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The European Power System
Decarbonization and Cost Reduction: Lost in Transmissions?

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Executive Summary

Europe's energy policy is commonly defined by three axes of equal importance: security of supplies, competitiveness and sustainable development. The European Commission is mandated to develop the policy tools that allow the implementation of this common policy. Early on, challenges arose from the trade-offs to be made not only between these three pillars but also between a common European policy and national approaches. The European Commission has always had to struggle in attempting to keep a balanced line.

Over the past twenty years, the EU has been engaged in the liberalization of the electricity and gas sector. For a long time, liberalization was the main objective of European energy policy. Liberalization of the electricity sector was supposed to bring many benefits. Foremost, these included the more efficient allocation of generation and transmission capacities, and the enhancement of the competitiveness of the European economy as a whole, through lower energy costs. The trading of electricity output between countries was part of this strategy. Interconnections are vital to facilitating electricity trade between Member States. It is in this context that interest in cross-border interconnections has increased. However, new constraints have emerged and have put climate change at the top of European agenda.

In December 2008, as part of the fight against climate change, the European Union adopted its Energy and Climate package endorsing three objectives for 2020: i) a 20% increase in energy efficiency, ii) a 20% reduction in GHG emissions (compared to 1990), and iii) a 20% share of renewable energy sources in final energy consumption. A direct consequence of the later objective is that renewable energy sources (RES) in electricity generation are expected to expand from 20.3% of electricity output in 2010, to around 33%, in order to meet the objective set by the European Commission. Hydroelectric power has limited additional potential due to geographical constraints. Wind energy is expected to provide most of the extra renewable energy required in electricity generation to meet this objective. Even though photovoltaic electricity production is less mature than wind energy, this technology is also strongly supported by new energy policies. Overall, the variability of these intermittent technologies can be dealt with by interconnection capacities, to a certain extent. Strong interconnections between neighboring countries are crucial for greater wind-power and solar penetration in the European system.

Main observations

A quick overview of European energy policy over the past 15 years shows that rationales for interconnections have evolved as new concerns have reinforced their importance. Originally they were seen as an instrumental part of the liberalization process. They are now considered as key to move renewable electricity across Europe. One immediate implication is that the building of new interconnection lines is no longer driven by the circulation of electricity related to production costs, but rather by policy objectives which aim to transport electricity produced by intermittent renewable energy sources (and not low carbon energy sources that would include nuclear power). The objective of the Internal Electricity Market is to bring competitive electricity prices to end-users, but as these prices are linked to the composition of the power generation mix, it is easy to see that there is a clear discrepancy in the rationales pushing for corridors aiming at transporting RES across Europe and a market-driven logic that will favor the building of transmission lines based on a competitive power generation mix.

The lack of consistency between European objectives could endanger the balance between the three pillars of European energy policy. Indeed, if the network is not upgraded in time, development of RES will not yield significant benefits in GHG emission reduction, as countries will have no choice other than to develop and to rely on fossil fuel capacity to deal with intermittency. An objective on capacity production, such as the European objective on the share of RES in final energy consumption, without a strategy to develop these links is bound to fail. In this sense, the submission of the infrastructure package in November 2010 is an important step forward. However, it does not address the full complexity of the problem as the allocation of generation capacity remains essentially national, while a discussion on a European energy mix, as a collection of national energy mixes, is not possible at the EU level. There is still an important missing link arising from the fact that the specificity of national energy mixes, and in particular their competitiveness are not acknowledged. The European objective on RES requires a broad vision that would adequately prepare the European network to receive a massive amount of energy from wind power. But this should be done in a way that is socially and economically acceptable.

There are no technical limits to the extension of a power network. Limitations remain essentially political, economic and physical. National strategies prevailed during the development of the European network and they will continue to override a European vision, as long as Member States refuse to discuss a power generation mix (as a collection of national energy mixes) at the EU level. If coordination between Member States remains at the minimal level witnessed today, there are few chances that a low carbon and cost efficient internal European grid will emerge. A strategy on transmission, however ambitious it is, is bound to fail if it is not part of a broader vision able to clarify the trade-offs to be made in indicating how the benefits (social & environmental) and the costs could be shared among all actors. An intermediate solution would be a bad compromise, as it will amplify all the disadvantages of RES development, including the need to develop back-up capacities, interconnection costs, and the persistent need for subsidies such as Feed-In-Tariffs (FITs). At the same time, it will not yield its benefits, including a higher penetration of RES that would replace higher GHG energy sources, the smoothing of intermittency, and congestion management.

Important decisions are taken at the national level without cooperation or coordination with neighboring countries. This is true for the establishment of the NREAPs, but also for decisions regarding the structure of the power generation mixes. The fact that Member States are sovereign with regard to their energy mixes should not prevent them from coordinating major decisions, such as a significant reduction of generating capacity, as has been the case in Germany but also in Belgium and in Switzerland. The measures that are planned so far to replace nuclear power in these countries are highly hypothetical (the pace of expected benefits from energy efficiency improvements) or costly (development of renewable energy sources at a time when they are still far from markets). This will probably lead in the short and medium term to the development of fossil fuel power plants, which will have an impact on GHG emissions, pushing the CO2 price up on the European market. This in turn will translate into higher electricity prices.

Interconnections have many benefits but increasing the dependence on them from a national point of view creates risks elsewhere. Indeed their efficiency and reliability also depend on what happens in other markets. Decisions might be national, but the system is European. Furthermore, interconnections take time to build. It is not certain that they will be ready in time to receive and transport power produced by wind farms in the North or PV panels in the South. Already, price spikes occur as soon as most of the available capacity across Europe is used. Volatility of electricity prices could increase if the development of interconnection does not meet the growth of renewable energy sources.

Priorities of European energy policy have shifted from a market-driven approach to policy objectives. The de-carbonization of the power sector, RES deployment and the development of interconnections are all tools that are to be implemented to answer the three pillars of European energy policy. However, the tools seem to have become goals in themselves. This could already be observed with the objective of RES development that has been reinforced, though it has not yet led to significant benefits in terms of GHG reduction, although it is one of the priorities of EU energy policy. But, RES development has affected the rationales for interconnections. An immediate consequence is that European energy policies seem to be heading for a significant increase in electricity costs.

The lack of coordination between all actors involved will definitely lead to underinvestment. The EIP Blueprint attempts to improve the regulatory framework to speed up authorization processes and to limit the delays that have been observed so far in the completion of cross-border interconnections, but this requires a transfer of decision-making from Member States to the EU. Only the resolution of the shortcomings listed above could encourage Member States to give up part of their national prerogatives. Furthermore, the provision aiming at overcoming local opposition to the building of interconnections will certainly clash with existing environmental regulations. Too many voices still have the power to block the construction of interconnection lines.

The pace of RES deployment and interconnection development are significantly different. So too are the lifetimes of generation capacities (about 30 to 50 years), and of networks which are longer still. The fight against climate change requires urgent action, but if Europe does not succeed in developing an appropriate framework that will favor the de-carbonization of the power sector, which involves a low carbon energy mix and a transmission network that is able to transport low carbon energy sources at a cost that is socially acceptable, then there is a huge risk that decision-makers and investors may prefer to ignore the long term consequences of global warming.

Contents

Introduction

In December 2008, as part of the fight against climate change, the European Union adopted its Energy and Climate package endorsing three objectives for 2020: i) a 20% increase in energy efficiency, ii) a 20% reduction in GHG emissions (compared to 1990), and iii) a 20% share of renewable energy sources in final energy consumption. A direct consequence of the later objective is that renewable energy sources (RES) in electricity generation are expected to expand from 20.3% of electricity output in 2010, to around 33%, in order to meet the objective set by the European Commission. Hydroelectric power has limited additional potential due to geographical constraints. Wind energy is expected to provide most of the extra renewable energy required in electricity generation to meet this objective. Even though photovoltaic electricity production is less mature than wind energy, this technology is also strongly supported by new energy policies.

These technologies are special due to their intermittent nature. Overall, the variability of wind-power generation can be dealt with by interconnection capacities to a certain extent. Strong interconnections between neighboring countries are crucial for greater wind-power and solar penetration. Today, this is one of the main rationales behind numerous publications of the European Commission and one of the main drivers of infrastructure development across the European Union.

However, another important driver lies in the building of the Internal Electricity Market (IEM). Indeed, interconnections are vital to facilitating electricity trade between Member States. This is not a new concern as the European network was built early on, around cross-border transmission lines whose role was limited until recently in helping congestion management, enhancing security of supply, and acting as an instrument of solidarity. Under some conditions, they were also considered as an alternative to investment in new capacity.

The objective of the Internal Electricity Market is to bring competitive electricity prices to end-users, but as these prices are linked to the composition of the power generation mix, it is easy to see that there is a clear discrepancy in the rationales pushing for corridors aiming at transporting RES across Europe and a market-

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driven logic that will favor the building of transmission lines based on a competitive power generation mix.

The lack of consistency between European objectives could endanger the balance between the three pillars of European energy policy: security of supply, competitiveness and sustainable development. Indeed, if the network is not upgraded in time, development of RES will not yield significant benefits in GHG emission reduction. On the other hand, the European objective requires a broad vision that would adequately prepare the European network to receive a massive amount of energy from wind power, but in a way that is socially and economically acceptable. Yet, energy mixes are designed by Member States and are part of the solution.

This paper examines the main challenges facing the development of interconnections. The paper is organized in four parts:

- The first part discusses the rationales for building interconnections and the shift of priorities in European energy policy. It sets out the context in which new cross-border transmission lines will be built.

- The second part presents a global outlook of a sample of European countries and the role of interconnections.

- Eight case studies are described in the third part, in order to identify the main issues related to development of interconnections.

- Finally, the last part compares the situation today with the EU's 2020 objectives, by observing the European Infrastructure Package Blueprint (EIP Blueprint), and it discusses the main political and economic issues at stake.

The Context

Interconnections across borders are not new. The European electricity network such as we know it was developed as part of nation-building efforts in the aftermath of WWII. Engineers understood early on the benefits brought by the linkage of national grids. In mutualizing capacities over a larger area, interconnected systems allow for a better coverage of the load and improve the stability of technical characteristics of the grid, such as voltage and frequency. They can also lead to reduced investments in generating capacities, through the better use of power plants and smaller operating reserves.

A shift in the rationales for interconnections

In the European context, cross-border interconnections at first played a marginal role, limited to help regulating the system and compensating exceptional variability in the supply/demand balance. Since 1996, the date of the founding text for the construction of an integrated European energy market, the functioning of the electricity system has evolved in line with the liberalization process. Liberalization of the electricity sector was supposed to bring many benefits: among them, the most commonly cited were the increase in the efficient allocation of generation and transmission capacities, and the enhancement of the competitiveness of the European economy as a whole through the diminution of energy cost. Trading electricity between countries was part of this strategy. Indeed, enhancement of power exchanges between countries can lead to a competitive market across Europe. Interest in cross-border interconnections increased because the ability to trade electricity efficiently across Europe is becoming an impediment due to the lack of connecting lines between Member States (but also inside countries) to provide a more efficient energy system.

Transmission: A Natural Monopoly

The European grid is the backbone of a well-functioning and integrated power system. A rough breakdown of the cost of supplying electricity to businesses or households is: generation 30%, transmission 40%, and distribution 30%. Historically, the three functions where generally carried out by vertically integrated companies. The liberalization of the European market has led to the unbundling of these activities, allowing competition in generation and services. The electricity business is particular, as electricity must be used when it is produced. Electricity storage is not yet cost efficient and the balance between demand and supply needs to be insured in a continuous way. The physics of electricity transmission require centralized coordination, which makes operating the grid in a market-based setting very difficult. Therefore, transmission (and distribution) remains a natural monopoly, managed by Transmission System Operators (TSOs), whether national (in France, with RTE acting as the only TSO) or regional (in Germany, with 4 TSOs).

The liberalization of energy sectors across the world began in a context of abundant and cheap energy, and when capacity was plentiful. However, new constraints began to emerge, highlighted by the release of the 1995 UNFCCC report. It concludes that human activities are likely responsible for most of the observed increase in global warming. In 1997, countries supporting the Kyoto protocol committed themselves to a reduction of greenhouse gases (GHG) compared to their 1990 emission levels. In 2002, the European Union ratified the protocol, and decided to implement a carbon market: the EU ETS which was to come into force in 2005, in order to decrease the CO2 emissions of power-generation and industry. Step-by-step, global warming and sustainability have made their way onto the European energy policy agenda. Climate concerns have become increasingly present in the debate among energy policy makers and, in 2006, the Green Paper definitely broke down the European energy policy along three axes of equal importance: security of supplies, competitiveness and sustainable development.

This evolution is not without consequences for the need for improved interconnections, as new policies call for the development of renewable energy sources as part of the fight against climate change. In December 2006, the TEN-E (Trans-European Energy Network) guidelines linked – potentially for the first time – the upcoming 3 x 20 objectives to the building of an internal market: "The priorities for trans-European energy networks stem from the creation of a more open and competitive internal energy market… A special effort should be undertaken to achieve the objective of making greater use of renewable energy sources as a contribution to further a sustainable development policy. However, this objective should be achieved without creating disproportionate disturbances to the normal market equilibrium."[1] In 2007, in endorsing the 3 x 20 objectives, the European Council intended to provide the necessary tools to transform Europe with low carbon technology. Under this unilateral commitment, the EU is to cut its emissions by 20% of 1990 levels, by 2020; to bring the share of RES in final energy consumption up to 20%; and to improve its energy efficiency by 20%. The first two objectives are legally binding. This strong political support has helped to develop significant new renewable energy sources across Europe, mostly wind power and also photovoltaic electricity, as hydroelectric resources are limited. But as wind power, and to a lesser extent solar power penetration increase, the effect of intermittent sources on the whole electrical system is no longer trivial.

The Challenge To Integrate Intermittent Res

Upgrading of national grids is a prerequisite to managing efficiently the integration of renewable energy sources. Development of renewable energy sources has an impact on the level of investments needed to upgrade the network. For example, when production is not in phase with electricity demand, the network needs to be able to adjust faster. This is often the case for photovoltaic electricity. Problems might arise when the energy mix is not flexible enough to adjust to high concentrations of wind output. Also, when wind farms are isolated and far from areas of consumption, networks will often be too weak or insufficient to accommodate electricity production.

Historically, electricity production and the associated network for transmission and distribution have been based on centrally located large blocks of power generation capable of delivering large electricity output. With the integration of new RES, electricity supply must be considered from a new perspective: electricity generated from wind or solar power must be used when it is produced. Furthermore, new RES are often connected to the distribution network, downstream from the transportation network. TSOs lack information on their production and availability, which could endanger the overall stability of the network. Upgrading of the electricity network must take into account these new parameters.

The 2008 Energy and Climate package acknowledges this issue in requiring that Member States develop the network in accordance with a greater penetration of RES. This was reinforced by the blueprint for a European integrated energy network (European Infrastructure Package, known as the EIP blueprint), released in November 2010. This infrastructure package is to be seen as a top-down umbrella that should compensate for the slow progress of the TEN-E bottom up approach that listed 32 projects of "European interest", of which just a few has been completed so far (see Annex

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[1] http://eur-lex.europa.eu/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&lg=en&type_doc=Decision&an_doc=2006&nu_doc=1364

and Part 4 of this study). In particular, the blueprint focuses on a limited number of infrastructures that will help the EU to respect its objectives by 2020, and beyond that, to cut GHG emissions by three-quarters, by 2050. The EIP blueprint is extremely ambitious and paves the way for European electricity highways (4 electricity corridors), able to move solar power from Spain and offshore wind power from the North Sea to Continental Europe. The blueprint emphasizes decentralized power generation capacities and the need to connect major areas of consumption. The upgrading of the existing network and new DC transmission lines will play a key role in this ambitious scenario.

Ac/Dc Technologies

The "war of currents" goes back to the end of the 19th century and illustrates the industrial and technological battle between Thomas Edison, who promoted the use of DC (Direct Current) technology to transport and distribute power, and AC technology proponents who included Nikola Tesla and George Westinghouse. The first whole power system was based on DC technology (1882, New York), but DC technology was flawed by power loss in conductors. AC was more efficient, allowed transport of power over longer distances, was more easily converted at high voltage levels, and was soon accepted as the only technology for generation, transmission and distribution of power. The beginning of the 20th century marked the progressive expansion of AC systems worldwide.

However, high-voltage AC transmission lines also have disadvantages and the development of new technologies has showed that HVDC (High Voltage Direct Current) lines are now technically feasible. Today, with regard to public opinion that regularly opposes the building of new overhead electric lines and because of the introduction of offshore wind farms in the power generation mix, alternatives to AC lines are being considered. Under certain conditions, HVDC links could be better adapted to transport great amounts of electricity between two points.

Cost studies indicate that economic feasibility is a function of the length of the line but several technical challenges remain to be solved regarding HVDC technology. Systems are still new for the power industry and currently have only a limited capacity. The development of HVDC links also implies developing convertors so they can function efficiently with the AC network. Yet there is a lack of standardization concerning types of HVDC converters and DC voltage levels.

The so-called infrastructure package also calls for the development of a smart grid at the EU level.

What Will the European Smart Grid Look Like?

The definition of a smart grid is slowly beginning to take shape even though the vocabulary used might be misleading. Smart grids refer to two main areas. First, it concerns the management of the high voltage grid (transmission network), through the implementation of advanced monitoring systems that will help to accommodate growing volumes of renewable energy sources. It also includes the upgrading of the network and the development of new infrastructures. Second, smart meters installed on the consumer side, whether households or industry, will allow demand to be managed better. Smart meters can facilitate the provision of new price signals to customers in the form of electricity prices related to the network situation. These "smart meter tariffs" can then induce customers to shift demand to off-peak periods or to invest in equipment to offset peak costs (and invoicing effects).

Smart grids are a very important tool to integrate the decentralized production of RES, by allowing the transmission network to receive information from the suppliers and from the consumers while maintaining the security of the network. But beyond this broad concept, several factors will shape the future network. Indeed, as long as electricity storage technologies remain are not ready for the market, grid operators will have to balance electricity supply with demand at anytime within the network. Only a thorough understanding of the electricity grid's needs and consumers' loads will make the network efficiently smart. Smart grids are about new technologies applied to the network, but they also call for an efficient allocation of generation units along the network and for management of demand response. Demand side management will involve both households and industrial that can contribute greatly to peak shaving with power curtailment programs. Big consumers, such as industries, can play a significant role on demand side management, as offset programs can diminish the need for peak capacities. The electricity grid was originally conceived to function in a unilateral direction, from the producer to the consumer. It will now have to work both ways. New use of power, such as electric vehicles (EV), will also impact the design of the network and will introduce a new parameter, as EV can act both as consumers and producers, but are mobile loads.

The design of the European smart grid should be linked to the evolution of storage technologies, to the level of demand side management, and to the development of new capacities, their location and their characteristics (base load generation, peak load generation, intermittent generation, and flexibility of the power mix).

This quick overview of European energy policy over the past 15 years shows that the motivations for interconnections have evolved as new concerns have reinforced their importance. Originally they were seen as an integrated part of the liberalization process. They are now considered as key to move renewable electricity across Europe. One immediate implication is that the building of new interconnection lines is no longer driven by circulation of electricity related to production costs, but rather by policy objectives that aim at move electricity produced by intermittent renewable energy sources (and not low carbon energy sources that would include nuclear power). As an example of this shift in thinking, liberalized electricity markets are now occasionally presented as a way to offer consumers the choice for generating energy sources, even though the network takes and mixes all electrons, green or otherwise.

European objectives and Member States: competitive visions in a difficult context

The past efforts to deregulate electricity markets in Europe and initial observations show that electricity is not a common commodity and that its physical particularities call for ad hoc monitoring and careful regulation. The liberalization process is still ongoing, but major inefficiencies affect important investment decisions. In particular, the current lack of visibility causes insufficient investment in generation and transmission capacity. Overtime, it translates to more congestion in the network and higher electricity prices.

New investments are necessary to meet the expected increase in electricity demand, an average of 1.5% annually in Europe for the coming decade. The European grid is aging and requires modernization and upgrading. Most power infrastructure was built before the 1970s. Existing network infrastructure will not be sufficient to meet the increase of electricity demand across the EU. At the same time, European Energy policy requires more grids to enhance market integration, optimize resource sharing and transmit electricity produced from RES.

The European objective on the share of RES in final energy consumption calls for a new model of electricity production that would be able to integrate both centralized and distributed electricity production. It requires a large, shared vision by all actors that would adequately prepare the European network to receive a massive amount of energy from RES. Even though energy is a shared competence between the EU and the Member States, since the Lisbon treaty, Member States remain sovereign with regard to their energy mixes. The discrepancy between European objectives and national energy mixes could therefore lead to two competing visions that could be articulated around a “low level integration scenario”, that would more or less prolong the current situation, and a “high level integration scenario” of RES, where all major hindrances would have been resolved.

There are no technical limits to the extension of a power network. Limitations remain essentially political, economic and physical. National strategies prevailed during the development of the European network and they will continue to override a European vision, as long as Member States refuse to discuss a power generation mix at the EU level. If coordination between Member States remains at the minimal level witnessed today, there are few chances that a low carbon and cost efficient internal European grid will emerge. A strategy on transmission, however ambitious it is, is bound to fail if it is not part of a broader vision able to clarify the trade-offs to be made in indicating how the benefits (social & environmental) and the costs could be shared among all actors. A middle ground solution would be a bad compromise as it will amplify all the disadvantages of RES development, including the need to develop back-up capacities, interconnection costs, and the persistent need for subsidies such as Feed-In-Tariffs (FITs), without yielding its benefits, including a higher penetration of RES, the smoothing of intermittency, and congestion management.

The role of TSOs and ENTSO-E

The role of a Transmission System Operator (TSO) is to ensure the security of the network and to provide power to all consumers. It must maintain a continuous balance between supply and demand at all times. The TSOs are also responsible for planning, building, financing and operating the electricity grid infrastructure. They must provide access to the grid for generators, distributors, and traders. Even though electricity markets in Europe remain essentially national and are linked at the margin, TSOs must take into account the power that flows through the cross-border interconnections. Management of an interconnected system is difficult. In 2006, the lack of a centralized management at the EU level was the source of major blackouts all over Europe, due to local congestion in Germany (see part 3, the case study of Germany).

Fig. 1.1 Regional groups in ENTSO-E

Source: ENTSO-E

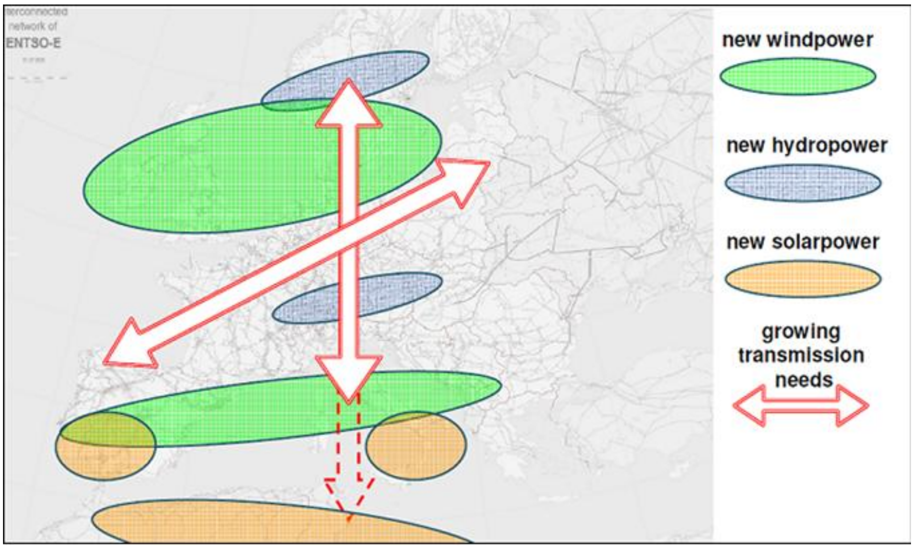
The third energy package (August 2009), enhanced greater cooperation between TSOs through a European Network for Transmission System Operators for electricity (ENTSO-E). ENTSO-E has been fully operational since July 2009 and replaces the former TSOs organizations UCTE, ETSO, NORDEL, UKTSOA, ATSOI and BALTSO. Among its tasks, ENTSO-E must ensure the completion and the functioning of the single electricity market and of cross-border trade. It must establish network codes and publish non-binding, community-wide, ten-year electricity network development plans every two years. Similarly, national TSOs have to publish ten-year network development plans.

According to the ten-year network development plan (TYNDP) developed in 2010 by ENTSO-E, meeting European 2020 goals demands about 35,000 km of new transmission lines, while 7,000 km of existing lines need to be upgraded, of which 20,000 km are directly related to the development of RES and 28,500 km are needed for the integration of the internal electricity market.[2] Overall, the total

[2] https://www.entsoe.eu/fileadmin/user_upload/_library/SDC/TYNDP/TYNDP-final_document.pdf

represents 14% of the existing transmission lines (305,000 km). The TSOs collective ambition is to complete 44% of the work by 2015. The TYNDP estimates investment needs to be €23-28 billion over the first five years.

Fig. 1.2 Growing transmission needs



Source: ENTSO-E

ENTSO-E plays a key role enacting the future European energy system. However, TSOs have been designed as part of national strategies that were looking to build an optimized energy mix as a function of demand requirements and of historical and national choices of energy sources. On another hand, ENTSO-E must enhance the evolution of the network, so it can meet EU energy and climate policies goals. This represents a formidable challenge, especially since allocation of generation capacities are the sole responsibility of Member States. An ideal solution would be to have a single European transmission operator. This is not realistic in the middle and even long term, since it would imply Member States giving up major decisions, regarding their energy system and would solve only one part of the whole equation, as long as the structure of energy mixes remains national.

Regulation of Interconnectors: Different Options

Regulated approach: Inside the European Union, TSOs usually recover their investment costs through regulated transmission tariffs set up by the regulator. They can also use revenues from auctioning of interconnection capacities[3]. If auction revenues are inferior to the transmission tariff, customer will have to supplement the difference. This approach can be seen as linking recovery costs to the costs of providing the transmission service.

Regulated cap & floor approach: Revenues collected by the auctioning of interconnector capacity can be partially used to cover investments costs. For example, revenues superior to the cap must be reinvested in increased capacity or returned to the customers.

Merchant line approach (private investors): This approach links recovery costs to future use of investments. Revenues are determined by auctioning. They depend on the price difference between the two systems to be interconnected. Uncertainty on future prices increases the risk related to the project. National regulators may grant (total or partial) exemption of obligation to provide Third Party Access (TPA) to merchant interconnectors. They may also grant exemption from the obligation to use the revenues resulting from congestion (congestion rents) for the objectives listed in the Regulation.

Merchant investment might be interesting to compensate lack of investment in transmission capacity, in particular when there is not enough political support or incentives to trigger TSOs to invest in some interconnectors. However, economic theory shows that merchant investors have an interest to keep the market partly disintegrated[4] in order to keep collecting congestion rents. This issue might be taken care of in granting TPA for a limited number of years, the regulatory framework of the connector evolving then from a private to a regulated approach.

[3] Auctionning of interconnection capacity is allowed in specific cases such as existing congestion

[4] http://www.nextgenerationinfrastructures.eu/download.php?field=document&itemID=449424

Sample of European Countries – the Overall Outlook

Power generation varies greatly across Europe due to historical choices and depending on whether countries have or had domestic energy resources. Fossil fuels are the most preferred energy source, followed by nuclear power. Over the past few years, the EU has added more power capacity from renewable sources such as wind and solar power than from conventional energy sources. With more than 75 GW of wind generation capacity and 5700 MW of solar power capacity, RES capacity in the EU (excluding hydro-electric power) has experienced the biggest increase among energy sources. This trend is expected to continue, especially if the diverse NREAPs (National Renewable Action Plans, see below) are implemented by each Member State and do actually meet their targets.[5] The share of gas in European member states is also expected to grow, firstly because its flexibility helps to balance the intermittency of RES, and secondly because market forces favor the choice of gas power plants as the preferred primary energy source. Also, the latest announcements by several countries to phase out nuclear power or to diminish its share in electricity generation call for an increasing role of gas in the power mix, and to a lesser extent for a return to coal, along with more emphasis on the development of carbon capture and storage (CCS) technology.

National Renewable Energy Action Plans, June 2010

Member States are required to present National Renewable Energy Action Plans (NREAPs) setting out in detail their roadmaps towards their legally binding European target for the share of renewable energy in final energy consumption. NREAPs were submitted to the EC in 2010. They describe the measures and actions that will be taken at the national level, in order to reach their objectives. All of them have been designed unilaterally.

This study will look more particularly at eight countries including seven Member States: Belgium, Denmark, France, Germany, Italy, the Netherlands, Spain, and Switzerland which represent parts of the North Sea and of the South west zones. These two areas account for more than 60% of European electricity production. They

[5] as part of the European objective on the share of renewable energy in final consumption (20% by 2020)

also represent 60% of the projects of "European interest" identified in the TEN-E guidelines (see Annex). Denmark, Spain and Germany are relevant to this study because the penetration of RES is among the highest in Europe. However, their geographical and "electrical" situations are different: Denmark is particularly well interconnected to its neighbors whereas Spain remains an electricity island. Germany is central to the interconnection challenge due to its geographical position, the size of its market, and its recent decision to phase out nuclear power. France is the only country with an energy mix dependent on nuclear power for 75% of its electricity production. The Netherlands and Belgium, although relatively small markets, are at the crossroads of power flows circulating on this European scale electric plate. They are also associated in an innovative market mechanism with France (see §2.1). The case of Italy is interesting not only because it is a huge importer but also with regard to the challenges associated with the aging of its distribution and power plant networks. Lastly, Switzerland can be considered as an energy hub because of its central position in continental Europe and could play an increasing role to back up intermittent energy sources due to its large hydro-electric reservoirs. Overall, these countries are part of a relatively well integrated network. All TSOs belonging to these countries are part of the ENTSO-E, which covers 34 countries and is made up of 42 TSOs supplying 525 million customers. Installed capacity represents more than 828 GW for a consumption of 3400 TWh. Exchanges between countries amounted to about 400 TWh in 2010.

Management of interconnections

In an increasingly interconnected system, coordination and transparency are very important to help TSOs to operate the power system efficiently. For example, since 2006, all TSOs must comply with an inter-TSO contract. A verification process has been implemented to check the compliance of continental TSOs with this multi-lateral agreement. This set of rules is perfectible and might be difficult to implement and some TSOs have suggested assigning some of their activities to other structures that would be better adapted.[6]

Such is the case of CORESO (Coordination of Electricity System Operators), a Brussels-based technical coordination center which, since 2009, has provided reliability analyses and coordinated resolution proposals for a large portion of the European network representing today 215 million customers (about 43% of the European Union's population). Initial shareholders, TSOs from France

[6] RTE, 2010 Reliability report

[6] http://www.audeladeslignes.com/importer-exporter-electricite-france-exceptionnel-habituel-8976

(RTE), Belgium (Elia), have been joined recently by the United Kingdom's TSO (National Grid), and then in November 2010 by the TSOs of Italy (Terna) and North and East of Germany (50Hertz Transmission).

Physical Flows and Commercial Exchanges

Commercial exchanges and physical flows are different. The former is the result of contracts agreed between economic actors at the European level. The amount of power can then transit through different routes according to physical constraints (Kirchhoff's laws), and not necessarily through the shortest or most direct line connecting the countries associated to the economic actors involved in the transaction.

TSOs manage the physical flows and are responsible for maintaining the security and the stability of the networks. It is therefore important to have a very good knowledge of the existing contracts at all times, in order to anticipate potential loop flows that could result from commercial contracts and the physical constraints of the network.

Since November 2010, a market coupling model has been implemented for electricity exchanges between Germany, Belgium, France and the Netherlands. This model takes root in a trilateral mechanism originally launched in 2006 and involving France, Belgium and the Netherlands. It is now also linked to Denmark and to the Norwegian market. This model allows better integration of local spot markets. It does not discriminate between countries and optimizes the circulation of electricity. Power flows from generation plants with the lowest marginal cost to the customers that value it the most.[7] This model in particular optimizes the use of cross-border capacity. It calls for reinforced technical cooperation between the different TSOs. The CWE (Central West European) TSOs appointed CORESO as service provider in the framework of the market coupling experimentation in April 2009.

[7] Nicolas Pierreux, Ifri energy breakfast roundtable, Nov 21, http://ifri.org/?page=detail-contribution&id=6878&id_provenance=88&provenance_context_id=16

The N-1 Criterion

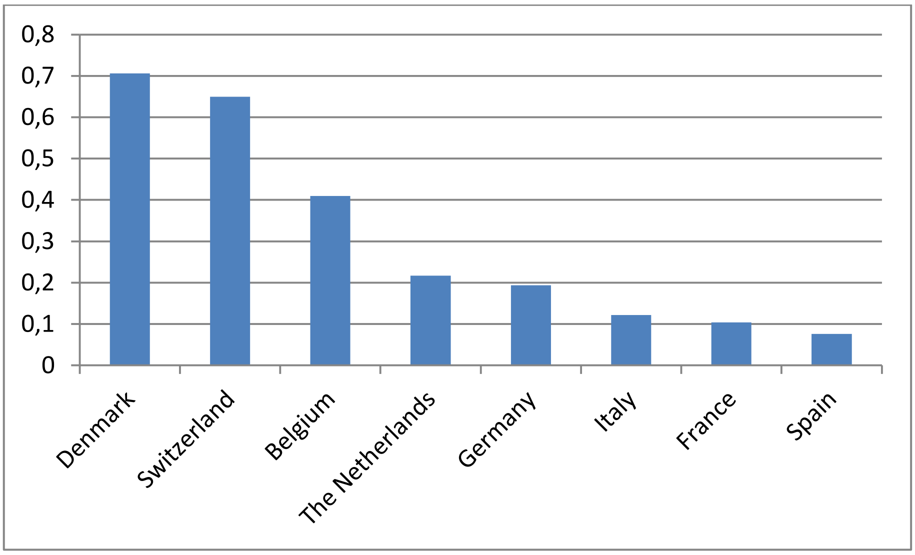
Maintaining N-1 security means that the power system must be able to put up with the outage of one component of the system. It insures better security of the system as a whole. Several conditions are required to satisfy such a level of security:

- spinning reserves - flexible generators that can instantaneously be solicited to face frequency variation (for example, when demand does not match supply) - must be sufficient;

- the system must be able to restore operating conditions rapidly in order to avoid cascading blackouts, additional reserves must be sufficient to maintain the integrity of the system.

Transparency is important since electricity circulation obeys physical laws and does not necessarily match commercial contracts. Each TSO bases its forecast on commercial contracts passed with neighboring TSOs. However this might not be sufficient as flows between two countries can be impacted by special conditions in a third country. For example, In November 2010, a line between Slovenia and Italy was at risk of not respecting the N-1 reliability criterion. CORESO's intervention allowed a solution considered by TERNA (the Italian TSO) to be implemented, in evaluating the impact on the French network (operated by RTE).

Fig 2.1 Ratio between interconnection capacity (MW) and peak load (MW)[8]



Source: ENTSO-E

[8] Maximum load (MW) compared to import NTC values (MW)

Another important component when operating the network and that might have an impact on the management of interconnections is the adequacy of the system to follow the evolution of electricity demand. Indeed the operator needs to know the available generation capacity as all capacities might not be available at a given time (maintenance or planned interruption), the status of remaining capacity to cover unexpected load variations, and the flexibility of the system to operate, especially including the use of interconnection exchanges.

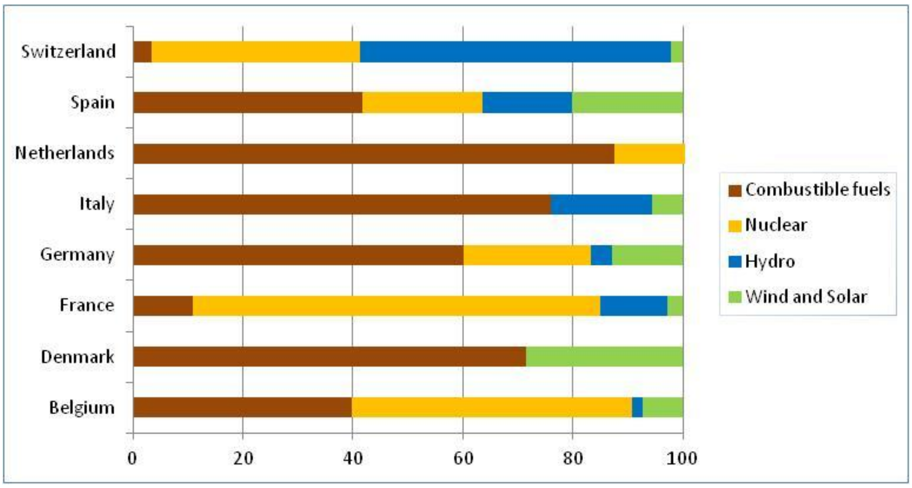
Also, the ability to match peak demand is crucial to analyzing and balancing the system at all times. Risk factors affecting peak load levels are closely related to climatic conditions that can affect demand. Extreme cold weather in winter or particularly hot days in summer will require the use of all available generation capacities, including more extensive reliance on interconnections, which may possibly result in grid tightening.

Imports and exports play an important role in the evaluation of the adequacy of the system. At times, generating capacities might be available for export. At other times, security criteria might require reliance on imports, in order to maintain the overall security of the network. However, trade capacities may be limited by occasional congestion, leading sometimes to loop flows, preventing the operators from using these capacities efficiently.

Overview of power generation in Belgium, Denmark, France, Germany, Italy, Netherlands, Spain, and Switzerland

France, Germany, Italy, and Spain are among the biggest contributors to generation capacity in Europe. Of the countries observed in this study, power generation mainly relies on fossil fuels, despite the growth of RES capacity (see Fig. 2.2.1). Exceptions include: France with its power generation mix that is essentially nuclear (74% in 2010); Belgium which also has significant nuclear capacity (51% in 2010) along with combustible fuel use; and Switzerland which mainly runs on hydro-electric power but also relies significantly on nuclear energy (38% in 2010). Hydro-electricity remains the main renewable energy source with 63.4 TWh produced in France, 50 TWh in Italy and 18.9 TWh in Germany. Next comes wind generation with 42.7 TWh produced in Spain, 26.5 TWh in Germany and 9.6 TWh in France. With a production of 9 TWh, solar generation has significantly increased within the whole ENTSO-E area but remains marginal in all countries except in Spain (2.4% of total net electricity generation) and in Germany (1.9% of total net electricity generation). Biomass generation for electricity is important in Germany (31.2 TWh) and worth mentioning concerning the Netherlands (6.2 TWh) and Belgium (5.1 TWh).

Fig. 2.2 Share of power supply by energy sources in 2010



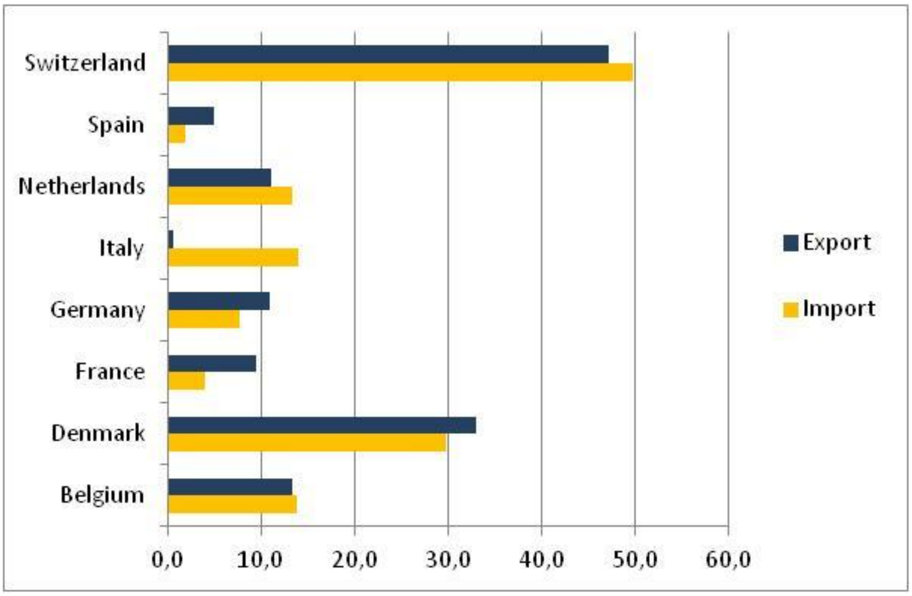
Source : ENTSO-E

Power Exchanges

France and Germany are the main exporting countries, whereas Italy is the top importer. Denmark and Switzerland are very well interconnected and demonstrate very high percentage of trade in both directions with neighboring countries (see Fig 2.3.1). The situation in Switzerland reflects its geographical position, as it acts as a transit country inside the continental Central South region. Denmark's trade depends heavily on wind output: it imports hydro-electric power from Scandinavia to balance wind supply, and exports cheap wind power when demand in Denmark falls below supply.

The nature of trade varies depending on the structure of national energy mixes. They can be effected by a lack or a surplus of power generation (as the example of Denmark shows) or result from economic choices. Indeed, when electricity demand increases, power plants are brought on-line according to their economic merit order, so the most cost-effective power plants are the first to be used. Sometimes it makes more economic sense to rely on cheap imports rather than operating more expensive domestic power plants. Italy relies heavily on imports to balance demand and supply domestically, due to a lack of competitive generation capacity. Germany, although a net exporter at least until 2010, imports cheap nuclear base load power from France and exports more expensive coal peak load power. Another factor that can push a country to rely on imports is the lack of peak power plant capacity which is the case for France from time to time. Base load power is abundant in France, whereas the demand peak is very sharp during the winter, due to the use of electricity for heating. When tight market conditions arise, usually triggered by harsh climatic conditions, France imports power from neighboring countries to cover peak demand.

Fig 2.3 Imports/Exports as % of national consumption in 2010



Source : ENTSO-E

Case Studies of some European Countries

Belgium

Overview of the power generation mix

In 2010, net generating capacity in Belgium was 18.7 GW. The peak load was about 14 GW. Net electricity generation was 89.8 TWh, while final consumption amounted to 88.6 TWh. Belgium relies mainly on nuclear power generation (51% in 2010). In November 2011, the main political parties agreed to phase out nuclear power without deciding upon a date. This agreement confirms a decision taken in 2003. The three oldest reactors would be shut down as early as 2015. The phase out of nuclear power in Belgium will involve replacing 5900 MW of power. The fraction of fossil fuel generation (45% in 2010) is mainly composed of natural gas and coal.

According to the development plan of the Belgian TSO (Elia), 1200 to 3200 MW of additional capacity is required to supply the Belgian load by 2020.[9] The lowest figure assumes the postponement of the nuclear phase out, which seems quite unlikely in view of recent developments. If the phase out were to be accelerated, the lack of additional capacity estimated by Elia could be higher than 3200 MW. From 2016 on, Belgium will have to develop additional capacity so it does not need to rely on structural imports from neighboring countries. Already, interconnection transmission capacity is important to secure power supply to Belgium during extreme (weather) situations and will remain crucial for the years to come. [10] Planned import capacity is probably insufficient to compensate for the lack of new generation.

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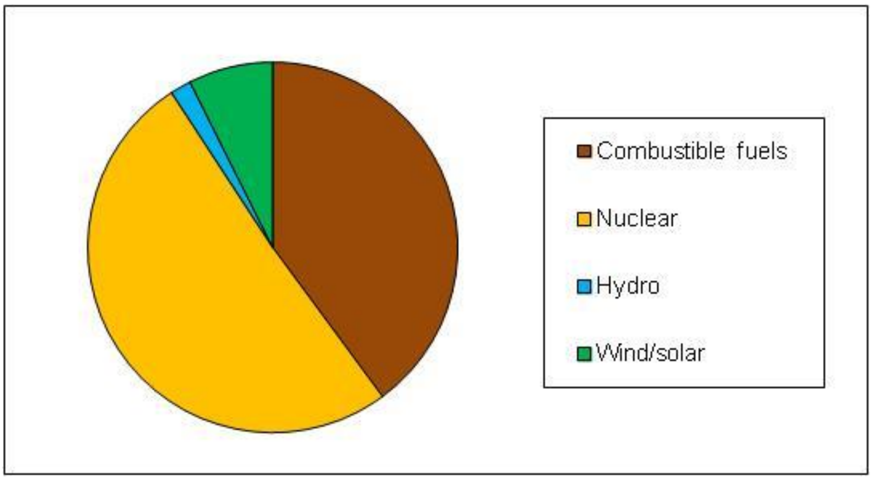
[9] http://www.elia.be/repository/Lists/Library/Attachments/1021/PlandeDeveloppementFederal15092010_FR.pdf

[10] System Adequacy Forecast 2010-2025, https://www.entsoe.eu/resources/publications/system-development/

Fig 3.1 Total Net Electricity Generation – Belgium 2010



Source: ENTSO-E

Tab 3.1.1 Total Electricity Trade (GWh)

	Total 2000	Total 2009	Total 2010
Net production	80162	87524	89864
Imports	11525	9366	12287
Exports	7318	11314	11843

Source : ENTSO-E

Tab 3.1.2 Electricity Imports (GWh)

year	FR	LU	NL
2000	8393	----------	3132
2008	7286	1629	8121
2009	1709	1868	5789
2010	3048	1847	7392

Source: ENTSO-E

Tab 3.1.3Electricity Exports (GWh)

year	FR	LU	NL
2000	201	1967	5150
2008	2036	1517	3008
2009	6630	911	3773
2010	5402	1123	5318

Source: ENTSO-E

Projections of the NREAP

The share of RES in electricity production is expected to reach 20.9% in 2020, compared with 9.2% in 2010, far below the European average. More specifically by 2020, photovoltaic capacity should reach 1340 MW (363 MW in 2009) and wind power, 10474 MW (606 MW in 2009), including 2000 MW of offshore capacity. The challenge is huge for Belgium which has so far invested very limited efforts in RES deployment, while hydroelectricity is limited. If Belgium were to proceed with nuclear phasing out, this would automatically lead to higher GHG emissions through the development of conventional capacities, probably gas power plants, in addition to RES development.

Interconnections

The Belgian transmission system, operated by Elia, is one of the most important electrical crossroads in Europe. International power flows take a large share of the available transmission capacity inside Belgium. The Elia network is able to guarantee about 5000 MW [11] of trade capacity, both ways with neighboring countries.

In recent years, the Belgium TSO has sought to reinforce Belgian interconnection capacity with neighboring countries through a number of investments. So far, the projects undertaken have concerned essentially the reinforcement of existing connections and the installation of phase-shift transformers.

The latest projects completed by RTE and Elia in mid-2010 include the reinforcement of the electrical interconnection between Moulaine (Belgium) and Aubange (France). The total cost was €13.2 million, split into €11 million paid by RTE, the French TSO (most of the line is in France) and €2.2 million paid by Elia. [12] Further increases in capacity are under study in order to make use of the development of generation in Northern France (with a time horizon set at 2012-2015). These undertakings are part of the projects of European interest identified in the TEN-E guidelines (see Annex).

Belgium will be directly affected by the large scale development and integration of RES in Germany, on the Belgian coast and on the Dutch coast. More important developments are currently under consideration: the reinforcement of interconnections with Luxembourg (2012), the development of a HVDC line between Belgium and the UK (project NEMO, see box below) and the installation of an electrical power supply line for a direct connection between Belgium and Germany (see box below).

[11] NTC from Belgium to France is 2300 MW, from France to Belgium is 3400 MW; to the Netherlands it is 2400 MW; and from Netherlands to Belgium 2400 MW.

[12] http://www.rte-france.com/uploads/media/pdf_zip/presse/dp-2010/2010_06_25_DP_RTE_ELIA_Moulaine_Aubange_EN_v1.pdf

More on nemo

Connections between the UK and continental Europe require HVDC lines, as the UK is not synchronized with Europe. The NEMO project, an HVDC line of 1000 MW, presents regulatory challenges as the UK and Belgian regimes are significantly different. A new regime is currently under consideration to avoid risk of asymmetric interests for investors associated with the project and to protect consumers from market power. Conclusions are expected end of 2011. This new regime is based on a cap-&-floor system, and will serve as a pilot for UK interconnectors. Belgium will rely on this model only for this project. The expected date of operation is set at 2016-2018. The project is linked to the North Seas Countries Offshore Grid Initiative.

More on the germany-belgium link

Even though Germany and Belgium are neighbors, there is no direct connection between the two countries. Environmental issues and very limited potential for increase in import capacity for Belgium killed first attempts to build overhead AC lines between Belgium and Germany. [13] A DC connection could increase import capacity but would require upgrades at other interconnections (in particular between France and Germany). Such a project could lead to significantly higher costs and will also require public consultation even though opposition should be less important compared to overhead lines. Elia and Amprion (the German TSO associated with the project) are currently considering a HVDC line of 1000 MW that could be realized by 2016-2017.

Denmark

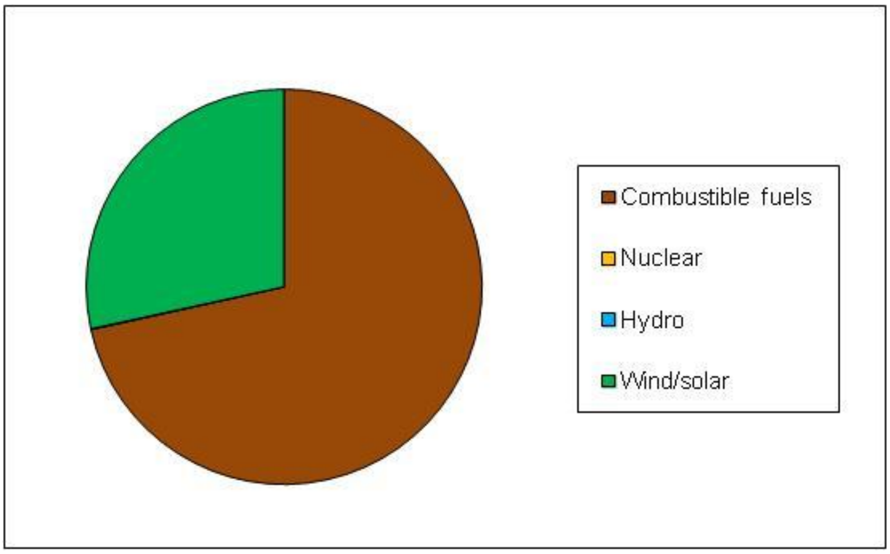
Overview of the power generation mix

In 2010, net generating capacity in Denmark was 14 GW. The peak load was about 6.3 GW. The net electricity generation was about 37 TWh, whereas electricity consumption amounted to 35.6 TWh.

The Danish electricity supply is mainly based on hard coal and gas. Denmark has one of the highest penetrations of wind power in its electricity supply system of any country. Wind power supplies just over 20% of gross electricity production. Western Denmark also has a high amount of combined heat and power (CHP) systems which can be constraining for the system during winter time. When wind is blowing and demand is low, Denmark has to export its excess production to neighboring countries as it cannot turn off the CHP plants.

[13] Connecting Belgium and Germany using HVDC: A Preliminary Study, S. Cole, Member, IEEE, D. Van Hertem, Member, IEEE, R. Belmans, Fellow, IEEE

Fig 3.2.1 Total Net Electricity Generation – Denmark 2010



Source: ENTSO-E

Tab 3.2.1 Total Electricity Trade (GWh)

	Total 2000	Total 2009	Total 2010
Net production	36053	34585	36899
Imports	8417	11209	10599
Exports	7752	10875	11735

Source: Eurostat

Tab 3.2.2 Electricity Imports to Western Denmark (GWh)

year	SE	NO	DE	East DK*
2010	514	1452	3662	1

Source: energinet.dk ; *since August 2010

Tab 3.2.3 Electricity Imports to Eastern Denmark (GWh)

year	SE	NO	DE	West DK*
2010	2248		2736	1543

Source: energinet.dk ; *since August 2010

Tab 3.2.4 Electricity Exports from Western Denmark (GWh)

year	SE	NO	DE	East DK*
2010	1596	4050	2015	1543

Source: energinet.dk ; *since August 2010

Tab 3.2.5 Electricity Exports from Eastern Denmark (GWh)

year	SE	NO	DE	West DK*
2010	3391		686	1

Source: energinet.dk ; *since August 2010

Projections of the NREAP

The share of RES in electricity production is expected to reach 51.9% in 2020, compared to 28.5% in 2010. More specifically by 2020, photovoltaic capacity should amount to 6 MW (3 MW in 2010), onshore wind power to 2.6 GW (2.9 GW in 2010, with a peak at 3 GW in 2016) plus 1.3 GW of offshore wind capacity (661 MW in 2010).

Role of interconnections in Denmark

Denmark is an example of where the ability to cooperate between countries to manage surplus wind power has stimulated a more integrated power network. Denmark profits from the interconnections with Germany and with Nordic countries. Part of Danish wind-power production is exported to Sweden and Norway in order to balance the power system. Several studies show a strong correlation between high-wind situations and exports, in particular in cold weather when Denmark is obliged to run its CHP for heat. Given the dimension of the wind park in Denmark and domestic demand, wind can supply up to 60% of electricity during peak load periods and all demand in periods of low demand. In times of excess production, Danish exports can be used to pump hydroelectricity storage in Norway for later use. Power trade varies considerably from year-to-year depending on local conditions. These imports are particularly useful to reduce the need for additional back-up capacities.

The Danish example shows that it is important to look at the system as a whole, when increasing wind-power penetration. For example, increasing intermittent production in Sweden and Norway could lead to large amounts of wind power spill-over since the Nordic countries would no longer be able to absorb the full surplus of Danish wind-power production. Interconnection with Germany cannot always be expected to play a significant role since high wind conditions in Western Denmark are correlated with high wind conditions in Northern Germany. So, during periods of high wind, wind-power production in Northern Germany necessarily limits the amount of electricity that can be taken from the Western Danish system. According to Energinet, owner of the main electricity and natural-gas grids in Denmark, power over-supply occurs for approximately 100 hours a year. [14] The problem is expected to become three to five

[14] Power oversupply: when the amount of power available exceeds power consumption.

times worse within a few years, unless other means become available to dispatch the surpluses further afield.

The grid

Interconnection capacities are large with regard to Danish wind-power capacities, since peak load can reach about 6.2 GW and transmission capacity normally represents 3600 MW in the southbound direction and approximately 6400 MW northbound. [15]

Western Denmark belongs to UCTE, the grid of central Europe, and synchronizes with Germany through AC connection lines. Reinforcement of these lines is under study but no time horizon has been set. In addition, Western Denmark is linked through DC links to Nordel, the Scandinavian system, to Sweden (Konti Skan 1 &2, 250/300MW and 300 MW) and Norway (Skagerrak 1&2, 250 MW; Skagerrak 3, 440 MW).

Eastern Denmark belongs to Nordel, and is linked to Germany through DC lines (Kontek, 500 MW and 550 MW).

Since August 2010, the Eastern and the Western parts of Denmark are now connected through the "Great Belt Power Link", a 57 km DC link with a capacity of 600 MW. It will be interesting to follow the impact of this link on the convergence of prices between the two areas and to see if Western Denmark will remain closely linked to Germany, while Eastern Denmark will continue to be influenced by the Nordic area. Until now, prices in Western Denmark are driven by wind output in Germany, whereas availability of nuclear power plants and hydroelectric capacities in Sweden have had the greatest impact on Eastern prices. Prior to the establishment of this link, conditions led to sharp price differences between the two areas. For example, during the first quarter of 2010, the combination of low hydroelectricity reserves, the maintenance of two nuclear power plants in Sweden, colder-than-average weather conditions and tight grid conditions led to high prices in the Nordic area that also impacted on the Eastern part of Denmark. Spot-market prices stood above €1000 per MWh for several hours on January 8th and February 22nd 2011. [16] At the same time, Western Denmark benefited from high wind output in Germany, which led to low prices (even negative prices for a couple of hours). Generally, most of the time prices are lower in Western Denmark. This price difference has caused eastbound trade on the "Great Belt Power Link", since its commissioning in August 2010. [17]

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[15] 2 x 950 MW both ways to and from Norway (DK West); 2085 MW to Germany; 1550 MW from Germany; 2440 MW from Denmark to Sweden, 1980 MW from Sweden to Denmark.

[16] Quarterly Report on European Electricity Market, Volume 3, Issue 1: January 2010 – March 2010.

[17] http://www.energinet.dk/SiteCollectionDocuments/Engelske%20dokumenter/El/Market%20report%20-%20September%202010.pdf

Projects in the pipeline

Installation of phase shifting transformers on AC lines connecting Denmark to Germany should increase the import/export capacity between Sweden, Denmark and Germany to 1500/2000MW in 2012, which will allow the potential of offshore wind farms to be included.

A new DC link to Norway (700 MW) is under construction and expected to be commissioned by the end of 2014. The total budget for the installation is about €370 million. Danish investment is expected to amount to some €200 million, while the European Union should provide with €1.9 million for the project.

A grid is being planned to connect the Kriegers Flak wind farm to Germany and Denmark. This grid will consist of a 600 MW DC link to Germany and a 600 MW DC line to Denmark. The grid will depend upon the decision of the offshore construction of wind turbines and their location. Plans are also underway (for 2016) to set up on HVDC cable (Cobra, 600-700 MW in both directions), linking Denmark to the Netherlands.

Kriegers flak

Kriegers Flak is part of the Baltic Sea, at the border of the Exclusive Economic zones of Germany, Denmark and Sweden. These three countries plan to install offshore capacity in this area. A pre-feasibility study has argued that a combined solution based on an international grid provides greater benefits than separate grid connections. This solution however raises legal issues, as support schemes for wind power, grid codes and regulatory frameworks are different in these three countries. Additional challenges are technical (the project includes the connection of two asynchronous power systems) and economic. In May 2010, Svenska Kraftnät (Sweden) cancelled its participation. The TSOs now participating in the project are Vattenfall Europe Transmission (Germany) and Energinet.dk (Denmark). Operation should start sometime between 2018 and 2020.

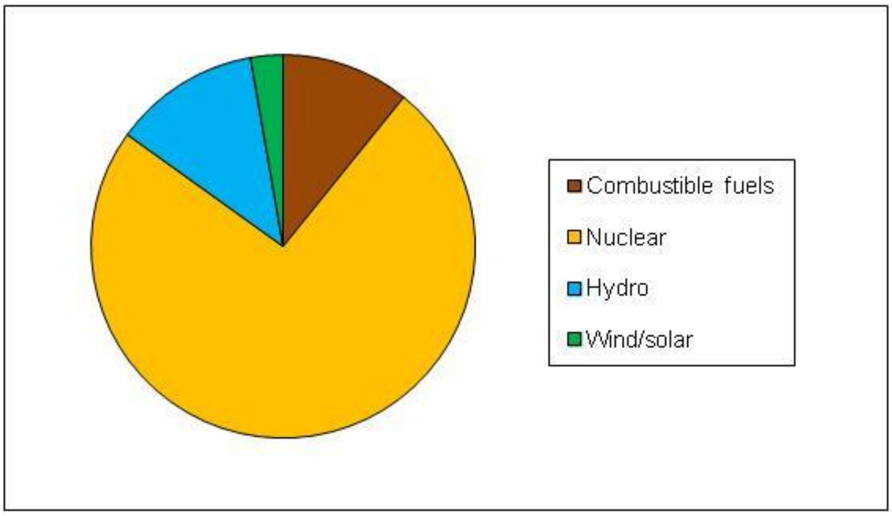
France

Overview of the power generation mix

In 2010, net generating capacity was 123 GW in France, and net electricity generation was 547 TWh. Final consumption amounted to 513 TWh. The peak load was 97 GW and has been steadily increasing since 2001 (about 80 GW at the time). Peak consumption is particularly sharp in France, aggravated during cold weather by the use of electric heating systems largely used in the residential sector. Peak demand is strongly correlated to temperatures. A fall in temperature of 1°C in winter triggers an additional need of 2300 MW. France relies essentially on nuclear generation that provided 75% of electricity supply in 2010. Hydropower is the second source of supply with 12%, whereas the share of conventional thermal generation is mainly based on natural gas.

Following the decisions of neighboring countries to end nuclear generation (Germany, but also Italy and perhaps Belgium) in the aftermath of Fukushima, several studies have been launched to examine the future of France's energy mix and assess the cost of nuclear power generation including decommissioning. The UFE (Union Française de l'Electricité) that brings together the French power generators estimates that the cost of reducing the share of nuclear generation to 50% by 2030 will lead to supplementary costs of €60 billion. Civilian nuclear technology will be significant in the debates prior to the French presidential elections in 2012. The main opposition candidate has stated he would consider a reduction in the share of nuclear energy, whereas the present government would probably support the nuclear industry and more or less maintain France's current reliance on nuclear electricity generation.

Fig 3.3.1 Total Net Electricity Generation – France 2010



Source: ENTSO-E

Tab 3.3.1 Total Electricity Trade (GWh)

	Total 2000	Total 2009	Total 2010
Net production	519585	518802	550309
Imports	3059	19213	20153
Exports	71934	44914	50601

Source: ENTSO-E

Tab 3.3.2 Electricity Imports (GWh)

year	BE	CH	DE	ES	GB	IT
2000	201	1652	226	587	------------	393
2008	2036	3548	868	1661	923	1140
2009	6630	4164	1436	2351	3358	1215

Source: ENTSO-E

Tab 3.3.3 Electricity Exports (GWh)

year	BE	CH	DE	ES	GB	IT
2000	8393	9357	15201	8479	14362	16142
2008	7286	8787	10569	4564	12448	12841
2009	1709	8311	10607	3957	6889	11808
2010	3048	9679	15126	1991	7136	11583

Source: ENTSO-E

Projections of the NREAP

The share of RES in the gross final consumption of electricity production is expected to reach 27% in electricity generation in 2020, compared to 15.1% in 2010. In mid-2011, about 5.7 GW (900 wind turbines) of wind power capacity and 1.5 GW (200,000 installations) of photovoltaic capacity were connected to the distribution network. As part of the NREAP, the French authorities' ambition is to increase onshore wind power capacity to 19 GW, plus 6 GW of offshore wind power capacity, and solar photovoltaic output to 5.4 GW. This will require developing the French network as the sites for future generation capacities will be farther away from the existing grid. Already, numerous RES projects are set to be connected to the grid but cannot yet be done so due to insufficient network capacity.

Interconnections

Imports are particularly important in France to help cover peak demand. Over the past ten years, French peak demand has increased twice as much (+15%) as power consumption (+8%). [18] In 2010, France hit a new record with a peak at almost 97 MW. The French TSO (RTE) has warned that sufficient capacity to limit power cuts below the allowed threshold of 3 hours per year, might be lacking, as early as 2016. [19] Yet RTE remains optimistic, counting on new CCGT projects that could be in use by then and on the fact that import capacities should remain available in the short term. However, the German decision to phase out nuclear power could have dire consequences on the French situation should extreme cold weather conditions take place during the forthcoming winter. Less German capacity would be available for the French market at periods of peak demand.

French capacity is about 15000 MW for exports and 10000 MW for imports. Interconnections link France to Spain, the United Kingdom, Belgium, Germany, Switzerland and Italy. France is a net electricity exporter; more than 50 TWh was exported in 2010 (20 TWh imported). Typically, France exports electricity produced from nuclear power plants (to cover baseload purposes) and imports electricity generated by fossil-fuel power plants in Germany or RES in Spain to cover peak demand periods.

The optimization of the existing network has permitted an additional transit capacity of 400 MW between France and Belgium (see the section on Belgium, Moulaine-Aubange). Construction works have begun on the creation of a HVDC link of around 2000 MW between Baixas (France) and Santa-Llogaia (Spain). More details on the project are discussed below. Other projects are under considera-tion to increase the interconnection capacities between France and Great Britain as well as France and Belgium.

More on the French-Spanish line

France and Spain are currently connected through 4 AC lines with a total capacity of 1400 MW. The most recent line was built in 1982. The construction of the new HVDC lines (2 x 1000 MW, for an increased transit capacity of 1400 MW) will double this capacity, to raise the trade capacity between France and Spain to 6% of installed capacity, compared to 3% now. This line will allow Spain to export its increasing intermittent RES production to Europe through France, and to integrate better Spain which remains an electricity island. The estimated cost is €700 million. The EU will provide €225 million, the EBI (European Bank of investment) will provide a €350 million loan to Inelfe (France-Spain ELectrical INterconnection), the corporation jointly-owned by Spain’s and France’s TSOs: REE (Red Eléctrica de España) and RTE (Réseau Transport d’Électricité). RTE and REE will finance the balance equally. Preparatory work started in 2011 and commissioning is expected in 2014 for a project that has been on the

[18] http://www.smartgrids-cre.fr/index.php?rubrique=dossiers&srub=integrationenr
[19] Bilan prévisionnel de l’équilibre offer-demande d’électricité en France, RTE, edition 2011

table since the European Council of Essen in 1994. The original project was an overhead AC line and faced strong local opposition. The intervention of Mario Monti, appointed coordinator for the interconnection, allowed a breakthrough in reconciling all actors on a new project that would be buried, though costing seven times the overhead power line costs. The latest route was agreed after 15 months of discussions.

The line Moulaine (France) - Belval (Luxembourg)

The creation of a 225 kV line between France and Luxembourg is another example of the difficulties arising from reconciling the interests of all actors. Originally expected for 2009, the line should secure the supply of the Luxembourg grid, managed by SOTEL, and to supply several heavy energy intensive industries in the area. The project has been delayed by environmental NGOs and local oppose-tion. Construction works started in 2010 but court decisions are still pending.

Reinforcement of interconnections with Italy

Several projects are under construction to smooth congestion on the French-Italian border. Four AC lines currently link France to Italy. In 2007, RTE and Terna (the Italian TSO), agreed to increase exchange capacity between France and Italy by 60%, from 2650 MW to 4200 MW.[20] This increase in capacity would be significant both for Italy, which is a huge importer of electricity and for France, which will secure the supply of the PACA (Provence Alpes Cotes d'Azur) region. Indeed, South Eastern France faces an imbalance between production capacity and consumption, and is similarly an electricity island.

The first part of the agreement concerns the upgrading of the existing network for an estimated cost of €160 million. Construction works started in 2008 and are expected to be completed by 2012.

The launch of a feasibility study on the building of a HVDC line between Grande-Ile (France) and Piossasco (Italy) completes the agreement.

Germany

Overview of the power generation mix

Net generating capacity was 152 GW in 2010. Net electricity generation was 580 TWh. Final consumption amounted to 547.4 TWh. The peak load was about 80 GW. Germany relies mainly on fossil fuel production (coal and gas). The share of nuclear power in electricity generation dropped from 43% in 1997 to 23% in 2010 due to strong opposition to nuclear power in the society. Environmental policies

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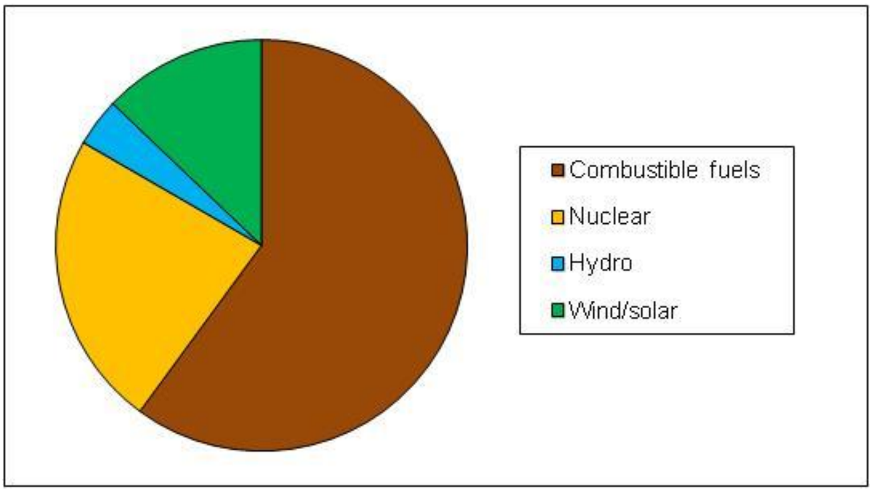
[20] http://www.rte-france.com/fr/actualites-dossiers/a-la-une/rte-et-terna-concluent-un-accord-favorisant-le-developpement-de-l-interconnexion-electrique-france-italie

have also led Germany to diminish the use of coal in electricity generation as it is a high GHG-emitting energy source. However the portion of electricity from coal-fired plants is still 43%. German electricity prices are among the highest in Europe.

Fig 3.4.1 Total Net Electricity Generation – Germany 2010



Source : ENTSO-E

In the aftermath of Fukushima, Germany has decided to close seven nuclear power plants as early as mid-March 2011 (and not to restart an additional one). This move has translated into giving up 8000 MW of generation capacity. Later, Germany has decided to phase out all its nuclear power plants by 2022, cancelling the 2010 December decision concerning the lifetime extension of most of them. The German environment agency reckons that Germany can fill the nuclear gap by faster development of RES and the construction of 5,000 MW of new natural-gas-fired generation. However, several voices and preliminary data show that Germany has become a net importer overnight (see box). This is a situation that Germany will not accept for too long and that will probably lead to the building of more fossil fuel power plants than originally planned: gas power plants but also coal fired power plants. As a consequence, GHG emissions will increase and will have an impact on the European carbon market leading to higher CO2 prices, which will reflect on electricity bills all over Europe.

The Domestic Impact of Germany's Decision to Phase out Nuclear Power

Germany has become an electricity importer almost overnight. In 2010 the balance export/import over the period April to July was +1859 GWh, in favor of Germany. [21] It was -5029 GWh over the same period in 2011 according to available data. Germany is relying on increasing nuclear power imports from the Czech Republic and France, and coal power imports from Poland. German utilities are the first to have been affected by this decision, while they must still pay the nuclear tax: EoN and RWE had to announce cost-cutting measures, including job reductions. Cash-strapped, RWE had to give up its projects at the international level to re-center its activities in Germany. It is also considering a partnership with Gazprom to secure gas supplies that will relieve some of the financial pressure and that will guarantee gas supplies that will become increasingly important in power production. Energy intensive companies are also worrying about the expected increase of electricity prices. Peak load prices might be affected by wind power supply. EEX monitored an increase in electricity prices in Germany of about 10%. The chemical company Bayer has threatened to relocate production should its energy bill become too substantial. The OECD chief economist has mentioned the "uncertain consequences of the nuclear phase out" as one of the causes that could lead the country toward an economic downturn. Lastly, citizens will also have to pay higher fees for an increasingly expensive electricity mix.

Tab 3.4.1 Total Electricity Trade (GWh)

	Total 2000	Total 2009	Total 2010
Net production	533964	548371	573150
Imports	44156	41857	42957
Exports	42598	54133	57918

Source: ENTSO-E

Tab 3.4.2 Electricity Imports (GWh)

year	AT	CH	CZ	DK W/E	FR	LU	NL	PL	SE
2000	5608	5150	8932	6288	15201	737	897	689	654
2008	5607	2709	7940	7180/1973	10569	835	829	96	2507
2009	7061	2636	8687	4946/1286	10607	728	3510	135	968
2010	6750	2581	9400		15126	1361	3072	167	1007

Source: ENTSO-E

[21] ENTSO-E

Tab 3.4.3 Electricity Exports (GWh)

year	AT	CH	CZ	DK	FR	LU	NL	PL	SE
2000	7246	10101	231	460	226	4441	17798	2004	91
2008	14997	13858	1326	586/778	868	5302	18859	5578	543
2009	14956	13142	965	1814/1801	1436	5115	8870	5618	1189
2010	14705	14553	564	6471	795	6159	8942	5334	2355

Source: ENTSO-E

NREAPs projections

The share of RES in the gross final consumption of electricity production is expected to reach 38.6% in electricity generation in 2020, compared to 16.7% in 2010. In 2009, about 26 GW of wind power capacity and almost 10 GW of photovoltaic capacity were connected to the distribution network. As part of the NREAP, Germany has the ambition to increase onshore wind power capacity to 36 GW, plus 10 GW of offshore wind power capacities, and solar photovoltaic to 52 GW. Hydroelectricity pumped storage power plants would represent 7900 MW of capacity, compared to 6500 MW in 2010, therefore playing a limited role in the balancing of intermittent energy sources.

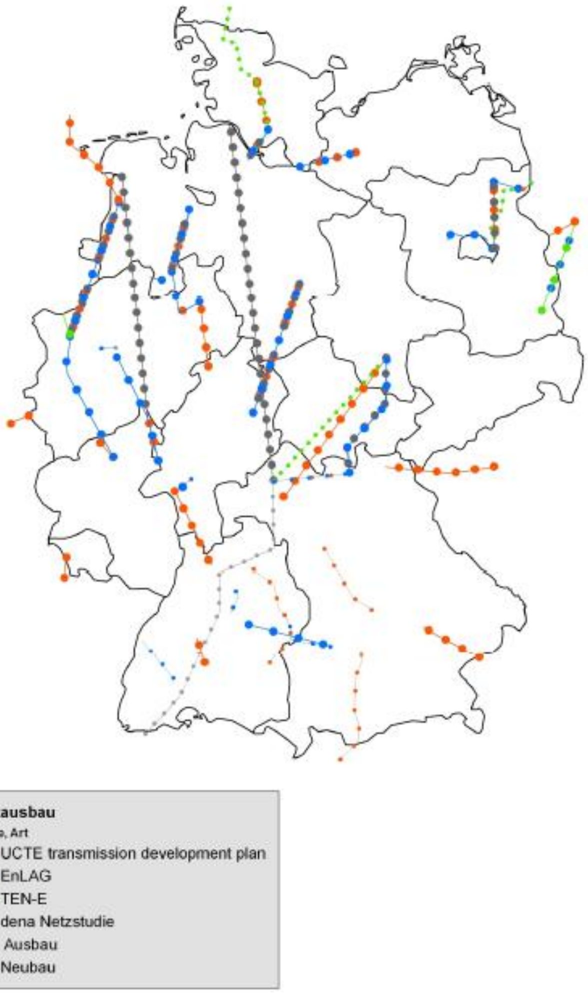
The grid

Germany faces an imbalance between the South where many major consumption centers are located, and the North that hosts a large share of power generation including large wind power capacity. This imbalance is aggravated by the lack of connection capacities between the North and South and by the closing of five nuclear power plants in the South. Congestion inside Germany creates loop flows: the power generated in the North going through the Czech and Polish grids to reach German citizens in the South, which might create a tense situation on grids outside the German network. Reinforcement and adaptation of transfer capacity in this area is required.

Increased penetration of RES in the grid will require an expansion and reinforcement of this network. The Energieleitungsausbaugesetz (Act on the Expansion of the Electricity Grid – EnLAG) has identified 24 priority projects to this effect.

Among them, the Federal Network Agency approved the investment budget for a 128 km extra-high voltage line running along a North-South axis (Kruckel-Dauersberg) and to be built by Amprion GmbH, one of the four German TSOs. Amprion has also scheduled the upgrading of three lines along the North South axis between 2010 and 2017, to increase the capacity of this particularly congested area.

Fig 3.4.2 Grid expansion in Germany



Source: Germany NREAP[22]

The North-South Axis

The Halle/Saale-Schweinfurt project consists of five separate sections that, once completed, will improve the transmission capacity along the North-South corridor to move RES from the North Sea to major consumption areas in the South. Part of the project is heavily opposed by local populations and stakeholders. Two sections are already completed but the overall project has faced many years of delay. Completion is now scheduled for 2013.

22 http://ec.europa.eu/energy/renewables/transparency_platform/doc/national_renewable_energy_action_plan_germany_en.pdf

Interconnections

Germany imports from Denmark, the Czech Republic and France, whereas it exports to Austria, Switzerland, Luxembourg, Netherlands, Poland, and Sweden. Congestion may occur at the French border, but generally trade through the Southern borders is fluid. Congestion is more frequent at the Czech Republic border. Cross-border connections are regularly congested in the North. Usage of the capacity exchange depends highly on wind output in Germany. When wind is blowing hard, the total output cannot be used locally. It then flows toward farther consumption centers and travels long distance along the transmission grid, carrying the risk of "flooding" them. Increasing penetration of wind power impacts the cross-border electricity transits between neighboring countries, particularly concerning the flows from Denmark to Germany and from Germany to the Netherlands.

The November 2006 Incident

On November 4, 2006, an incident in the German network triggered a cascading breakdown. The European transmission grid split into three independent parts leading to a drop in frequency of the network in each area. The immediate consequences were huge power outages. The TSOs reacted fast to reestablish the balance between demand and supply. In particular, France mobilized its hydroelectricity production. Coordinated actions by the TSOs avoided a generalized "black out". Resolution of this incident shows that interconnections can play a solidarity role between EU Member States. It also shows that the diversity of the power generation mixes across Europe is definitely an asset.

Links to the Czech Republic

An new 400 kV double circuit overhead interconnection line through two 400 kV substations is under consideration between Germany and the Czech Republic. Initial planning is expected to be completed by 2016. Also under consideration is a possible new overhead line (new route) or the reinforcement of an existing line (OHL Hradec-Röhsdorf).

Links to Poland

There are also projects to increase the exchange capacity through reinforcement of existing links and the development of a new interconnector between Germany and Poland to decrease the loop flow (resulting from the lack of connections inside Germany) from Germany to Poland and to the Czech Republic.

Links to Austria

Regarding links with Austria, a new 380 kV double circuit overhead interconnection is expected in 2017. Another interconnection between Germany and the Alpine region through Austria is under consideration over a longer time horizon. This new link could help to evacuate the future generation capacity in the Alps. [23] Austria seems keen to develop two "pumped-storage" facilities (Mooserboden and Wasserfallboden) that could help to compensate the change of flow patterns resulting from the increase of RES in the North Sea. The balance of exports/imports between Germany and Austria could be modified, especially with regard to a nuclear phase out in Germany. Austria will use these reservoirs to store electricity on windy days and at low demand periods or at night, importing cheap nuclear power from the Czech Republic, and will release electricity for the market when demand and prices increase.

Links to the Netherlands

A 60km double circuit line is in the process of approval and expected after 2013. Amprion and TenneT will manage this 380 kV line (2 x 1800 MW, Doetichem-Niederrhein). This line should help to manage overloads due to high power flows along the North-South axis during high wind output.

Links to Norway

A feasibility study is being performed by Statnett (Norway TSO) and EON.Netz (German TSO) to build an HVDC line between Germany and Norway (700/1400 MW) to couple the hydro-dominated Norwegian power system and the wind and thermal dominated power system in Northern Germany. Completion is expected after 2015.

Options are being investigated to link Germany to Belgium, as well as to strengthen interconnections with Denmark and France (see the respective sections on Belgium, Denmark and France).

Italy

Overview of the power generation mix

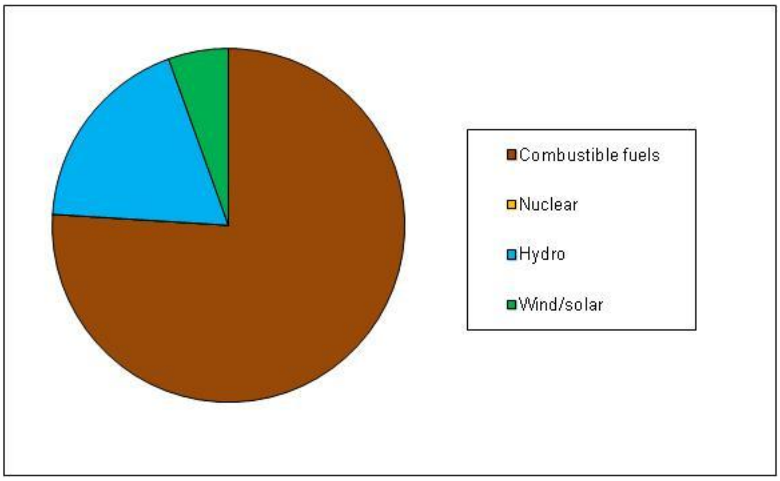
In 2010, net generating capacity was 106.5 GW. The peak load was about 56 GW. Net electricity generation was 290.7 TWh. Net electricity consumption was 330.5 TWh. Italy mainly relies on fossil fuel generation, essentially gas, but still a significant share of oil compared to neighboring countries. Hydropower accounts for an important share of power production (18.5% in 2010), whereas intermittent RES are steadily increasing (5.5% in 2010).

Previous plans to develop nuclear capacity have been cancelled following a referendum called by Prime Minister Sylvio Berlusconi in the aftermath of Fukushima. 94% of voters opposed the government's plans to resume nuclear power generation. Italy relies heavily on electricity imports. As a consequence, electricity prices in Italy are well above the European Union average. Over the past few years, nearly all increases in capacity have been from gas power plants

[23] A similar link is considered to Switzerland

(CCGT). The latest blow to nuclear development will probably maintain Italy in its state as the world's largest net importer of electricity.

Fig 3.5.1 Total Net Electricity Generation – Italy 2010



Source: ENTSO-E

Tab 3.5.1 Total Electricity Trade (GWh)

	Total 2000	Total 2009	Total 2010
Net production	262426	281218	290706
Imports	44932	46570	46937
Exports	73	2121	1709

Source: ENTSO-E

Tab 3.5.2 Electricity Exports (GWh)

year	AT	CH	FR	GR	SI
2000		10	393		73
2008	0	400	1140	1758	95
2009		510	1215	314	60
2010		493	1012	72	120

Source: ENTSO-E

Tab 3.5.3 Electricity Imports (GWh)

year	AT	CH	FR	GR	SI
2000	1946	22335	16142		4509
2008	1367	24162	12841	181	4733
2009	1198	24958	11808	2184	6799
2010	1328	23176	11583	2299	7513

Source: ENTSO-E

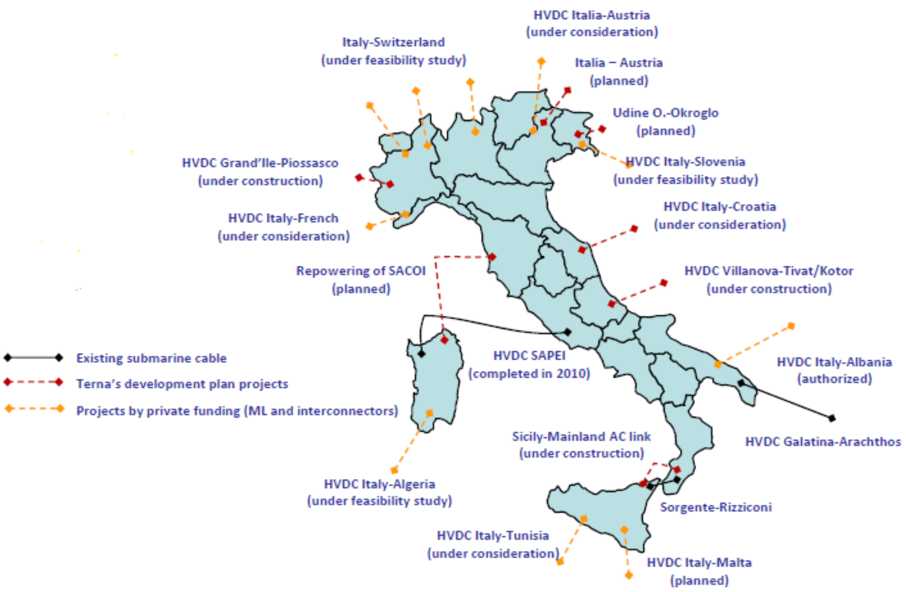
Projections of the NREAP

The share of RES in the gross final consumption of electricity production is expected to reach 26.4% in electricity generation in 2020, compared with 24% in 2010. In 2010, about 5.8 GW of wind power capacity (+260% over the past 5 years) and 2.5 GW of photovoltaic capacity were installed (+160% over 1 year). As part of the NREAP, Italian government ambitions to increase onshore wind power capacity to 12 GW, plus 680 MW of offshore capacities, and solar photovoltaic to 8 GW. Wind capacity is expected to increase significantly in the South, photovoltaic capacity in the North.

The grid

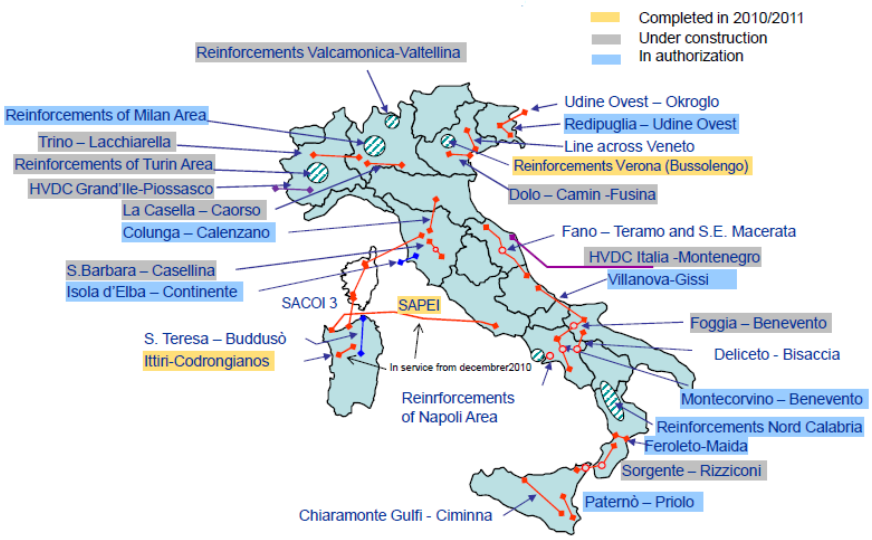
The current state of the network infrastructure is not appropriate and too weak to integrate large amounts of intermittent RES, particularly in the South of Italy and in the large islands. The situation is aggravated by the fact that most consumer areas are located in the North of Italy. Congestion could occur especially as high generation cannot meet local load in the South. The Italian TSO is regularly forced to curtail wind power supply to maintain grid stability. Italy undertook a huge program of upgrading the network to collect wind power electricity produced in the South of Italy and improve transmission along a North-South axis. Different operations are scheduled from 2010 until 2014 to reinforce the grid. The national 2011-2020 ten-year plan includes investments for over €7 billion.

Fig 3.5.2 Projects under development



Source: Terna

Fig 3.5.3 Possible main interconnectors



Source: Terna

Interconnections

The current net transfer capacity consists of 3250 MW in exports and 7550 MW in imports over the Northern border through four lines connecting to France, nine to Switzerland, one to Austria and two to Slovenia. Italy imports about 14% of its requirements every year through the Northern border. An additional line (500 MW) links Italy to Greece. Italy is seeking to increase export capacity on the Northern border to 5000 MW. It also has plans with regards to the East European border, with a project for a connection with the Balkans (500 MW, partly underground, partly undersea). A positive Environmental Impact Assessment has been issued for this project. HVDC lines are also under consideration with Algeria and Tunisia (2016).

Among the projects, several involve the private sector through a “merchant line model”. Two merchant lines are already operating between Italy and Switzerland and one is pending between Italy and Austria. However, the merchant model is by definition driven by financial returns and needs an adequate rate of return to justify the risks taken by the investors. The commercial model must be sustainable in the long term. Main limitations are political, financial and regulatory. It requires consistency between Italian laws and neighboring countries, market conditions can change as delays in the authorization process slow down implementation, and low exemption from the obligation of third party access (TPA) can diminish the profitability (see Part 1 on the merchant line model).

The first merchant interconnection power lines between Italy and Slovenia (Zaule-Dekani) received the authorization by the Friuli-

Venezia Giulia Region in 2011 to launch the project developed by Enel Produzione. [24] The 11 km underground line will increase the interconnection capacity by approximately 150 MW. Plant construction and operation permits should be issued in the forthcoming months for a second interconnection with Slovenia (150 MW, Redipuglia – Vrtojba). Enel Produzione has also received authorization for a medium-voltage interconnection line with Switzerland (North Como – Chiasso), and is also developing an overhead line with Austria (300 MW, Somplago – Wurmlach). The authorization procedure and the request of exemption from the obligation of connection to third party networks (TPA) are ongoing.

Mid-term to longer term projects

A second HVDC link and a new direct 400 kV HVDC subsea cable is under consideration with Greece and Croatia. Also, a new 380 kV double circuit line between Slovenia and Italy should smooth congestion between Slovenia and Italy. Development of two 380 kv lines, one 220 kv line, and one 110 kV/132 line should diminish the constraints over the Italy-Austria border. Various projects are being investigated to increase the exchange capacity at the border of Italy and Switzerland.

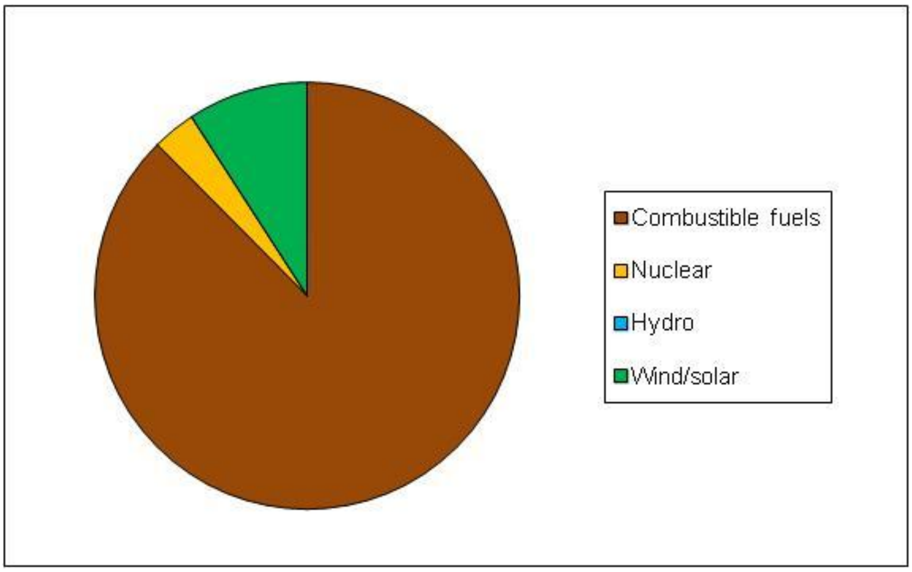
The Netherlands

Overview of the power generation mix

In 2010, net generating capacity was 25.5 GW. The peak load is about 18 GW. Net electricity generation was 114 TWh, and final consumption 116.5 TWh. The Netherlands mainly relies on fossil fuels, essentially gas but also hard coal, the latter being a rationale for Dutch interest in CCS technology development.

[24] http://www.enel.com/en-GB/media/news/merchant_line/index.aspx

Fig 3.6.1 Total Net Electricity Generation – The Netherlands 2010



Source: ENTSO-E

Tab 3.6.1Total Electricity Trade (GWh)

	Total 2000	Total 2009	Total 2010
Net production	85644	107920	113685
Imports	22948	15452	15584
Exports	4029	10562	12809

Source: ENTSO-E

Tab 3.6.2 Total Electricity Imports (GWh)

year	BE	DE	NO
2000	5150	17798	----------
2008	3008	18859	3156
2009	3773	8870	2814
2010	5318	8942	1329

Source: ENTSO-E

Tab 3.6.3 Total Electricity Exports (GWh)

year	BE	DE	NO
2000	3132	897	--------
2008	8121	829	332
2009	5789	3510	1257
2010	7392	3072	2347

Source: ENTSO-E

Projections of the NREAP

The share of RES in the gross final consumption of electricity production is expected to reach 37% in electricity generation in 2020, compared to 9.1% in 2010. In 2010, about 2 GW of onshore wind power capacity, 0.2 GW of offshore wind power capacity and 68 MW of photovoltaic capacity were installed. As part of the NREAP, the Dutch government is seeking to increase onshore wind power capacity to 6 GW, offshore capacity to 5.2 MW, and solar photovoltaic to 0.7 GW, by 2020.

The grid

Transmission capacity inside the Netherlands will need to increase and to be reinforced in order to accommodate the 5.2 GW forecasted for 2020. The Dutch TSO, Tennet, plans to build more than 400 km of new 380kV connections in the years ahead. Already, a new 85 km long 380kV electricity line is being developed, partly underground (Randstad).

Interconnections

The Netherlands are interconnected with Belgium, Germany and Norway. In 2008, a 580 km HVDC submarine line (Norned, 700 MW) between Norway and the Netherlands entered into operation. A second project (Norned 2, 700-1400 MW) is under consideration (2015-2017). In April 2011, Britned, a HVDC line (1000 MW, €600 million) connecting the Netherlands to the UK launched its first commercial operations, 12 years after the start of the feasibility study. On the German border, interconnection lines are often overloaded due to wind generation in Germany. A new 380 kV interconnection is in preparation (2013). Also under consideration, the Cobra line (600-700 MW) will link the Netherlands to Denmark. The construction of these new interconnections will significantly raise the capacity of the network. It is likely that the Netherlands will become an exporter as aggressive development of RES will be combined with the reinforcement of the network and with a very flexible generation mix resulting in increasingly reliable generation capacity.

Construction of an offshore power grid

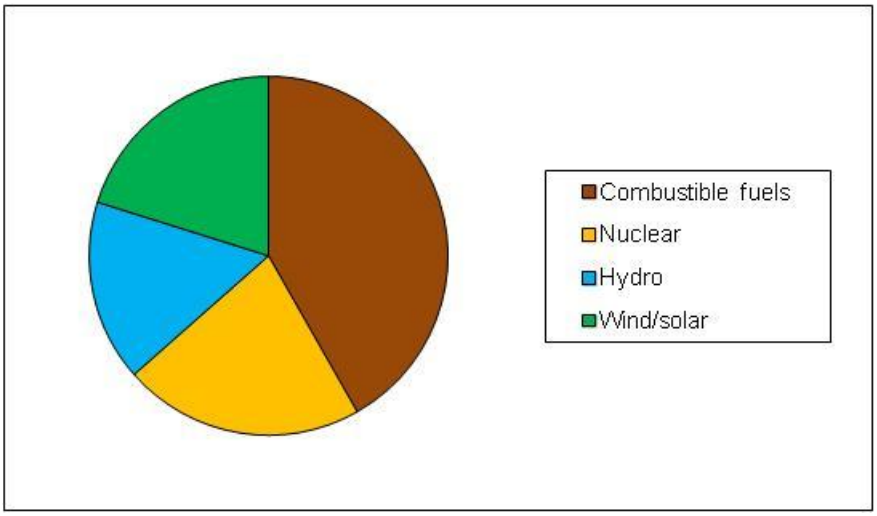
The Netherlands benefits from high offshore wind power resources. Two offshore wind farms whose capacity amounts to 228 MW, have already been developed. Two additional phases will follow. First, 950 MW offshore wind power will be developed and will include the HV network necessary to bring the power onshore. The last phase seeks to develop offshore wind capacity up to 4800 MW. Regulations are currently being modified so the national TSO will have a legal obligation to construct the associated offshore grid.

Spain

Overview of the power generation mix

In 2010, net generating capacity was 96.3 GW. The peak load was about 96 GW (2009). The net electricity generation was 280 TWh, and final consumption amounted to 267 TWh. Spain relies on fossil fuel power generation, essentially gas, with significant shares of nuclear power, hydroelectricity and intermittent RES. The Spanish government has made developing RES a priority.

Fig 2.7.1 Total Net Electricity Supply – Spain 2010



Source: IEA Data services

Tab 3.7.1 Total Electricity Trade (GWh)

	Total 2000	Total 2009	Total 2010
Net production	207954	270732	279825
Imports	12244	6756	5064
Exports	5184	14859	13431

Source: ENTSO-E

Tab 3.7.2 Electricity Imports (GWh)

year	FR	PT	MA
2000	8479	3765	---------
2008	4564	1315	15
2009	3957	2819	8
2010	1991	3190	33

Source: ENTSO-E

Tab 2.7.3 Electricity Exports (GWh)

year	FR	PT	MA
2000	587	4597	2262
2008	1661	10597	4227
2009	2351	7439	4598
2010	3512	5667	3938

Source: ENTSO-E

Projections of the NREAP

The share of RES in the gross final consumption of electricity production is expected to reach 40% in electricity generation in 2020, compared to 35.6% in 2010. In 2009, about 19 GW of wind power capacity and 3.5 GW of photovoltaic capacity were installed. As part of the NREAP, the Spanish government is seeking to increase onshore wind power capacity to 35 GW, plus 3 GW of offshore capacity, and solar photovoltaic power to 8.3 GW. The Spanish electrical operator (REE) regularly announces new achievements in wind penetration levels. At times, wind power is able to supply as much as 45% of Spain's electricity demand, under the right wind conditions. But when high winds occur during off-peak demand, management of the system becomes more difficult. International interconnections are therefore crucial to increasing the penetration of renewable energy sources in the Spanish power generation mix and beyond that, in the European generation mix.

Interconnections

Spain, like the UK, is a virtual electricity island. Interconnections with other countries are too weak to allow it to regulate wind intermittency through exports to its neighbors. The EU has recommended a minimum interconnection capacity of 10% between neighboring countries, but current cross-border power lines with France can cover just 4% of Spain's installed capacity. This makes the Spanish electrical system one of the most isolated in Europe. Moreover, the link from France to Spain is often saturated. According to the NREAP, the two new electricity connections planned with France – one of which is expected to be up and running in 2014 (see the section on France) and the other still to be defined – remain insufficient to reach the 2020 target of an interconnection capacity of 10% of installed capacity. This would mean approximately 10,000 MW against 1400 MW today and 2800 MW in 2014. Spain also has interconnections with Portugal and Morocco.

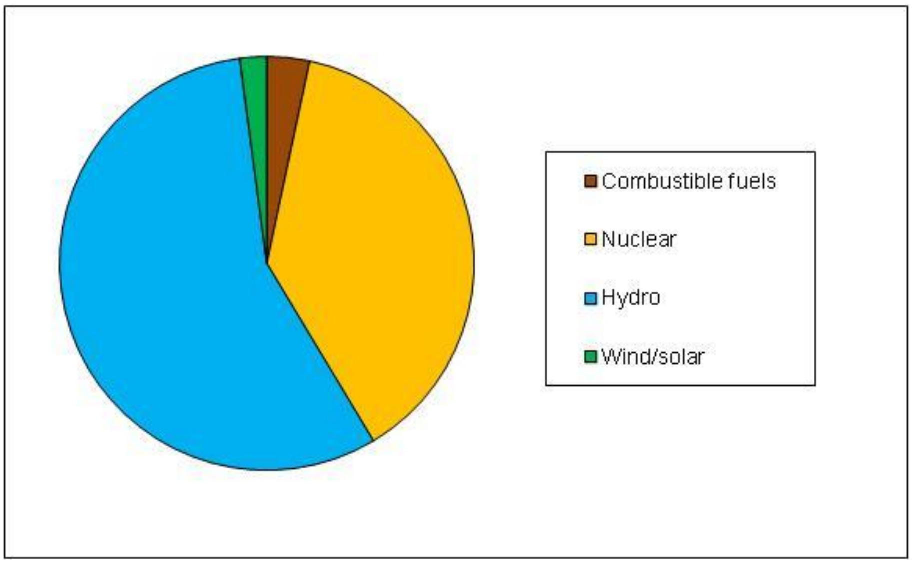
Projects

Beside the Santa Llogaia-Baixas line (see the section on France), a new interconnection through the Central Pyrenees is under consideration. The Spanish and French TSOs are currently studying the exact definition. The time horizon is not set. In light of the delays that have impeded the development of the Santa Llogaia-Baixas line, and because this potential increase in capacity will not be enough to trigger a large-scale integration of renewable energy, the Spanish government is looking at alternatives. First, Spain is a strong supporter of the development of a European super grid. Also, Spain is planning the development of energy storage systems. The NREAP forecasts 3000 additional MW of pumping power to be installed using the same reservoirs, including the repowering of existing pumps.

Switzerland

In 2010, net generating capacity was 17.6 GW. The peak load was about 11 GW. Net electricity generation was 66.2 TWh, and final consumption amounted to 65.7 TWh. However, 2494 GWh were requested for consumption of pumps, which explains that the export/import balance was negative in 2010. Switzerland relies on hydroelectricity, with a significant share of nuclear power. Still, Switzerland is on track to phase out nuclear power, a policy that has been introduced into the Energy Strategy 2050. [25] Existing nuclear power plants are to be decommissioned at the end of their operational lifespan and not be replaced by new nuclear power plants.

Fig 3.8.1 Total Net Electricity Supply – Switzerland 2010



Source : ENTSO-E

[25] http://www.bfe.admin.ch/themen/00526/00527/index.html?lang=en&dossier_id=05024

Tab 3.8.1 Total Electricity Trade (GWh)

	Total 2000	Total 2009	Total 2010
Net production	65392	66494	66252
Imports	23629	30616	32640
Exports	29351	31782	30930

Source: ENTSO-E

Tab 3.8.2 Electricity Trade imports (GWh)

year	AT	DE	FR	IT
2000	4161	10101	9357	10
2008	7449	13858	8787	400
2009	8653	13142	8311	510
2010	7915	14553	9679	493

Source: ENTSO-E

Tab 3.8.3 Electricity Trade exports (GWh)

year	AT	DE	FR	IT
2000	214	5150	1652	22335
2008	106	2709	3548	24162
2009	24	2636	4164	24958
2010	53	2581	5120	23176

Source: ENTSO-E

Switzerland is at the crossroads of Europe's trade in electricity. Its geographical position at the center of Europe and at the heart of the Alpine water resources makes Switzerland a key player as a backup reservoir to balance intermittent flows. It has perhaps the best hydroelectric storage infrastructure in Europe and disposes of large electricity reserves which allow greater flexibility to operate the network.

Switzerland is not a member of the European Union and as such not committed to the European objectives. It is however totally integrated in the European power network. Switzerland has extensive interconnection capabilities with neighboring countries which are reflected in the huge amounts of trade compared to its own production. Switzerland is linked to Austria, Italy, Germany and France.

Should Switzerland proceed with a nuclear phase out, the country will have to replace the power generated by its five nuclear power plants, representing a total capacity of 3,238 MW. The time horizon is quite far away, but three power plants could be decommissioned by 2022 (one in 2019, the other two in 2022). To replace nuclear power capacity, the Energy Strategy 2050 indicates that

Switzerland will have to rely on increasing electricity imports, improvement of energy efficiency and promotion of renewable energy sources.

The decision to not replace nuclear power plants will have important consequences on the security of supply of the region, not only in Switzerland but also in Germany, France, Austria and Italy. In light of Germany phasing out too, it needs to be asked whether Germany will be able to maintain its leading role as an exporter to Switzerland. Also, will Switzerland be able to provide as much power to Italy? And will France be able to provide enough baseload supply to its “no longer nuclear” neighbors?

A short assessment of the lessons learned from case studies

When reviewing the case studies, it is striking to see that important decisions are taken without cooperation or coordination with neighborrring countries. This is true for the establishment of the NREAPs, but also for decisions regarding the structure of the power generation mixes. The fact that Member States are sovereign with regard to their energy mixes should not prevent them from coordinating major decisions, such as a significant reduction of generating capacity, as has been the case in Germany but also in Belgium and in Switzerland.

So what can be said of the expected plans to cut of nuclear capacity? The balance between supply and demand at the EU level has been relatively manageable over the past three years, consecutive to the economic slowdown. Reduction of electricity demand in Europe was one of the first consequences of the crisis, which led to a state of overcapacity. This could stop the European Union from facing a shortage of reliable capacity in the short term, even though a lot of countries are planning to give up nuclear power. However, time horizons are important and the measures that are planned so far to replace them are highly hypothetical (the pace of expected benefits from energy efficiency improvements) or costly (development of renewable energy sources at a time when they are still far from markets). This will probably lead in the short and medium term to the development of fossil fuel power plants, which will have an impact on GHG emissions, pushing the CO2 price up on the European market. This in turn will translate into higher electricity prices.

Furthermore, interconnections take time to build. It is not certain that they will be ready in time to receive and transport power produced by wind farms in the North or PV panels in the South. Already, price spikes occur as soon as most of the available capacity across Europe is used. Volatility of electricity prices could increase if the pace of interconnection development does not meet the growth of renewable energy sources.

Interconnections have many benefits but increasing the dependence on them from a national point of view creates risks elsewhere. Indeed their efficiency and reliability also depend on what happens in other markets. Decisions might be national, but the system is European, as the incident in November 2006 displayed.

Based on these first observations, the following chapter will discuss the European Infrastructure Package (EIP) Blueprint and will compare it to the status of the European grid today.

The Policies of the EU and Meeting the 2020 Objectives

In 2011, out of the total 32 projects of European interest (see Annex TEN-E), six have been completed. One project between Slovakia and Hungary has been cancelled due to environmental problems on the Hungarian side; another one between Austria and Italy has been reconsidered and is subject to a re-design of the route, because of increasing public opposition to new power lines. Most of the projects are still under study or in the process of authorization. The bottom-up approach initiated by the TEN-E guidelines is clearly not in phase with the pace required by the European energy and climate policies. Acknowledging this failure, the European Commission has proposed, by way of the EIP Blueprint, a new top-down methodology that prioritizes projects in line with the Europe's 2020 objectives. Regarding electricity, the EIP Blueprint identifies four corridors (electricity highways) and provides a long term perspective for the elaboration of a smart grid at the European level.

The EIP Blueprint's priority projects

The EIP Blueprint focuses on four priority corridors: an offshore grid in the North Sea, interconnections in South Western Europe, connections in Central Eastern and South Eastern Europe and completion of the BEMIP (Baltic Energy Market Interconnection Plan).

The European Blueprint views the development of an offshore grid in the North sea as a top priority. Nine Member States are concerned by these projects: Belgium, the Netherlands, Luxembourg, Germany, France, Denmark, Sweden, the UK and Ireland. They are part of the NSCOGI (North Sea Countries Offshore Grid Initiative) with Norway. 38.2 GW of installed capacity is projected to be built by 2020. The European Commission expects that offshore wind power will yield sufficient output to trigger further developments, along the European network. The offshore grid should activate a better integrated European network.

The Blueprint recommends increasing the interconnection capacity between Spain and France from 1400 MW to 4000 MW by 2020 (to date, the new 400 kV line in the Eastern Pyrenees will bring the current capacity to 2800 MW in 2014… but will have taken almost 20 years from planning to completion).

It encourages the connection of production sites in the North sea and consuming areas, notably in Germany, which suffers an imbalance between consumption centers located in the South, and wind generation capacity in the North. This imbalance has been aggravated by the phase out of eight nuclear power plants, five of them located in Southern Germany.

The Blueprint also enhances the development of smart grids and deplores the slow pace currently displayed in their completion. However, as already underlined previously (see part 1), "smart grids" should not be reduced to smart technologies. Instead they should be part of a broader strategy that will include storage capacities and the efficient allocation of generation capacities along the network and dependent on local resources.

Projects of Common Interest (PCI)

By 2020, the Blueprint forecasts €500 billion investments in power generation of which €310-370 billion in RES. Investment in the power network should amount to €140 billion, broken down into €70 billion for interconnectors, €30 billion for offshore grids and €40 billion for smart grid installation in transmission (compared with the TYNPD estimation of €23-28 billion investment needed over the first five years – see Part 1). The EC is fully aware that this huge amount of money will be difficult to find as long as authorization procedures remain complicated and lengthy, and that existing regulations do not provide sufficient incentives for investors, while financial support is scarce.

In October 2011, the EC set out with a follow up proposal to provide regulation on "guidelines for trans-European energy infra-structure." [26] The Commission identifies 12 priority corridors and areas covering electricity, gas, oil and carbon dioxide transport networks. It proposes a regime of "common interest" for projects contributing to implementing these priorities and having obtained this label. The proposal establishes a regime of common interest for such projects, giving particular responsibilities to member states to carry out the projects in order to accelerate the permit granting procedures. The adoption of the Union-wide list of Projects of Common Interest (PCI) will imply the full commitment of all Member States. The proposed Regulation gives responsibility to national regulatory authorities and ACER (Agency for the Coordination of Energy Regulators) for cross-border allocation costs. Member States will have to take these into account when setting transmission tariffs and also to grant appropriate incentives in terms of tariffs for projects facing higher risks. Finally, the proposal determines the conditions for

[26] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0658:FIN:EN:PDF

eligibility of these projects for EU financial assistance. The European Commission has reserved €9.1 billion to spend on energy infrastructure in the period 2014-2020.

To date, this proposal is an interesting and very bold move that would give more leverage to the EC with regard to prerogatives usually solely held by Member States. The proposal still has to go through the European Parliament and the Council of Ministers, and as ever the "devil is in the detail":

- So far, the text identifies 12 priority areas (see Annex). Deciding which project qualifies as a PCI promises to be a difficult and lengthy process. Even though the EC will have the final say, member states must approve all projects on their territory. The EC aims to establish the list of PCI by 31 July 2013 at the latest.

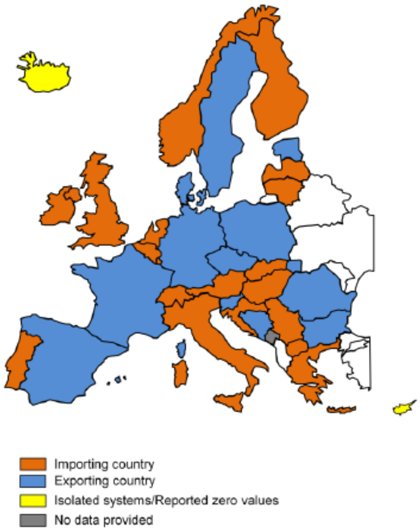
- Getting planning permission has been a recurring problem in launching interconnection projects. According to the proposed text, PCI "should be given priority status at national level to ensure rapid administrative treatment". The permit granting process should not exceed three years. The text also proposes to establish a single competent authority at the national level to coordinate/integrate all permit granting procedures ("one-stop shop") in order to speed up the process. The proposal goes very far in indicating that "Authorization should be given to projects which have an adverse impact on the environment, for reasons of overriding public interest, when all the conditions provided for under Directives 92/43/EC and 2000/60/EC are met". This provision is set to meet strong opposition from environmental organizations, although it is crucial to accelerate the authorization process.

- Financing remains an important problem. Even though the €9.1 billion (to be shared across the twelve priority areas) are far more significant than the €155 million available through the TEN-E financing regulation, a lot remains to be done to cover the €500 billion needed for the power sector.

Projects to be carried out between 2010 and 2020

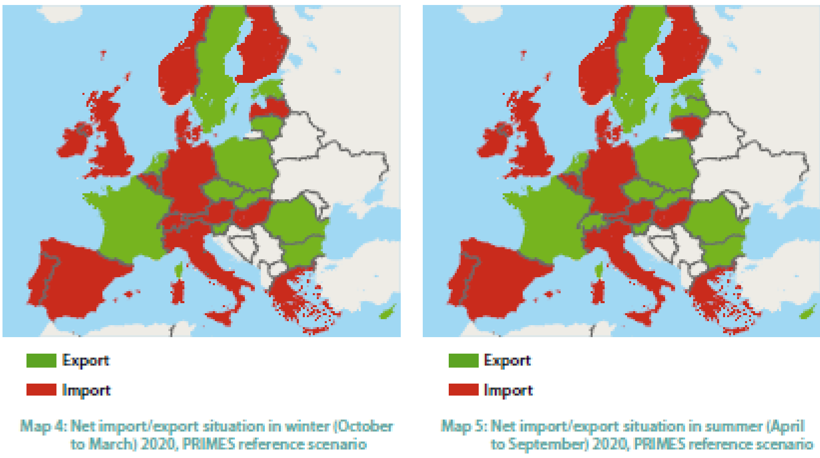
Increasing the development of RES in the North Sea, in Southern Europe and in other areas modifies the generation patterns and affects the circulation of electricity across Europe. These new power flows must be accommodated within the whole European network, as local demand cannot absorb the bulk of RES production. It impacts the European system entirely and emphasizes the need to develop new interconnections in these areas.

Fig. 4.3 Net import/export situation, 2010



Source : ENTSO-E [27]

Fig. 4.4 Net import/export situation in winter and summer, 2020, PRIMES reference scenario



Source : http://ec.europa.eu/energy/publications/doc/2011_energy_infrastructure_en.pdf

Analysis of Figures 4.3 and 4.4 shows that the Blueprint forecasts Spain, Germany and Belgium to become net importers both

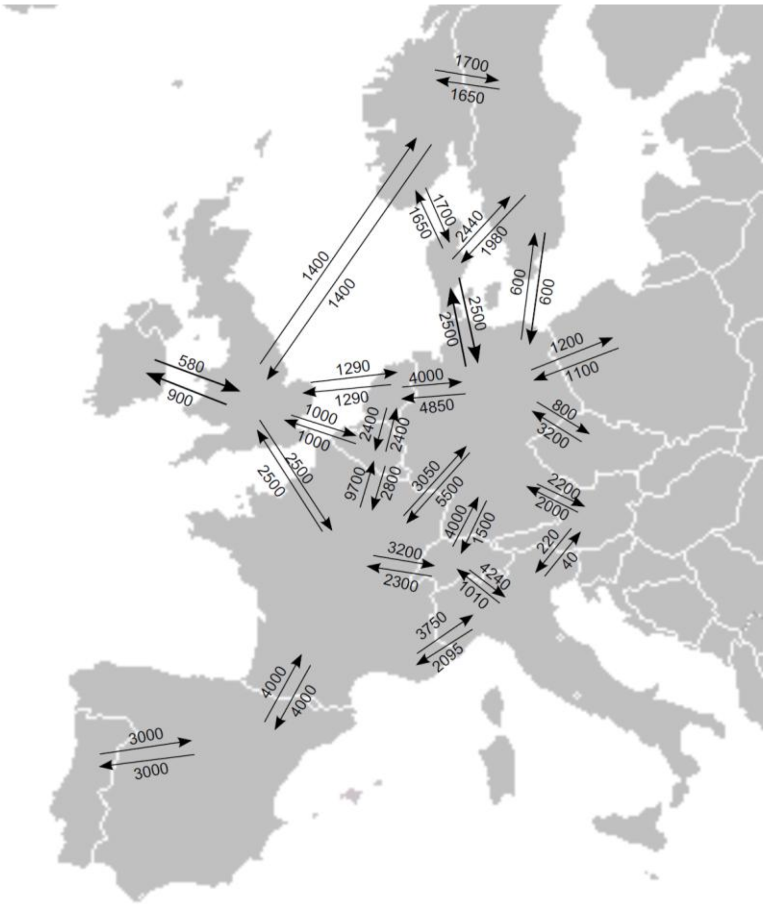
27 https://www.entsoe.eu/fileadmin/user_upload/_library/publications/entsoe/SAR/ENTSO-E_SAR_2010.pdf

in winters and summers, whereas in 2010 these three countries were net exporters. Implicitly, the EIP Blueprint acknowledges the fact that countries relying on nuclear power (France, the Czech Republic, and Sweden) or fossil fuels (Poland and the Netherlands) are necessary to provide base load capacity, whereas hydroelectricity in Switzerland, Norway and Sweden may help to smooth the intermittency of RES flows.

This raises two main issues. First, it underlines the need to discuss the allocation of generation capacity/generation choices at the European level. Second, as many countries, including France, are debating the future of nuclear power in their electricity generation mixes, it is necessary to know what additional efforts will have to be made to cover the phasing out of nuclear power. It is easy to see that the elaboration of a European vision that sees energy policy only through the prism of RES development fails to take into account the needs of the overall system. Issues cannot be dealt with one-by-one, or even one after the other. They need to be part of a comprehensive vision that will take into account not only transmission but also generation capacity, its location, its contribution to the energy mix (baseload, peak load, intermittent) and its impact on climate policy.

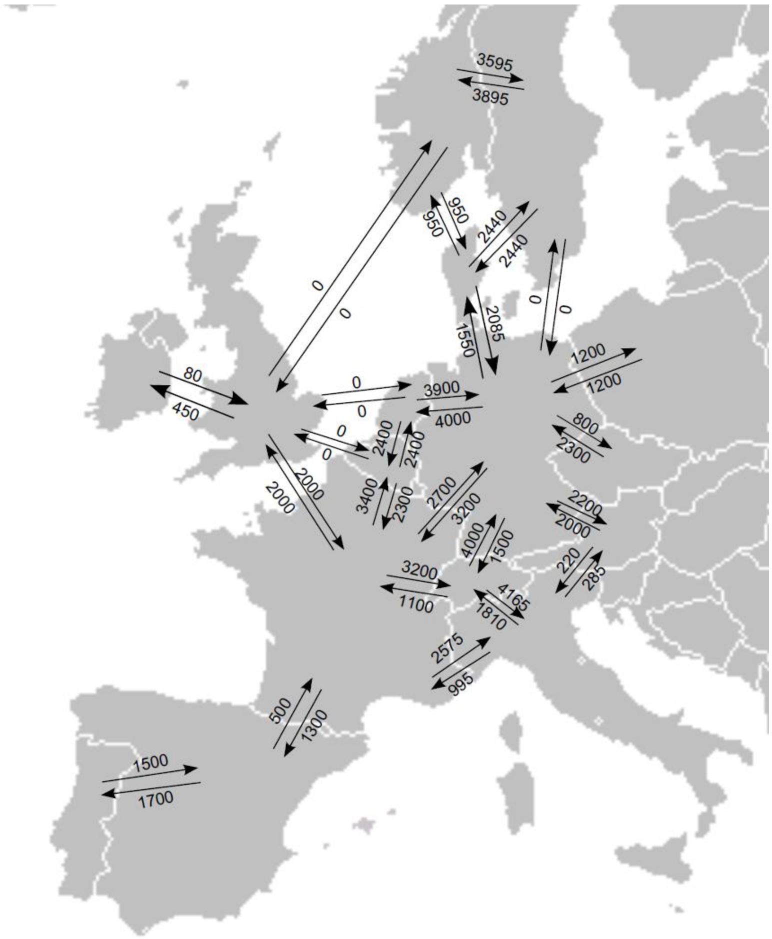
The EIP Blueprint gives some indications on what interconnection capacity will be required by 2020 (see Fig 4.1). The comparison with 2010 (see Fig. 4.2) is striking. Interconnections between France and Spain should amount to 4000 MW in both directions, as opposed to 500/1300 MW in 2010, and 2400 MW in 2014. Even when this line is completed, congestion is still expected due to ambitious RES development plans in the Iberian Peninsula. It will not be possible to use the Catalunya/Eastern Pyrenees corridor to reach the 4000 MW target. This new project is surely likely to face strong local opposition in areas hosting several national parks and tourism destinations.

Fig 4.1 Interconnection capacity requirements 2020 in MW, PRIMES Reference scenario



Source: Energy infrastructure priorities for 2020 and beyond: A blueprint for an integrated European energy network.

Fig 4.2 2010 interconnection capacity in MW



Source: NTC values (winter 2010-2011; summer 2010) available on the ENTSO-E website

Table 4.1 Interconnection capacity 2010-2020
(as shown in the maps above)

Interconnection		Year		Interconnection		Year	
From:	**To:**	**2010**	**2020**	**From:**	**To:**	**2010**	**2020**
Portugal	Spain	1500	3000	Spain	Portugal	1700	3000
France	Spain	1300	40000	Spain	France	500	40000
France	England	2000	2500	England	France	2000	2500
France	Belgium	3400	9700	Belgium	France	2300	2800
France	Germany	2700	3050	Germany	France	2300	3300
France	Switzerland	3200	3200	Switzerland	France	1100	2300
France	Italy	2575	3750	Italy	France	995	2095
England	Ireland	450	900	Ireland	England	50	580
England	Norway	0	1400	Norway	England	0	1400
England	Netherlands	0	1290	Netherlands	England	0	1290
England	Belgium	0	1000	Belgium	England	0	1000
Norway	Denmark	950	1700	Denmark	Norway	950	1650
Norway	Sweden	3595	1700	Sweden	Norway	3895	1650
Norway	Netherlands	0	1150	Netherlands	Norway	0	1150
Sweden	Denmark	1980	1980	Denmark	Sweden	2240	2440
Sweden	Germany	0	600	Germany	Sweden	0	600
Denmark	Netherlands	0	700	Netherlands	Denmark	0	700
Denmark	Germany	2085	2500	Germany	Denmark	1550	2500
Germany	Netherlands	4000	4850	Netherlands	Germany	3900	4000
Netherlands	Belgium	2400	2400	Belgium	Netherlands	2400	2400
Germany	Switzerland	1500	1500	Switzerland	Germany	4000	4000
Germany	Austria	2200	2200	Austria	Germany	2000	2000
Germany	Czech Republic	800	800	Czech Republic	Germany	2300	3200
Switzerland*	Austria	1200	1200	Austria*	Switzerland	540	470
Belgium*	Luxembourg	0	1000				
Norway*	Germany	0	1400				
Germany*	Luxembourg	980	980				
							* Connection not shown in map

If the pace of network development does not match the increasing capacity of RES, the European Union will not succeed in harvesting the maximum potential of RES. On the other hand, TSOs needs to handle simultaneously the reinforcement of their national grids in some areas (for example, to face the imbalance between production and consumption in Brittany in France, or along the North-South axis in Germany to move power from areas of generation to centers of consumption), abolish the barriers to the integration of the electricity market and connect new RES generation. Corridors for the integration of the electricity market and for connecting RES are not necessarily the same. The former is driven by economic aspects, whereas the later is motivated by policy choices. Again, this discrepancy emphasizes the need to discuss generation sources at the European level and to take into account their economic performance for a competitive and sustainable energy mix.

The main bottlenecks: regulation, finance and public opinion

Forecasting investment costs is a difficult exercise. For projects to be completed in the short term, costing is relatively accurate. But numbers for mid-term and longer term projects depend largely on technical choices or on route design. For example, the France-Spain interconnection was originally planned to be an overhead high voltage line. Eventually, it was decided to settle for a DC underground cable, which multiplied the initial planned cost by a factor 7. New interconnections are more sophisticated, using more DC technologies. To prevent public opposition they are buried or pass under the sea where possible.

From a TSO perspective, the investments to be carried out first are the less risky. Beyond security aspects that are their main responsibility, the decision to build a transmission line depends on how investment costs can be recovered. Cross-border projects are also the most political, and countries involved both need to agree on which project to succeed with. Very often, from a consumer perspective, the connection of two systems results in gains for the less competitive electricity production mix (as electricity prices become cheaper) and a loss for the most competitive mix (due to higher electricity prices, but which also create rents for the producers). Some complementarities may exist between the two systems, due to the difference of their energy mixes and lead to mutual benefits for the system as a whole. But they then need to be compared to equivalent investment in generation capacity. For example, an interconnection could reduce the need to invest in peak generation capacities. Again, it is difficult to separate an analysis of the transmission network from the allocation of generation capacity. Without coordination at the European level on both transmission and generation, it is difficult to trigger enough incentives on both sides of a border to establish a regulatory framework capable of laying the ground for the implementtation of a cross-border project. Even though the European Commission has increased its pressure on member states to speed up the development of an integrated network, TSOs will first build the projects that present the least uncertainty.

Lastly, public opinion is increasingly adverse to any type of infrastructure project and has led to many years of delay in numerous cases. As long as public opinion does not understand the potential benefits of interconnection lines, NIMBY attitudes will add to the uncertainty of these projects. Reversing this trend is a long and costly process, as many TSOs need to persuade local authorities in supporting the building of social infrastructures, and to convince NGOs of the overall advantages of projects.

Conclusion

Due to strong political support and subsidies, renewable energy sources (RES) in electricity production are steadily increasing. As the penetration of wind power, and to a lesser extent solar power increase, the effect of intermittent sources on the whole electricity system is no longer trivial. It affects the reliability of electricity supply, merit order and dispatching decisions, the cost of electricity, and the operation of power plants. Already, the larger penetration of wind power affects electricity prices. Electricity generated by intermittent energy sources has to be used when available. Wind power electricity can be sold even at zero or negative prices in Denmark, Germany and Spain. Negative prices reflect bottlenecks in the transmission system. They might not yet have a big negative effect on the electricity utilities, but occurrences will increase with wind power expansion, threatening utilities' profits and therefore future investments. Electricity prices will remain highly volatile until the network is more integrated and transmission capacity is developed.

As long as transmission capacity is lacking, the mutualization of renewable energy resources across Europe will remain inefficient, countries having no choice other than to develop and to rely on fossil fuel capacity to back up intermittency. Overall, the variability of intermittent RES generation can be dealt with by interconnection capacities to a certain extent, while the availability of sufficient thermal power plant capacity is maintained. Interconnection capacities could enable optimum use of RES potential distributed across Europe, such as wind resources in the North and solar energy along the Mediterranean. If the network is not upgraded in time, this could jeopardize the benefit expected in GHG emission reduction. Strong interconnecttions between neighboring countries are crucial for greater windpower penetration. An objective on capacity production, such as the European objective on the share of RES in final energy consumption, without a strategy to develop these links is bound to fail. In this sense, the submission of the infrastructure package in November 2010 is an important step forward. However, it does not address the full complexity of the problem as the allocation of generation capacity remains essentially national, while a discussion on a European energy mix, as of a collection of national energy mixes, is not possible at the EU level. There is still an important missing link arising from the fact that the specificity of national energy mixes and in particular their competitiveness are not acknowledged.

Over the past 15 years, priorities of European energy policy have shifted from a market-driven approach that puts emphasis on cost and competitiveness to policy objectives. To date, the three pillars of European Energy policy remain: i) the security of supply, ii) competitiveness and iii) climate change. Decarbonization of the power sector, RES deployment, the development of interconnections are all tools that are to be implemented to answer these three priorities. However, the tools seem to have become goals in them-selves. This could already be observed with the objective of RES development that has been reinforced, though it has not yet led to significant benefits in terms of GHG reduction, which is one of the priorities of European energy policy. But, RES development *has* affected the rationales for interconnections. Originally, cross-border transmission lines were seen as an integrated part of the liberalization process. They are now considered as key to move renewable electricity across Europe. The building of new interconnection lines is no longer driven by the circulation of electricity related to production costs, but rather by policy objectives that aim to move electricity produced by intermittent renewable energy sources (and not just low carbon energy sources that would include nuclear power). An immediate consequence is that European energy policies seem to head for a significant increase of electricity cost. Furthermore, this inconsistency between these European objectives needs to be better addressed if the EU and its Member States want to create sufficient incentives to make the European grid happen.

Indeed, the lack of coordination between all actors involved will definitely lead to underinvestment. The EIP Blueprint attempts to improve the regulatory framework to speed up authorization processes and to limit the delays that have been observed so far, but this requires a transfer of decision-making from Member States to the EC. Only the resolution of the shortcomings listed above could encourage the Member States to give up part of their national prerogatives. Furthermore, the provision aiming at overcoming opposition will certainly clash with existing environmental regulations. Too many voices still have the power to block the construction of an interconnection line.

However, the pace of RES deployment and interconnection development are significantly different. So too are the lifetime of generation capacities – about 30 to 50 years – and of networks which are longer still. The fight against climate change requires urgent action, but if Europe does not succeed in developing an appropriate framework that will favor the decarbonization of the power sector, which involves a low carbon energy mix and a transmission network able to transport low carbon energy sources at a cost that is socially acceptable, then there is a huge risk that decision-makers and investors may prefer to ignore the long term consequences of global warming.

Annexe 1

Trans-European Energy Networks

Electricity Network - Decision 1364/2006/EC

Axes for priority electricity projects, including sites of projects of European interest, as defined in Articles 7 and 8

The priority projects, including projects of European interest, to be carried out on each axis for priority projects are listed below.

EL.1. France — Belgium — Netherlands — Germany

Objective: electricity network reinforcement in order to resolve congestion in electricity flow through the Benelux States.

Projects of European interest:

- Avelin (FR) — Avelgem (BE) line (completed)
- Moulaine (FR) — Aubange (BE) line (completed)

EL.2. Borders of Italy with France, Austria, Slovenia and Switzerland

Objective: increasing electricity interconnection capacities.

Projects of European interest:

- Lienz (AT) — Cordignano (IT) line
- New interconnection between Italy and Slovenia
- Udine Ovest (IT) — Okroglo (SI) line
- S. Fiorano (IT) — Nave (IT) — Gorlago (IT) line (completed)
- Venezia Nord (IT) — Cordignano (IT) line
- St. Peter (AT) — Tauern (AT) line
- Südburgenland (AT) — Kainachtal (AT) line (completed)

- Austria — Italy (Thaur-Brixen) interconnection through the Brenner rail tunnel.

EL.3. France — Spain — Portugal

Objective: increasing electricity interconnection capacities between these countries and for the Iberian Peninsula and grid development in island regions.

Projects of European interest:

- Sentmenat (ES) — Bescanó (ES) — Baixas (FR) line
- Valdigem (PT) — Douro Internacional (PT) — Aldeadávila (ES) line and 'Douro Internacional' facilities.

EL.4. Greece — Balkan countries — UCTE System

Objective: development of electricity infrastructure to connect Greece to the UCTE System and to enable the development of the south-east European electricity market.

Project of European interest:

- Philippi (EL) — Hamidabad (TR) line.

EL.5. United Kingdom — continental Europe and northern Europe

Objective: establishing/increasing electricity interconnection capacities and possible integration of offshore wind energy.

Project of European interest:

- Undersea cable to link England (UK) and the Netherlands (completed).

EL.6. Ireland — United Kingdom

Objective: increasing electricity interconnection capacities and possible integration of offshore wind energy.

Project of European interest:

- Undersea cable to link Ireland and Wales (UK).

EL.7. Denmark — Germany — Baltic Ring (including Norway — Sweden — Finland — Denmark — Germany —Poland — Baltic States — Russia)

Objective: increasing electricity interconnection capacities and possible integration of offshore wind energy.

Projects of European interest:

- Kassø (DK) — Hamburg/Dollern (DE) line
- Hamburg/Krümmel (DE) — Schwerin (DE) line
- Kassø (DK) — Revsing (DK) — Tjele (DK) line
- Vester Hassing (DK) — Trige (DK) line
- Submarine cable Skagerrak 4: between Denmark and Norway
- Poland — Lithuania link, including necessary reinforcement of the Polish electricity network and the Poland-Germany profile in order to enable participation in the internal energy market
- Submarine cable Finland — Estonia (Estlink)
- Fennoscan submarine cable between Finland and Sweden
- Halle/Saale (DE) — Schweinfurt (DE).

EL.8. Germany — Poland — Czech Republic — Slovakia — Austria — Hungary — Slovenia

Objective: increasing electricity interconnection capacities.

Projects of European interest:

- Neuenhagen (DE) — Vierraden (DE) — Krajnik (PL) line
- Dürnrohr (AT) — Slavětice (CZ) line
- New interconnection between Germany and Poland
- Veľký Kapušany (SK) — Lemešany (SK) — Moldava (SK) — Sajóivánka (HU) line
- Gabčíkovo (SK) — Vel'ký Ďur (SK) line
- Stupava (SK) — south-east Vienna (AT) line.

EL.9. Mediterranean Member States — Mediterranean Electricity Ring

Objective: increasing electricity interconnection capacities between Mediterranean Member States and Morocco — Algeria— Tunisia — Libya — Egypt — near eastern countries — Turkey.

Project of European interest:

- Electricity connection to link Tunisia and Italy.

Proposal for a Regulation of the European Parliament and of the Council on guidelines for trans-European energy infrastructure and repealing Decision No 1364/2006/EC

The twelve Energy Infrastructure Priorities of the European Commission

- North Sea offshore grid
- North-South electricity interconnections in South-Western Europe
- North-South gas interconnections in Western Europe
- North-South electricity interconnections in Central Eastern and South Eastern Europe
- North-South gas interconnections in Central Eastern and South Eastern Europe
- Oil supply connections in Central Eastern Europe
- Baltic Energy Market Interconnection Plan in electricity
- Baltic Energy Market Interconnection Plan in gas
- Southern Gas Corridor
- Smart grids deployment
- Electricity highways
- Cross-border CO2 network

Annex 2

State of implementation of projects of European interest in the electricity sector involving Belgium, Denmark, France, Germany, Italy, Netherlands, Spain, Switzerland (cases study)

Axis	Country	Project	Status	Add. Capa-city (MVA)	Length (km)	Estima-ted cost (€M)	Oper-ation date	EIB loan (M€)	EEPR grants(M€)	TEN-E grants (€)	Comments
EL1	BE,FR	Avelin (FR)-Avelgem (BE)	done	1000-1500	43	RTE:15.7 ELIA: 17.3	2005			1.1M	5 years delay on initial schedule
EL1	BE,FR	Moulaine (BE)-Aubange (FR)	done	400	15	RTE: 11 ELIA: 2.2	2010	4		503000	
EL2	AT,IT	Lienz (AT)-Cordignano (IT)	pre-study	1000	154	140	2015?			82500 355000	Due to local public opposition against new line projects, a new line routing is necessary Terna expects commissionning on the long term

Axis	Country	Project	Status	Add. Capa-city (MVA)	Length (km)	Estima-ted cost (€M)	Oper-ation date	EIB loan (M€)	EEPR grants(M€)	TEN-E grants (€)	Comments
EL2	IT, SI	Vrtojba (SI)-Redipuglia(IT)	US	500	20		?				Plant construction and operation permit is to be issued; merchant line model; developed by Adria Link (Enel Produzione, AcegasAps and Tei-Energy)
		Dekani (SI)-Zavlje (IT)	US	1000	5		?				Authorization has been notified, the project is launched; first "merchant" interconnection power line between Italy and Slovenia, owned by Adria Link (Enel Produzione, AcegasAps and Tei-Energy)
		Divaka (SI)- Italy	US	?	?		?				
EL2	IT,SI	Udine Ovest (IT)-Okroglo (SI)	study phase	1000-1500	120	80	2018			467630	Faces local opposition; important delay of 7 years; partner: Terna
EL2	IT	Venezia Nord (IT)-Cordignano (IT) re-routed to Volpago (IT)	US/AP	1000	75	25	2014				Consultation with local authorities ongoing
EL2	AT	St Peter (AT)-Tauern (AT)	UC/US	1800 2*1525	161	450	2017		yes	2.7M 844000 1.2M	one section (Salzach Neu-St Peter) is completed, the other one (Salzak Neu-Tauern) is facing strong opposition of local population”

Axis	Country	Project	Status	Add. Capa-city (MVA)	Length (km)	Estima-ted cost (€M)	Oper-ation date	EIB loan (M€)	EEPR grants(M€)	TEN-E grants (€)	Comments
EL2	AT	Südburgenland (AT)-Kainachtal (AT)	done	1800	98	146	2009	90		1.5M	
EL2	AT,IT	Austria-Italy (Thaur Brixen)	US	2*1000 2*1500	57-65	300	2025			964000 449500	Crossing the Alps constitute a major challenge; merchant line
EL3	ES,FR	Sentmenat (ES)-Bescano (ES)-Baixas (FR)	UC	1400 MW	257	700 EU : 225 RTE and REE will finance equally the balance	2014	350	225	220000 394000	The project was suspended due to strong local opposition causing many years of delay.The project Baixas-Santa Llogia should be operational in 2014
EL5	UK,NL	BritNed	done	1000	260	600	2011			total 13M	partners: JV between National grid and TenneT (Netherlands)

Axis	Country	Project	Status	Add. Capa-city (MVA)	Length (km)	Estima-ted cost (€M)	Oper-ation date	EIB loan (M€)	EEPR grants(M€)	TEN-E grants (€)	Comments
EL7	DK,DE	Kasso (DK)-Hamburg/Dollern (DE) (Kriegers Flak)	AP	3500	215		2018			150000	It is estimated that the Combined Grid Solution Project could be realized between October 2012 and June 2016 to be in operation from July 2016. The grid will depend upon the decision on the erection of offshore wind turbines and their location. Partners: 50Hertz Transmission, Energinet.dk, and Svenska Kraftnät
EL7	DK,DE	Hamburg/Krümmel (DE) -Schwerin (DE)	UC	2*1800	90	85	2010				one year delay due to local opposition
EL7	DK	Kasso(DK)-Revsing(DK)-Tjele(DK)	UC	2000	170	200	2012			1.5M	Faces local opposition
EL7	DK	Vester Hassing(DK)-Trige(DK)	UC	900	114	160	2014				Depends on other projects (between DK and DE) and wind power allocation Faces local opposition
EL7	DK,NO	Submarine cable Skagerrak 4	UC/done	700	260	375	>2012			856000	Technical difficulties; under construction; partners: Statnett-Energinet.dk

Axis	Country	Project	Status	Add. Capa-city (MVA)	Length (km)	Estima-ted cost (€M)	Oper-ation date	EIB loan (M€)	EEPR grants(M€)	TEN-E grants (€)	Comments
EL7	DE	Halle(DE)-Schweinfurt(DE)	AP/done	2*2400	205	350	2013		100	290000	One section has been completed in 2008; section 2 should be operational in 2011; section 3 is scheduled for 2012; three years delay due to increasing public opposition
EL8	DE, PL	Neuenhagen(DE)-Vierraden(DE)-Krajnik(PL)	US		125-65	746	2015				
EL8	DE, PL	New interconnection	US				>2015				

UC : Under construction ; AP : Autorisation Phase ; US : Under Study
Source: TSOs press released; Annex to the report from the commission to the european parliament, the council, the European economic and social committee and the committee of the regions on the implementation of the transeuropean energy networks in the period 2007-2009

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