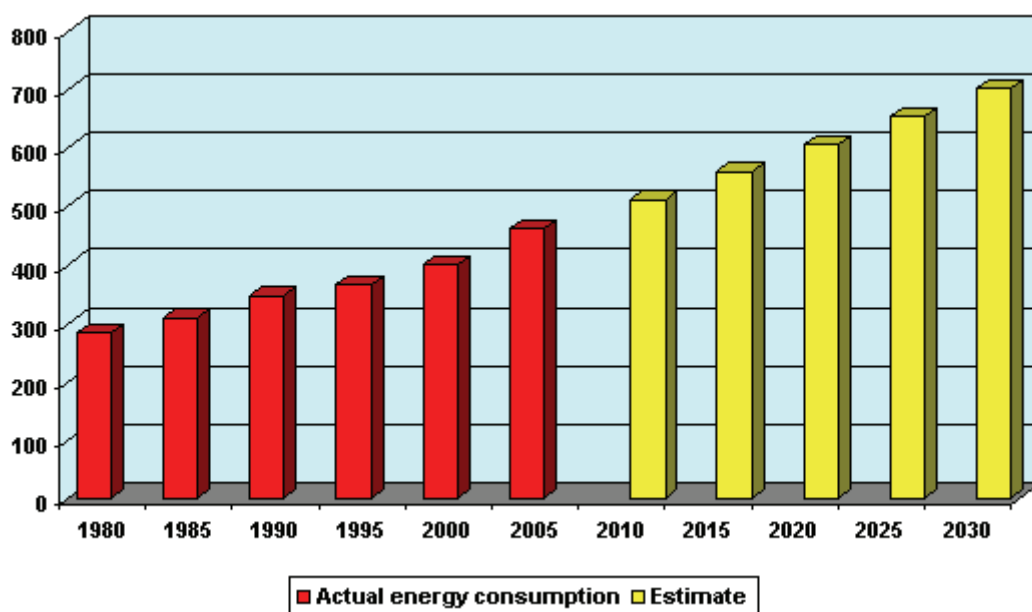
As mentioned earlier, the scenario-building technique implies that a couple of parameters are singled out to be decisive factors for the content of the individual scenario. While some parameters are simply delimited from the equation, other relatively significant parameters are taken into account as fundamental premises for the developments described in the scenarios. This section includes a description of the general assumptions that are taken into account as basic premises in all of the scenarios.

Rise in world energy demand

One of the main assumptions is that the demand for energy will grow continuously in the coming decades. This assumption is widely supported by research in this field, although slight divergences between researchers' expectations in terms of energy demand growth rates can be identified.

The annual *World energy and economic outlook* made public by the International Energy Agency (IEA) forecasts a significant development in world energy consumption. By 2030, the world's aggregate energy consumption will have risen to 702 quadrillion Btu – an increase of approximately 52% from the 2005 energy consumption level. Figure 5 shows the development of world energy consumption estimated by IEA. As illustrated, the estimated development maintains the energy consumption development rate of the past 25 years.

Figure 5: *Perceived and expected development in world energy consumption, 1980 to 2030*

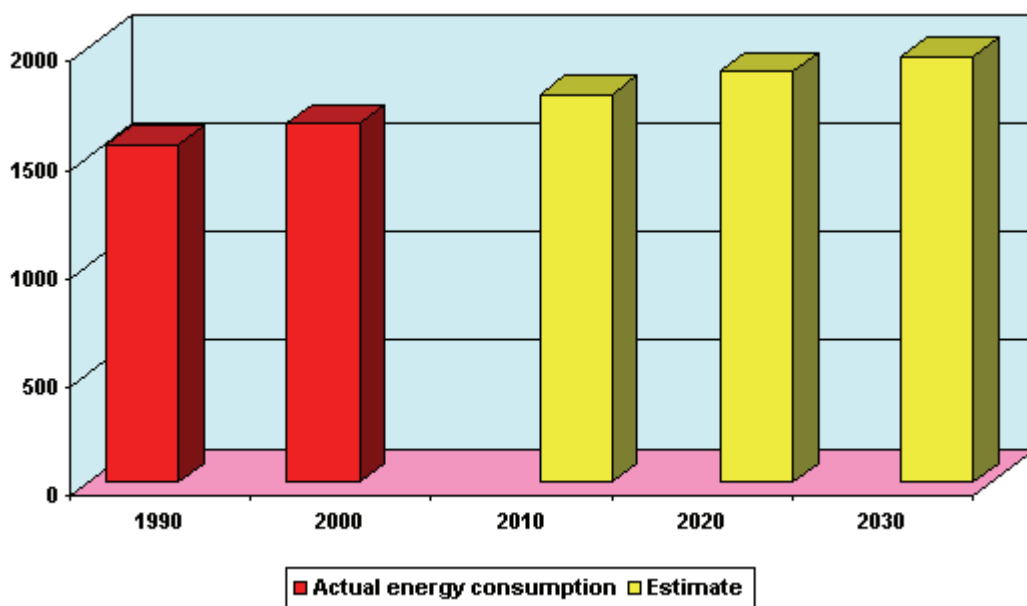


Source: IEA 2005, 2007

The key driver of the post-2005 developments in world energy consumption is the rise in energy consumption among non-OECD countries. This is due to the higher projected growth rates in terms of economy and population. The soaring growth rates of the Chinese and Indian economies are particularly significant factors for the development of the aggregated world energy consumption. In fact, Asian non-OECD countries (including China and India) account for about 65% of the post-2005 increase in energy use (IEA, 2005, 2007).

Though not of the same magnitude as the worldwide growth rate, the EU energy demand will grow significantly in the years to come. In the report *European energy and transport – scenarios on key drives*, published by the European Directorate-General for Energy and Transport in September 2004, it is estimated that the energy demand in the EU25 will grow approximately 19% between 2000 and 2030 (see Figure 6).

Figure 6: *Perceived and expected development in EU25 energy consumption, 1990 to 2030*



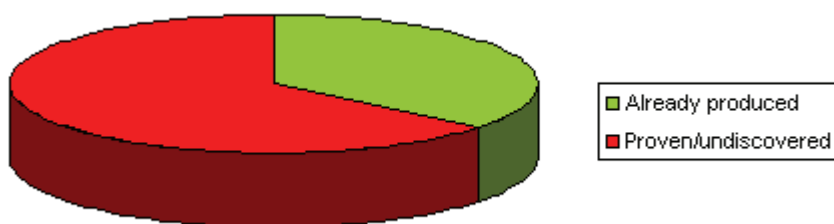
Source: *DG Energy and Transport, 2004*

The growth in energy demand cannot be explained by population growth, although the reason for the growth is closely connected to population trends: while the number of inhabitants in the EU25 is not likely to grow, the number of households will grow significantly. In fact, UN projections forecast that the average household size in the EU15 is expected to decline from 2.4 people in 2000 to 1.97 persons in 2030, yet the number of households in the EU25 will grow from 185 million in 2000 to 227 million in 2030, leading to higher energy consumption per person. The economic growth in the EU is also a significant parameter for the growth in energy demand, and the region is expected to maintain a steady growth rate in the years to come – a growth rate to which the new Member States are making a significant contribution (DG Energy and Transport, 2004).

Running out of oil, gas and coal

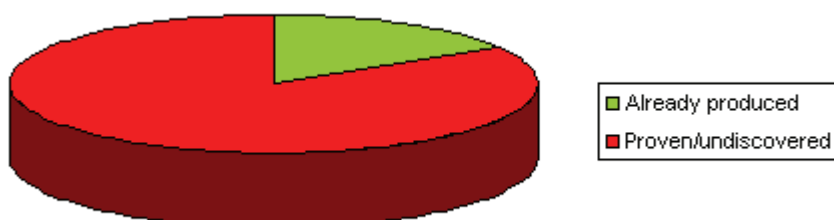
The subject of oil and gas supply has recently become an increasingly intense controversy. Whereas some analysts fear that the world's oil and gas supplies will be depleted during the next couple of decades, other groups are convinced that the progress of technology and the continued discovery of new sources of conventional oil and gas recovery will ensure that the steadily growing energy demands will be met in the next century too. Nevertheless, in general, it is agreed that oil, gas and coal are goods of a limited supply. It is therefore important that the future risks of oil, gas and coal shortages and legislators' and business partners' motives created by such energy shortages are taken into account in the scenarios.

Figure 7: World oil reserves



Source: IEA, 2005

Figure 8: World gas reserves



Source: IEA, 2005

In a report prepared by the IEA, the future supplies of conventional oil and gas are estimated. The main finding in the report is that conventional oil and gas are resources of a limited supply and that technological breakthroughs in terms of oil and gas recovery are requisite if the world's growing energy demand is to be met. While approximately one-third of the world's supply of recoverable oil (IEA estimation) has already been used (see Figure 7), only about 16% of the world's recoverable gas supply (IEA estimation) has been produced at this time (see Figure 8) (IEA, 2005).

Coal is another major energy source, and in comparison to oil and gas, it has relatively voluminous reserves. British Petrol (BP) considers the total of recoverable reserves of coal to be reflecting a current reserves-to-production ratio of 147, while the reserves-to-production ratios for oil and gas are considered to be just above 40 and 60 years, respectively (BP, 2007).

However, at this time, some districts have already experienced coal shortages. In January 2008, Indian power plants suffered from coal shortages due to bottlenecks in the supply from Coal India. In spite of this, at this time, coal must in general be considered to be a relatively 'safe' source of energy in terms of supply.

At the time of writing, oil prices are subject to massive fluctuations, among which most have an upward tendency. These price rises are not only due to shortages (although the correlation between supply and demand, of course, should never be ignored as a significant parameter for commodity prices), but also reflect the fact that the physical sources of energy, e.g. oil and gas, are subject to political conflicts.

The immense rise in oil prices since the 1990s (see Figure 9) led to a price peak of US\$100 per barrel at the end of 2007 – about three times the price level in 2000. Analysts consider the recent drastic oil price rises to be more than partially

caused by the political instabilities in the regions in which the oil is recovered. Even though the first US\$100 per barrel ceiling burst happened under rather peculiar conditions, analysts consider future oil prices above US\$100 per barrel to be highly plausible (<http://www.business.dk>, 2007).

Figure 9: Oil prices 1987 to 2007, BRENT spot



Source: IEA, 2007

The 'X factor' – international conflicts

Recent years have proven that gas and oil are still major political means and that the prices of these goods are susceptible to internal political relations. Conflicts within some of world's key energy supply regions is an X factor that can lead to energy price explosions and serious energy shortages, thereby also changing the premises for the future scenarios of the European energy sector. These potential conflicts are not considered in general in the scenarios, but in the following, some important examples on political conflicts that may cause instability are described.

Parts of the Middle Eastern region in particular (the principal world oil supplier) can be characterised by instabilities in external and internal political relations, leading to massive oil price fluctuations. The war in Iraq and the discrepancies between Middle Eastern and Western countries, plus the Israel–Palestine conflict, can be characterised as having significant effects on oil and gas prices. The recent intense oil price rises are partly caused by these instabilities, as political instability easily leads to drops in world oil and gas supply.

Among the countries with the largest oil reserves and oil supply market shares, Middle Eastern countries such as Iran and Saudi Arabia are prominent. Iran holds the world's third largest oil reserves as well as the second largest natural gas reserves (<http://www.iea.org>, 2007). However, at this time, Iran is OPEC's second largest and the world's fourth largest oil producer, and the economy of the country is highly dependent on its oil sales. In addition to being a major oil supplier, Iran is also an important power centre in the Muslim world, and the country's government, which is characterised as 'theocratic' by the CIA (CIA, 2007), often acts in opposition to the strategies and ambitions of Western countries.

Saudi Arabia is the world's largest oil producer and possesses one-fifth of the world's oil reserves (<http://www.iea.org>, 2007). The country is also a power centre in the Islamic world, as the two holiest places in Islam, Mekka and Medina, are located in Saudi Arabia and also because the rule of the kingdom is based on the recommendations of the Koran. The country has long been a rather stable non-democratic monarchy, but social unrest and discontent with the ruling class, especially from young parts of the population, has shaken the regime several times in recent years.

Being a region with many social, religious and economic tensions, the risk of future conflicts in the Middle East is prevalent. International as well as civil conflicts in this region almost always affect the world oil and gas supply. Hence, if the tensions escalate into civil or internationally armed conflicts, this could change the world energy situation quickly and dramatically, with supply shortages and price explosions. A major conflict in the Middle East will thus also clearly change the premises for the scenarios.

The Middle East is not the only cause for anxiety regarding energy price fluctuations. At the time of writing, the conflict in Nigeria – a major oil exporter – has been a driver of the current oil price rises, and further price rises may follow if the conflict escalates. The re-election of President Hugo Chavez in Venezuela has also led to further energy insecurity, as Chavez is willing to use the major Venezuelan oil resources as a means in reaching his political goals. For instance, Venezuela supplies Cuba with cut-price oil in exchange for highly educated labour, e.g. doctors and engineers, from Cuba while demanding a higher oil price when trading with countries such as the US.

The utilisation of energy sources as a means to meet political goals is also characteristic of other countries. In 2005, Russian government-owned gas supplier Gazprom decided to cut off gas supply to Ukraine, apparently due to the gas price debate between the two countries, which led to gas shortages in Ukraine. Critics state that the cut-off was Russia's punishment for the Orange Revolution in Ukraine and thus a political action. This criticism was repeated in 2007 when Gazprom threatened to cut off gas supply to Ukraine again. Since the threats were concurrent with the Ukrainian election, accusations of the Kremlin using energy as a political lever have re-entered the international political debate (www.cnn.com, 2007). Russia is the single most important supplier of natural gas to the EU and cut-offs in gas supply to, for example, Ukraine and other neighbouring countries also affects EU gas supply, as distribution pipelines from Russia pass through these countries.

Continued liberalisation

The last general assumption on which the scenarios are based is the continued liberalisation of the energy markets. In recent years, national and international legislators have carried out a vast number of initiatives in order to ensure improved competition on the energy market. In particular, the EU has launched initiatives leading to a higher degree of liberalisation and integration on the European energy market. The recent liberalisation of the individual countries' energy markets has led to changes in the overall structure of the European energy market – developments which in the years to come are likely to be followed by further restructuring initiatives.

The process of liberalising energy markets renders it possible for autonomous energy companies to enter new markets. The development towards a higher degree of liberalisation is widely supported among analysts and most energy sector stakeholders. (see, for example, <http://www.eurelectric.org>, 2007).

Since the support for further liberalisation is relatively salient, it is quite plausible that the liberalisation of the energy sector will continue in the years to come. This will result in market forces becoming increasingly prevalent within the European energy sector and energy markets. As described in the 'business as usual scenario', the situation where no international agreements on climate and energy exist will lead to an energy sector primarily driven by market forces and the privatised energy companies' search for maximising profits.

The continued liberalisation will most likely have a limited effect on the size of the European energy labour force. Employment has been declining significantly during the last decade within the EU energy sector, but most experts are convinced that we have now reached the bottom, where no further major rationalisations are possible. However, the skills and job profiles demanded by the energy sector will change together with further liberalisation and skills within marketing, PR, customer services, legislation and contract management will increase in all of the scenarios.

The 'business as usual' scenario

In this first scenario, the lack of both international agreements on climate as well as technological breakthroughs result in an energy sector mostly relying on doing *business as usual* and characterised by conservativeness and slow development. Since no or only few international obligations exist for the energy sector on, for example, cutting down CO₂ emissions and turning to renewables, the main drivers of developments in the sector are left to market forces. As such, the increased demand for energy and the privatised energy companies search to maximise profits.

With its mixture of increased dependency on ever-scarcer fossil fuels, low investments in R&D in renewables and an energy sector lacking skilled labour due to its faded image, the final outcome of this scenario could be a downward spiral with incalculable consequences for the sector itself as well as for the whole of society.

Plausibility of the scenario

Although not the most likely of the four scenarios, the 'business as usual' scenario unfortunately is not that unrealistic. Fossil fuels are increasingly being used as geopolitical instruments and fierce global economic competition between nations and regions seems so far to have been an effective doorstop for a global treaty on reducing CO₂ emissions.

Further, a lack of political will and measures in climate and renewable energy issues can easily lead to a vicious circle where lowered investments in R&D will mean even fewer technological breakthroughs, which again makes the transformation to cleaner and CO₂-neutral energy sources even more expensive and hence less politically attractive. However, if the consequences of the climate change suddenly accelerate, it might very well be a strong motivational factor for political action.

Renewables and R&D

Even though the few obligations to further CO₂-neutral energy production and the lack of technological breakthroughs make renewable technologies disadvantageous to coal and gas, the share of renewables will increase during the first years. However, this is only due to the already existing EU agreement on increasing the share of renewable energy sources to 21% of the total EU electricity production by 2010 (European Commission, 2006) and the Kyoto Protocol, whereby the EU is obliged to cut CO₂ emissions by 8% by 2012 (DG Environment, 2007).

When these goals have been reached, the most urgent priority for energy companies will be shareholders' requirements to maximise profits and the rising energy demand will be met with more gas, coal and nuclear-powered utilities, which will be cheaper than investing in renewable energy sources. Due to the lack of technological breakthroughs, installed renewable utilities will be the ones known today, e.g. wind turbines and solar power, which demand great investments and are not cost effective. Thus, the actual amount of renewably-produced energy might increase, but renewables' share of the total energy production will decrease in the long run.

R&D activities will mainly be driven by market forces and most privately-funded research will be dedicated to developing energy efficiency technologies and technologies to cut down costs in traditional energy production and distribution. In this way, energy production in fact becomes more effective and hence less polluting, but these gains are of minor importance since the increased fossil fuels-based energy production will result in rising pollution and CO₂ emissions.

Some R&D activities within renewables will continue, but they will mostly be driven by public funding and political concerns about energy security as international disputes about access to fossil fuels intensify in line with the increased demand. Also, the fact that oil, gas and coal are of limited supply makes governments and some companies invest in developing alternative energy solutions.

Structure of the sector and location patterns

In the 'business as usual' scenario, the structure of the European energy sector will be driven by the same trend of company concentration as seen today. As energy production and distribution is mostly 'business as usual', the prominent players in today's European energy market will continue to dominate. The low level of innovation and changes creates few new entry possibilities and an ever-greater company concentration might occur. Price-driven market forces continue to make large, cost-effective companies advantageous. Further, in the increased competition and fight for getting access to the scarce fossil fuels, big multinational corporations will have more powerful voices and negotiation power. By 2050, a handful of companies will completely control the EU energy market.

The limited use of renewable energy sources will result in quickly rising prices of fossil fuels due to the increased demand for them and the limited supply. This will generate a revival of nuclear power both as a cost-effective alternative to fossil fuels and also as a means to secure energy supply, which for most EU countries becomes a serious problem as dependency on primary energy imports from unstable regions grows. However, this new development will not result in major structural changes at market and company level. Most of today's dominant European energy companies, such as E.ON, EDF and Iberdrola, all have major activities in nuclear power generation and hence possess the needed competences and know-how in the field. Also, constructing nuclear power plants requires huge investments, which only financially strong companies can make.

Energy companies' location patterns will not differ much from today. Since fossil fuels will remain dominant, access to coal and gas infrastructures will be of major importance when locating power plants. Continued liberalisation and the improvements of the internal European energy market will widen energy companies' decision power and possibilities when deciding where to locate activities. Nevertheless, location possibilities will still be rather limited for most energy companies due to the nature of centralised energy production, transmission and distribution, which demands proximity to customers and grids. A rise in political conflicts and location disputes will be seen as several new nuclear utilities have to be constructed to meet the rising energy demand.

Employment and skills needs

In this scenario, the recent massive job losses within the European energy sector (Eurostat, 2007) will turn into more stable employment levels and a slightly increasing demand for labour. The renewed demand for labour is mostly due to the increased energy demand and Europe's ageing workforce. The rising labour demand will to a certain extent be moderated, since continued mergers and company concentration result in further processes of rationalisations.

The tasks of renewing and extending the European energy infrastructure will be started, resulting in an extensive need for training and upgrading, since know-how on construction of energy infrastructure is hardly present in the European energy workforce any more.

However, the overall problem for the European energy sector will be to recruit young and new employees, particularly young engineers specialising in the different branches of the electricity and gas sector. Due to the slow progress and low level of innovation, the sector will keep on struggling with an unattractive image of cables, coal and heavy power plants, making it unattractive to young people. Even though the number of jobs will only increase slightly, the failure to attract new employees will result in the European energy sector actually not being able to recruit the needed labour. This will have massive consequences for the sector, as salaries will rise significantly and understaffed energy companies must struggle hard just to get basic things done.

Impact on society

In the 'business as usual' scenario, energy prices will increase only slightly during the first decades due to the low level of new investment in renewable energy utilities and the fact that an increased share of electricity will come from cheap coal-fired power stations. In the long run, as fossil fuels become scarce and more expensive to extract, there will be a dramatic rise in energy prices. International conflicts and civil unrest may arise or be strengthened as disputes about fossil fuels increase. This will lead to higher energy prices, which again could generate and worsen international and regional tensions.

The significant rise in energy prices and low energy security will have negative consequences for the world economy. Poor countries and regions within Africa, Asia and Latin America with little access to energy-efficiency technologies will suffer the most. The European economy will also suffer significantly, being highly dependent on primary energy imports. Energy-intensive sectors such as paper, iron and chemical production will experience an economic downturn. The regions in the EU with many poor consumers, much heavy industry and little energy-efficiency technologies, such as many parts of Eastern Europe, will experience the most significant economic downturn.

As the use of fossil fuels continues and even increases, pollution and CO₂ emissions will be a tremendous problem. Global warming will not be stopped, resulting in rising water levels and extreme weather conditions with tremendous human, social and economic consequences all over the world.

The 'renaissance' scenario

In the 'renaissance' scenario, the lack of international agreements on climate and climate-friendly energy sources will slow down developments and changes in the energy sector, as in the 'business as usual' scenario. However, in this second scenario, a number of technological breakthroughs will generate some sudden changes and restart innovation and development in the sector and hence result in what could be called the renaissance (rebirth) of the European energy sector.

With no existing political obligations on lowering CO₂ emissions or increasing renewables' share of energy production, the main drivers will be market forces and hence mostly price driven. In the beginning, this will lead to a significant demand for fossil fuels, putting pressure on the energy sector. However, the combination of rising prices of fossil fuels and the new possibilities created by the technological breakthroughs in renewables will lower the dependency on fossil fuels in the long run.

Plausibility of the scenario

As described in the 'business as usual' scenario, the risk of failure of uniting the world's most important countries in a global treaty on cutting down CO₂ emissions is prevalent. Geopolitical disputes about energy and the fierce economic competition between regions and nations have so far been an effective doorstop for a global treaty on reducing CO₂ emissions.

However, the combination in the scenario of no political agreements on climate and energy and a relatively high level of technological breakthroughs is less likely to happen. The plausibility of technological breakthroughs happening largely depend on the amount of money and resources being spent on R&D, and with no political incentives to develop new renewable technologies, the level of R&D activities in the energy sector is likely to decline. The possibility of important technological breakthroughs are, however, still prevalent, making this scenario a real possibility.

Renewables and R&D

The share of renewables will increase during the first years as a result of the already existing EU obligations on lowering CO₂ emissions and increasing the share of renewable energy sources. As political obligations for the energy sector to cut down CO₂ emission fade, companies will be focused on revenues and a rising demand for fossil fuels will be seen. In the long run, technological breakthroughs will start changing this.

With no obligations to lower CO₂ emissions, R&D activities will focus on energy-efficient technologies and promising renewable technologies that in time could become a cheaper and more secure energy source than fossil fuels. Technologies such as CO₂ storage will naturally be given less attention. Breakthroughs could come in the use of hydrogen and fuel cells, but they would most likely be improvements of more well-known renewable energy sources such as wind, wave and solar power, which for most energy companies would be far more attractive to invest in, as they are already being used today and are known in large electricity productions.

Between 2030 and 2050, the combination of technological breakthroughs and ever-rising prices of fossil fuels will make renewable sources favourable. As payback times typically reach 30 to 60 years in a electricity utility, the massive investments in traditional electricity production from coal, gas and nuclear done in the first period of this scenario to meet the increased energy demand will slow the transformation to renewables.

The proof that alternative energy sources actually can be economically favourable to fossil fuels will motivate both governments and companies to make further investments in R&D activities, promising new profitable technological

breakthroughs. In the long run, this will speed up the pace of innovation and progress in the energy sector and renewables' share of total energy production will quickly become dominant from this point.

Structure of the sector and location patterns

In the short term, the European energy sector will keep today's structure with a high degree of company concentration. The dependency on fossil fuels and on well-known technologies will favour existing companies dominating Europe's energy sector.

In time, breakthroughs and technological progress will create some openings for new companies and add dynamism to the otherwise inert European energy market traditionally carved up between huge international energy companies and strong national interests. Location patterns might change with technological developments within renewables as huge offshore wave and wind turbines become major contributors to European energy production. As progress speeds up, the lack of well-educated labour (see 'Employment and skills needs' section below) will force European energy companies to outsource R&D activities to countries with a highly skilled labour force but higher unemployment rates.

Employment and skills needs

As in the 'business as usual' scenario, the European energy sector will experience a slight but renewed increase for labour due to the increased energy demand, Europe's ageing workforce and the tasks of renewing and extending the European energy infrastructure. As technological breakthroughs facilitate the transformation to renewable energy sources, the demand for labour will increase further. Together with the task of renovating the energy infrastructure, the application of new technologies will result in significant needs for new skills, job profiles and hence the upgrading of existing employees as well as the recruitment of new and well-educated employees.

With the beginning of the transformation to renewable energy and increasing levels of innovation and R&D, the European energy sector will be able to refurbish its somewhat dusty image and experience a degree of renewed popularity among young and well-educated employees. However, it will still be hard for the sector to recruit the needed employees, as an ageing European population makes competition for well-educated candidates fierce and the sector will have to struggle with an image that might be improving but is still severely damaged after many years of stagnation and lack of progress.

Impact on society

In the 'renaissance' scenario, energy prices will increase steadily but only slightly. The pressure from increasing gas and coal prices will be relieved by the gradually introduced renewable technologies, which, thanks to technological breakthroughs, will be much more cost effective than today. Hence, in this scenario, energy prices are an issue of less importance regarding impact on society.

CO₂ emissions will be –reduced, but too late to avoid serious climate change. Though not apocalyptic, Europe and the rest of the world will experience extreme weather conditions and rising water levels with the attendant social and economic consequences. In contrast to the 'business as usual' scenario, there is hope that further and more destructive climate changes will be stopped in time.

The 'evolution' scenario

The 'evolution' scenario is characterised by the energy sector progressing slowly but steadily, as in the process of evolution, and relying heavily on improvements and the expansion of existing renewables and CO₂-neutral technologies.

The presence of international treaties on climate and energy puts strong pressure on the energy sector to change. Together with the internationally-agreed obligations to cut down CO₂ emissions, there are also significant public subsidies for the development and expansion of renewable energy sources and favourable guaranteed minimum prices for renewably generated electricity and heat.

Though significant resources are being spent in developing renewable energy sources, the lack of actual technological breakthroughs hinders the transformation to new technologies to some degree and slows down the overall progress and development of the sector. Nevertheless, the international obligations on lowering CO₂ emissions and increasing renewables results in an energy sector working hard to progress. This ensures the slow but steady evolution and transformation of the European energy sector.

Plausibility of the scenario

Clearly, the escalating climate changes have the potential of sweeping away national and geopolitical interests that so far have blocked binding international agreements on climate and climate-friendly energy production. Further, though the consulted experts were not consulted on the four scenarios presented here, most of their own opinions on the most likely future of the energy sector look much like the 'evolution' scenario.

At first it may seem unrealistic that the huge investments in R&D which are likely to come will not result in major technological breakthroughs during the next 30 to 50 years, but if we look back 30 to 50 years, it clearly gives the impression of an energy sector developing steadily but with very few revolutions and technological breakthroughs. So far, evolution seems to have been the developing mode for the energy sector.

Renewables and R&D

After a successful UN meeting in Copenhagen in 2009 on climate change where China, the EU, India, Japan, Russia, the US and several other countries agree to cut down CO₂ emissions both in the short term (the next 10 to 15 years) and in the long run (the next 30 to 50 years), the share of renewable energy sources will increase steadily.

Following the successful outcome of the Copenhagen treaty on climate change, more international as well as national and regional treaties and instruments will be introduced. Among others, the CO₂ trading scheme will be harmonised and applied in all countries that sign the Copenhagen treaty. This will make CO₂ quotas an international good with rapidly increasing prices. Together with strengthened obligations and favourable subsidies and minimum prices on renewables, the expensive CO₂ quotas will be a strong motivational factor for energy companies to increase their use of renewable energy sources and other technologies to cut down on CO₂ emissions.

Hoping to develop the future's clean, cheap and effective energy sources, enormous amounts of money from both public and private stakeholders are being spent in R&D activities. Yet even though great results are achieved in making existing technologies cheaper and more efficient, the actual technological breakthroughs are lacking.

The lack of technological breakthroughs makes it impossible to reach the goals of cutting down CO₂ emissions and meeting a rising energy demand solely by turning to renewables. Installed renewable utilities will mostly be the ones known today, e.g. wind turbines and solar power, which demand great investments and are not cost effective compared to fossil fuels.

As it is realised that goals cannot be reached solely by turning to renewables, R&D in CO₂ storage, pyrolysis and other technologies binding CO₂ emissions from fossil-based energy production will receive much focus. CO₂-storing techniques develop promisingly but still too slowly to be applied in a large scale within the first decades of the scenario. This will undoubtedly lead to at least a minor comeback for nuclear power, and countries such as Denmark that have previously decided not to have nuclear utilities will have to reconsider this or else increase electricity imports from countries with nuclear power production, since they will most likely be unable to meet the increased electricity demand by depending solely on renewable energy sources.

The use of combined heat and power generation (CHP) will also be increased in order to improve the supply systems' efficiency. In the longer term, decreasing demand for heat due to global warming and improved insulation and energy efficiency and the potential for producing heat from alternative renewable sources will limit the expansion possibilities of CHP.

In the struggle to reach the goals of cutting down CO₂ emissions without the needed CO₂-neutral energy production technologies, energy-efficiency technologies will come to play a key role as well as being the focus of many R&D investments.

Structure of the sector and location patterns

The few new entry possibilities due to new technological developments will result in only minor changes in the primary structure of the European energy sector. The huge international corporations will continue to dominate the European energy sector, but at other levels a number of changes will happen.

The great amount of public and private funds invested in R&D will create some openings for new engineering and R&D companies and a booming world market for know-how and technology within renewables and energy efficiency will create great export and expansion possibilities for European energy-related companies. In general, a future world market for energy technology relying mostly on the renewable technologies known and applied today will place the European energy sector, being the world leader within renewables at present, in a very favourable position.

A huge number of new networks and clusters will appear. Public authorities, universities and companies all along the energy value chain will be interested in joining forces to improve innovation, acquiring the badly-needed skilled labour and to be able to exploit the many new possibilities in the world market for CO₂-neutral energy technology and know-how.

New investors such as pension funds will also enter the European energy sector, which will be in great need of capital. The enormous tasks of renewing the infrastructure, meeting rising energy demand and turning to renewable energy sources will require huge investments. Though bringing in new investors, it will definitely favour the existing structure with a few big energy companies.

In general, location patterns will not differ from today, since both structure and technology will remain the same. The energy system will also remain highly centralised due to the need for huge production utilities. The exact location of power stations will change as renewable energy utilities such as wind turbines become major contributors to European energy production, but the nature of centralised energy production will still demand proximity to customers and grids and hence limit location possibilities. The boom in R&D activities and the shortage of skilled labour (see below) will force European energy companies to outsource some R&D activities.

Employment and skills needs

As in the two former scenarios, the expansion and renewal of the European energy infrastructure will lead to significant needs for new skills, job profiles and hence the upgrading of existing employees as well as the recruitment of new and well-educated employees. To this should be added the many new jobs and skills needs created by the task of adapting the electricity infrastructure to the many new renewable energy utilities, which will be far less controllable in terms of production regularity and output quantity.

However, as well as the need for new skills, the most significant increase in employees will be within the renewables sector itself and its suppliers that produce and maintain the renewable utilities such as wind farms and solar power utilities.

New jobs will appear within engineering and R&D, but less 'technical' skills will also increasingly be demanded. Employees with skills and competences within multi-stakeholder corporations and project management will be much in demand due to many large-scale development programmes with high interaction between public and private stakeholders and investors. Further, the internationalisation of the market for renewable energy with the European energy sector as dominant player will also require employees with international competences and profiles in terms of, for example, languages, cultural knowledge and intercultural competences.

Altogether, the need for skilled labour within the European energy sector will increase dramatically in this scenario, but the new dynamism and focus on innovation and renewable energy will improve the image of the energy sector, making it easier to attract young and well-educated candidates. Still, the high increase in labour demand combined with an ageing European population will make it impossible to recruit all the needed employees in Europe. This will lead to outsourcing of some activities, as previously described, as well as increased pressure for easing the entry of foreign workers to Europe.

Impact on society

First of all, the 'evolution' scenario will result in high energy prices. Prices will not explode, but will rise quickly and steadily. Electricity and heat will be much more expensive to produce when having to rely mostly on using the renewable technologies known today, which are not cost effective compared to fossil fuels. Also, the great investments in R&D will have to be paid by consumers to some degree.

The high energy prices will naturally have the worst social and economic consequences for the European regions with large impoverished population groups and with a high share of heavy and energy-intensive industries. In general, the high energy prices might result in a global economic recession. As energy-efficiency technologies are increasingly introduced and the market adapts to the high energy prices, the world economy will flourish again, supported by the sustainable development of the energy sector and the many technological and scientific spin-offs generated from the huge investments in R&D within energy but applicable in many other sectors as well.

CO₂ emissions will gradually be cut down, but some further climate changes will inevitably occur, potentially destabilising the world economy. However, in the long run, the worldwide decrease in CO₂ emissions will avoid climate changes becoming a serious threat to mankind and the world as we know it today.

The 'revolution' scenario

As the name suggests, the 'revolution' scenario implies a true revolution and complete restructuring of the energy sector. Binding international agreements on cutting down CO₂ emissions kick starts the fast development of and changes in the energy sector. Many resources are put into R&D activities within renewable energy sources and CO₂ storing, which generates important technological breakthroughs, soon starting a revolution of the European energy sector.

The development and use of renewable energy sources will speed up, resulting in a rapid development of the energy sector, as has been seen within computer and communication technologies, which today are available and accessible for most people in the EU and indeed the world. In line with this development, the energy system will be decentralised and 'popularised' as small, decentralised renewable heat and electricity utilities at low prices are invented and made available to the public.

The significant technological breakthroughs will in the long run make international agreements unnecessary, as the cost of fossil-based energy production will exceed that of the highly effective decentralised renewable energy sources. Hence, in the 'revolution' scenario, we will experience a shift from a highly politically regulated sector during the first decades to an energy sector mainly driven by market forces as new and cheap renewable energy sources render political regulation on CO₂ superfluous.

Plausibility of the scenario

As formerly described in the 'evolution' scenario, it is plausible that the serious threat of climate change can sweep away the problems and disputes which so far have made it impossible to reach a binding international agreement on cutting down CO₂ emissions.

Though the energy sector has experienced very few, if any, revolutions during the last 30 to 50 years, an international treaty on lowering CO₂ emission could be perceived as a revolution in itself, potentially revolutionising the whole energy sector as major efforts are made to develop new, alternative and CO₂-neutral energy sources. The huge amounts of money put into R&D activities could potentially generate the technological breakthroughs needed to kick start the revolution of the European energy sector.

Renewables and R&D

With the presence of binding international agreements on lowering CO₂ emissions which began with the Copenhagen treaty on climate change, the process of increasing the share of renewable energy is kick started. During the first decades, however, the transformation to CO₂-neutral energy sources is steady but rather slow, since the energy sector must rely on the costly and ineffective renewable technologies we know today.

With the pressure from the international climate obligations, the energy sector invests enormous resources in R&D to develop clean and cheaper energy technologies. Public authorities also support R&D activities with significant resources as well as the implementation of renewable energy sources. After a couple of decades of intensive R&D activities, the efforts pay off as significant breakthroughs are made within biofuels, solar, wave, wind and geothermal power. These energy sources are already utilised on a large scale at this point, but the technological breakthroughs will make them much more effective and expand their possible use. The use of photovoltaic solar cells is particularly widened – their ability to transform solar energy into electricity is improved to a degree that even makes them applicable in northern and less sunny countries. Even in heavily cloudy weather, they are now able to produce a significant amount of electricity.

The technological breakthroughs making renewable energy ‘good business’ generates an upward spiral where companies are motivated to invest in further R&D activities. This generates new developments and, potentially, new technological breakthroughs, which again will motivate companies to make further investments in R&D.

The successful development of CO₂ storage techniques as well as increased use of combined heat and power generation (CHP) also helps to cut CO₂ emissions significantly. But as renewable energy sources are developed and made economically advantageous compared to fossil fuels, the role of CHP and CO₂ storing is decreased.

Nuclear power generation experiences a minor comeback in the first decades of the scenario, where the transformation to CO₂-neutral energy sources is slowed due to the lack of efficient renewable energy technologies. After this, the technological breakthroughs within renewables largely render nuclear technology superfluous and the technology is completely being phased out as Europe’s energy system is decentralised, since this makes the integration of nuclear utilities difficult and expensive.

The possibility of a hydrogen economy

Hydrogen is not a primary energy source, but an energy storage medium. It does not exist in pure form in nature, which means that it has to be extracted from, for example, water by using electrolysis.

The vision of a hydrogen-based economy relies on the expectations that hydrogen can be produced from cost- and environmentally-effective sources and that applications using hydrogen, such as fuel cell vehicles, will be effective and affordable enough to gain leading market shares.

The actual plausibility of a world economy fuelled by hydrogen is a highly debatable matter and many experts doubt it. Technologically, we are still far from being able to extract, distribute and store hydrogen in cost-effective and safe ways.

Nevertheless, a breakthrough in hydrogen technologies will result in major changes in the energy sector.

First, hydrogen will change the transport sector, which today is heavily dependent on expensive and insecure fossil energy sources.

Second, developments will potentially also enable hydrogen use in power generation utilities. This will make small-scale generation utilities much more effective and thereby change the electricity sector dramatically.

Source: *European Foundation, 2008*

In 2050, around 90% of Europe’s total electricity and heat production comes from renewable sources. Further, since the transport sector has introduced several new technologies, including, for example, biofuels and electricity-driven vehicles, the total energy consumption will also be dominated by renewables, though to a lesser degree than electricity and heat consumption.

The development of hybrid vehicles using mixtures of electricity and bio or fossil fuels, thus increasing the demand for electricity even further, will be a major new feature with great importance for overall energy consumption. Besides this, the new ability to store huge amounts of electricity in batteries developed by the automotive industry will influence the electricity system as a whole as the controllability of weather-dependent energy sources, such as wind power, will be improved considerably.

Structure of the sector and location patterns

To achieve higher efficiency and diminish distribution losses, the energy system will be decentralised, meaning that heat and electricity are generated at or very near the point of use. Today's centralised systems waste around two-thirds of their energy (EREC, 2007). Decentralisation is made possible by the new and improved renewable energy technologies such as solar and geothermal power and biofuels.

The decentralisation tendency will restructure the energy sector completely, marking an end to company concentration and the advantages of huge multinational corporations within energy generation and distribution. Most decentralised energy utilities will be owned by the people depending on them, be it households or larger cooperatives covering housing blocks or neighbourhoods.

The rapid increase in demand for renewable energy technologies and solutions will generate many export and expansion possibilities for European companies. But the rapid development and the many technological breakthroughs will also open up the market for many new players and result in decentralisation of the world market, with many local SMEs supplying local markets.

The development of electric vehicles will integrate the transport and electricity sectors to a high degree, as they now depend on each other and are able to extract many synergies in the improvement and development of new technologies, such as rechargeable batteries.

In summary, we will see a deeply changed energy sector with many new players, new consortia, clusters and others forms of radical cooperation modes, including various public and private stakeholders.

Employment and skills needs

As in all of the other scenarios, the expansion and renewal of the European energy infrastructure will lead to significant needs for new skills and hence the upgrading of existing employees as well as the recruitment of new and well-educated candidates. Also, the development, installation and maintenance of the many new renewable energy technologies will increase labour demand.

However, this is only the situation in the first decades of the 'revolution' scenario, where changes in the energy sector are still limited. As the decentralisation tendency comes to dominate the structure of the energy sector, the personnel needed for generating and distribution activities will decline dramatically.

This job decline will be more or less equalled by the new tasks of installing and maintaining the millions of decentralised power utilities, which create thousands of new jobs as well as needs for new skills and job profiles. Also, the demand for highly-skilled R&D personnel will explode especially for engineers specialised in electricity and renewable energy sources.

Executives, marketing experts and project managers from other, traditionally much more dynamic and decentralised sectors will increasingly be employed in the energy sector, which badly needs their competences and experiences as a result of the complete restructuring of the sector. The new dynamism and the extremely high level of innovation will improve the image of the energy sector, making it one of the most attractive sectors in Europe. At the same time, the complete restructuring of the sector will be a major challenge concerning employment, since it will result in massive needs for retraining existing staff and recruiting new types of employees, creating new education and reorganising the entire workforce.

Impact on society

In the first decades of the scenario, energy prices will rise significantly as huge investments are needed in order to improve the European energy infrastructure and reach the goals of increasing renewables' share of energy production. However, in the long term, the technological breakthroughs will lead to cheap energy prices as the investments for the decentralised renewable energy utilities will be low.

Together with the many technological spin-offs from the many R&D activities within the energy sector, the low energy prices and the high degree of energy security will be some of the most decisive drivers in a booming world economy. Oil and gas will lose importance, resulting in less international conflicts. Oil-producing countries, many of them heavily dependent on oil exports, will experience economic decline and a need to restructure their economies and industry to better fit the post-oil world economy. Other developing countries will experience high growth rates as cheap, decentralised, renewable energy utilities help bring economic development to distressed and inaccessible regions.

Though by far the most positive scenario in terms of lowering CO₂ emissions, some climate changes will occur, though mostly as the result of past CO₂ emissions. Climate changes will be minor and the rise in temperature will stay under the critical two degree Celsius level.

Bibliography

British Petrol, *Statistical review of world energy June 2007*, 2007.

Cabinet Office, Performance and Innovation Unit, *A futurist toolbox. Methodologies in futures work*, Strategic Futures Team, 2001.

Chambers Dictionary, 10th edition, Edinburgh, Chambers Harrap Publishers Ltd, 2006.

CIA: *World factbook*, 2007.

DG Energy and Transport, *Scenarios on key drivers*, 2004.

EREC: *Energy [r]evolution. A sustainable world energy outlook*, 2007.

European Commission, *Green Paper: A European strategy for sustainable, competitive and secure energy*, Luxembourg, Office for Official Publications of the European Communities, 2006.

European Directorate-General for Energy and Transport, *European energy and transport – scenarios on key drives*, 2004.

European Foundation for the Improvement of Living and Working Conditions: *Trends and drivers of change in the EU energy sector: Mapping report*, Dublin, 2008.

IEA, *Resources to reserves*, 2005.

IEA, *International energy annual 2005*, 2006.

IEA, *World energy and economic outlook*, 2007.

Websites:

Analysys: http://www.analysys.com/default_acl.asp?Mode=article&iLeftArticle=84&m=&n=

CNN: <http://www.cnn.com>

DG Environment, European Commission: http://ec.europa.eu/environment/index_en.htm

Eurelectric: <http://www.eurelectric.com>

Eurostat: <http://epp.eurostat.ec.europa.eu> (themes: 'Industry, trade and services' and 'Energy and environment')

Gbn.com: <http://www.gbn.com>

Infinitefutures.com: <http://www.infinitefutures.com/resources/glossary.shtml>

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