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Maija Ruska & Lassi Similä

Electricity markets in Europe

Business environment for Smart Grids

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Abstract

This report takes a look on the current state and future development opportunities of electricity markets in the European Union (EU). The business environment established by electricity markets has an essential impact on the potential and development of so called Smart Grid concepts and technologies, currently under extensive research and development in the EU.

According to a comparison based on previously published scenarios, electricity demand is expected to increase in the European Union. The projections for 2020 range from 3 530 TWh to 3 795 TWh, being 150–420 TWh higher than the electricity generation in 2008.

EU's energy and climate policy commitments imply that the electricity supply structure of EU needs to change completely in the next decades, from the current fossil fuel and nuclear based system to a system based on renewable energy sources and other low-carbon technologies. According to National Renewable Energy Action Plans, the annual RES-E production is expected to reach 1 200 TWh by 2020, more than double the amount generated by RES-E technologies in 2010.

Integrating distributed and often non-dispatchable renewable energy resources – especially wind and solar power – in electricity and energy systems is a key driver of the European electricity grid development. The European Union aims towards a single European electricity market. With the help of a well interconnected grid, the cost of renewable energy deployment can be brought down.

As a result of expected changes in electricity demand and supply, demand for many technological solutions discussed in a context of Smart Grids, such as demand response, advanced metering and automation, will increase from current. Cost-efficient potential of these technologies as a part of electricity systems remains a key question in further research and development of Smart Grids.

Preface

This review of electricity market development in Europe has been prepared as a part of the Finnish Energy and Environment Competence Cluster's (Cleen) research program "Smart Grids and Energy Markets". The research resulting in this study was done by VTT Technical Research Centre of Finland.

26.4.2011

Authors

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List of abbreviations

CCS	Carbon Capture and Storage
EC	European Commission
EEGI	European Electricity Grid Initiative
ENTSO-E	European Network of Transmission System Operators for Electricity
ERGEG	European Regulators' Group for Electricity and Gas
ETP	European Technology Platform
EU	European Union
GHG	Greenhouse gas
IEA	International Energy Agency
NREAP	National Renewable Energy Action Plan
RES	Renewable Energy Sources
RES-E	Renewable Energy Sources: Electricity
SET-plan	Strategic Energy Technology Plan
SG	Smart Grids

1. Introduction

The European Union has committed itself to the target of keeping the global warming less than two degrees compared to pre-industrial level. This target requires the EU to cut greenhouse gas emissions by 80–95% by 2050. This large emission reduction means that virtually all electricity should be generated from carbon-neutral sources.

At present, over half of the electricity generation in the EU is based on fossil-fuel consuming technologies. In the next decades, the electricity generation structure needs to change completely, from a current fossil-fuel based system to a system based on renewable energy sources and other non-carbon emitting technologies, which may be fossil fuel plants fitted with carbon capture and storage technology (CCS), or nuclear power. Large part of the electricity production is going to be based on wind and solar power, and local small-scale generation will increase.

Wind and solar power are non-dispatchable forms of power generation in the traditional sense. They can only generate energy when the energy source is available. This creates a challenge for the power system: electricity production will no longer follow demand. In the future power system, demand needs to became more flexible and match the supply.

The change in electricity supply structure is one of the central drivers for Smart Grid (SG) technologies. Smart Grid concepts, currently under intensive research and development, are commonly characterised as “the electricity network of the 21st century”. Making the grid smarter means adding more information and communications technology to the electricity system.

This report takes a closer look on the current state and future development opportunities of electricity markets in the European Union, focusing on the wholesale markets. The business environment established by electricity markets has an essential impact on the potential and development of Smart Grid technologies in the EU. On the other hand, a move towards Smart Grids potentially affects the fundamentals of electricity markets and the nature of electricity trading. For example, compared to traditional grids, Smart Grids potentially increase information on electricity market conditions (e.g. real-time prices) available for market participants. Smart Grids may also improve demand response opportunities, price-responsive or other “smart” automatic control systems in electric devices may increasingly be enabled by Smart Grids. Consequently, Smart Grids increase the potential to utilize renewable energy resources. All of these potential changes have an influence in the development of electricity markets as discussed in the following parts of this report.

The results provide information on market development and, consequently, potentially improve decision support for business decisions of industrial actors.

2. Drivers of the European electricity market development

The European electricity market development can be stated to be centrally determined by the development of a few, possibly interdependent drivers. The drivers can be classified to those also relevant to global-scale development of energy use and production, and to those more specifically relevant to European electricity markets.

As an introductive and structuring section to this report, the following section considers the *drivers* i.e. *driving forces* of the development of European electricity market. Here, the driving force or driver is considered as a major external (or internal) phenomenon that influences decision-making and, thereby, shapes the development of European electricity market in the next few decades.

This report covers the drivers "top-down", from briefly introduced global energy sector drivers to those more specifically and directly influencing the development of European electricity market and Smart Grids. These drivers are also more analysed in more detail in the following chapters.

2.1 Global energy sector drivers

The global energy sector drivers not only influence the European electricity market but have significance from a global energy perspective in the next few decades as well. The most important global drivers of energy sector are (VTT 2009a):

- Economic growth and structure, which are largely related to the demand of energy
- Improvement of energy security
- Mitigation of climate change and other environmental impacts
- Development of technology.

The development of technology largely affects the technical or economic potential of decision-making options in the future shaped by other energy sector drivers. For example, development of low-carbon electricity generation technologies (renewables, nuclear, CCS) affects the potential of means of reducing CO_2 emissions. On the other hand, technological breakthroughs that impact on production of goods in the economies or lower the costs of energy efficient technologies may significantly affect the demand of energy.

2.2 Long-term fossil fuel price development

Similar to other goods, fossil fuel prices depend on supply and demand. In the next decades, world's energy demand will increase, largely driven by the growth of developing economies. Fossil fuel resources are by definition restricted, and they decrease over time when they are consumed. More costly resources will be needed to respond to increasing demand. These factors drive the prices up.

The International Energy Agency's annually published World Energy Outlook includes projections of energy demand, production, trade and investment, fuel by fuel and region by region. In the 2010 edition, three different scenarios were presented. "Current policies" scenario serves as a baseline scenario, "New Policies Scenario" anticipates future actions by governments to meet the commitments they have made to tackle the climate change and growing energy insecurity, and "450 Scenario" is a pathway with the objective of limiting the global temperature increase under 2°C. Figure 1 illustrates fossil fuel price projections for the period from 2009 to 2035 in the "New Policies Scenario". According to this scenario, the prices of crude oil and natural gas will go up in fairly close tandem, partly because of indexation clauses in long-term gas contracts and indirectly because of the fuel substitution possibility. Coal prices are much more stable, which is explained by larger reserves. Coal demand is also expected to flatten out by 2020 in this scenario.

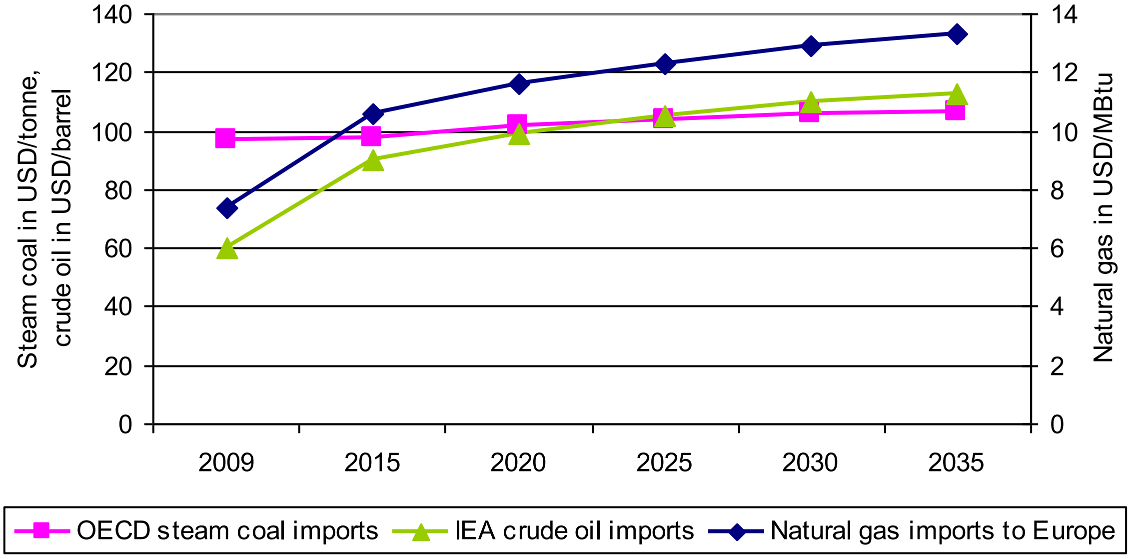

Figure 1. Fossil fuel price assumptions in IEA's New Policies Scenario (data provided by IEA 2010). Prices in real terms (2009 prices).

The presented price paths follow smooth trends. In reality, fossil fuel prices are and will be volatile, and the volatility will even increase because of presumably tightening supply and demand balance.

2.3 Decreasing indigenous fuel production

EU's indigenous coal, oil and gas production is in post-peak period (Figure 2), and the production of all of these fuels is projected to slowly decrease. Only lignite production is expected to remain quite stable in the period from 2009 to 2030 (EC 2008). However, EU primary energy demand is rising, and with decreasing indigenous fuel production, EU's import dependency is forecasted to increase. Figure 3 illustrates the expected import dependency development. The projections originate from "EU energy trends to 2030 – update 2007" (EC 2008).

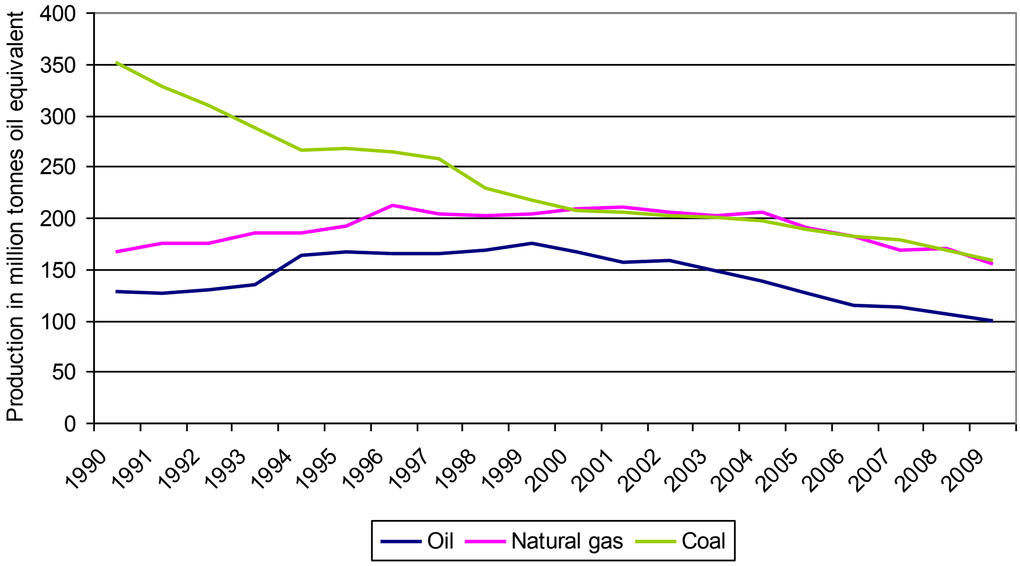

Figure 2. Indigenous production of fossil fuels in the EU (data provided by BP 2010).

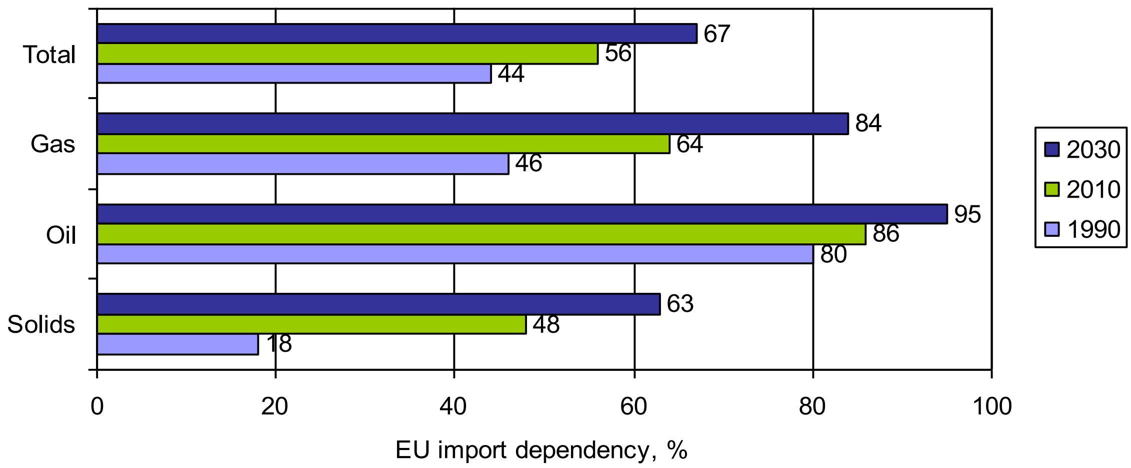

Figure 3. The EU's fossil fuel import dependency development in 1990, 2010 and 2030 (projection based on EC 2008).

2.4 EU climate and energy policy

The global drivers are reflected in the EU policy and national policies, aiming to steer the actions and decisions of a large number of decision makers (energy companies, energy users, authorities, etc.). Outcome of electricity market, reflected e.g. in investments in and usage of generation technologies, generation volumes, carbon dioxide emissions and other environmental impacts, and competiveness of electricity markets, is determined by the actions of decision makers in the environment affected by energy sector drivers.

The European Union has been active in its climate and energy policy. The goals of the EU energy policy reflect the global challenges, but are also intended to support the competitiveness of the EU, to increase the EU's self-sufficiency in energy supply, and to ensure sound environmental development in the EU area (VTT 2009a). The EU climate and energy policy has three key objectives:

- **Security of supply**: to better coordinate the EU's supply of and demand for energy within an international context
- **Competitiveness**: to ensure the competitiveness of European economies and the availability of affordable energy
- **Sustainability**: to combat climate change by promoting low-carbon and renewable energy sources and energy efficiency.

The European Union has proposed the two-degree limit for the global temperature rise and it has also been active in setting and proposing emission reduction policies and targets for the whole EU and for the Member States. In order to contribute to the two-degree target, the European Council has also given a long term commitment to the decarbonisation path with a target for the EU and other industrialised countries of 80 to 95% cuts in emissions by 2050 (EC 2010b).

In the past years, the EU's energy policy construction has been accelerated. This development goes back to October 2005, when the European Council requested the Commission to develop a long term and coherent energy policy in response to high oil prices. Commission reacted to this request by publishing the Green Paper "**A European Strategy for Sustainable, Competitive and Secure Energy**" in March 2006 (EC 2006). This paper stated that the European Union had entered to a new energy era, and identified six key areas where action was necessary to address the challenges. These areas were competitiveness and the internal energy market, diversification of the energy mix, solidarity, sustainable development, innovation and technology, and external policy.

In January 2007, the European Commission proposed a new energy policy in the communication "**An Energy Policy for Europe**" (EC 2007a). Commission introduced a comprehensive package of measures, to achieve a series of ambitious targets on greenhouse gas emissions and renewable energy, as well as to create a true internal market for gas and electricity, and to strengthen effective regulation.

The third legislative package[1] was introduced in September 2007 and agreed by the Council and the Parliament in July 2009. This package addresses the problems and acts to improve the regulatory

[1] Directive 2009/72/EC of 13 July 2009 concerning common rules for the internal market in electricity, Directive 2009/73/EC of 13 July 2009 concerning common rules for the internal market in natural gas, Regulation (EC) No 714/2009 of 13 July 2009 on conditions for access to the network for cross-border exchanges in electricity, Regu-

framework for energy market liberalisation in place since 2004. The package, including measures for electricity and gas markets, has been launched in order to ensure that all European citizens can take advantage of the considered benefits provided by a truly competitive energy market. The potential benefits include consumer choice, fairer prices, cleaner energy, and security. In order to achieve these goals, the Commission proposed

- To separate production and supply from transmission networks
- To facilitate cross-border trade in energy
- More effective national regulators
- To promote cross-border collaboration and investment
- Greater market transparency on network operation and supply
- Increased solidarity among the EU countries.

These proposals were transformed into regulations and directives. The requirements of the Directives must be transposed into domestic legislation by March 3rd, 2011. With regards to unbundling of transmission systems and transmission system operators, the schedule is set to March 3rd, 2012.

In March 2007, the European Council agreed to set precise, legally binding targets to tackle climate change. In January 2008, the Commission proposed **the Energy and Climate package**[2] with 20-20-20 goals for the year 2020. By 2020, the EU has committed itself to:

- Improving energy efficiency by 20%
- Reducing its greenhouse gas emissions by 20% (a 30% reduction if other countries make comparable commitments)
- Increasing the share of renewable energies to 20% of the total EU primary energy consumption
- Increasing the share of renewable energies in transport to 10%.

On 10 November 2010, the European Commission adopted the communication "**Energy 2020 – A strategy for competitive, sustainable and secure energy**". The communication defines the energy priorities for the period 2011–2020 and sets the actions to be taken to achieve the targets set for the year 2020. The presented energy strategy focused on five priorities:

- Achieving an energy efficient Europe
- Building a truly pan-European integrated energy market
- Empowering consumers and achieving the highest level of safety and security
- Extending Europe's leadership in energy technology and innovation
- Strengthening the external dimension of the EU energy market.

Achieving the goals of EU energy policy will require major technological breakthroughs. The EU has started a **Strategic Energy Technology Plan**[3] (SET-plan) to accelerate the development and market take-up of low-carbon technologies.

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lation (EC) No 715/2009 of 13 July 2009 on conditions for access to the natural gas transmission networks, Regulation (EC) No 713/2009 of 13 July 2009 on establishing an Agency for the Cooperation of Energy Regulators

[2] Directive on the Promotion of the use of energy from renewable sources (2009/28/EC), Emission Trading Scheme Directive (2009/29/EC) and the Effort Sharing Decision (406/2009/EC)

As a part of the European Union energy policy, the opening of electricity market to competition has been considered a direction efficiently supporting the policy goals. Open and integrated electricity markets are seen essential in order to meet the challenges of competitiveness, sustainability, and security of supply. The electricity market liberalisation process in the EU has been progressing gradually since the late 1990s, including the following legislation:

- **First Electricity Directive**[4] laying down rules for the internal market in electricity.
- **Second Electricity Directive**[5], replacing the directive (96/92/EC), and Regulation (EC) No 1228/2003. The Second Electricity Directive aimed at the full opening of electricity markets for all customers by July 1st, 2007. Commercial customers have been eligible since July 1st, 2004.
- **Third Electricity Directive**[6] focused on ensuring a high standard of public service obligations and customer protection and structural separation between transmission and production activities (unbundling). It also gave stronger powers and independence for national energy regulators, and introduced new institutional framework: ACER and the ENTSOs.

2.5 European Union Smart Grid policy activities

The challenges for the European networks can be formulated as: “need to renew Europe’s electricity networks, meet growing electricity demand, enable a trans-European electricity market and integrate more sustainable generation resources (including renewable sources)” (ETP 2006). The Smart Grid policies of the EU briefly reviewed in the following are a tool to partially address the challenges. Even though detailed analysis of the contents is not carried out here, reference for the EU’s development and demonstration (RD&D) efforts to accelerate innovation and the development of the electricity networks of the future is provided in the following.

In “Energy 2020 – A strategy for competitive sustainable and secure energy” the European Commission states that smart meters and power grids are the keys to full exploitation of the potential for renewable energy (EC 2010b). A clear policy and common standards on smart metering and smart grids are needed well before 2020 to ensure interoperability across the network. The EC has set up a smart grid task force to discuss the implementation of smart grids at the European level.

The European Electricity Grid Initiative (EEGI) is one of the European Industrial Initiatives under the SET-PLAN. It has published Roadmap and Implementation Plan (EEGI 2010), prepared by ENTSO-E and EDSO-SG in close collaboration with the European Commission, ERGEG, and other relevant stakeholders.

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[3] http://ec.europa.eu/research/energy/eu/policy/set-plan/index_en.htm

[4] Directive 96/92/EC of 19 December 1996 concerning common rules for the internal market in electricity

[5] Directive 2003/54/EC of 26 June 2003 concerning common rules for the internal market in electricity and repealing Directive 96/92/EC

[6] Directive 2009/72/EC of 13 July 2009 concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC

European Technology Platforms (ETPs) are organisations the creation of which has been supported by the European Commission. Their purpose is to enhance private-public research collaboration. The European Commission does not own or manage European Technology Platforms, which are independent organisations, but the EC remains engaged with the Technology Platforms in structural dialogue on research issues. There exists ETP for the Electricity Networks of the Future (Smart Grids), dealing with issues concerning Smart Grid research and development. The key publications of ETP for the Electricity Networks of the Future (Smart Grids) include a vision for Europe's electricity networks of the future (ETP 2006), Strategic Research Agenda (ETP 2007), and Strategic Deployment Document (ETP 2010).

3. Electricity demand and supply

In this chapter, the supply and demand of electricity in Europe are reviewed and discussed with respect to related drivers. This includes both historical development and a review of scenarios assessing the future pathways. The balance of supply and demand determines the market price for electricity, which has a direct effect on profitability of Smart Grid (SG) technologies. On the other hand, SG may boost renewable energy sources (RES) integration and demand response, which have influences on markets.

3.1 Demand

Historical data on electricity demand has primarily been obtained from Eurostat databases, where the most recent data is from year 2008.

3.1.1 Current situation and historical development

The European Union's final electricity consumption[7] totalled 2 856 TWh in 2008. Consumption has increased by 30% between 1990 and 2008 (Figure 4). Largest electricity consuming countries were Germany (526 TWh), France (433 TWh), and the United Kingdom (342 TWh). In comparison, the electricity consumption of the Nordic electricity market area (Denmark, Finland, Norway, and Sweden) totalled 356 TWh in 2008.

In autumn 2008, the European Union and the global economy entered the deepest recession since 1930's. Due to the downturn, energy intensive industry's electricity consumption decreased. Electricity consumption in 2008 did not increase as much as was expected, and for 2009, consumption growth rates were negative.

[7] **Final electricity consumption** is the total energy consumed by end users, not including the energy consumption of the energy sector itself and distribution and transformation losses.

3. Electricity demand and supply

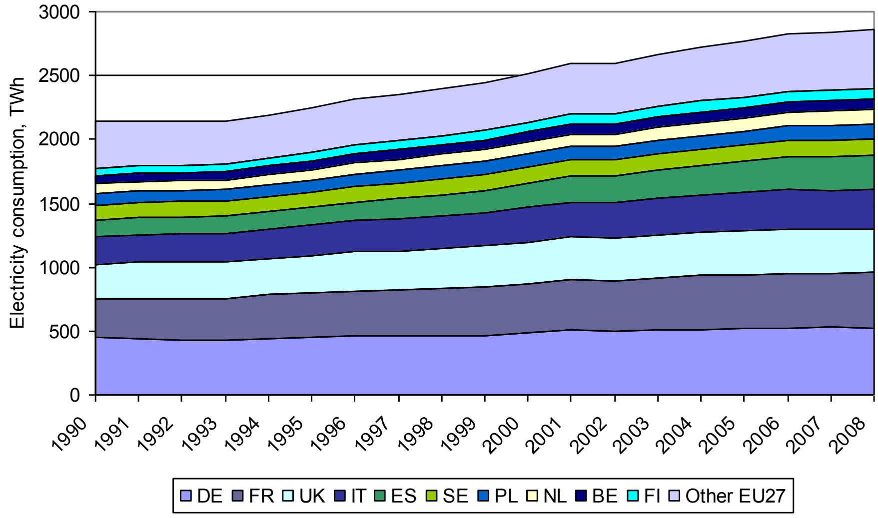

Figure 4. The EU final electricity consumption development in the period 1990 – 2008 (data source Eurostat).

Each Member State's electricity consumption mix and total final electricity consumption in 2008 is presented in Figure 5. In 2008, the industrial sector's share of the total electricity consumption was 40%, while household and services both accounted for 29% shares. The share of the transport was 2.5%. In some Member States, the share of the industrial sector's power consumption is more than half. These countries are Luxembourg (65%), Romania (55%), Finland (52%), and Slovakia (51%).

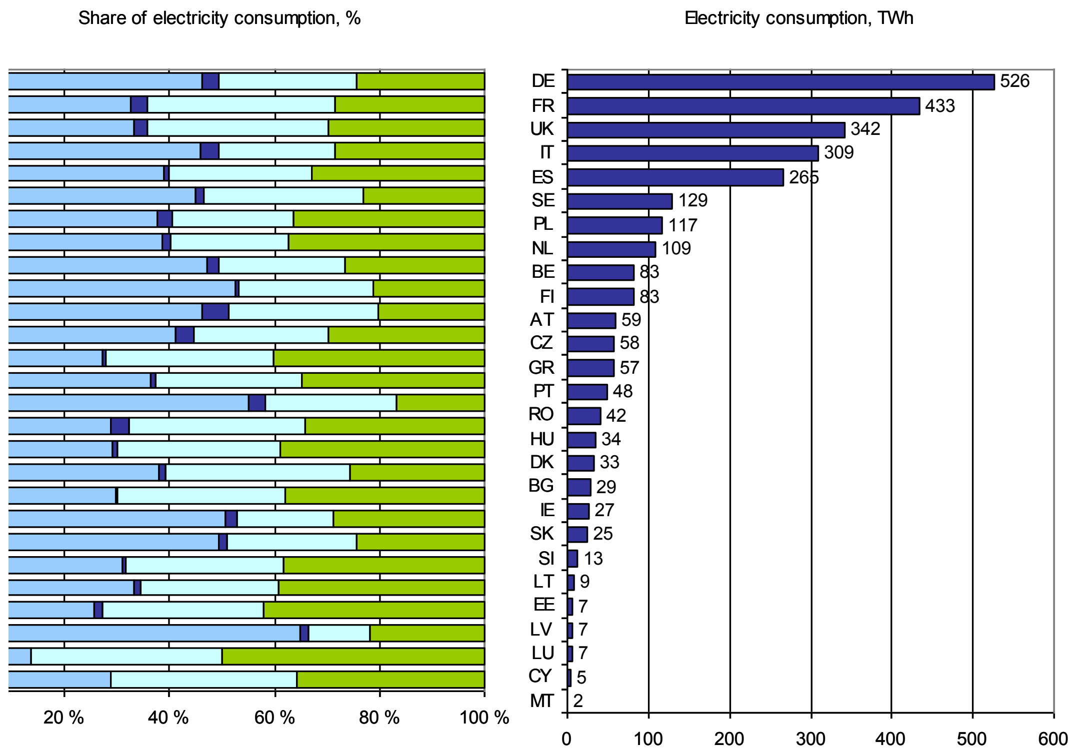

Figure 5. The EU Member States' final electricity consumption by sector in 2008 (data source Eurostat).

The European Union's electricity consumption mix development from 1990 to 2008 is illustrated in Figure 6. Industry's contribution to the total electricity consumption has decreased from 46% in 1990 to 40% in 2008. In the same time, service sector's power consumption has increased from 20% to 26%. In absolute terms, both sectors' electricity consumption has increased.

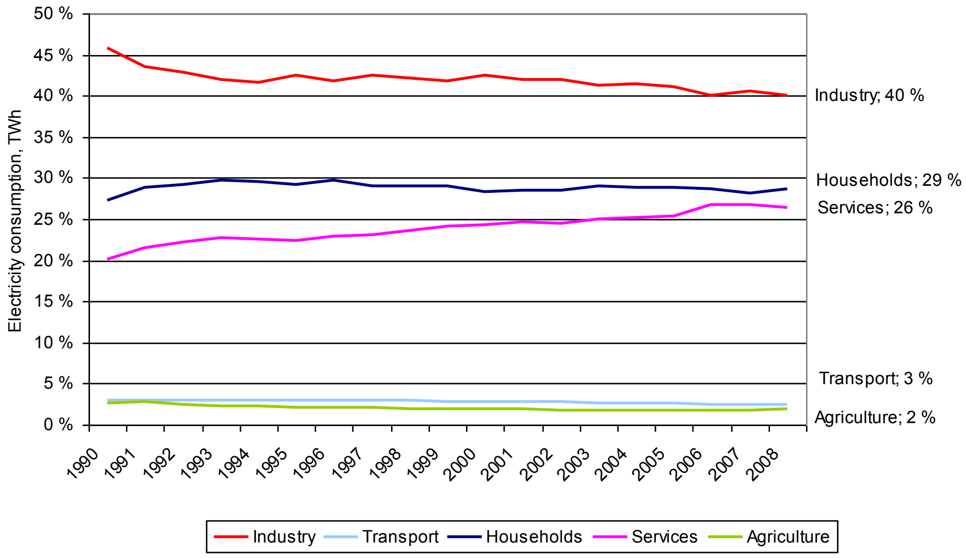

Figure 6. The EU27 electricity consumption mix development by sector from 1990 to 2008 (data source Eurostat).

3.1.2 Sectoral electricity demand trends

The EU has set a target of 20% energy efficiency improvement by 2020 and its realisation is a policy driver affecting the future electricity demand in Europe. With regard to technological development, the spectrum of measures to improve energy efficiency is wide. These include e.g. plug-in hybrid and electric vehicles, heat pumps, novel lighting technologies (LEDs, compact fluorescent lamps, etc.), and energy efficiency development of domestic appliances. However, a thorough analysis of the development of different energy efficient technologies is beyond the scope of this report. In the following, sectoral trends in electricity demand are shortly reviewed. The main reference is VTT's report "Future development trends in electricity demand" (VTT 2009b).

The main drivers of **industrial sector**'s electricity consumption are economic growth, structural changes, electricity price development, political decisions regarding emissions trading and emissions price development, technology change and improvement, development of energy saving and energy efficiency, and the choice of the energy carrier (gas or electricity). Historically, industrial electricity demand has increased in pace of GDP. This connection has recently weakened, as industry's structure has changed to less energy-intensive and energy efficiency has increased. Energy-intensive industry is sensitive to energy prices. In the long-term, electricity-intensive industry tends to prefer regions with low electricity prices.

Heating and cooling consume at least 40% of all primary energy within the EU. Especially in northern countries, heating sector's energy choices are a central driver for electricity demand. In recent years, the prices of fossil fuels and energy have been relatively high, and heating systems based on alternative technologies have increased their market shares. The European Union and its Member States also support the use of renewable technologies. Importantly from the electricity demand point of view, especially the market for heat pumps has grown fast. However in 2009, the heat pump market was influenced by the global economic crisis, and the sale numbers decreased in most of the market areas (Figure 7; EHPA 2010).

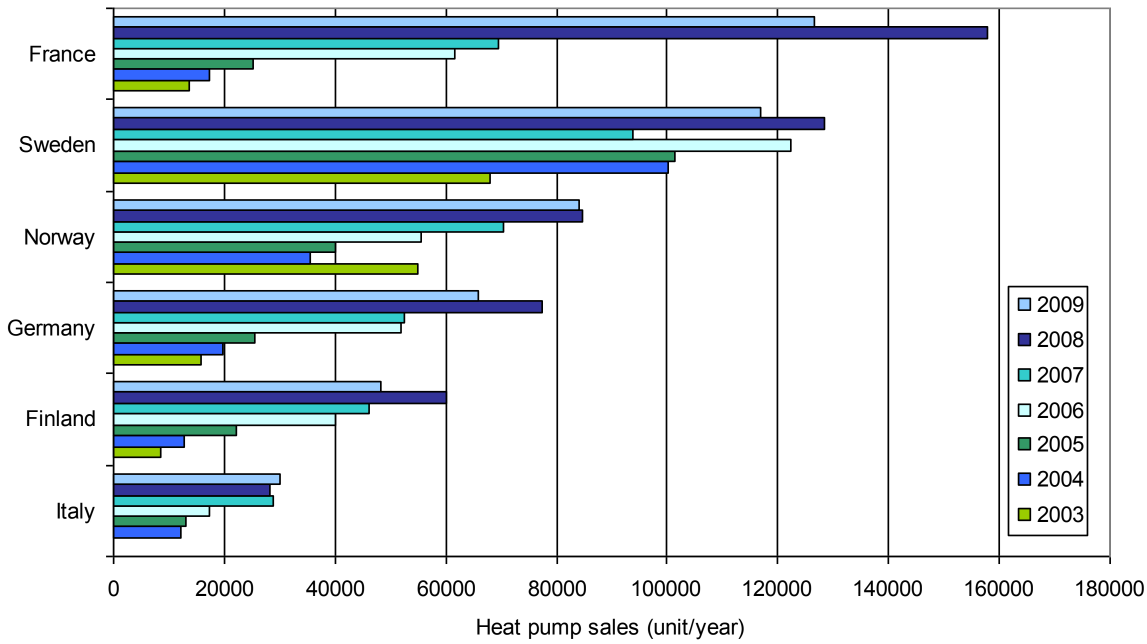

Figure 7. Heat pump units sold 2003–2009 in selected European countries (original data from European Heat Pump Association).

Currently, the **transportation sector's** electricity consumption mainly consists of rail transport, undergrounds, and trams. However, the reduction of GHG emissions in the transportation sector is a challenging task. In the light-weight vehicle sector, electrification is seen as the most promising decarbonisation pathway. Extensive use of electricity in transport sector still requires significant development in the battery technology and cost reductions. For cost-competitiveness and availability reasons, electric vehicles market penetration in 2020 is considered moderate in most forecasts. In the long-term, a widespread electrification is likely.

3.1.3 Electricity demand scenarios

The demand of energy is centrally driven by economic growth and industrial structure, which, correspondingly, is related to productivity, population, and the development phase of economies. As a counterforce, penetration and development of energy efficient technologies has a reducing effect on energy use.

The global recession which started in autumn 2008 slowed down the growth of electricity demand, and year 2009 showed even negative growth rates for the EU electricity demand. The electricity demand outlooks have been drastically changed since 2009, and the downturn will have an effect on long-term electricity demand forecasts. In this report, the analysis of future development of electricity demand in Europe is carried out by a review of scenarios of electricity demand in the EU area. This produces a rough picture of future electricity demand under different assumptions. The significance of economic development is seen, for example, in the load and consumption estimates of European Network of Transmission System Operators for Electricity (ENTSO-E 2010a). The effect of economic and financial crisis of 2008–2009 is cautioned to possibly cause some uncertainty in the estimates, mainly from 2010 to 2015. This can be seen as an indication of the sensitiveness of estimates to economic growth parameters.

Different projections on the EU electricity consumption for 2020 and 2030 are illustrated in Figure 8.

- **Ten-year network development plan 2010–2020 by European Network of Transmission System operators for Electricity (ENTSO-E 2010b)**. The European transmission system operators published their first community wide network development plan in 2010. The first publication was a pilot project, where new RES-E generation was forecasted as a bottom-up approach based on individual forecasts made by national TSOs. According to ENTSO-E (2010b), both overall load and consumption is expected to increase throughout the period 2010-2025 for the whole ENTSO-E area. The ENTSO-E electricity consumption forecast for the EU (without Malta) is 3 657 TWh for 2020. Ten-year network development plan 2010–2020 was published before the publication of NREAPs.
- **EU energy trends to 2030 – update 2009 by European Commission (EC 2010a)**. This report includes two scenarios: a baseline scenario and a climate policy scenario called "reference scenario". The scenarios have been derived with the PRIMES energy system model by a consortium led by the National Technical University of Athens. The scenarios give detailed data for each 27 Member States. The study has been commissioned by the Directorate General for Energy in collaboration with the Directorate General for Mobility and Transport.
- **World Energy Outlook 2010 by International Energy Agency (IEA 2010).** Annually published World Energy Outlook includes projection of energy demand, production, trade, and investment, fuel by fuel and region by region to 2035. In 2010 edition, three different scenarios were presented. "Current policies" scenario serves as a baseline scenario, "New Policies Scenario" (in figure marked as IEA's climate policy scenario 'a') anticipates future actions by governments to meet the commitments they have made to tackle the climate change and growing energy insecurity and "450 Scenario" is a pathway with the objective of limiting the global temperature increase under 2°C (in figure marked as IEA's climate policy scenario 'b'). The study has been prepared by the International Energy Agency.
- **National renewable energy action plans.** Article 4 of the renewable energy Directive (2009/28/EC) required the Member States to submit National Renewable Energy Action Plans (NREAP) to the European Union by 30 June 2010. These plans provide detailed roadmaps of how each Member State expects to reach its legally binding 2020 target for the share of renewable energy in their final energy consumption. The plans also include projections of final electricity consumption for two different scenarios. Here, only additional energy efficiency

scenario is presented, since some Member States have not published data for the baseline scenario. This scenario has been categorised as a climate policy scenario.

The Figure 8 also includes the actual gross electricity generation from the years 2000–2008.

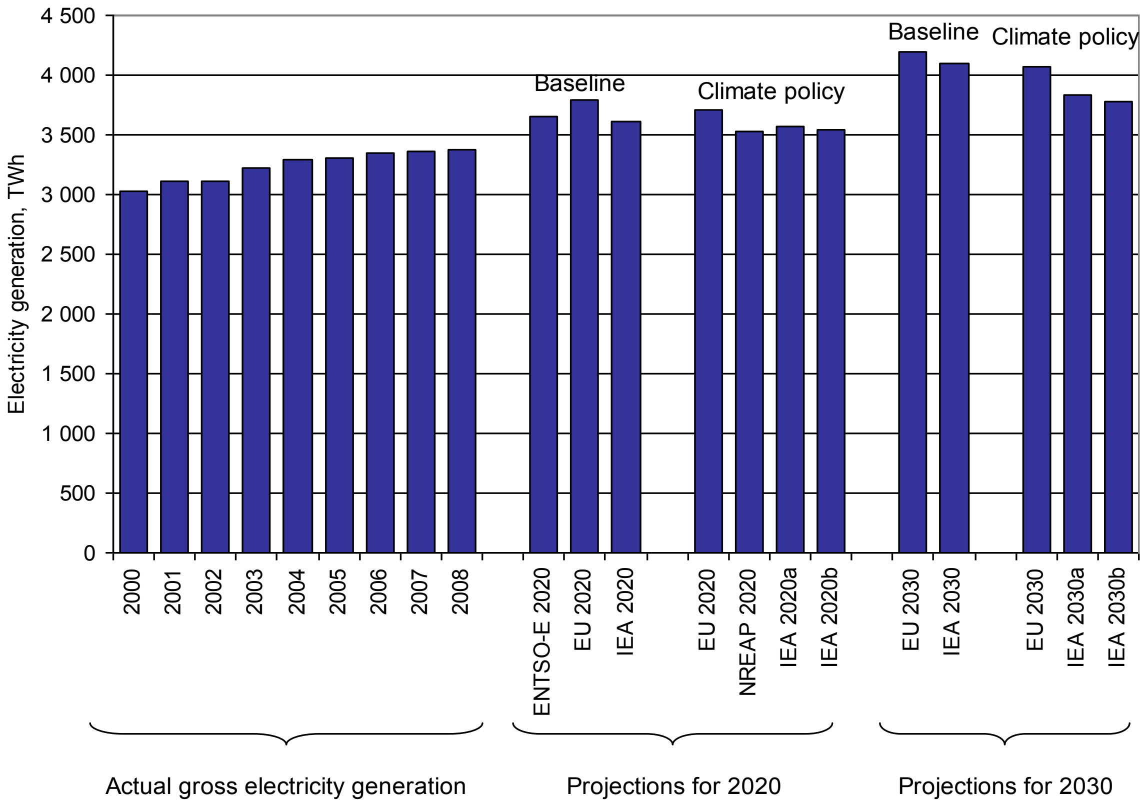

Figure 8. A comparison of different projections for the EU electricity demand in 2020 and 2030.

The projections for 2020 range from 3 530 TWh (NREAPs) to 3 795 TWh (EU baseline). Baseline scenarios are close to climate policy scenarios (largest difference 265 TWh). This can be interpreted as that, according to the projections, the EU climate policies for 2020 can be considered effective and the related legislation is already in force.

The projections for 2030 range from 3 771 TWh (IEA 2030b, 450 ppm scenario) to EU's baseline 4 192 TWh. Here, the range is larger, and the largest difference is 421 TWh. Achieving climate targets for 2030 demands more pronounced policies.

On average, climate policy scenarios project smaller electricity demand than baseline scenarios. Climate policy scenarios include policies enhancing energy efficiency, which can lower electricity demand, but also increase electricity demand if the policies include shifting energy demand from other sectors to electricity sector (e.g. increasing electricity consumption in transport sector, when fossil fuel consumption is decreased and electricity consumption increased). Examples of long-term climate policy scenarios, where electricity demand increases are presented e.g. in VTT (2009a).

3.2 Generation capacity

3.2.1 Current situation and historical development

The EU power generation capacity[8] totalled 799 GW in 2008. The capacity consisted of

- Thermal power stations 458 GW or 57% of the total installed capacity
- Hydro power stations 142 GW or 18% of the total installed capacity
- Nuclear power stations 133 GW or 17% of the total installed capacity
- Wind turbines 64 GW or 8% of the total installed capacity.

Capacity structures differ between Member States. A large part of these differences originate from differing natural endowments: hydropower is used in the Nordic countries, the Alps, France, and on the Iberian Peninsula, and countries with domestic fossil fuel resources utilise them in power generation (e.g. coal and lignite in Poland and Germany, natural gas in the Netherlands). National energy policies also affect power generation structures. This has been most pronounced in case of nuclear power. Non-hydro renewable power generation is another example. Wind and solar power are seldom profitable without support schemes.

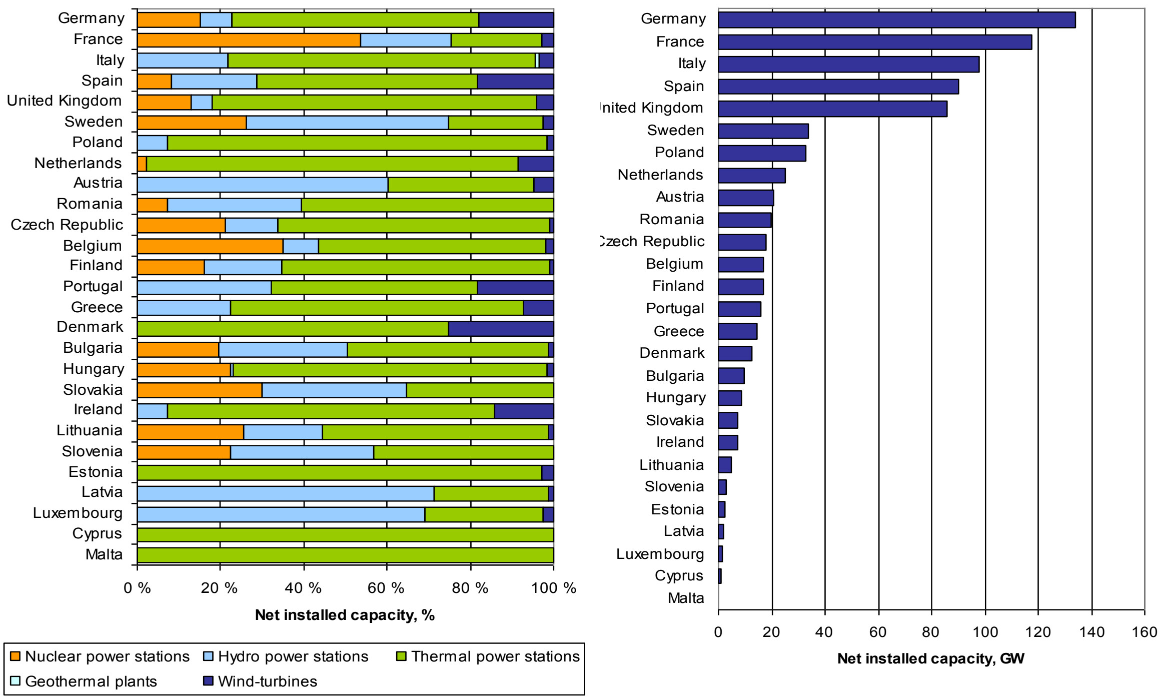

Figure 9. Net installed capacity in 2008 (data source Eurostat).

[8] Net installed capacity.

Currently, nearly half of the total installed capacity is carbon-neutral. The European Union's climate policy commitments have accelerated the development of the renewable electricity sources. Renewable power generation capacity has doubled from around 100 GW in 1995 to 200 GW in 2008 (Figure 10). In 2008, hydropower capacity amounted to about half of the total renewable power capacity. During the last 13 years, wind power capacity has more than 25-folded, and nowadays wind power dominates the non-hydro capacity mix (Figure 11). Due to the relatively small capacity factor, the share of wind power in the total renewable power capacity is more pronounced in terms of capacity than generated power.

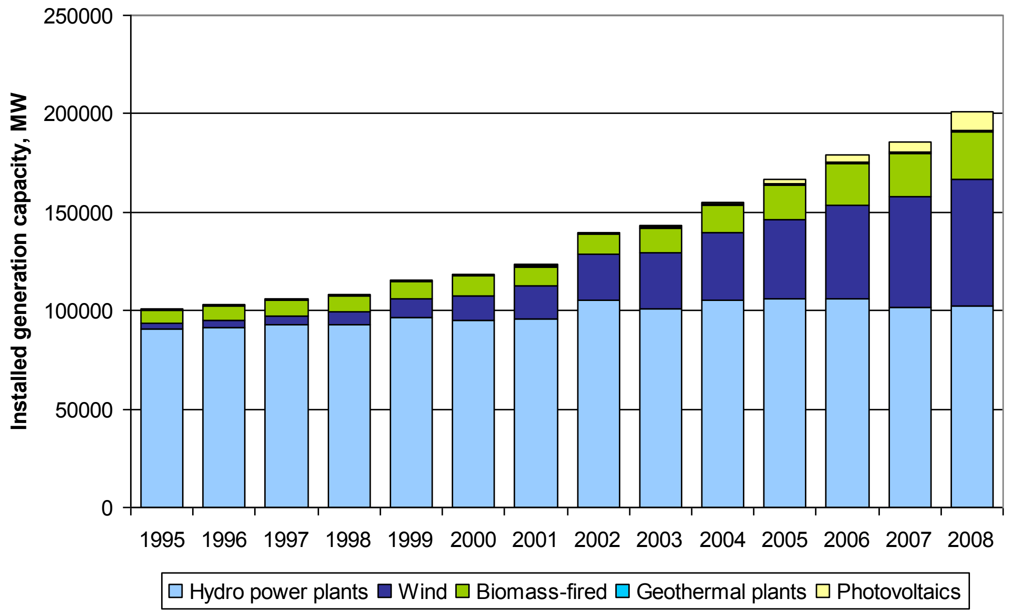

Figure 10. RES-E power generation capacity development in the European Union.

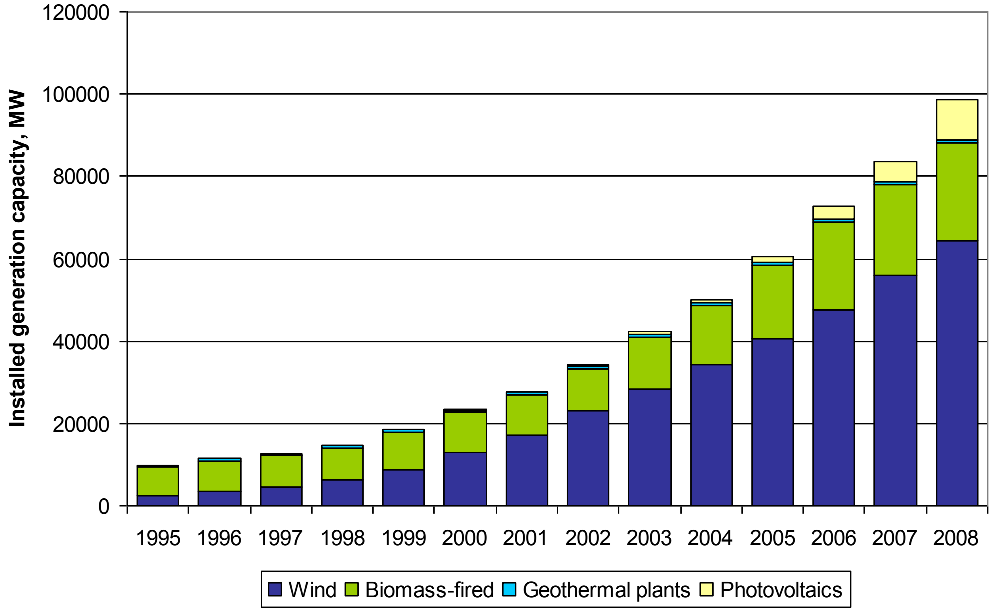

Figure 11. RES-E power generation capacity development in the European Union excluding hydro-power.

3.2.2 Drivers for new capacity

In liberalised power markets, power market actors decide new generation capacity investments based on the comparison of the investment price and expected outcome. Electricity market price should give an incentive to investments on different power generation technologies and levels of marginal costs, which can then be economically used to serve the fluctuating demand. However, national and EU level energy and climate policies affect strongly the investment decisions, and investments decisions are affected by legislation.

There exists a wide variety of policy instruments applicable to steer electricity market participants' operational and investment decisions. Taxes, different support schemes such as investment subsidies, feed-in tariffs and emission trading are examples of the instruments, which potentially significantly impact on electricity market participants' actions and outcome of markets. These are largely designed and implemented on national level policies, but the processes can be largely driven by EU legislation and directives.

Consequently, for an investor, several aspects should be taken into consideration. Some factors that affect the investment decisions are presented in the following (VTT 2009a):

- Electricity price development and the future integration of the internal market
- Uncertainty about political steering regarding different subsidies, taxes, greenhouse gas reduction goals etc.
- Fossil fuel and emission allowance price level and price volatilities
- Uncertainty about electricity demand growth (GDP growth, the migration of energy-intensive industry)

- Other players' investment decisions, together with capacity phase out
- Environmental restraints and construction permits
- World economic development
- Technological development (breakthroughs in CCS, nuclear technologies, solar, wind, ocean energy etc.).

In the following, some of the key drivers behind investment decisions in Europe are discussed in more detail. This is done with regard to technology categories where most significant changes are foreseeable by the year 2020. That is, drivers of renewable electricity, nuclear power, and large combustion plants (mostly considering coal and oil plants substituted by gas) based electricity are considered. In addition, gas based electricity production remains an important option.

Renewable electricity

The European Union has the target to increase the share of renewable energy sources (RES) in its gross final consumption of energy to 20% by 2020 (9.2% in 2006). Besides electricity sector, primary energy consumption covers heating, cooling and transportation. Increasing RES in transportation is more costly than in electricity generation, and hence the share of renewable energy sources in electricity generation will be significantly higher than 20%, if the target for the year 2020 is achieved.

Member States were required to publish National Renewable Energy Action Plans (NREAP) by the end of July 2010. These plans provide detailed roadmaps on how the Member States expect to reach their legally binding targets for 2020. The plans include sectoral targets, the technology mix expected to be used and the trajectory each Member State will follow. They also include the measures and refoms that will be undertaken to overcome the barriers to develop renewable energy. The NREAP plans were analysed and summarised in VTT's report "Renewable electricity in Europe. Current state, drivers, and scenarios for 2020" (VTT 2011). Figure 12 illustrates the projected trajectory of RES-E technologies in terms of installed capacity. Largest additions will be made in wind power capacity, which is projected to more than double to 213 GW in 2020. Solar and biomass-sourced electricity generation capacity will also increase substantially.

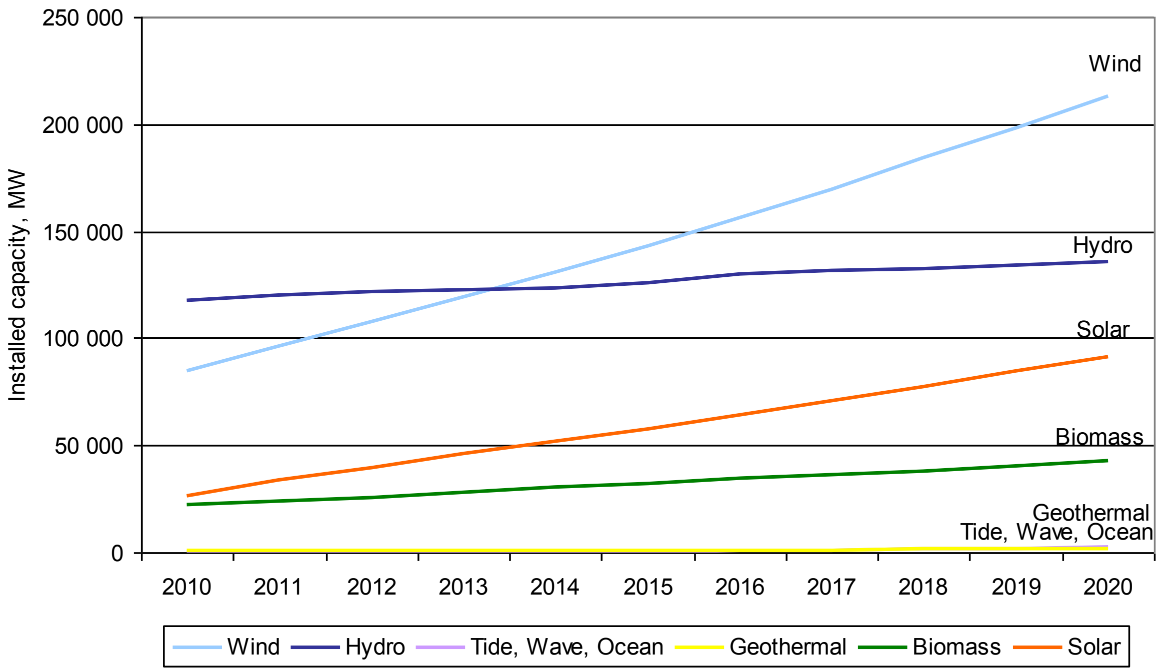

Figure 12. Individual RES-E technologies' projected trajectory for EU27 based on NREAPs in terms of installed capacity. The figures for biomass-sourced capacity do not include Czech Republic and Finland, and are thus not comparable to other technologies.

Nuclear power

The current nuclear power capacity in the European Union is 133 GW. Nearly half of this capacity is situated in France (63 GW), 15% in Germany (20 GW) and 8% in the UK. Nuclear power is also used in Sweden, Spain, Belgium, Czech Republic, Finland, Slovakia, Hungary, Bulgaria, Romania, Lithuania, Slovenia, and the Netherlands.

The future of nuclear power in the European Union is highly dependent on political decisions. The international political debate arisen after Fukushima nuclear power plant accident in Japan in March 2011 will probably not make the picture of the future of nuclear power clearer. As an example of the uncertainty, in March 2011, after the Fukushima accident, German government decided to shut down seven reactors that began operating before 1980 for at least three months. Currently, it is unclear if these units will ever start again. Recently in last autumn, German coalition took a decision to extend the operational life time of the German nuclear power plants. This decision was also suspended.

Large combustion plant directive

The EU's Large Combustion Plant Directive[9] (LCP Directive) sets new limits for the emissions of sulphur dioxides (SO_2), nitrogen oxides (NO_x), and dust emitted by large combustion plants (> 50 MW). The directive entered into force on 27 November 2001. New plants licenced after November 2002 have to comply with the stricter emission limit values. Plants licenced after July 1987 and before November 2002 have to comply with less strict emission limit values, and for "existing" power plants (licenced before July 1987), the directive requires significant emission reductions. New limits for existing plants will be binding from 1st January 2008.

According to the LCP directive, existing plants may be exempted from compliance with the emission limit values and from their inclusion in the national emission reduction plan if the operator undertakes not to operate the plant for more than 20 000 operational hours starting from 1 January 2008 and ending no later than 31 December 2015. At the end of the 20 000-hour derogation for opted-out plants or from 1st January 2016 for existing plants, all affected plants will have to meet the new build standard or face closure.

Due to the LCP directive, oldest thermal power plants are decommissioned by the end of 2015. According to ENTSO-E, only very general information on the amount of decommissioning that will take place is available. Foreseen decommissioning is mainly coal and oil-fired units, which are usually substituted by gas. In the System Adequacy Report 2010–2025 (ENTSO-E 2010a), the following results are obtained for hard coal fired power plants

- In scenario A (conservative) hard coal capacity decreases by 11% between 2015 and 2016. Considering the period between 2015 and 2025, the decrease is 24%. Main contributors are Poland (total decrease of 9 GW between 2015 and 2025) and Great Britain (total decrease 8 GW between 2015 and 2025). In addition, Denmark, France, Spain, Portugal, and Finland show decreases in hard coal capacity.
- In scenario B (best estimate) the total hard coal capacity decreases by 5% between 2015 and 2016. Main contributors are Poland and Great Britain, but also to a smaller extent Spain, Denmark, France and Romania. After this period, the total hard coal capacity increases slightly, and between 2020 and 2025 there is again a hard coal capacity decrease (Great Britain, Denmark, Finland, Portugal, Germany, and others).

[9] Directive 2001/80/EC of the European Parliament and the Council of 23 October 2001 on the limitation of emissions of certain pollutants into the air from large combustion plants.

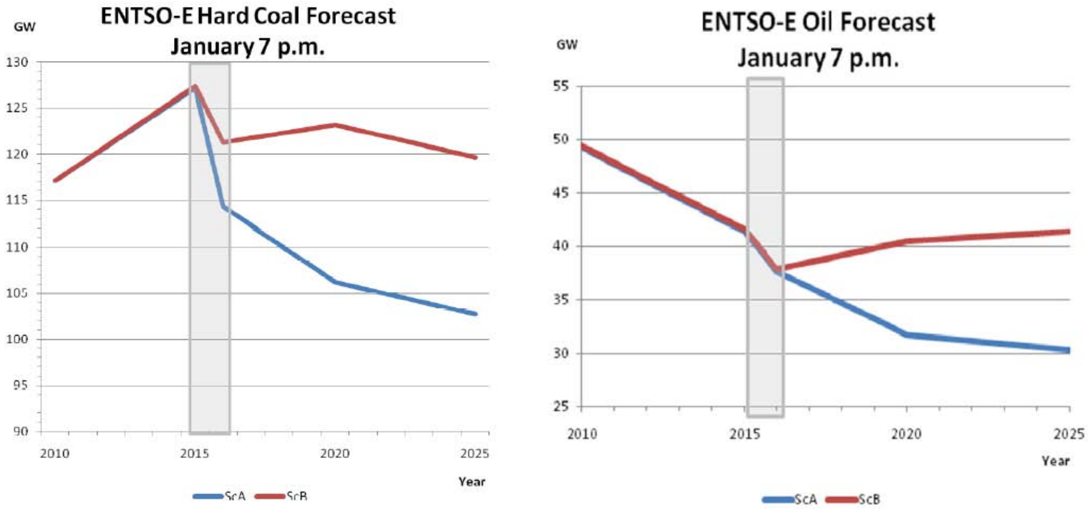

Figure 13. ENTSO-E Hard coal and oil power plants capacity forecasts (ENTSO-E 2010a).

3.2.3 ENTSO-E capacity forecast

The ENTSO-E (2010a) analysis of the future power generation capacity is carried over two scenarios covering generating capacity evolution ("Conservative Scenario A" and "Best Estimate Scenario B"). The analysis is based on the comparison between available generation and load at given three reference time points of the year (3rd Wednesday in January at 11 a.m. and at 7 p.m., 3rd Wednesday in July at 11 a.m.) over the time period 2010–2025.

According to ENTSO-E, the Net Generating Capacity (NGC) is increasing until 2015 in both scenarios, with a small exception in Scenario A between 2015 and 2016 when there is a small decrease (-3 GW). The biggest increase of primary energy sources is estimated to take place in Renewable Energy Sources (excluding hydro power generator), especially in wind power, and in fossil fuels. Capacity developments in both scenarios are presented in Figure 14 and Figure 15, and the values are given in Table 1 .

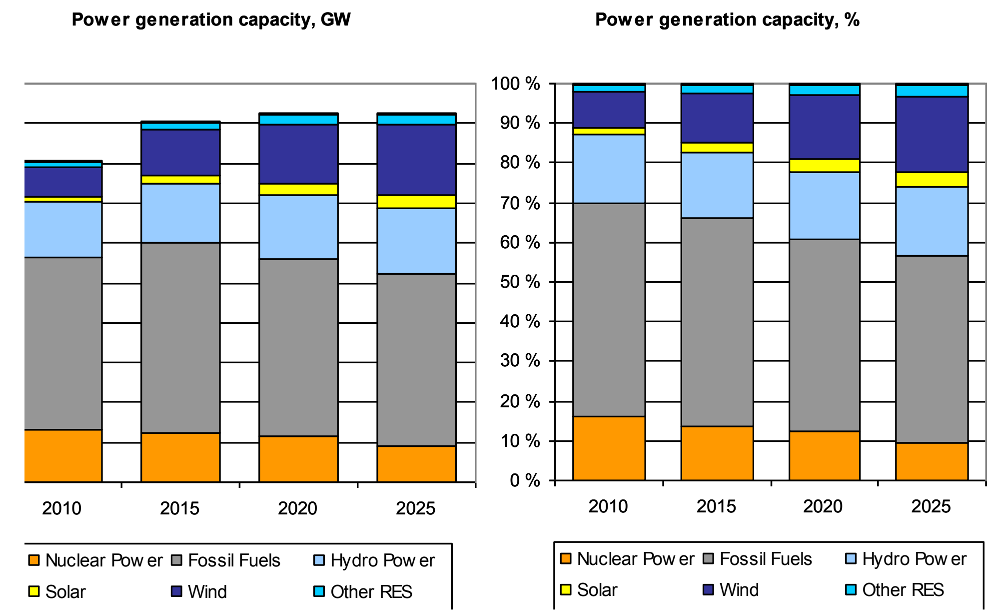

Figure 14. EU-27 (not including Malta) capacity development in Scenario A (conservative). Data provided by ENTSO-E.

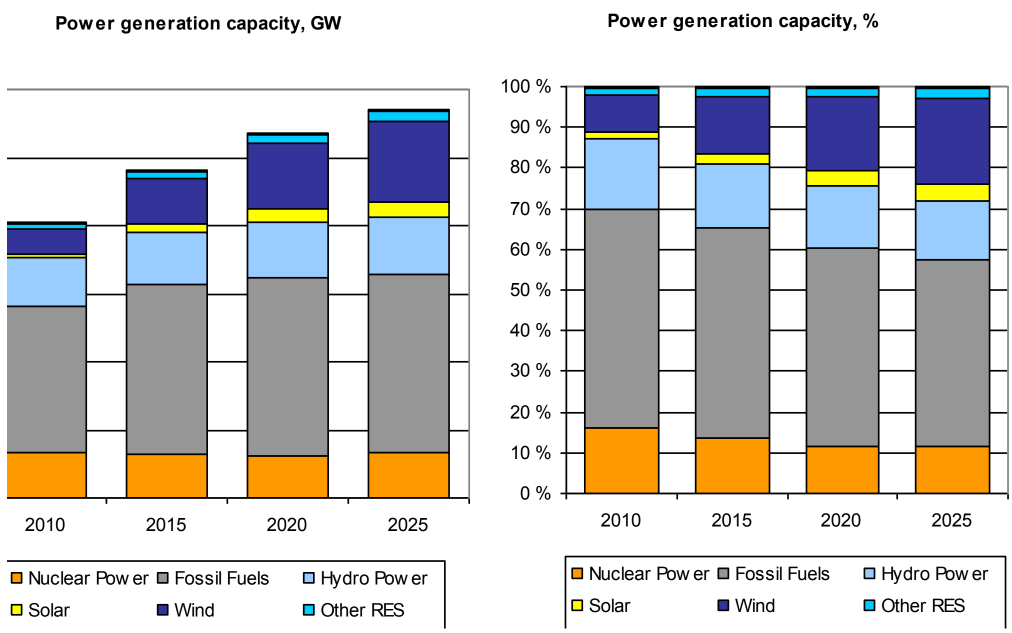

Figure 15. EU-27 (not including Malta) capacity development in Scenario B (best estimate). Data provided by ENTSO-E.

Table 1. Net generation capacities for EU-27 (not including Malta) in ENTSO-E scenarios A and B (data provided by ENTSO-E).

	Net generation capacity, GW					Net generation capacity, %				
	2010	2015	2016	2020	2025	2010	2015	2016	2020	2025
Scenario A										
Nuclear Power	131	125	123	115	89	16 %	14 %	14 %	12 %	10 %
Fossil Fuels	432	474	459	447	436	54 %	52 %	51 %	48 %	47 %
Hydro Power	142	148	150	158	161	18 %	16 %	17 %	17 %	17 %
Wind	74	114	121	149	177	9 %	13 %	13 %	16 %	19 %
Solar	11	23	25	31	35	1 %	2 %	3 %	3 %	4 %
Other RES	13	18	19	22	25	2 %	2 %	2 %	2 %	3 %
Other	3	4	4	4	4	0 %	0 %	0 %	0 %	0 %
Total	**807**	**905**	**901**	**925**	**927**	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**
Scenario B										
Nuclear Power	131	131	129	125	134	16 %	14 %	13 %	12 %	12 %
Fossil Fuels	433	499	497	521	523	54 %	52 %	51 %	49 %	46 %
Hydro Power	142	151	155	163	166	18 %	16 %	16 %	15 %	15 %
Wind	75	133	146	194	238	9 %	14 %	15 %	18 %	21 %
Solar	11	24	28	38	47	1 %	2 %	3 %	4 %	4 %
Other RES	13	19	19	23	27	2 %	2 %	2 %	2 %	2 %
Other	3	5	5	5	6	0 %	0 %	0 %	1 %	1 %
Total	**808**	**962**	**979**	**1070**	**1141**	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**

A comparison of projected wind and solar power capacities for 2020 and 2030 are provided in Figure 16 and Figure 17. The scenarios included are

- NREAP: Summary of the National Renewable Energy Action Plans
- EU: EU Energy Trends to 2030–Update 2009 (EC 2010a)
- IEA: World Energy Outlook 2010, which includes two climate policy scenarios, „New policies scenario' is IEA 2010a and „450 ppm scenario' is IEA 2010b (IEA 2010)
- ENTSO-E: Ten-Year Network Development Plan 2010–2020 (ENTSO-E 2010b)
- Eurelectric: Power Choices. Pathways to Carbon Neutral Electricity in Europe by 2050 (Eurelectric 2010).

Projected wind power capacities are roughly in line, and most of these are larger than capacities in ENTSO-E's system adequacy forecast. Eurobserver has published wind power capacity figures for 2010, and in the European Union, the actual installed capacity was 84 GW in the end of 2010. The projected capacities for 2020 vary from 172 GW (EU's baseline scenario) to 222 GW (EU's climate policy scenario).

Projected solar power capacities vary more. Smallest value for 2020 is 38 GW and given by ENTSO-E in its Ten-Year Network Development Plan. The summarised NREAP plans have a capacity of 91 GW, which is more than double the smallest value. The assumed full load hours also differ remarkably; ENTSO-E assumes only 620 h, while the summarised NREAPs provide 1 130 h.

For both wind and solar power, ENTSO-E's system adequacy forecast provides smaller capacities than most other projections.

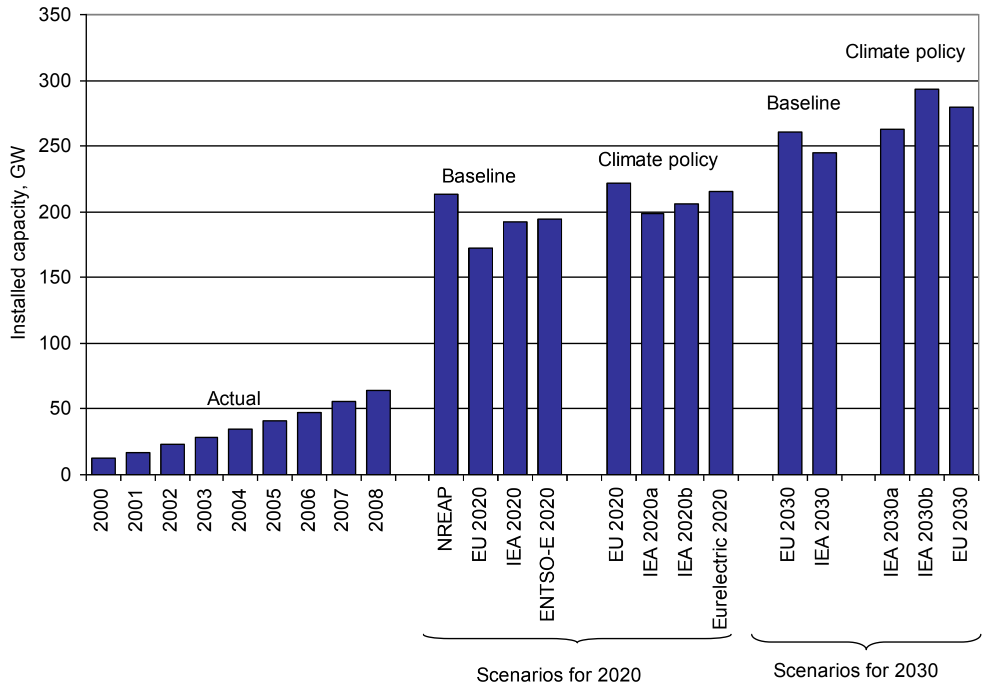

Figure 16. A comparison of projected EU-27 wind power capacities in 2020.

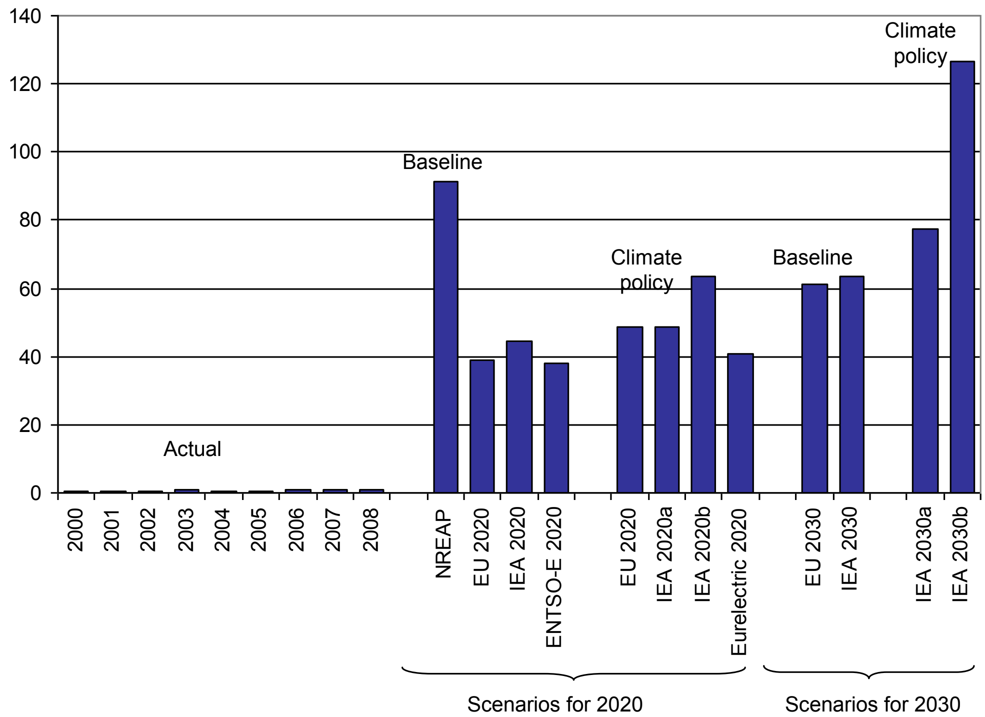

Figure 17. A comparison of projected EU-27 solar power capacities in 2020.

3.3 Supply

3.3.1 Electricity production

The European Union's electricity production development by fuel type is illustrated in Figure 18, and Figure 19 illustrates the evolution of the generation mix in relative terms. From 1990 to 2008, the total power generation has increased from 2 425 TWh in 1990 to 3 205 TWh in 2008. Fossil fuels dominate the fuel mix, summarised fossil fuel based electricity production was 1 709 TWh in 2008. Nuclear power ranks second with 888 TWh power generation in 2008. Hydropower generation has varied from year to year according to hydrological conditions, and in 2008, hydropower production was 352 TWh[10] in the EU.

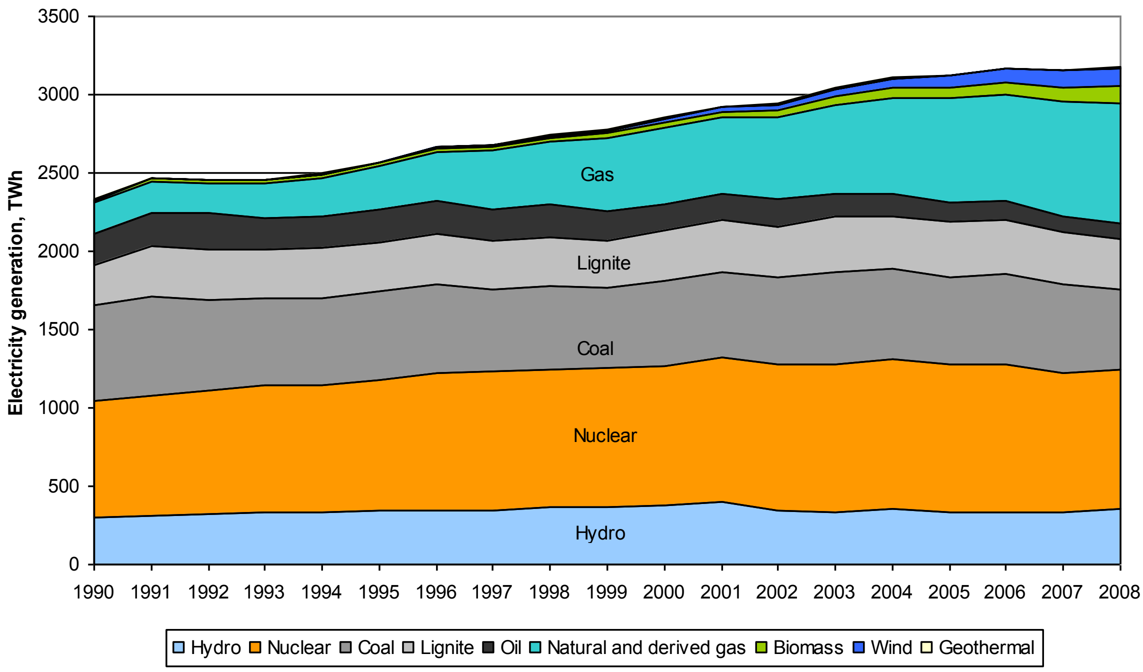

Figure 18. Electricity production development from 1990 to 2008 (data source Eurostat).

In relative terms, largest change has occurred in natural gas based power production, the share of which has increased from under 10% in 1990 to 24% of the total power production in 2008. In the same time, other fossil fuels, mainly oil and coal based power production's shares of the total generation mix have decreased. Since the turn of the decade, wind power and biomass-sourced electricity generation have increased both in absolute and in relative terms.

[10] Large hydro power producers Norway and Switzerland are not members of the European Union. Their hydro power production in 2008 was 141 for Norway TWh and 38 TWh for Switzerland.

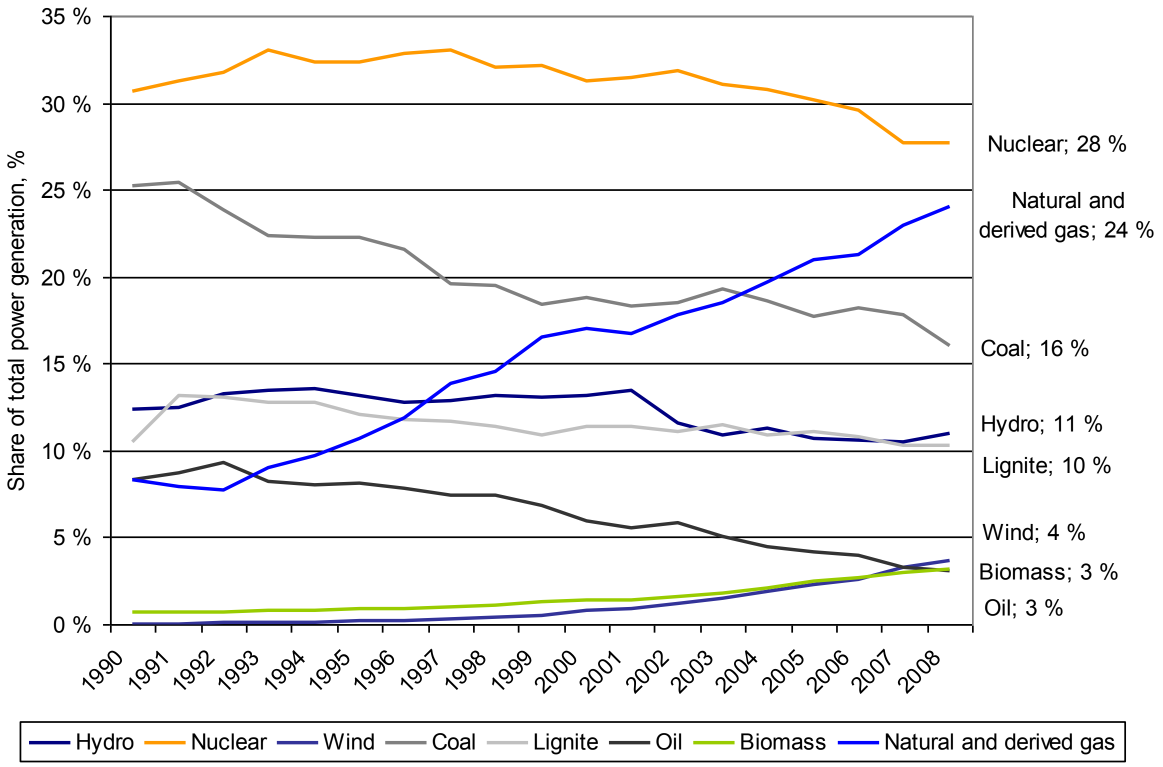

Figure 19. The EU power generation mix development from 1990 to 2008 (data source Eurostat).

The generation mix and total generation by Member State are presented in Figure 20. Largest power producers are Germany, France, the United Kingdom, Italy, and Spain. In 2008, fossil fuel based power generation totalled 1709 TWh and accounted for 53% of the total net power generation in the EU. Gas-based power generation was 770 TWh, coal-based 512 TWh, lignite-based 328 TWh and oil-based 99 TWh.

The total nuclear power generation in 2008 was 888 TWh. Some countries, most notably France, rely heavily on nuclear power production. Also Lithuania, Slovakia, and Belgium source over 50% of their electricity production from nuclear power plants.

Hydropower is used where it is available. In 2008, largest hydropower producers were Sweden (69 TWh), France (68 TWh), Italy (47 TWh), Austria (37 TWh), Germany (27 TWh), and Spain (26 TWh). The total hydropower production was 352 TWh.

In 2008, wind power generation was 118 TWh. Wind power capacity is rapidly increasing, and in 2010, the wind power generation was 147 TWh. At present, the second largest RES-E technology is biomass-sourced power generation, which accounted for 102 TWh in 2008.

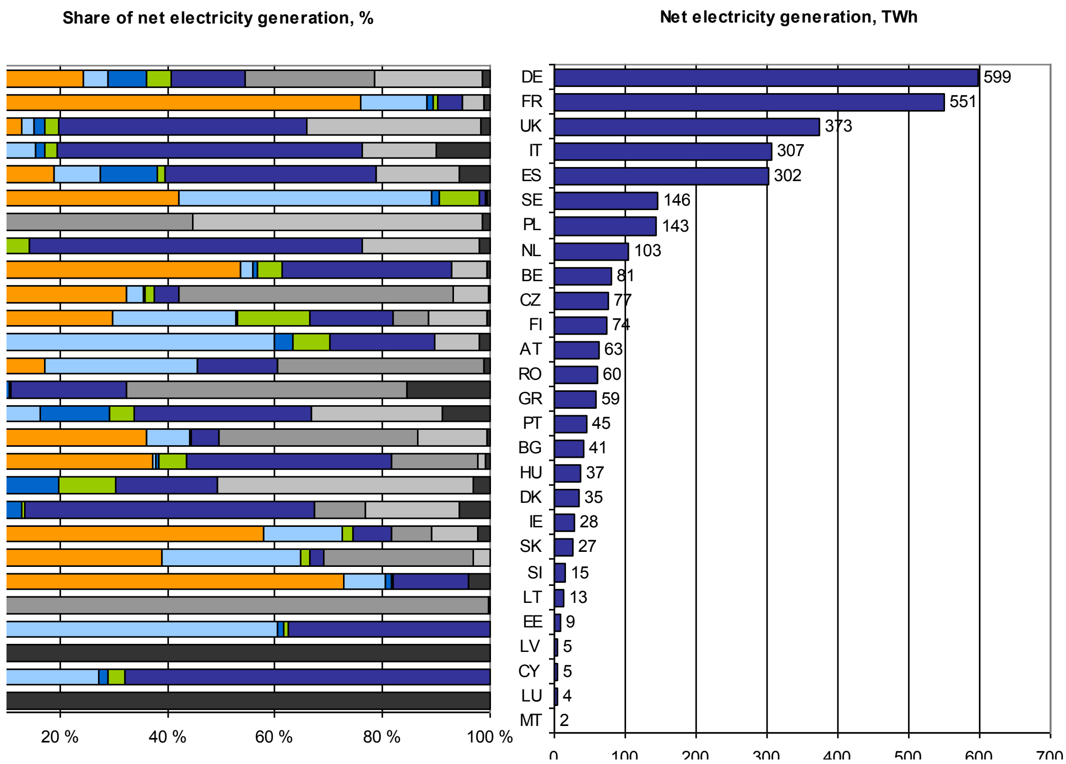

Figure 20. The EU net electricity generation in 2008 (data source Eurostat).

3.3.2 Scenarios for power generation

Future power generation structure is highly dependent on political decisions, and changes are challenging to predict. This section focuses on describing how the increased RES-E generation affect the merit order for the whole European Union. The analysis is based on the National Renewable Energy Action Plans, where the projected trajectory of RES-E generation for each Member State and technology is included.

Figure 21 shows the summarised projected trajectory for different renewable electricity generation techniques. Each Member State's estimation of the total contribution (gross electricity generation) expected from each renewable electricity technology has been summarised to reach an estimate for the whole European Union. RES-E generation is expected to almost double from 653 TWh in 2010 to 1 217 TWh in 2020. Largest addition is expected in wind power production. Onshore wind power production is projected to more than double between 2010 and 2020, while offshore wind power production is projected to increase from 9 TWh in 2010 to 134 TWh in 2020. High growth is also expected in solid biomass-based electricity production (78 TWh between 2010 and 2020) and photovoltaics (63 TWh). Hydropower production will increase only slightly.

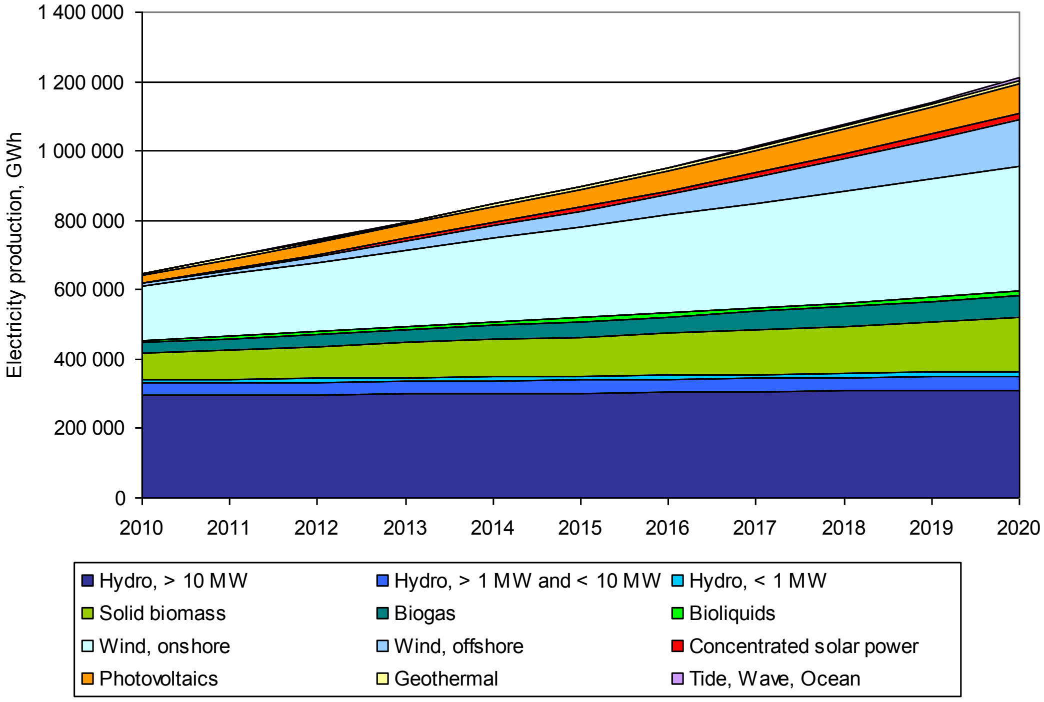

Figure 21. Projected trajectory of RES-E production for the EU based on NREAPs.

In liberalised electricity markets, merit order (the order in which capacity is put into use) and market price is defined in the equilibrium point of supply and demand. In principle, all generation facilities with lower operating costs than the defined market price benefit from selling their generation to markets. If operating costs are larger than the market price, generator loses money if he sells power to the markets. In real life conditions, power plants do have start-up costs etc. which also affect the profitability, and generation decisions need to be made for longer timeframes. Thus, it is possible that power plants run even if the market price is smaller than the operational costs for individual hours.

- **Wind power** has zero or almost zero operational costs. This capacity is always used if the price of electricity is positive.
- Like wind power, **hydro power** has almost zero fuel costs. Hydro power's output capacity is easily regulated, and this is why bids from hydro power are strategic and depend on the level of water in the reservoirs and precipitation.
- **Nuclear power**'s operational costs are low, and the output capacity is usually not adjusted from hour to hour.
- **Fossil fuel power plant**'s operational costs depend largely on fuel and emissions allowance costs. These plants tend to have high operational costs.

In the European electricity markets, renewable-sourced electricity benefits from different support schemes. RES capacity is preferred against other capacity, and these plants are always run independently of the power price. This "must-run" capacity varies from country to country depending on the support scheme.

Figure 22 illustrates a theoretical year-level merit order in EU27 for 2008[11]. Power generation totalled 3 200 TWh in 2008. Actual production costs vary by each power plant's specific conditions. Especially the order of fossil fuel fired power plants' variable power production costs vary between power plants, and also the prices of coal and gas have an impact on the cost-effectiveness.

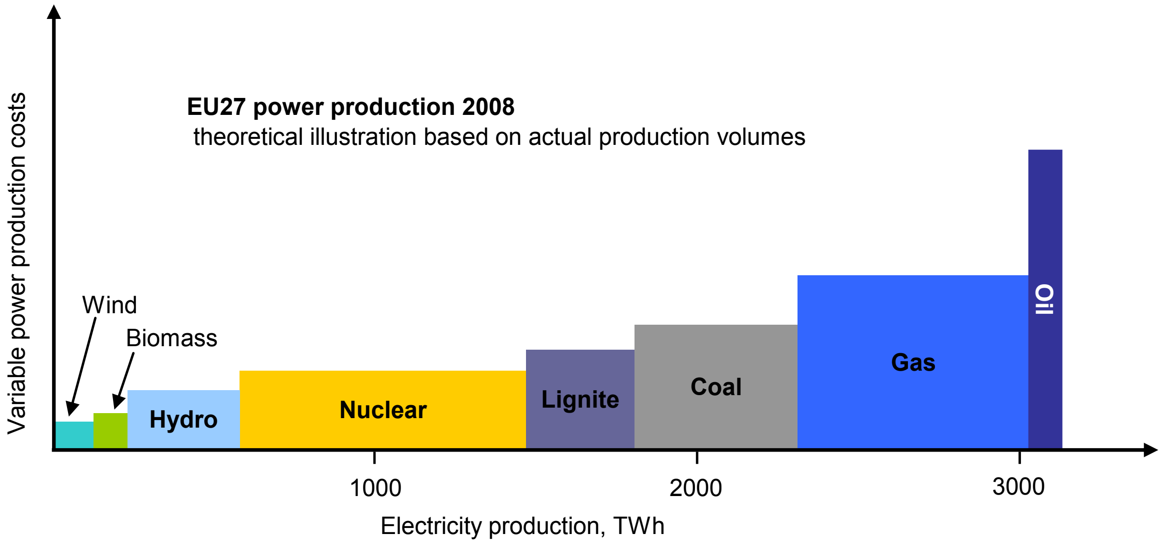

Figure 22. Theoretical illustration of the year-level merit order for EU27 in 2008.

In Figure 23, RES-production in 2008 is replaced by planned RES-E production for 2020 (obtained from NREAPs), and fossil fuel generation is at 2008 level. RES-E generation is expected to more than double between 2008 and 2020. In the same time, electricity consumption is expected to increase by 150–420 TWh. These figures suggest that the projected new RES-E generation will cover the expected increase in electricity demand. If climate policy targets are realised, the fossil fuel based power generation will decrease.

According to the National Renewable Energy Action Plans, by 2020, wind power production is expected to cover 14% of the total electricity consumption and solar power is expected to cover 3% of the consumption in the EU. Wind and solar power are not dispatchable forms of power generation in the traditional sense. They can only create electricity when the energy source is available. Rest of the power system needs to accommodate the variation from the variable forms of renewable energy.

[11] Please note that the EU has several regional electricity market areas. Current interconnector capacities are too small to ensure a true internal market, and thus the merit order for the whole European Union is a theoretical illustration.

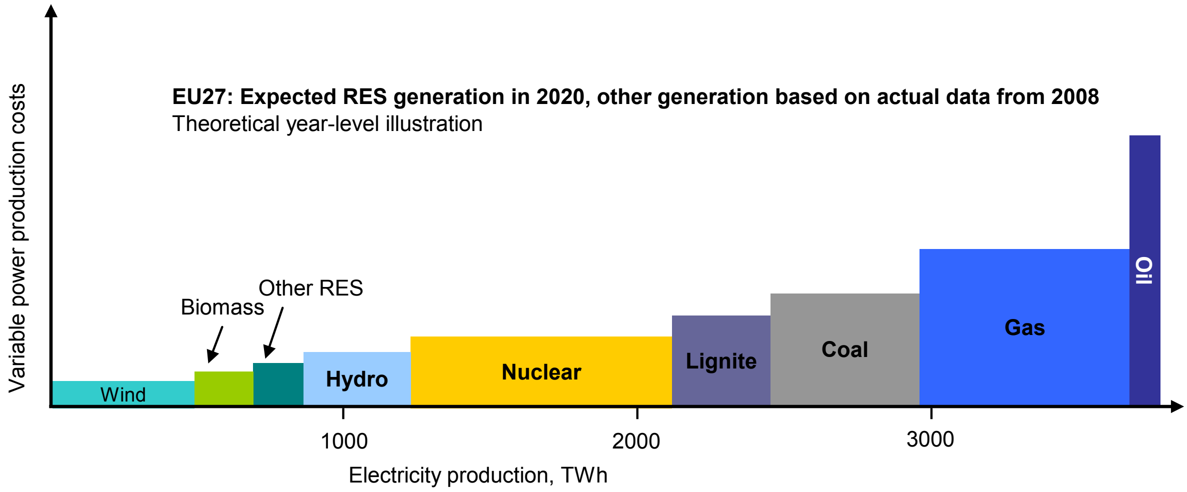

Figure 23. Theoretical illustration of year-level merit order for EU27 in 2020. The projected RES-E generation figures are based on NREAPs.

4. Grid as a marketplace

The European Union's political aim towards a single European electricity market calls for investments in the grid infrastructure as well as harmonisation in electricity trading procedures. Integration development is influenced by physical cross-border transmission capacity development and allocation methods. The electricity market design harmonisation will potentially have an impact on market procedures in individual countries.

Market integration is a key driver of the price of electricity and prices essentially determine the profitability of Smart Grid technologies and solutions. Correspondingly, active demand – in forms of increased customer choice and price-responsiveness – as well as advances in grid control potentially brought by SG has an influence on the markets.

With regard to a target of European-wide electricity market, a pan-European grid forms an integrated marketplace for electricity market participants. This Chapter deals with a development of grid towards this target from physical point of view.

4.1 Physical grid integration

Adequate, integrated, and reliable electricity networks are a crucial prerequisite for achieving the EU energy policy objectives. Developing energy infrastructure is essential for a properly functioning internal energy market, but also needed for enhancing the security of supply, enabling the integration of renewable energy sources, increasing energy efficiency, and enabling customers to benefit from new technologies and intelligent energy use.

EU agreed in 2002, that minimum interconnector capacity between Member States should be at least 10% of the Member State's installed generation capacity. However, a rigid threshold value for cross-border transmission capacity does not take into account different geographies and actual transmission needs, which are determined by price differences between regions.

Main policies to increase cross-border capacity have included the TEN-E (Trans-European Energy Networks) guidelines[12] specifying which projects are eligible for EU funding under the TEN-E budget line, and a priority interconnection plan (PIP) which set out five main priorities (EC 2007b):

[12] Decision No 1364/2006/EC of the European Parliament and of the Council of 6 September 2006 laying guidelines for trans-European energy networks and repealing Decision 96/391/EC and Decision No 1229/2003/EC.

- identifying the most significant missing infrastructure up to 2013 and ensuring pan-European political support to fill the gaps
- appointing European coordinators to pursue the most important priority projects
- agreeing a maximum of five years within which planning and approval procedures must be completed for projects that are defined as being of European interest under the TEN-E guidelines
- examining the need to increase funding for the trans-European energy networks, particularly in order to facilitate the integration of renewable electricity into the grid
- establishing a new mechanism and structure for transmission system operators, responsible for coordinated network planning.

Many of the electricity infrastructure projects of European interest have faced delays. Delays are most often caused by the complexity of planning and other authorisation procedures, but also local opposition, varying regulatory regimes on either side of the border and the lack of cooperation between transmission system operators cause delays. PIP identified the following three transmission links as the most important infrastructure projects encountering significant difficulties:

- high voltage electricity connection between France and Spain
- Baltic and North Sea offshore wind connections
- The northern Europe power link (between Germany, Poland, and Lithuania).

European coordinators were appointed for these projects in September 2007. The aim was to boost projects that had faced technical, political, or financial difficulties. Coordinators' work is still ongoing, but some progress has been made. For instance for the northern Europe power link, the project development company LitPol Link has been established and investment plan is under preparation.

In March 2009, EU set aside €3.98 billion to assist European economic recovery. In December 2009, Commission agreed to support Carbon Capture and Offshore Wind Projects with €1.5 billion. In March 2010, Commission decided to grant €910 million for 12 electricity interconnection projects and €1 390 million for 31 gas pipeline projects[13]. EU will co-finance parts of these projects with up to 50%. The electricity and gas infrastructure projects selected reflect the energy priorities of the EU, and will help to better interconnect all EU Member States and to reduce the isolation of remoter parts (ITRE 2010).

In Communication "Energy infrastructure priorities for 2020 and beyond – A Blueprint for an integrated European network" a vision of what is needed for making the networks efficient was outlined. The major drivers for grid improvement are identified as (EC 2010c):

- **Increasing demand** due to a major shift in the overall energy value chain and mix but also the new applications and technologies such as heat pumps and electric vehicles.
- **Electricity generation from renewable sources** is expected to more than double in the period 2007–2020. Up to 12% of renewable generation in 2020 is expected to come from offshore installations, most notably on Northern Seas.

[13] http://europa.eu/rapid/pressReleasesAction.do?reference=IP/10/231.

With the help of a well interconnected and smart grid the cost of renewable energy deployment can be brought down. In November 2010, the Commission proposed changing the TEN-E practise and introduced a new method including the following steps (EC 2010c):

- Identify the energy infrastructure map leading towards a European supergrid interconnecting networks at continental level
- Focus on a limited number of European priorities which must be implemented by 2020 to meet the long-term objectives and where European action is most warranted
- Identify the concrete projects necessary to implement these priorities (projects of European interest).

The Commission proposed following priority corridors (also presented in Figure 24):

1. Offhore grid in the Northern Seas and connection to Northern as well as Central Europe to integrate and connect energy production capacities in the Northern Seas with consumption centres and hydro storage facilities in the Alpine region and in Nordic countries.
2. Interconnections in South Western Europe to accommodate wind, hydro, and solar and to make best use of northern African renewable energy sources.
3. Connections in Central Eastern and South Eastern Europe to assist market and renewables integration.
4. Completion of the BEMIP (Baltic Energy Market Interconnection Plan) to integrate Baltic States into the European market.

The Commission prioritises also the roll-out of smart grid technologies, and aims to provide the necessary framework and initial incentives for rapid investment in intelligent network infrastructure.

Figure 24. Priority corridors for electricity, gas, and oil (Reprinted from EC 2010c).

In 2010, European Transmission System Operators (TSOs) published the "Ten-year Network Development Plan 2010–2020" (ENTSO-E 2010b). This plan provides the most up-to-date and accurate information of the planned or envisaged transmission investment projects of European importance. Main investment needs recognised were

- **Massive renewable integration in the North part of Europe**. In this region, the main driving force is increasing wind power generation. Wind farms are usually located in remote areas where the network was not initially developed to accommodate them.

- **Massive renewable integration in the South part of Europe**. Transmission investments are driven by the connection of renewable sources, mainly wind, hydro, and solar in the Iberian Peninsula and in Italy.
- **Important North-South and East-West flows in the Central South / South-East region**. These investment needs are dictated by the power balances and market price differences.
- **Baltic States integration**. The EU aims to the full integration of the three Baltic States into the European energy market.
- **Interconnecting of new, conventional power plants** totalling more than 100 GW is foreseen all over Europe. These plants wil replace old, decommissioned plants and help to cope with the load growth and system balancing.
- **The power supply of some European cities and regions**.
- **Market integration.**

Figure 25 provides a map of the planned new interconnectors in the Nordic electricity market. The total new transmission capacity from the Nordic countries to the other parts of Europe is currently 4 500 MW. It the plans for the next decade are realised, the transmission capacity to the other European countries will more than double to about 9 500–11 500 MW (without Kriegers Flak offshore wind park connection).

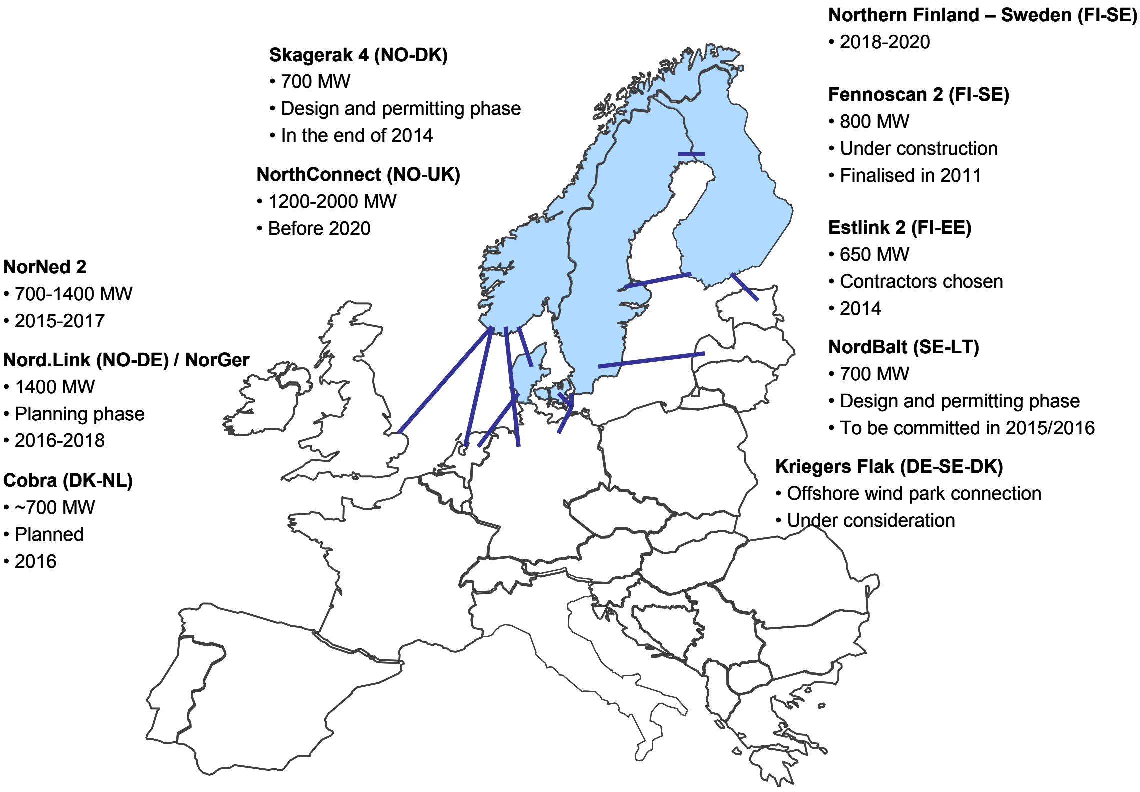

Figure 25. Nordic interconnector plans in the years 2010–2020.

Beyond 2020, electricity system will need to change more fundamentally to allow the shift to a low carbon economy. In the longer term, EU decarbonisation goal is to decrease greenhouse gas emissions by 80–95% by 2050 (EC 2010c). Practically this implies a virtually carbon-free power sector (Eurelectric 2010). Electricity system will change, and this will include high-voltage long distance and new electricity storage technologies (EC 2010c).

4.2 Market coupling

Differences in trading regimes and in the calculation, allocation, and the management of the available capacity are the primary obstacles to the efficient use of existing interconnection capacity. In fully integrated electricity markets harmonised rules for capacity allocation methods and other trading regimes are needed. The European Union aims at pan-European price coupling by 2014. The target model for day-ahead markets is market coupling/splitting:

- **Market splitting** is a cross-border trading and congestion management method where the available transmission capacity on all interconnectors between bidding areas is utilised by an implicit auction. The mechanism ensures that the market balance between supply and demand per bidding area automatically is determined by the combination of bids and offers in all bidding areas, and that the available transmission capacity is utilised efficiently. Market splitting is used within a single power exchange.
- **Market coupling** is a mechanism, which uses implicit auctioning involving two or more power exchanges. The mechanism ensures that all the available trading capacity is utilised with power flowing towards the high price area. Market coupling is used to integrate a market with more than one power exchange.

When markets are coupled, the existing transmission capacity is either fully used and the power is flowing towards the higher electricity price area, or the transmission capacity is only partially in use and the prices converge.

Market coupling/splitting was initially used in the Nordic electricity market, and spread to other regions. It is nowadays used in the Nordic countries, Belgium, Estonia, France, Germany, Luxembourg and the Netherlands, on the Iberian Peninsula, between Italy and Slovenia, and between the Czech Republic and Slovakia. There are also two borders without congestion (Austria–Germany and Ireland–Northern Ireland). The current state of market coupling/splitting is shown in Figure 26.

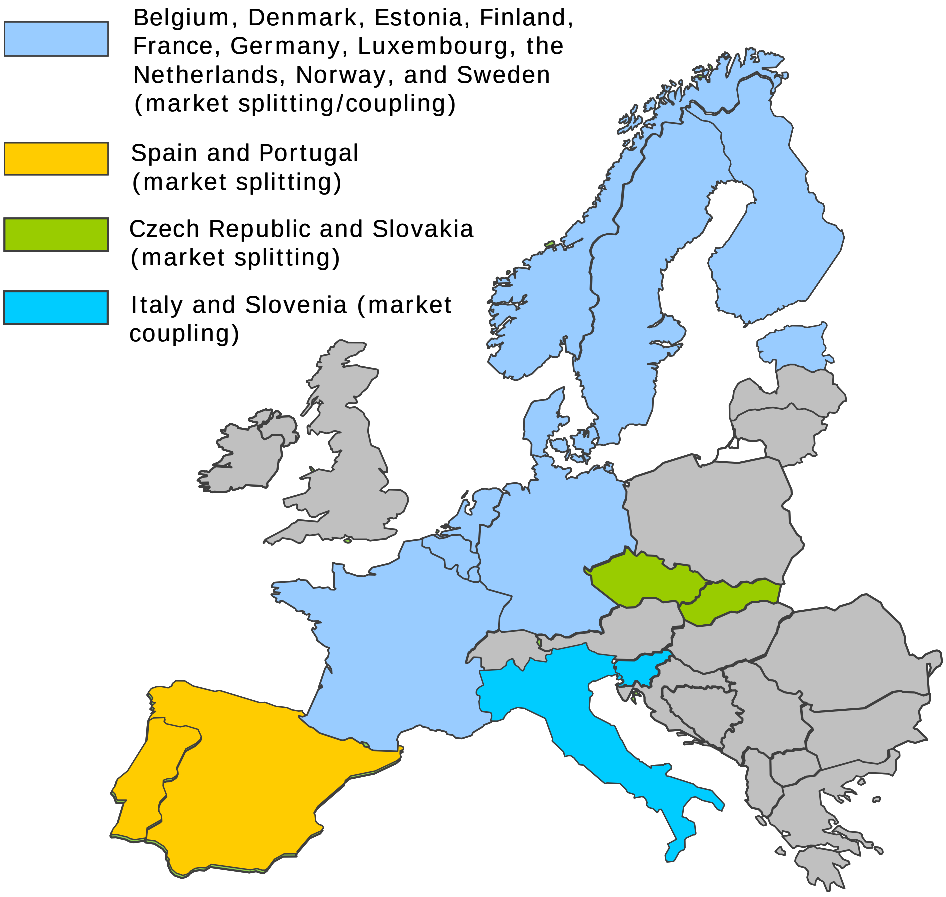

Figure 26. Market splitting/coupling – situation in March 2011.

5. Power trading and electricity market design

Despite the general aim towards liberalisation in European electricity markets during the last two decades, electricity trading arrangements vary according to countries and areas in the EU. First, there are physical differences in electricity generation structure and in grid design, and also in market concentration and in the level of competition there are differences. Second, bidding procedures, pricing method, dispatching of power plants, settlement systems, congestion management, and transmission pricing, are among typical elements that have been differently implemented in different wholesale markets. **Market design** is a term often used of these arrangements, constituting a "playing field" of market participants. To support market integration and harmonisation in a most efficient way, a common European market design should be aimed. This goal is also parallel to harmonisation of legislation of electricity sector, which could be supported by a European law and regulatory framework. For example, different support schemes between areas may cause distortions and inefficiency in markets.

Substantial part of changes in electricity trading brought by new variable RES-E generation (varRE, mainly wind and solar power) concern markets in short-term, i.e. after current day-ahead market gate closure. For example, variable renewable power generation and end-users' option to short-term price-sensitivity and demand response included in Smart Grid concepts are adjustments potentially taking place after gate-closure. Therefore, the development of short-term markets is of paramount importance for the successful integration of variable generation. Both arrangements and liquidity[14] of intra-day market are crucial from the varRE and demand response market penetration point of view.

5.1 Power market structure

European power markets are increasingly integrated, and as the integration project proceeds, the structure of power trading and markets is given reason to become more harmonised. Typically, the power market is organised into financial power markets and physical power markets as presented in Figure

[14] **Liquidity** is generally understood to describe the easiness of trading a particular asset and the fact that any transaction in the asset will not significantly affect its value. However, liquidity is not a straightforwardly defined concept and not directly observable (Weber 2009).

27. This structure applies to most of the European power markets including the Nordic countries, Germany, France, and the Netherlands.

Largest physical power market is the day-ahead power market, where a spot market price for electricity for each hour of the delivery day is determined. These prices are determined according to supply and demand bids of market participants. Bidding closes 12–36 hours before the delivery hour.

Intraday market is a continuous trading market where adjustments to trades done in the day-ahead market are typically made until one hour prior to delivery. The market opens after the day-ahead market is closed.

The regulating or balancing power market is a tool for the TSO to keep balance between generation and consumption in real time. Since the electricity market liberalisation, TSO's no longer hold generation resources in direct ownership, and balancing services need to be procured. It must be noticed that terminology related to markets, especially considering intra-day and balancing markets, is not always unambiguously used.

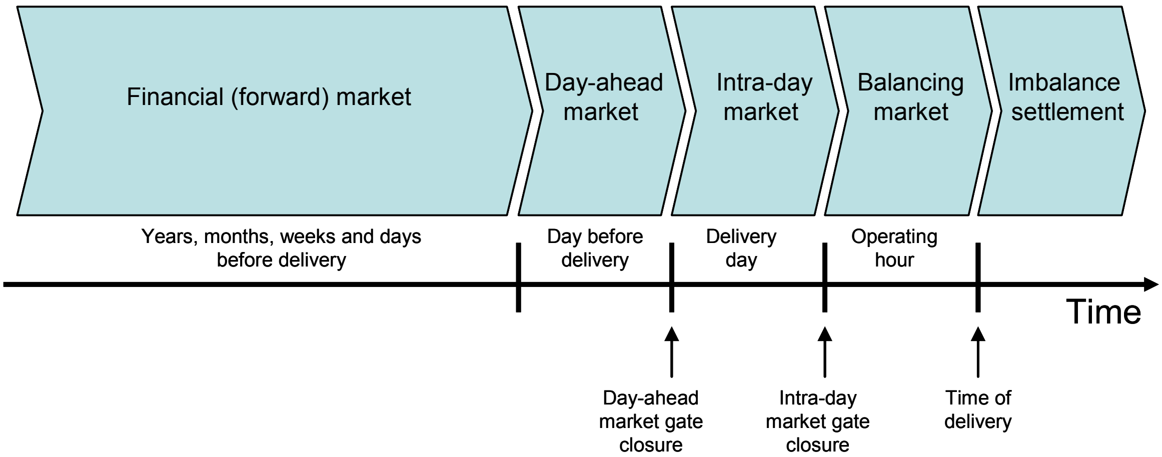

Figure 27. Structure of power trading. Gate closure refers to the moment after which the bids submitted to the exchange cannot be modified.

5.1.1 Day-ahead markets

European power exchanges can be differentiated into two categories, power pools and power exchanges. Exchanges can also fall in-between of these groups. Typical of power exchanges, scheduling procedures of most European markets are only partially integrated to system operation.

Participation in power exchanges is voluntary, and they are privately owned for-profit market institutions. For instance Nord Pool, EPEX and APX are organised as power exchanges. Power pools are mandatory, cost-of-service -regulated institutions whose income depends on approved costs for approved tasks. Italian GME and Irish SEMO are organised as power pools. Spanish OMEL is an in-between exchange (Mihayolova 2009). Power pools typically perform several tasks that go beyond providing trading services. For instance in Spain OMEL has the additional task of allocating capacity services and in Italy GME has the additional task of managing internal congestions in the country (Meeus 2011). In both Italy and Spain, only generators participate on the market.

Figure 28 illustrates the most important European electricity exchanges including their average day-ahead market prices and volumes in 2010:

- Nord Pool is the largest power exchange in Europe, both in terms of physical and financial trade volumes. Nord Pool operates in Denmark, Estonia, Finland, Norway and Sweden, and the market is coupled with Central Western European power markets (Belgium, France, Germany, Luxembourg, and the Netherlands).
- European Electricity Exchange (EPEX) is based in Germany. The company operates spot markets for Germany, Austria, France, and Switzerland.
- The volume of Italian power exchange (IPEX) is large both in absolute terms and compared to consumption. The exchange is organised on the basis of the pool system. The exchange is managed by a market operator (Gestore Mercato, GME), who collects all the bids and determines the merit order. Demand bidding started in 2005.
- Iberian power exchange (MIBEL) operates both Spanish and Portuguese spot trading. Trading is voluntary but encouraged with capacity payments.
- Anglo-Dutch APX group operates markets for electricity and gas in the Netherlands, the United Kingdom, and Belgium.
- Belgian power exchange (Belpex) operates only physical short-term power market.
- Polish Power Exchange (Polpx) was established in 1999 and trading was launched in 2000.

According to European Energy Regulators ERGEG, increased spot and futures trading at power exchanges contribute to more liquid and transparent wholesale markets. Liquid wholesale markets are central to efficient competition and competitive retail markets. The volumes traded in the European power exchanges have been increasing in the recent years. On the whole, one third of the total generation is traded in EU/EEA spot markets (ERGEG 2010). However, the volume of trades settled in power exchange varies. Largest volumes compared to consumption are traded in the Nordic power exchange Nord Pool, where day-ahead market's market share is about 70% of the total electricity consumption. Even if the volumes compared to consumption were much lower than this, the spot price is a benchmark and reference price also for OTC[15] market, since buyers and sellers always have an arbitrage option (Nicolosi 2010).

[15] Over the Counter, trading outside the exchange.

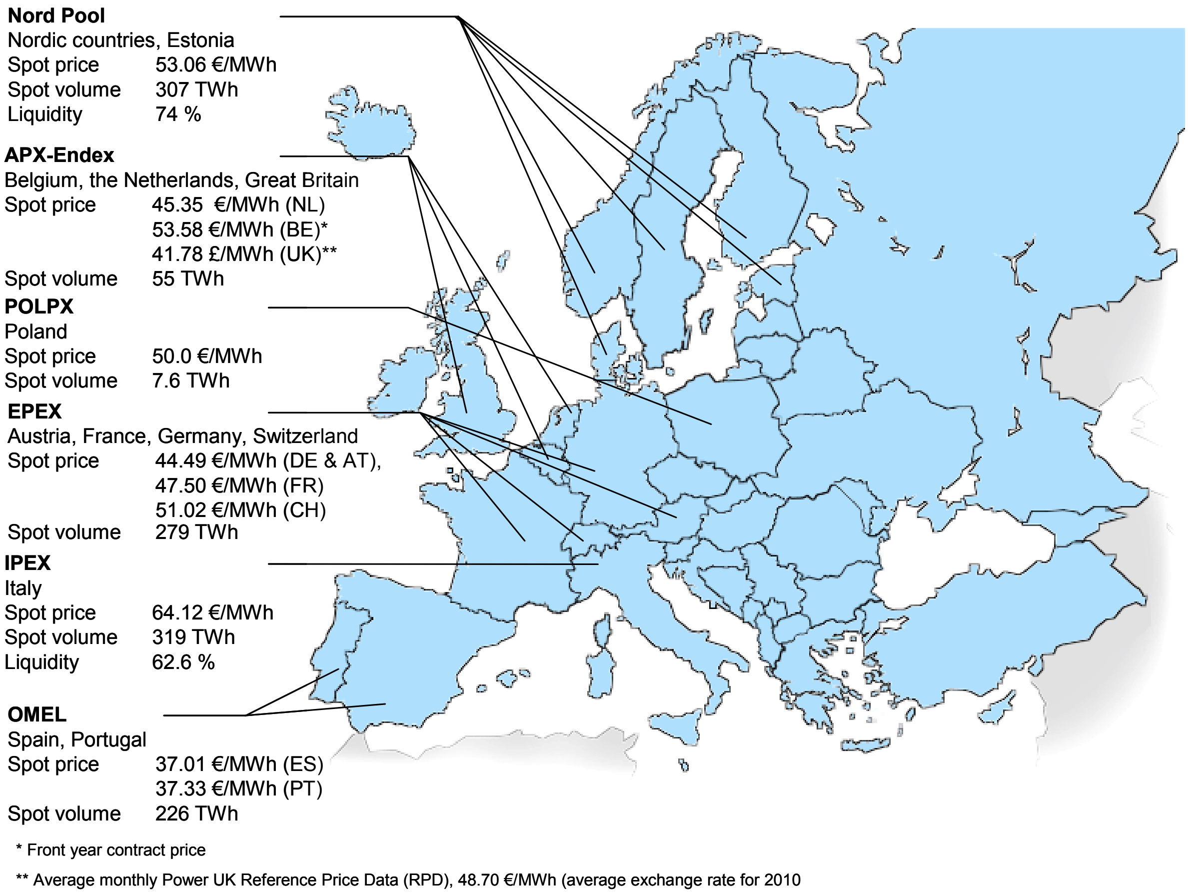

Figure 28. European power exchanges, their volumes and average day-ahead power prices in 2010.

An ongoing trend is the consolidation of European power exchanges. In 2009, EEX (European Energy Exchange based in Germany) and Powernext (France) launched EPEX (European Power Exchange), which is a spot market for Austria, France, Germany, and Switzerland. APX-Endex covers currently Belgium, the Netherlands, and the UK. There is also a pan-European project for market coupling by Nord Pool, EPEX Spot, and OMEL.

5.1.2 Intra-day markets

After day-ahead market's gate-closure, market participants may need to adjust their generation or consumption plans. Traditionally, this has happened due to unplanned plant outages, unanticipated changes in consumption patterns and weather conditions. Also the uncertainty about wind projections decreases significantly during the last 24 hours.

Formerly, intra-day trades were typically possible on a national basis. In recent years, European intra-day markets have been consolidating quite fast. The arrangement of intra-day markets differs among European countries (Weber 2009). Table 2 shows the trading volumes in some European intra-day markets. Very low numbers indicating low intra-day market liquidity in the Table 2 may be related to market design or market structure.

Table 2. Intraday markets in some European regions.

	Market operator	Gate closure	Trading volume
France, Germany	EPEX Spot	45' before delivery	2010: 11.3 TWh
The Nordic countries, Germany, Estonia	Nord Pool	60' before delivery	2010: 2.2 TWh
Spain, Portugal	MIBEL	6 auctions per day	2009: 34.0 TWh
UK	Not relevant since spot market closes only 1 h before delivery		

The growing share of variable RES generation in the European power generation increases the uncertainty about power production in the day-ahead markets. However, the forecast error for wind decreases distinctly with a shorter lead time. Observed data in Germany indicates, that the wind forecast uncertainty decreases from 15% to 4% in the last 24 hours before actual generation (Borggrefe & Neuhoff 2011). An effective intra-day market allows the system to re-dispatch after the spot market gate-closure, and thus reduces the costs for electricity generation due to the increased start-up and part load costs and the need for a significant amount of more expensive balancing reserve capacity.

5.1.3 Balancing markets

Electricity markets must include an appropriate mechanism to maintain a real-time balance between consumption and generation of electricity. The task of balancing (regulating power) is typically managed by transmission system operators (TSOs). Therefore, TSOs must be provided with appropriate tools to deal with sudden deviations from day-ahead (or hour-ahead) trading based schedules.

Currently there are significant differences between balancing market designs in Europe and a coordinated approach is lacking (Vandenzande et al. 2008). The distortion from insufficient cross-border harmonisation is discussed, and minimum prerequisites and long-term recommendations for the cross-border balancing in Europe are given in Vandenzande et al. (2008).

According to ERGEG Annual Report 2009, inadequate integration of balancing markets is a key barrier when a single European electricity market is aimed. There has been progress in cross-border balancing between France and the UK, where a new model became operational in 2009. Additionally, a report of integration of balancing markets in Baltic region was finalised and cross-border balancing proposal was presented. (EGREG 2009)

5.2 European and US market designs

Green (2008) thoroughly describes the differences between the US and European approaches in the light of determined six criteria of functionality of electricity markets. A forward-looking approach analysing low-carbon future, is chosen. The fundamental difference between the US and European markets design is that in the US, the main electricity wholesale markets are run by the Independent System Operator (ISO) responsible for transmission within each market area, while in Europe, separate companies usually run the wholesale markets and the transmission system.

The difference in wholesale market organization forces the European system operators to acquire ancillary services to maintain the electricity system balance, such as reserve, separately from the energy market, while the US ISOs can acquire energy and most of their ancillary services in a single, co-optimized, process. In some US markets, in response to fears that this process would not give peaking generators sufficient revenues, *capacity markets* have been created to provide an extra revenue stream. The US markets can set separate prices for every point on the network, and use these to charge for transmitting energy from point to point (i.e. nodal pricing or locational marginal pricing principle), whereas European prices cover either a whole country or a large zone within one. Thus, European system operators have to take separate actions to deal with constraints on the transmission system (when present), whereas the main market prices signal these constraints, and the actions required, to US market participants. (Green 2008)

6. Electricity price development in Europe

Electricity price level and volatility have a significant influence on the profitability of Smart Grid applications and technologies. This chapter takes a closer look on the price drivers and the actual prices in the European electricity markets. Europe has still several regional electricity markets. The interconnector capacity between these markets is not adequate to ensure a truly uniform market. In fact, it is not cost-effective to build enough interconnectors to remove all the bottlenecks in transmission, and the markets will remain at least partly separated.

Some key price drivers are common for all European electricity markets. These include coal, gas, oil, and emission allowance prices. Local demand and supply conditions still have a major contribution to prices. In the areas with large hydropower production capacity, hydrological situation does have a large impact on prices.

This chapter focuses on the Nordic power market. In the Nordic markets, short-term variations in the price of electricity have been rather low, because the share of easily regulated hydropower is high. For example, the intra-day variations of electricity price in Germany are significantly larger than in the Nordic countries. Through market integration and growing share of variable renewable electricity generation, the price volatility may increase in the Nordic markets.

6.1 Price drivers

Fundamentally, power prices depend on the level of electricity demand and the available supply and its cost. Power price drivers are the drivers behind these factors (Figure 29):

- Electricity **demand** has been highly inelastic to price variation, although especially electricity-intensive industry is becoming more and more price sensitive. In the near future, demand response is expected to increase due to the increased adaptation of time-of-use tariffs and smart metering. Electricity consumption also depends on weather. In northern countries, demand peaks are experienced during cold winter working days, while in southern Europe demand peaks occur during hot summer days due to air conditioning and cooling loads.

- Total consumption must be matched by the exactly same level of **generation**. In the Nordic countries, a significant amount of electricity is produced with hydropower. Electricity cannot be stored economically in large quantities, but water reservoirs near hydropower stations can be used to store water for electricity generation during the times of high electricity prices. The water level in the reservoirs is the key pricing factor in the Nordic day-ahead market. The reservoirs are ample, with sufficient water to produce electricity equivalent to 1–3 months of Nordic consumption. Also nuclear power availability affects the power prices.

- For fuel-consuming power plants, the short-term marginal costs are determined largely by **fuel and emission allowance prices**, and thus these commodity prices affect power prices. In the Nordic power market, the marginal production is usually coal condensing, and thus the future electricity prices (forward prices) are highly correlated with coal and emission allowance prices. In the continental European power markets, both coal and gas can be in the margin.
- Nordic power market has **interconnectors** to other continental European power markets. The availability of the interconnector capacity and electricity prices in these neighbouring markets affect Nordic power prices.

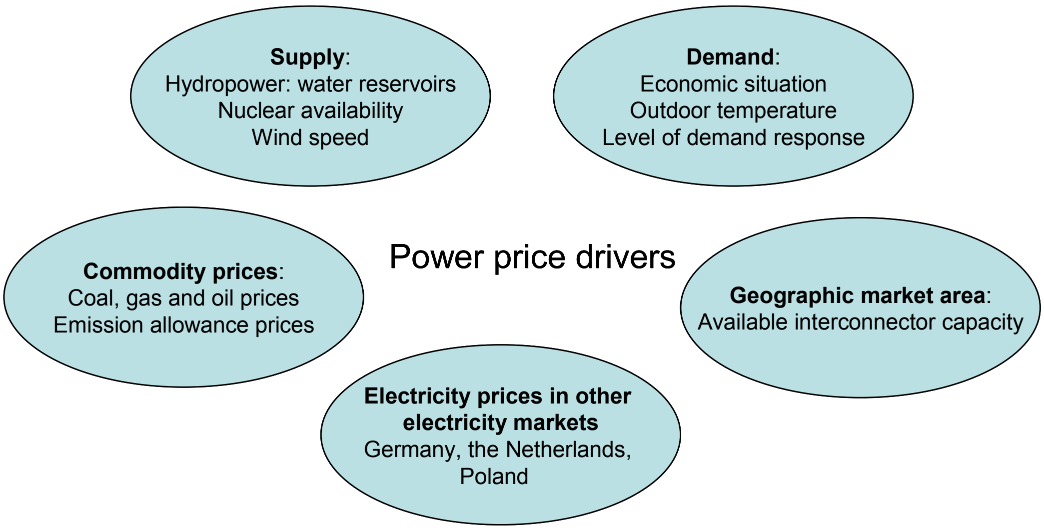

Figure 29. Short-term power price drivers in the Nordic electricity market.

Figure 30 provides an illustration of the fossil fuel price development from January 2008 to March 2011. All the prices experienced peaks in 2008, and then decreased because of the global downturn. Since then prices have been rather steadily increasing. Oil and gas prices are directly linked, partly because of contractual indexation clauses and partly because of the product substitution possibility. Historically, coal price has been lower and more stable than the prices of oil and gas. While oil and coal have global markets and uniform reference price for all the European market areas, natural gas prices depend on the geographical location and other factors.

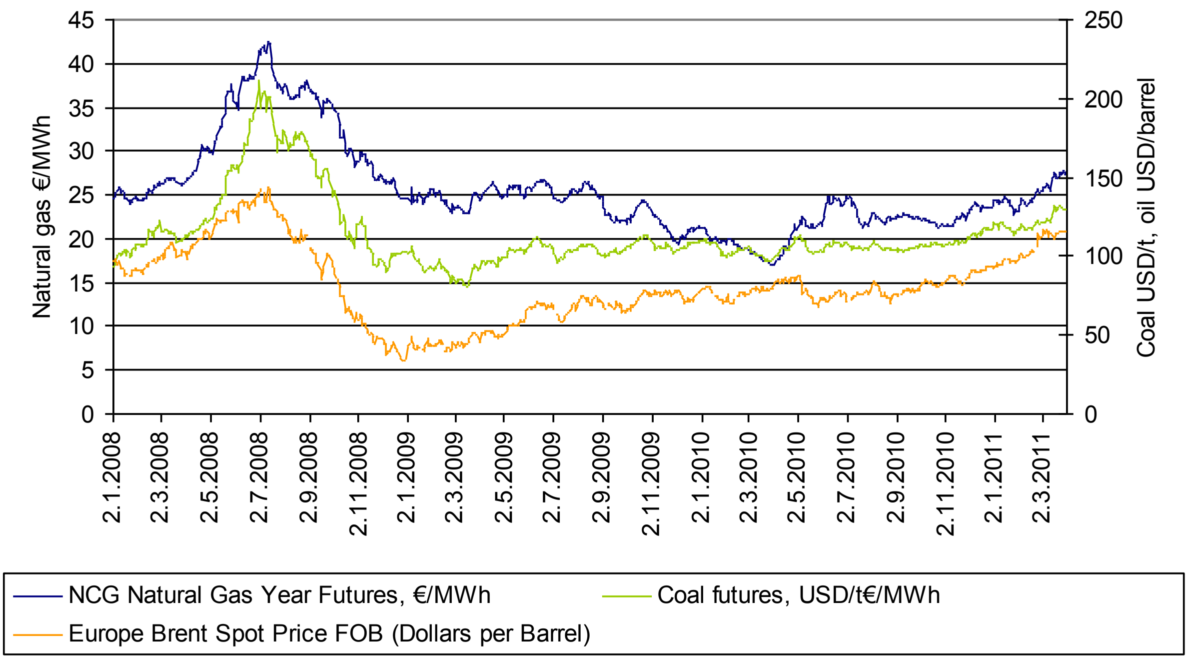

Figure 30. Fossil fuel price development from January 2008 to March 2011(data provided by EEX and EIA).

6.2 Wholesale price development

6.2.1 Spot prices

Wholesale electricity prices in Europe are not uniform. While some of the most significant price drivers are the same for all European regional or national markets, local demand and supply conditions still have a major contribution to prices. In the areas with large hydropower production capacity, hydrological situation does have a large impact on prices.

Figure 31 shows day-ahead spot price behaviour in major European power exchanges in the first quarter of 2009. Main reasons for price divergence are dissimilar generation capacity and bottlenecks in transmission capacity between market areas. Italian power prices are the most separated from other prices, and the high level of prices is mostly explained by insufficient generation and interconnection capacity, and the fact that Italy's power generation capacity is mostly fossil-fuel based. There is a high correlation between German and French power prices, which indicates that these markets are reasonably well interconnected. In regions where hydropower production is large (Spain and the Nordic countries) intra-week (and intra-day) variations are smaller. The low level of the Nordic prices is explained by the large hydropower production, which is usually about half of the consumption (ITRE 2010).

Several recent research reports state that the correlation of European day-ahead power prices is increasing:

- In 2008, Ecorys published an analysis of the European wholesale energy markets (Ecorys 2008). For exchanges over the 2002–2007 period, Ecorys found a clear increase in traded volumes, market participants and price correlations among various exchanges. Price correlation was 28% in 2002, and increased to 67% in 2007. It was also concluded, that an increase in physical connection capacities and market coupling initiatives had been increasing liquidity and price correlations in the European power market.
- In January 2010, ESMT Competition Analysis published a report about German electricity wholesale market integration and competition. German power prices from years 2004, 2005, 2008, and 2009 were compared with its neighbouring countries' power prices. The analysis showed that correlations increased or remained stable. The report was commissioned by RWE AG (ESMT CA 2010).

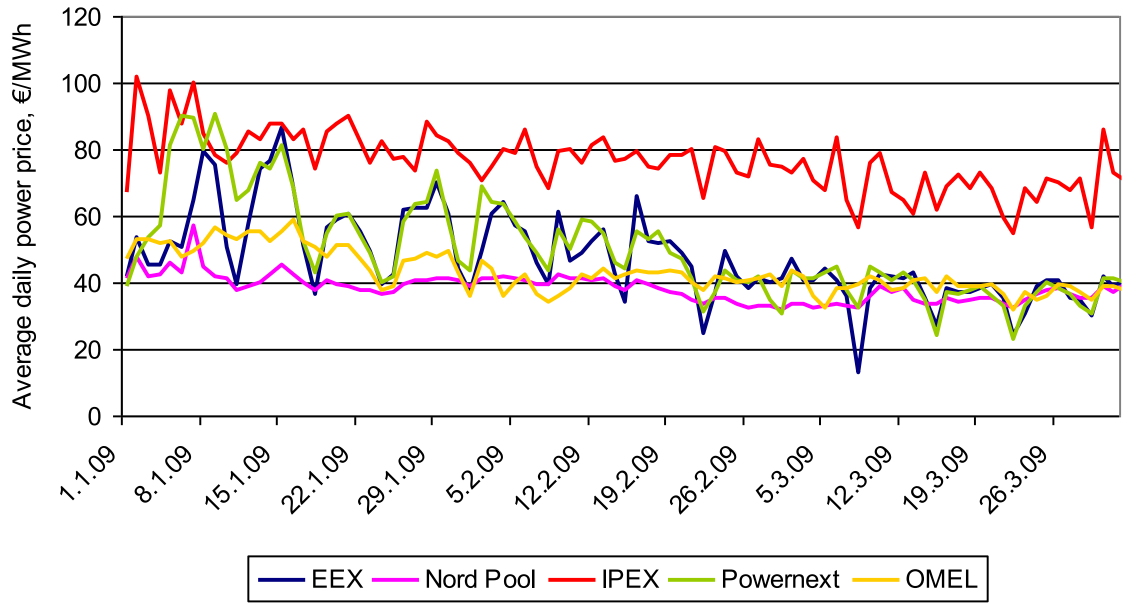

Figure 31. Average daily day-ahead power prices on Europe's electricity exchanges in the first quarter of 2009.

In recent years, the electricity market areas with large wind power generation compared to consumption have experienced volatile and sometimes even negative power prices. One example of these areas is Germany, where wind power production accounted for 8% of the final electricity consumption in 2008. In times of low demand and high wind power infeed the market has reacted with bids underneath variable costs in order to avoid ramping-down base load power plants. Negative bids were allowed in autumn 2008, and in October 2008, a European wholesale market closed with a negative price for the first time. Until November 2009, 71 hours with negative prices were observed at the EEX. Ten of these had a price under -100 €/MWh (Nicolosi 2010).

Nicolosi (2010) shows that the current flexibility limits of the German power system are earlier reached than probably anticipated. With the increasing wind and solar power share, the situations with negative power prices become much more likely in the future. The power system needs to be flexibilised through adaptations of all systems components. These include the flexibility of the demand side, the grid and the supply side.

6.2.2 Forward prices

While spot prices reflect the momentary supply and demand situation, forward power prices are influenced by fuel prices, the structure and cost of the new generation capacity, capacity retirement, water reservoir levels, weather trends, interconnector capacities, CO_2 prices and economic growth (ITRE 2010). Asymmetries in forward prices reflect market participants' expectations of differing spot prices (differences that cannot be equalised in cross-border trade).

The development of European power and commodity forward prices for year 2011 is presented in Figure 32. German and French power prices are quite similar, while Nordic price follows the same trend but the level is lower. This can be again explained by large hydropower production and restricted transmission capacity to continental Europe. Nordic prices follow closely coal prices, because coal is usually the marginal production technology in Nordic power exchange. In continental Europe, marginal technology is either gas or coal, and both of these prices affect power prices. The price of emission allowance affects all power prices. (ITRE 2010)

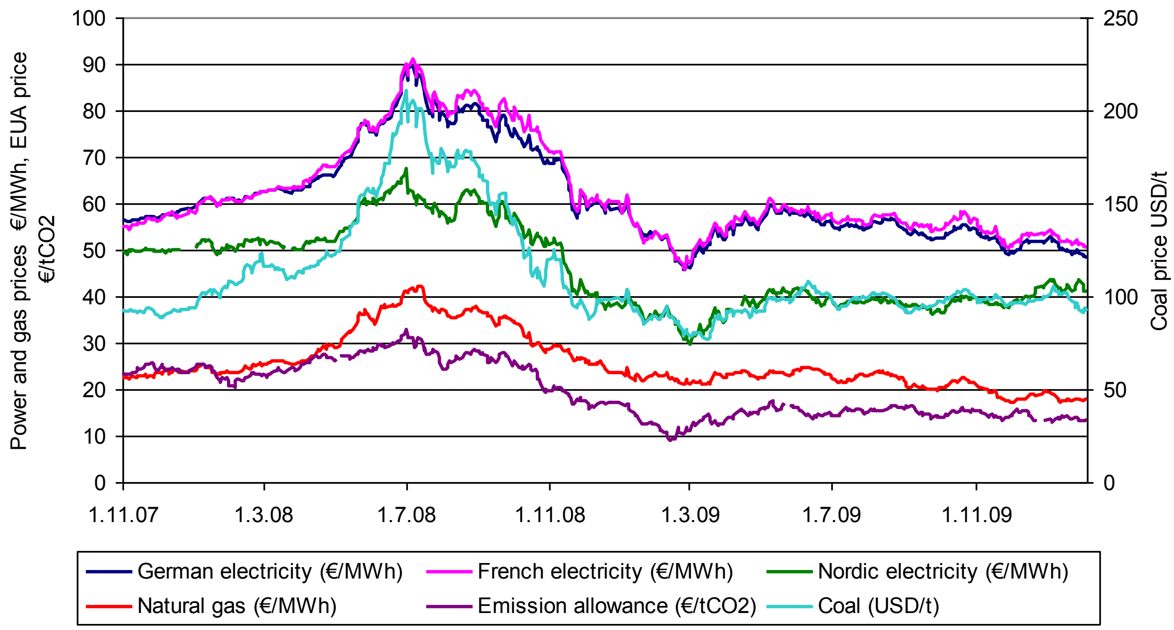

Figure 32. Development of electricity, coal, gas, and emission allowance forward prices for 2011 (data source: respective exchanges; gas, coal, and CO_2 price from EEX).

6.3 Retail prices

6.3.1 Retail price composition

End-user prices can be divided into three components. In the following, these components are explained and the price levels for household[16] consumers are compared:

- In competitive markets, the price of **energy** component is determined by the wholesale electricity prices and retailer margin. This component varies according to the wholesale power price. In the second half of 2009, the energy component varied between 3.1–12.2 c/kWh, average energy cost was 6.7 c/kWh. While a large part of the variation is explained with different wholesale prices, also retailer margins vary between Member States.
- **Network costs** are more similar in different Member States. In the second half of 2009, these varied between 2.2–7.5 c/kWh. Average network cost was 4.8 c/kWh.
- **Taxes and other levies** vary largely between Member States. In the second half of 2009 smallest tax component was 0.7 c/kWh and largest 14.4 c/kWh. The countries with largest energy prices for household consumers usually have also large PSO-fees (Public Service Obligation), including for instance RES-E feed-in tariff fees. Electricity-intensive industry is often exempted from these levies. This component has been quite stable in recent years, but increases in renewable electricity feed-in fees are expected.

Household electricity prices are illustrated in Figure 33. In the second half of 2009, highest total household electricity prices were paid in Denmark, Germany, and Italy. Lowest prices were paid in Bulgaria, Estonia, and Lithuania. For industrial customers[17], Cyprus, Slovakia and Italy had highest price levels, while lowest prices were paid in Bulgaria, Estonia, and France (ERGEG 2010).

Theoretically, demand response is most cost-efficient in the countries with the highest and most volatile electricity prices. An essential requirement for demand response is that real-time price information is effectively brought to the customers.

[16] Consumer band Dc with an annual consumption between 2500 and 5000 kWh.
[17] Consumer band Ic with an annual consumption between 500 and 2000 MWh.

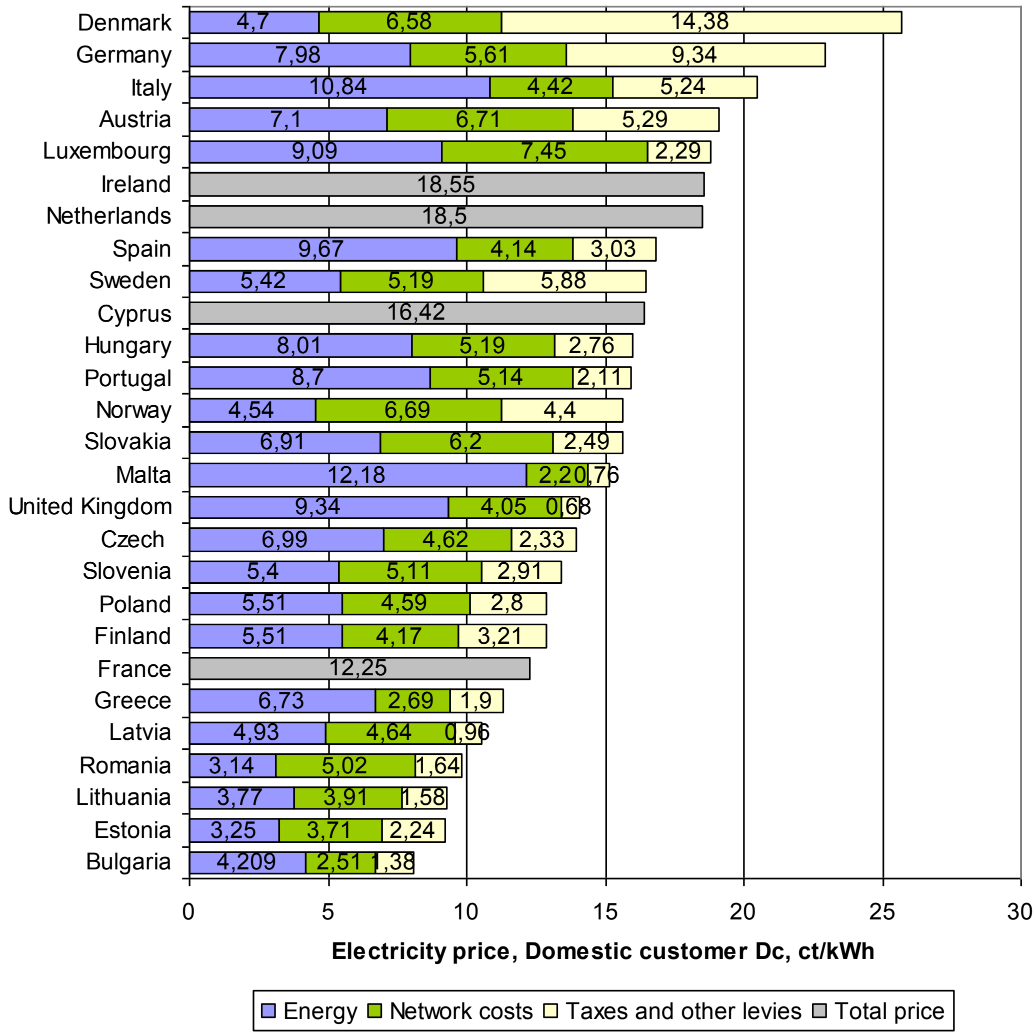

Figure 33. Electricity prices for household domestic consumers (band Dc, annual consumption between 2 500 and 5 000 kWh), second half of 2009 (data provided by ERGEG).

6.3.2 End-user price regulation

In the EU, it is still quite common that regulated electricity prices exist. In 2008, 135.5 million households and 14.3 million non-household consumers had regulated electricity prices. Largest volumes of electricity sold under regulated prices are in France, Spain and Italy (Figure 34).

In a position paper published in 2007 European Energy Regulators ERGEG states, that end-user price regulation in electricity (and gas) markets distorts the functioning of the market and jeopardises both security of supply and the efforts to fight climate change. End-user price regulation should be abolished or brought in line with market conditions. ERGEG also says that “vulnerable customers” should still be protected, but this should not be confused with guaranteeing regulated tariffs to all customers (ERGEG 2007). Also, the EC Sector Inquiry highlights the concern with regulated tariffs, pointing out that if regulated tariffs are kept low, new entrants are excluded from the market and market players will not invest in new capacity, which is detrimental to the security of supply (EC 2007c).

When considering demand response development, end-user price regulation distorts the price signals and is thus a barrier to Smart Grid development.

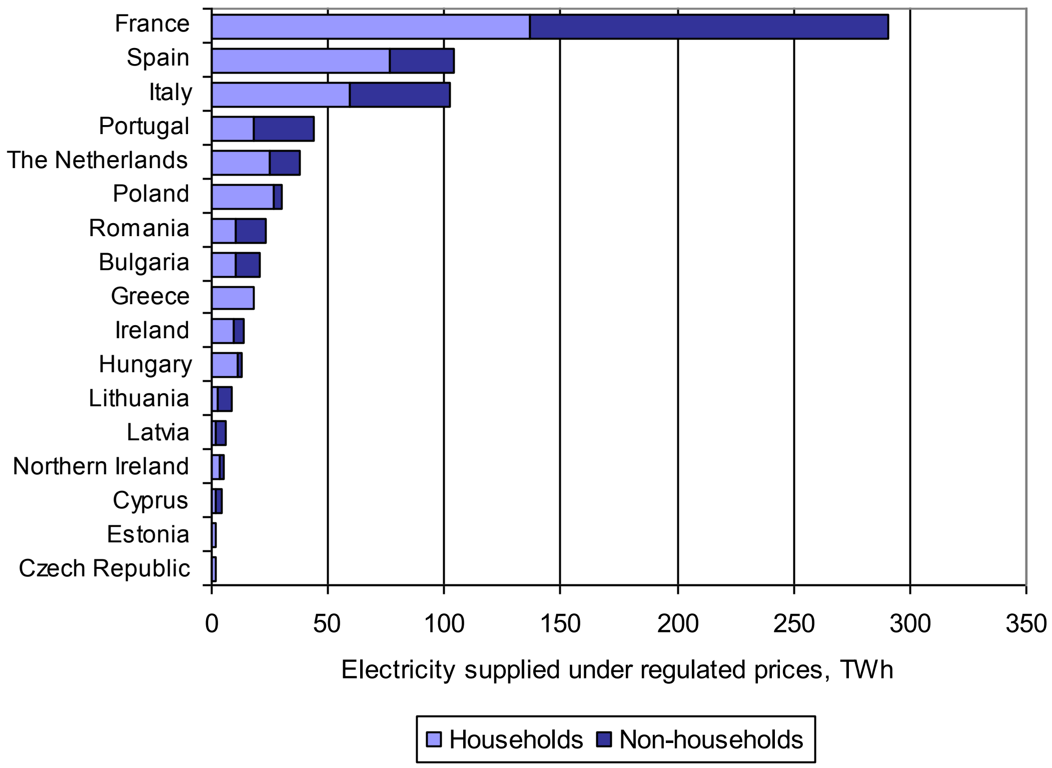

Figure 34. Existence of regulated prices in the EU in 2008 (data provided by EC 2010d).

7. Smart Grids and electricity markets: discussion on the business environment of the future

7.1 General

The changes in electricity systems and markets in the future are considered to be mainly driven by factors reviewed in chapters 2 and 3. These changes consider generation and consumption of electricity and may call for more efficient utilisation of grids and management of energy systems. The efficient utilisation of grids considers not only technological improvements but also market design and operational practices.

Efficient integration of intermittent, mainly renewable power generation, is one of the main drivers of changes towards the future business environment of electricity markets in Europe. In this environment, business cases for various solutions and technologies referred under concept of Smart Grids, are potentially increasing. The term Smart Grids is sometimes used of an evolution of electricity systems as a whole, efficiently managing the change towards more renewables-based electricity system. In this case, generation technology structure, end-use technologies etc., are also referred to.

From the pure grid development viewpoint, Smart Grids can be briefly characterized to increase the role of IT technologies creating value in electricity systems through efficient utilization of information. As many characteristics discussed with Smart Grid concepts (Demand Response, hourly metering, automation…) already exist in transmission systems to a large extent, distribution networks are more likely to reform more substantially. In this report, Smart Grids from the pure grid viewpoint are considered to be a partial enabler for the changes of electricity systems in the future driven by factors reviewed in chapter 3. Especially, Smart Grids are a part and potential enabler of a smarter electricity system, which allows efficient integration of RES.

However, an evolution of electricity systems towards a state where Smart Grids concepts are more justified reshapes the investment and operation environment for electricity market participants. This chapter takes an initial look at the potential implications and requirements that changes in the business environment implicate. The changes concern many participants: e.g. technology manufacturers, energy companies and end-consumers. As the viewpoint of this report is to take a broad look of the electricity markets over the whole Europe, detailed analysis of single market areas or technologies are left outside. Instead, a more qualitative approach is taken, where key technologies and phenomena are listed.

Fostering the development towards Smart Grids also calls for consideration of electricity market design, such as pricing methods.

7.2 Business impacts and opportunities

7.2.1 Key changes from electricity market participants' viewpoints

In liberalized markets, the market outcome is determined by supply and demand. As changes in supply or demand arise, changes in market outcome might be expected. In a case of European electricity markets, the future changes are considered to be mainly driven by factors presented in chapter 3. The impacts of changes on technological choices will also depend on political decisions and regulation and on local conditions.

It is not the purpose of this report to forecast the outcome in electricity markets until 2020; instead, it is aimed that the potential key development trends of supply and demand sides will be identified in this section, which takes a closer look at potential implications and requirements that changes in the business environment implicate in supply and demand. Especially, the roles of technologies discussed in a context of Smart Grids are specified.

Supply side: The drivers of different generation technologies are discussed on chapter 3.2 and 3.3. Emission reduction targets and depleting fossil fuel resources are reflected in the EU policies, which shape the business environment towards the year 2020. Generally, importantly from the (Smart) grid development point of view, the significance of varying RES electricity is estimated to increase in Europe. Small distributed generators may be able to provide useful ancillary services as well as energy (Hogan 2010).

Demand side: Generally, the drivers will probably imply the increase of significance of solutions providing energy efficiency and smarter use of energy. As many characteristics discussed with Smart Grid concepts already are significantly used by large-scale energy users, the operation environment of small-scale retail energy users is more potentially to go through more substantial changes. The potential changes discussed in a context of Smart Grids include:

- More options for customer choice (e.g. to rate structures) may arise due to advanced metering solutions
- Real-time price signals may be utilized by home automation and smart appliance solutions, whose operation is controlled according to (hourly) price of electricity and customers' preferences
- The potential of demand response may rise due to the dynamic rates and automation
- In-home displays are a novel technology delivering real-time information of electricity consumption and price.

The above changes generally imply more active end-customers and potentially increase the functionality of markets. Not all the changes are necessarily customer-driven but are indirect consequences of renewal needs. The cost-efficient potential of these solutions depends on several factors, such as the supply side structure of (local) electricity markets.

Aggregators: as incentives for single retail customers to demand response may be small, aggregators are discussed as a new type of actors operating in electricity markets. Aggregators are actors who manage flexible resources of a large number of retail customers. Aggregators and the related business models are more closely discussed e.g. in WP 5.2 of the SGEM research program.

7.2.2 The role of intelligent networks

The role of the electricity grids is, one the one hand, to support the integration of European electricity markets. The changes in future integrating electricity markets in Europe might also indicate changes to regulated network business, a sector where Smart Grids are considered. Thus, the development in this sector is also considerably dependent on regulatory actions. However, business opportunities for technology manufacturers, software and service providers may arise in this sector also in order to efficiently utilize the information and control the grid. The relative cost-efficiencies of technological options differ from case to case, for example depending on the availability of hydro resources as a cost-efficient regulative power option.

The supply of wind power will vary to a greater extent compared with traditional electricity generation. The Nordic electricity market has a high proportion of hydroelectric power, mainly in Sweden and in Norway. This will contribute to equalising the total supply of electricity, which will in all probability reduce the need for advanced forms of storage facilities. In the longer term, there will be need for more storage capacity. It is also believed, that the consumer side will need to be used more to adjust for variable wind power generation. Plug-in hybrid cars or electric cars have also been discussed as potential flexible resources in the future.

7.2.3 The increasing role of information technologies

Smart Grid concepts typically imply a mix of control technologies, information systems, and information distribution that allow for much finer control of all the devices connected in the electricity grids (Hogan 2010). The management of this information can open up possibilites for completely new types of businesses compared to traditional electricity business (e.g. software developers, service providers, IT technology manufacturers).

Smart Grids may include more flexible controls in the transmission grid, better monitoring of grid and distribution flows, real-time status and fault monitoring, automatic meter reading and, importantly, real-time automation of end-use devices. (Hogan 2010)

7.3 Implications for markets design in the development towards Smart Grids

It can be concluded from the EU's RES targets (see chapter 3.3.2) that integrating distributed and renewable energy resources in electricity and energy systems is a key driver of the European electricity grid development – towards a target often referred to as Smart Grid. The EU is simultaneously aiming at electricity market integration and liberalisation. In a market-based system, price signals set the incentives of market participants to operate. Thus, the role of the market design is not indifferent in the development towards Smart Grids.

It seems probable that the significance of intra-day and balancing markets in Europe is growing from the market functioning and integration point of view. This is due to the fact that this type of production often depends on short-term conditions challenging to predict (e.g. windiness) which, correspondingly, calls for operative actions by market participants. Functioning intra-day markets could provide efficient price signals for market participants and also enhance potential for demand response as a part of Smart Grids.

The development will pose additional challenges also for balancing and, correspondingly, strengthen the call for demand response, energy storages and other SG technologies for maintaining the grid balance. Thus, harmonised and market-based balancing market procedures are also of increasing importance to foster market integration and the penetration of SG technologies in Smart Grid environment. To foster market-based penetration of smart end-user appliances, retail consumers' rate structures should vary according to wholesale prices to provide incentives to shift load from high-price hours.

Wind power is the fastest growing technology for renewable electricity production in Europe. A significant part of it might be located considerably remotely from demand. This indicates power flows over the grid will also become more variable, and (unless large amounts of additional network capacity are added), it has been suggested that more transmission constraints will arise (Green 2008). These factors will increase the importance of scheduling plants as efficiently as possible, and maximizing the available transmission capacity (Green 2008).

The US-style market design enables efficient, centralized coordination and it is characterized by theoretical gains in the respect of efficient scheduling. This is due to that fact that scheduling procedures are more integrated to system operation. However, political difficulties might be faced if more centralized approach would be aimed in Europe. Brunekreeft et al. (2005) also emphasizes the efficiency of nodal pricing but recognizes the probable political difficulties in fully implementing it to the European system. This might be due to difficulties considered between central coordination and national interests of electricity systems. However, market coupling for network zones with identifiable single price areas are suggested as an intermediate solution (Brunekreeft et al. 2005), bringing improvement potential in efficiency of markets.

8. Summary and conclusions

The European Union has committed itself to limiting the global temperature increase to two degrees compared to the pre-industrial levels. In order to contribute to the two-degree target, the European Council has also given a long term commitment to the decarbonisation path with a target for the EU and other industrialised countries of 80 to 95 % cuts in emissions by 2050. This large emission reduction means that by 2050, virtually all electricity should be generated from carbon-neutral sources.

At present, over half of the electricity generation is based on fossil-fuel consuming technologies. In the next decades, the electricity generation structure needs to change completely, from current fossil fuel and nuclear based system to a system based on renewable energy sources and other non-carbon emitting technologies, which may be fossil fuel plants fitted with carbon capture and storage technology (CCS) or nuclear power. Large part of the electricity production is going to be based on wind and solar power, and local small-scale generation will increase.

Electricity demand is expected to increase

This report includes a review of different EU electricity demand scenarios. On average, climate policy scenarios project smaller electricity demand than baseline scenarios. Climate policy scenarios include policies enhancing energy efficiency, which can lower electricity demand, but also increase electricity demand if the policies include shifting energy demand from other sectors to electricity sector.

According to a comparison based on previously published scenarios, electricity demand is expected to increase in the European Union. The projections for 2020 range from 3 530 TWh to 3 795 TWh, being 150–420 TWh higher than the electricity generation in 2008. For 2020, baseline scenarios are close to climate policy scenarios, which can be interpreted as that the EU climate policies for 2020 can be considered effective and the related legislation is already in force. The projections for 2030 range from 3 771 TWh to 4 192 TWh. Here, the range is larger, and the projected demand increase compared to 2008 ranges from 400 to 810 TWh.

Renewable power generation to increase significantly

At present, electricity production in the European Union is based on fossil fuel consuming technologies, which account for 57% of the total installed capacity and 53% of the electricity generation.

Power generation capacity structures differ between Member States. A large part of these differences originate from differing natural endowments: hydropower is used where it is available, and countries with domestic fossil fuel resources utilise them in power generation. National energy policies also affect power generation structures. This has been most pronounced in the case of nuclear power. Non-hydro renewable power generation is another example.

Currently, nearly half of the total installed capacity is carbon-neutral. The European Union's climate policy commitments have accelerated the development of the renewable power production. According to National Renewable Energy Action Plans, the annual RES-E production is expected to reach 1 200 TWh by 2020, more than double the amount generated by RES-E technologies in 2010. This will exceed the projected demand increase, and RES-E generation is expected to replace fossil-fuel consuming power production.

Large additions in variable wind and solar power generation

According to the National Renewable Energy Action Plans, by 2020, wind power production is expected to cover 14% of the total electricity consumption and solar power is expected to cover 3% of the consumption in the EU. Wind and solar power are not dispatchable forms of power generation in the traditional sense. They can only create electricity when the energy source is available. Rest of the power system needs to accommodate the variation from the variable forms of renewable energy.

Electricity markets will be more interconnected

The European Union aims towards a single European electricity market. With the help of a well interconnected grid the cost of renewable energy deployment can be brought down. Integration development is influenced by the physical cross-border interconnector capacity development and capacity allocation methods.

At present, Europe still has several regional electricity markets. The interconnector capacity between these markets is not adequate to ensure a truly uniform market. In fact, it may not be cost-effective to build enough interconnectors to remove all the bottlenecks in transmission, and the markets will remain at least partly separated. There are ongoing projects and investment plans for a number of new interconnectors. For example, the capacity between the Nordic and continental European electricity markets will more than double in the next decade.

Differences in the trading regimes and in the calculation, allocation and the management of the available capacity are the primary obstacles to the efficient use of existing interconnector capacity. A fully integrated electricity market requires harmonised rules for capacity allocation methods and other trading regimes. The European Union aims at pan-European market coupling by 2014.

Electricity price level and volatility are expected to increase

Electricity price level and volatility have a significant influence on the profitability of Smart Grid applications and technologies.

Some key price drivers are the same for all European electricity markets. These include coal, gas, oil, and emission allowance prices. Local demand and supply conditions still have a major contribution to prices. In the areas with large hydropower production capacity, hydrological situation does have a large impact on prices. For instance in the Nordic system, intra-day variations in the day-ahead power price are small compared to markets with lower hydropower generating capacity.

Increasing physical grid integration will also increase the correlation between electricity prices in different European locations.

The growing demand and restricted resources of the fossil fuels will drive the prices up in the future. Emission allowance prices are also expected to increase. These drivers will have an effect on electricity prices as well.

In recent years, the electricity market areas with large wind power generation compared to consumption have experienced volatile and sometimes even negative power prices. With the increasing wind and solar power share, the situations with negative power prices become much more likely in the future. The power system needs to be flexibilised through adaptations of all systems components. These include the flexibility of the demand side, the grid, and the supply side.

Smart Grids and electricity markets: discussion on business environment of the future

Integrating distributed and often non-dispatchable renewable energy resources in electricity and energy systems is a key driver of the European electricity grid development – towards a target often referred to as Smart Grid. The changes imply the investment and operation environment for electricity market participants is changing. The changes in business environment concern many participants: technology manufacturers, electricity companies and end-consumers, among others.

Demand for many solutions discussed in a context of Smart Grids, such as demand response, advanced metering and automation, will increase from current. However, the cost-efficient potential of these technologies as a part of electricity systems of the future depends on several factors.

Fostering the development towards Smart Grids also calls for consideration of electricity market design, such as pricing methods. It seems probable that the significance of intra-day and balancing markets in Europe is growing from the market functioning and integration point of view. This is due to the fact that this type of production often depends on short-term conditions challenging to predict (e.g. windiness) which, correspondingly, calls for operative actions by market participants.

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Abstract
This report takes a look on the current state and future development opportunities of electricity markets in the European Union (EU). The business environment established by electricity markets has an essential impact on the potential and development of so called Smart Grid concepts and technologies, currently under extensive research and development in the EU.

According to a comparison based on previously published scenarios, electricity demand is expected to increase in the European Union. The projections for 2020 range from 3 530 TWh to 3 795 TWh, being 150–420 TWh higher than the electricity generation in 2008.

EU's energy and climate policy commitments imply that the electricity supply structure of EU needs to change completely in the next decades, from the current fossil fuel and nuclear based system to a system based on renewable energy sources and other low-carbon technologies. According to National Renewable Energy Action Plans, the annual RES-E production is expected to reach 1 200 TWh by 2020, more than double the amount generated by RES-E technologies in 2010.

Integrating distributed and often non-dispatchable renewable energy resources – especially wind and solar power – in electricity and energy systems is a key driver of the European electricity grid development. The European Union aims towards a single European electricity market. With the help of a well interconnected grid, the cost of renewable energy deployment can be brought down.

As a result of expected changes in electricity demand and supply, demand for many technological solutions discussed in a context of Smart Grids, such as demand response, advanced metering and automation, will increase from current. Cost-efficient potential of these technologies as a part of electricity systems remains a key question in further research and development of Smart Grids.

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