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Electric Networks and Energy Transition in Europe

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Summary

After a century of close development between power generation facilities and networks, the liberalisation of the electricity sector has broken this link in Europe. Long-distance transmission networks now play a key role in stimulating competition between generators by giving consumers access to remote power generation facilities. Consequently, a tight European regulatory framework is applied to these networks, in order to monitor their mandate and income,. However, it does not impose any common rules, so that tariff disparities might adversely affect competition. Today, "market coupling" facilitates intra-European electricity trading, despite the relative scarcity of cross-border connections between some countries in Western Europe. The rules are more heterogeneous for the distribution networks, which provide power delivery within a small area.

In most countries, the energy transition largely relies on renewable electricity sources, especially wind and solar. Two requirements appear with their development: reinforcing the distribution networks on the one hand to accommodate this new power generation, and increasing interconnections on the other to export excess volumes during certain periods. These requirements would be gaining a more acute nature if the objective for 2030 was confirmed, as the share of renewable electricity would then reach 45%. For the European Commission, increasing the interconnection capacity would bring two other advantages: firstly, extended access to the cheapest power generation facilities, which would be reflected by a drop in wholesale market prices and their convergence at European level; and secondly, improved security of supply, physically by expanding the scope able to assist when necessary, and economically by the opportunity to extend the role of market instruments. The European Union (EU) is therefore selecting an objective of 10% for 2020 and 15% for 2030 of interconnection capacity for each country.

Networks reinforced in this way are at risk of overcapacity and consumption only increases slightly with the introduction of new uses such as electric vehicles, or even reduces because of energy efficiency programmes, also conducted in the name of energy transition, or because of advances in power storage devices. The economic equilibrium of system operators will then require increasing transmission tariffs, and most probably an increase in the fixed component of the tariff. This may ultimately introduce a sort of

capacity compensation which could rise if energy efficiency policies were successful. This expectation undermines the expected wholesale market price gains, incidentally calculated with assumptions on the price of fuels and CO_2 that we are entitled to discuss. The convergence of the market prices will by no means be sufficient to affect the retail prices, or compensate for the differences from costs imposed nationally, or reduce the distortions of competition caused by the different exemption schemes for certain categories of consumers. Finally, by letting the markets act to better ensure their security of supply, several Member States run the risk of increasing their dependence on neighbouring countries, losing part of their power generation facilities, and incurring less choice of sources to make up their electric mix.

Emphasising the difficulties does not involve having to give the project up. However, the findings suggest vigilance in conducting network extensions and reinforcements, by continuously striving to control expenditure, boost the operation's growth potential through industrial policy measures, compensate for the resulting increased electrical interdependence with a common governing body, and to ensure the sharing of knowledge gained, so that the energy transition launched in this way is seen as a shared project.

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Introduction

For several years, the European Union (EU) has reiterated its commitment to an energy transition, understood as the combination of managing consumption and of using energies less harmful to the environment. In this regard the community policy, initiated in 1997, has taken a decisive step with the "Climate and Energy Package" adopted in 2009, setting objectives for 2020. Several Member States, including in particular Germany and France, have adopted national transition policies or even an energy "turning point" in addition to or outside of this framework. These always have the characteristic of being largely based on changes in the way electricity is generated or consumed.

Electricity is also subject to many attentions for two other reasons: on the one hand the recent development in power generation facilities seems to weaken the security of supply, and on the other hand, the increase in retail prices raises concerns about the purchasing power of households or the competitiveness of businesses.

For the European Commission, as well as for many stakeholders in the electricity sector, transition, security, and competitiveness would gain a joint advantage by reinforcing the networks. Locally, denser networks would facilitate the connection of decentralised power generation facilities and their distribution to an increased number of consumers. Nationally and at European level, an increase in transmission and cross-border connection capacities would improve security by pooling available resources and would promote competitiveness by expanding the prospects for cheaper power stations.

This study aims to analyse the main elements of the case in favour of heavy investment in the electricity networks, highlighting in particular the technical or economic uncertainties, as well as the discernible political consequences. The latter include the compatibility of a widely interconnected European network with the freedom of choice of energy sources that the Treaty of Lisbon concedes to the Member States, and with the ultimate responsibility in terms of security of supply, which also rests with the Member States according to the legislation in force.

The first chapter describes the current situation. Intended for readers unfamiliar with the roles performed by the system operators, it summarises the current regulatory framework at the end of the liberalisation process started two decades ago. The second chapter discusses the challenges that surfaced with the community's commitment to renewable electricity sources and the emergence of new needs, particularly surrounding electric vehicles. It presents measures to promote the development of networks. The third chapter introduces a discussion on the relevance of this development, emphasising on the one hand the weakness of the economic outlooks, and on the other the need to address future impacts of a major increase of interconnections in the European electricity network. Finally, some recommendations are presented in the conclusion.

The study focuses on electricity. Although the investment requirements of distribution networks appear greater than those of transmission networks, the diversity of local situations regarding distribution and the relative scarcity of homogeneous statistical data do not facilitate the approach. Therefore, the study mainly focuses on the long-distance transmission of electricity and the recently expressed commitment to increase the capacity of cross-border connections, which incidentally have the strongest political challenges. The examples and specific analyses involve five countries in particular: Germany, Spain, France, Italy and the United Kingdom.

The money that the EU is ready to invest in its electricity networks amounts to hundreds of billions of euros. Therefore, debating about this approach seems justifiable, and Ifri, faithful to its mission, hopes to encourage it with this report, which in turn draws on other contributions, taking into account the complexity of the case and the many angles from which it is possible to shed light on aspects of it.

Situational Analysis at the End of the Liberalisation Process

For nearly a century, the history of electricity networks was mixed with that of power generation facilities. From the 1980s, some Member States started a separation that the EU imposed on all of its members during a process spread over about a dozen years. The rules adopted jointly made transmission networks the key instrument for promoting competition among generators, firstly nationally and then at European level. The community's regulatory framework is relatively light for distribution networks.

Historical Background

The commercial use of electricity started with the construction of networks linking the first generators to the first clients from the 1880s. They transmitted direct current distributed at a voltage equal to that of the generation facility. The distances were limited by line losses. The development of transformers gave an advantage to alternating current and made it possible to move power stations further away from the end consumer. On leaving the generator, the voltage is raised for routing on the transmission network, the losses being lower when the voltage is higher, and it is lowered on entering the distribution network, which delivers power between customers in a small area.

Throughout the 20th century, the development of the electricity industry was based on a very close link between the power generation facilities and the network operation in all countries in the world. In practice, exclusive rights were awarded to companies in a legal (territorial monopoly) or contractual form (long-term concession) resulting in either fully integrated companies, such as EDF in France up to 2000, or in cartels sharing business and geographic areas without competing, like in Germany up to 1998. The economic security gained by companies in this way led to a remarkable development of power generation facilities and networks in all countries benefiting from a good industrial base and good public management.

The client paid for a single service, including the power and its transmission up to the delivery point. The electricity company tried to optimise a group made up of power stations and the lines. In periods of economic growth, potential optimisation errors were quickly overcome. From 1971, with the end of the guaranteed convertibility of the dollar and several successive oil shocks, the western world entered a period of instability, leading to a slowdown in growth and an increase in energy prices. Electricity companies were then suspected of incorrect forecasting, leading to overcapacity and disproportionate planning, and their regulatory authorities of not being able to effectively control them[1]. At the same time, many economists, inspired by the "Chicago School", advocated a new electricity model restricting the monopoly to "essential assets" such as the networks and creating competition among the other operations, power generation on the one hand, and sale to the end client on the other.

Several countries have applied these recommendations since 1980, isolating the entities responsible for the operation of the networks from an accounting, administrative, financial, and even legal perspective. These arrangements were made mandatory in the European Union by a directive adopted in 1996. Two later directives in 2003 and 2009 have reinforced the independence of system operators and imposed common principles for regulating their activities[2].

The community regulatory framework was developed for the main purpose of encouraging competition in the electricity market, and the stakeholders who were in competition were the generators, suppliers to the end client, and traders (middlemen between the generator and the seller)[3]. When the legislation mapping out this framework was adopted at the end of the 20th century and at the beginning of the 21st century, there was hardly any local generation from small power generation facilities (for example wind or solar), the greater majority of which are connected to the distribution networks. The competitive challenge is low and the regulation for these networks only focuses on a limited number of areas. It primarily aims at enabling the consumer to change supplier unhindered and to ensure a non-discriminatory tariff for network use.

Distribution networks, which provide the local service from the electricity source, often involve local public authorities that may be located, depending on the countries and their history, in the municipality, district, department, region, etc. Anxious not to open a front against local politicians during debates about the liberalisation of the electricity sector, the European Commission abandoned standardising in detail the operative procedures applicable to

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1. Either "information asymmetry", with governments not having the resources to fully assess the decisions taken by the companies, or "regulatory capture", the government's interests converging with those of companies which could affect its independence of judgement, was incriminated.
2. Directives 96/92, 2003/54 and 2009/72 on common rules concerning the internal electricity market.
3. Some suppliers are responsible for both power generation, marketing and trading on the Electricity Exchanges: these are known as integrated operators.

distribution networks, restricting itself to general principles and tolerating derogation situations. Thus, the complete separation of operations is not mandatory for networks serving fewer than 100 000 customers. Many distribution system operators benefit from this arrangement in Europe, mainly in Germany where there are 787 and 340 in Spain[4].

It should be noted that the disparity in local networks is accompanied by a diversity of burdens facing the operators. The licences awarded by the Member State (United Kingdom) are largely beyond community intervention. In contrast, the concessions awarded by the governments (Spain, France, and Italy) fall under the rules applicable to public procurement contracts, which are regularly under pressure from the European Commission to open up to further competition. Between the two, the municipal utilities (such as the *Stadtwerke* [public utility companies] in Germany) most often manage to obtain specific clauses making them immune from too pronounced community interventionism.

The System Operators' Tasks

Generally, system operators also perform the metering operations at the current inlet and outlet points. These tasks are burdensome in the distribution network, where the number of meters may reach several tens of millions. Metering at small clients is the responsibility of the Distribution System Operators (DSO) in Germany, Spain, France, and Italy, but it is the supplier's responsibility in the United Kingdom. Metering at large consumers and at delivery points on the distribution network is carried out by the Transmission System Operator (TSO). The number of meters they are responsible for does not exceed a few thousand.

The transmission networks provide long-distance connections. They receive the power generated from the large power stations and transmit it to inlet points on the distribution networks or to the premises of some very large consumers supplied with high voltage. Like their counterparts in the distribution network, the TSOs determine the investments and maintenance works required for the proper operation of the infrastructure.

They also perform tasks related to network operations, which are currently much more developed for transmission than for distribution. In the case of transmission networks, in addition to monitoring and intervention, the operator also ensures the balance between injections of power (by the generators) and withdrawals (by

4. European Commission, SEC document (2010) 251 dated 11 March 2010, page 36.

the consumers). The TSO performs this task by several series of actions:

They intervene as necessary with generators so that they adjust their deliveries, or with consumers so that they reduce their withdrawals.

They configure the network according to peak flow forecasts: the network is meshed (it can be represented by a grid) by manoeuvring devices online. It is indeed possible to deliver electricity flows in such a way that no plant risks overheating.

They implement auxiliary services (or network services) continuously ensuring proper adjustment of the frequency and voltage of the electric power.

Such opportunities for action currently remain lower on distribution networks, most of whose lines have an arborescent structure. Until recently, the operation mainly consisted of ensuring continuity of supply and of intervening when a failure occurs. But the injection of increasing quantities of electricity produced by small plants connected to local networks (wind, solar, biogas, etc.) now requires DSOs to control their infrastructure. In France, ERDF created network control agencies responsible for this task.

The TSOs have also been tasked with co-ordinating the physical flows with market exchanges. These include all transactions between generators, traders and suppliers, formalised through purchases and sales of electricity "blocks" for a given date and time range whether this transaction was conducted three years in advance or a few hours before delivery. Despite the extension of trading opportunities up to the day of consumption in some cases ("intraday" markets), the final adjustment is the sole responsibility of the TSO. It always has a portfolio of offers and chooses the best (depending on their price and location) to inject additional MWh or reduce the demand for surplus MWh to achieve a balance between generation and consumption at all times. Using a mechanism known as an "imbalance settlement", the cost of these additions or withdrawals is generally passed on by the TSO to the defaulting stakeholder, who has not honoured their generation commitment or when the client has exceeded the stated consumption, except in Great Britain, where this cost is shared between the consumer and generator according to a lump key.

Because of this responsibility, the TSOs are actively involved in the development of the products traded by stakeholders in the electricity market, whether these products are used in the Electricity Exchanges or in OTC transactions.

Finally, a specific task is assigned to the TSOs: the operation of interconnections, the sections of line connecting two transmission networks over a border. These crossing points have received particular attention for a long time for technical reasons, since they connect two independent areas for their balancing. With the spread of cross-border trade, congestion situations occur which require specific monitoring. By assuming the operation of interconnections, the TSOs have become the first truly European stakeholders in the electricity system and the body which brings them together, ENTSO-E, plays an important role in implementing community policies[5].

Compensation of a System Operator

The system operators bear the expenses relating to investments, maintenance, as well as operating the facilities, and in the case of TSOs, the operation of the electric system. By holding a monopoly on the networks, the operators operate under strict control of a national regulation authority.

With regard to distribution, the tasks described above are subject to a general authorisation procedure by the regulator. In the case of transmission, a specific approach is applied to investment in network extension and reinforcement: they can only be undertaken after approval by the regulator. Indeed, community law obliges operators to submit a 10-year development plan to their regulatory authority for the infrastructure[6] ; the regulator approves or requests changes, ensuring compliance with the 10-year plan developed at EU level by the joint system operators' body, ENTSO-E. In France, the CRE (Commission de Régulation de l'Energie [Energy Regulation Commission]) also has the authority to approve the implementation programme for the current year.

The transmission of the electrical power results in losses: a significant part of the energy injected in the network is lost as heat and is no longer found at the withdrawal point. In some countries, the generators or suppliers are required to compensate for these losses by increasing the injected volumes. They are responsible for the corresponding costs. Spain, Italy and Great Britain apply this rule. In Germany and France, the system operators compensate for the losses by purchasing the missing electricity on the markets. This is

5. ENTSO-E: European Network of Transmission System Operators – Electricity. This body received official recognition with the third directive on the internal electricity market (directive 2009/72) and its implementing regulations (714/2009), which assign specific tasks to it. While the first two directives provided the appropriate framework for the establishment of national markets, the 2009 directive was clear about the objective of seeing the foundation of a European-sized electricity market. Together with ENTSO-E, this third directive established ACER (Agency for the Co-operation of Energy Regulators), which is the embryo of a European regulator.

6. Directive 2009/72 dated 13 July 2009 on the internal electricity market (so-called third directive), article 22. This directive distinguishes between the owner of the infrastructure and its operator. The responsibility for extensions and reinforcements lies with the owner. In order not to complicate the writing, we are assuming here that the TSO is both the owner and operator.

not a small expense: it exceeds 2 billion euros per year in France for all of the losses on the RTE and ERDF networks[7].

In order to cover all of their expenses, the operators apply a tariff for network use set (or in some Member States only approved) by the regulatory authority. It accurately determines the "regulated asset base" which includes all the assets required for the operator's assignment, but only these, and regardless of the owner. The European rules enforce the so-called "postage-stamp" pricing principle and the costs borne by the consumer are independent of the distance the electric power has travelled[8]. The regulator seeks to establish a tariff that reflects the entire costs. This tariff provides for a change in the regulated assets to enable investments in modernisation and development; however it also has incentive provisions to improve productivity. The balance between the simple reflection of expenses ("*cost plus*" principle) and the pressure in favour of their reduction ("*yardstick competition*") always remains tricky to find. Excessive pressure leads to deterioration in the quality of service or unsustainable debt; conversely, the automatic passing on of costs discourages good management efforts.

As for distribution, most of the Member States make the scope of costs match those of the network. The "postage-stamp" is therefore paid at a different price depending on the area of residence, just like water or public transport, with a specific tariff for each community. France has chosen a novel approach by retaining full equalisation: the costs are aggregated nationally and then broken down into consumption, regardless of the place of connection. Therefore, the French model is the only one to offer a straightforward display of the expenses borne by the distribution network users. Due to tariff dispersion in other countries, comparison on a European scale is extremely difficult, with the costs varying according to population density, urban, rural or mountainous nature of the service area, local policies, etc.

The definition of the price zones for transmission has received special attention from the European Commission, since the long-distance network is the tool allowing generators to compete, which is the key objective of the liberalisation started since 1992. The more widespread the area covered by the "postage-stamp" is, the more fierce the competition will be. Consequently, the tariff structure was designed so that stakeholders in the market have a single area price by country for the transmission of electricity even when several TSOs operate there, as is the case of Germany, or where geographical restrictions warrant regional differentiation, as is the case of Italy.

7. Working group report chaired by M. Eric Dyèvre, Commissioner to the CRE: *Les dispositifs de couverture des pertes d'énergie des réseaux publics d'électricité*, March 2010, pages 11 and 33.
8. Regulation CE 714-2009 on the conditions for access to the network, article 14.

Therefore, the tariff is unique within each country, but the tariff components vary between countries. Figure 1.1 summarises these components.

Figure 1.1

Specific characteristics of tariffs in electricity transmission

		Cost allocation		Signal		Costs		Tariff
		Generator	Consumer	Temporal	Spatial	Losses	Auxiliaries	(€/MWh)
Germany		0	100 %	no	no	yes	yes	9.93
Spain		10 %	90 %	yes	no	no	no	12.02
France		2 %	98 %	yes	no	yes	yes	5.56
Great Britain	T	27 %	73 %	yes	yes	no	Included in A	10.25
	A	50 %	50 %		no			
Italy		0	100 %	no	no	no	yes	10.64

A: Adjustment cost
T: Transmission cost
Temporal signal: It is a tariff adjustment according to the season and the time of consumption (day or night, off-peak or peak period).
Spatial signal: A bonus or a malus affects the tariff applied at the injection and/or the withdrawal of power in some areas.
Losses: Here they represent the line losses affecting any electricity transmission.
Auxiliaries: This item includes the expenses incurred by the TSO to ensure the continuity of supply: compensation of units kept in reserve to offset for the sudden failure of a generator, consumption of devices stabilising the frequency and voltage, etc.
Tariff: This corresponds to transmission at a voltage of 150 to 220 kV, applicable under certain conditions specified in the methodological introduction on page 5 of the publication (power between 10 and 40 MW, duration equivalent to 5 000 hours per year, etc.)

Source: ENTSO-E, ENTSO-E Overview of transmission tariffs in Europe: Synthesis 2014, page 6 and page 10.

This table shows that the tariff applied to the transmission may impair competition between generators located on both sides of a border. Indeed, the share paid by the generator is set in the country where the power is injected, and that paid by the consumer, as well as the costs, in the country where it is withdrawn. For example, a French consumer buying German power will only pay the transmission expenses applied in France (5.56 €/MWh under the terms of the above table). A French generator wishing to export to Germany will pay an injection charge and their German purchaser will pay the transmission costs in force in Germany (9.93 €/MWh). The injection charge on the RTE high voltage network has a fixed component (up to 10 000 € per year) and a variable component (0.19 €/MWh)[9].

A wide disparity of situations also appears for new electricity generators, who bear the connection costs to the network which vary widely depending on the country. In some cases, the generator only pays for the connection between their plant and the existing network ("*shallow cost"*); in other cases, they are invoiced for the reinforcement costs of facilities downstream of the connection point ("*deep cost"*). The European legislation requires that the fees charged are based on the actual costs, but without detailing the range of expenses to be taken into consideration. Furthermore, the directive on the promotion of renewable energies allows the Member States who so wish to pool the entire costs across all network users. In the latter case, the generator does not pay for their connection to the network[10].

Finally, a unique factor worth mentioning: single transit is not compensated. "Single transit" is designated here by power flows which cross a country from one border to another pursuant to a contract negotiated between two third countries. Specifically, a contract for the supply of power from Spain to Italy, for example, would result in a transit flow through France without payment of transmission rights. The only compensation that France may claim is with regard to the line losses on its network, as RTE will be required to supply at the Italian border the volume entered at the Spanish border, while any transmission results in losses. This compensation is calculated by ENTSO-E according to a complex rule. If transit were to increase significantly with an increase in interconnection capacity, some countries would be compelled to reinforce their infrastructure favouring passage through their country without receiving any income to the tune of their investment. In March 2013, the Agency for the Co-operation of Energy Regulators (ACER) requested the European Commission to amend the regulation in force to introduce compensation for the costs incurred by transit flows (*loop flows*)[11].

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9. Consultation of the Energy Regulation Commission on 7 May 2014 with a decision to change usage tariffs for a public electricity network in the field of HV voltage on 1st August 2014, page 5.
10. Directive 2009/28 dated 23 April 2009 on energy generated from renewable sources, article 16.
France has chosen a middle path, concerning only a part of the reinforcements at the expense of newcomers. For example, the connection of a solar farm may require the installation of an additional transformer. Its capacity will be much higher than the additional power of the farm, as this will only pay a fraction of the corresponding cost, and each later newcomer will bear a part of the residual cost.
11. ACER: Recommendation dated 25 March 2013 advocating amending the European regulation CE 838/2010.

The Cross-Border Trade in Electricity

The first electric link between European countries was commissioned in 1921 and a co-ordination body was set up from 1925: UNIPEDE (Union Internationale des Producteurs et Distributeurs d'Electricité [International Union of Producers and Distributors of Electrical Energy])[12]. At the end of the Second World War, the United States, then ahead in the operation of interconnected high voltage lines, encouraged beneficiary countries of the Marshall Plan to develop their electricity trade. The existing connections between member states of the ECSC (European Coal and Steel Community) plus Switzerland were hence used to amalgamate the hydroelectric and thermal power generation to compensate for the lack of coal marking this period.

The networks have been gradually extended across Europe, crossing the Iron Curtain. The cross-border interconnections have helped to reinforce the security of supply through mutual assistance in the event of problems in a country. Subsequently, the role of economic optimisation regained importance with the development of "ad libitum sales" up to the end of the 20th century through agreements between generators, which then had a monopoly situation in each area. However, in most countries, the power generation facilities were intended for electrical self-sufficiency, so that exchange capacities at the borders remained limited.

With the end of the monopolies, competition between generators became the corner stone of the internal electricity market. After the market organisation in each Member State, the time came for the introduction of competition at European level. However, the cross-border infrastructure did not provide sufficient flow to meet all demands. In order to put all operators on equal terms in situations of scarcity, long-term contracts whereby former generators reserved exchange capacities at the borders were revoked and these capacities are now being allocated by an auction mechanism. The revenue from these auctions is subject to very restricted use, limited to the maintenance and development of interconnection infrastructure[13]. The prices resulting from this implemented mechanism are integrated with dedicated algorithms to the energy prices traded on either side of a border between traders (known as implicit auctions) on the Electricity Exchanges or in off-exchange transactions.

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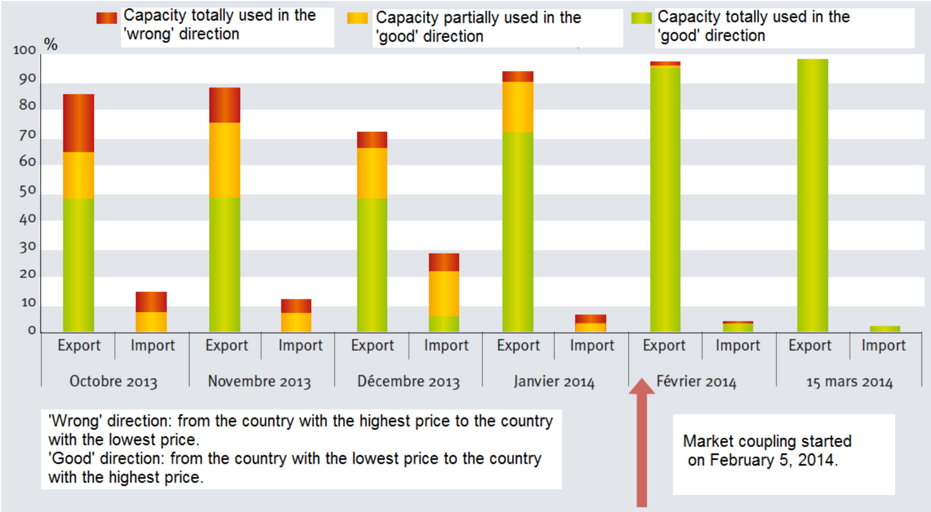
12. UCTE – UCPTE: The 50 Year Success Story – Evolution of a European Interconnected Grid, page 8.
13. Regulation CE 714-2009 on the conditions for access to the network, article 16.

This procedure has facilitated "market coupling", a device presenting the offers of foreign generators according to the same criteria as local offers; ensuring stakeholders active in the wholesale markets do not differentiate between them. This device specifically ensures that the interconnections are always used in the direction from the country where electricity is cheapest to the one where it is most expensive. In 2015, it will affect 19 countries. The graph in figure 1.2 shows the effect of market coupling on the use of the underwater link between France and Great Britain.

Figure 1.2

Effect of market coupling on the flows between France and Great Britain:



Source: CRE, *Décryptage n° 40*, March-April 2014, page 7

For the year 2012, the CRE estimated that market coupling between France, the Benelux countries and Germany saved approximately 50 million euros in procurement costs and that without electricity imports, French consumers would have suffered from load shedding and blackouts during the cold spell in February 2012[14].

Also new calculation methods should result in increased exchange capacities at the borders in 2015: the so-called flow-based market coupling whereby operators adopt the network configuration which satisfies the cross-border trading requirements at the lowest cost. These developments result largely from the standardisation of the procedures applied by the European TSOs, conducted through "network codes", whose revision was deliberately geared towards an increase in cross-border trade, under the auspices of ACER (Agency for the Co-operation of Energy Regulators). The flow-based coupling has been implemented in Western Europe since 21 May 2015.

14. CRE, Échanges d'électricité aux frontières et gestion des interconnexions en 2012, June 2013, page 3.

The complexity of the movement of electrical flow experienced a worrying demonstration on 4 November 2006. In the evening, work on a high voltage line located in the Bremen region, which was inadequately reported to the TSOs in neighbouring countries, caused load shedding for a period of an hour in several parts of Europe as far as Portugal! The Transport System Operators have since been provided with a European co-ordination body, CORESO (Coordination of Electricity System Operators), so that each operator takes the existing situation in neighbouring countries into account. It does not have an operational task, but constantly checks in advance the compatibility of decisions with regard to the highest possible security of supply.

Network and Interconnection Development Policies

Nearly 12 years after the liberalisation of the electricity sector, the interconnection of the long-distance transmission networks has become the key instrument which competition between the European operators is based on. Indeed, a development of the cross-border connections fulfils the objective of increasing competition beyond its current level. Regardless of this policy, the EU has chosen to increase the share of renewable energies in its energy mix and the situation of Member States ahead of this criterion shows that expansion of the electricity interconnections becomes essential for the development of these energies, in addition to the increased capacity of local networks. Finally, concerns relating to the security of supply recently experienced a new urgency; and the reinforcement of these trans-European networks is part of the effective instruments to improve this security. Three targets might therefore be achieved by a single effort in increasing the physical exchange capacities between countries.

Political Integration and Security of Supply

The foreign policy of the EU has for a long time consisted of replicating the model of its own history: freeing trade between parties to facilitate an institutional rapprochement. In this sense, it seems natural that networks are crossing the external borders of the EU towards the Balkans, the Maghreb, Turkey, Ukraine, and Russia...Economic interdependence is seen as the base of security of supply.

The events of recent years have challenged this doctrine. Two trade disputes between Ukraine and Russia led to Russia partly suspending its gas deliveries in 2006 and then in 2009. While it states its ambition to become a major energy "hub", Turkey’s government is keeping its distance from Europe. The ongoing civil war in Syria and Libya weakens neighbouring countries. Last but not least, a serious crisis has been pitting Ukraine against Russia again since the end of 2013, threatening to reach uncontrollable proportions. In all these situations, the political will of the stakeholders has made them put their economic interests to the background.

Faced with this new situation, the EU is refocusing its security policy by emphasising mutual assistance arrangements between its members, in the spirit of the regulation on gas approved after the 2009 Russia-Ukraine crisis[15]. For electricity, the pooling of resources to ensure the security of supply is now among the priorities that the European Commission has set itself, and appears as a major incentive for the "the energy union" proposed to the Member States on 25 February 2015[16].

The Council of Europe of 26 and 27 June 2014 specifically dealt with the "energy" part of the file relating to security within the European area. In its conclusions confirmed in the following October, the Heads of State s and of governments approved the guidelines set out by the Commission some months earlier[17]. They are mainly aimed at oil and gas; electricity is however affected by four recommendations:

Control demand by emphasising energy efficiency efforts.

Develop renewable sources, which reduce dependency on suppliers outside the EU.

Improve the operation of the internal market, because for the Commission, a well-integrated, liquid, and competitive market can provide short-term solutions in the event of disruption.

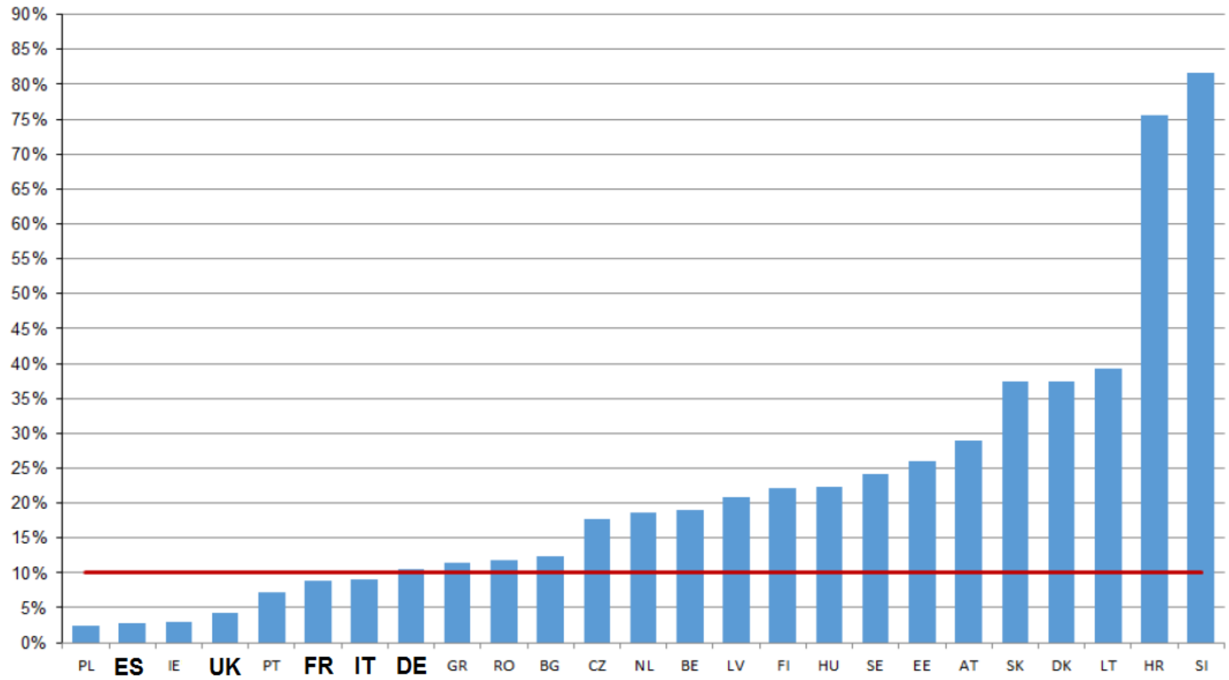
Aim for an interconnection level of 10 % of the installed capacity for all Member States from 2020 and 15 % in 2030. The Commission believes that such a level is required both for the proper operation of the market and for mutual aid in case of emergency.

It can be seen in figure 2.1 that the 2030 objective was already surpassed in 2012 for 14 EU Member States; however it is distant for France and four neighbouring countries: Germany (DE), Spain (ES), Italy (IT) and the United Kingdom (UK).[18]

15. Regulation 994-2010 to ensure the security of natural gas supply, dated 20 October 2010.
16. European Commission, A Framework Strategy for a Resilient Energy Union, COM (2015) 80 final.
17. European Commission, *European Energy Security Strategy*, COM (2014) 330 final dated 28 May 2014.
18. The ratio relating to the three Baltic countries is misleading, since it includes the countries' connections between each other. The interconnections with Scandinavia and Poland are low capacity.

Figure 2.1

Ratio of interconnection capacity to installed capacity:



Source: European Commission, *European energy security strategy - In-depth study of European Energy Security*, SWD (2014) 330 final/3, 2 July 2014, page 171.

If the objective intended by the interconnections was restricted to security of supply, the ratio to take into account would be "Interconnection capacity to Required capacity during consumption peaks". By setting installed capacity as the denominator, it is understood that the objective becomes power export, and quite specifically, the export of electricity from renewable sources, since these sources require a considerable installed capacity compared to the volumes produced. Indeed, they suffer from a low load factor, their output being concentrated in a small number of hours in the year (on average in Europe, 12 % for solar energy and 20-25 % for onshore wind energy[19]). The table in figure 2.2 clarifies this point based on the Spanish example.

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19. Sources: Solar: Author's calculation from published data in Observ'ER, *Photovoltaic Barometer*, April 2015, pages 9 and 10.
Onshore wind: European Commission, Joint Research Center, 2013 JRC *wind status report*, page 50.

Figure 2.2

Development of installed capacity in Spain between 2004 and 2014:

	Annual consumption TWh	Peak power demand GW	Installed capacity GW	Which is wind or solar capacity GW
2004	**235**	**37.7**	**67.9**	**7.8**
2014	**243**	**38.7**	**102.3**	**29.5**

Annual consumption:

- Year 2004: “El sistema electrico espanol” (“The Spanish Electricity System”) 2004, page 21
- Year 2014: “The Spanish Electricity System 2014”, preliminary report, page 7

Installed capacity & wind and solar capacity:

- Spreadsheet Potencia instalada – Marzo 2015 (Installed capacity - March 2015), sheet 3

Peak power capacity:

- Spreadsheet Maximo de potencia demanda horaria (Hourly maximum peak demand), sheet 3, line Demanda maxima horaria peninsula (Hourly maximum demand in the peninsula)

Sources: Red Electrica de Espana (Spanish Electricity Network) data relating to the peninsula only.

It can be seen that over the last ten years, consumption in Spain has only increased by 3.4 %, with the peak power demand experiencing an increase of 2.7 %. At the same time, the installed capacity rose by 51 %, mainly as a result of wind and solar generation whose capacity has been multiplied by 3.8. Hence, the Spanish decision to boost the use of renewable sources results in the increase of interconnection capacity with France. The objective of 10 % would have required 6.8 GW in 2004 and it now requires 10.2 GW in order to achieve it and 15.3 GW if this objective moves to 15 % of the installed capacity. For the record, the interconnection capacity between the two countries was increased to 2.8 GW with the new line (Baixas – Santa Llogaia) coming into operation in 2015[20], or 7.2 % of the peak power demand in Spain in 2014, but only 2.7 % of the installed capacity.

20. RTE, website visited on 26 April 2015: <www.rtefrance.com/fr/projet/franceespagnecreationdunenouvelleinterconnexionsouterrainede65km?profil=42>.

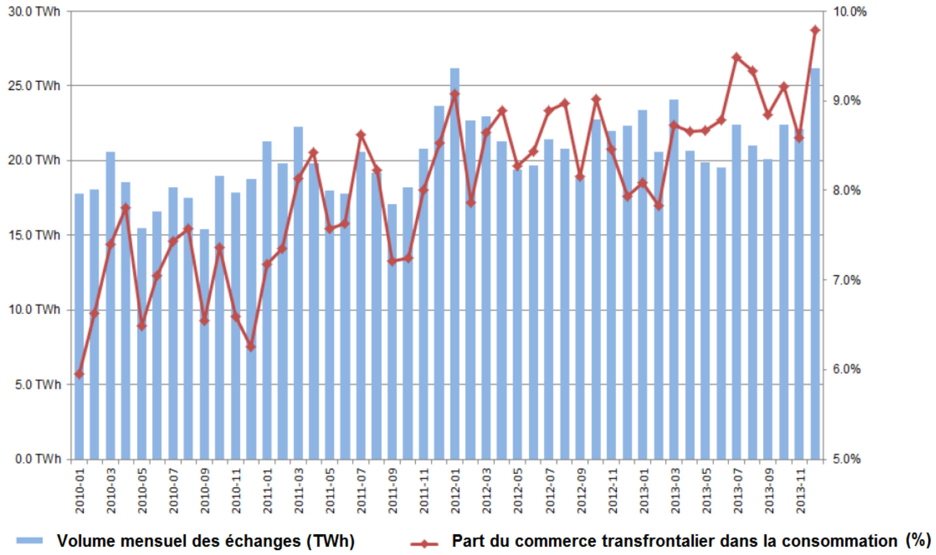
The Requirements Related to the Internal Electricity Market

We saw in chapter 1 that new operation methods, as well as economic (auction process of cross-border capacities) and technical methods (standardised network code and market coupling) have enabled the most to be made of the existing electricity interconnections between the Western European countries. The developments can be measured using several criteria: the European Commission includes the growth of cross-border electricity trade and the convergence of wholesale market prices.

The graph in figure 2.3 illustrates the increasing share of electricity that has passed through at least one border before consumption between January 2011 and December 2013. The corresponding volumes were between 15 and 20 TWh per month in 2011. They reached the region of 20-25 TWh per month in 2013. In relation to the total volume consumed, the share of intra-community trade has increased from the mean level of 7 % in 2011 to 9 % in 2013.

Figure 2.3

Cross-border exchanges in electricity consumption (2011-2013):

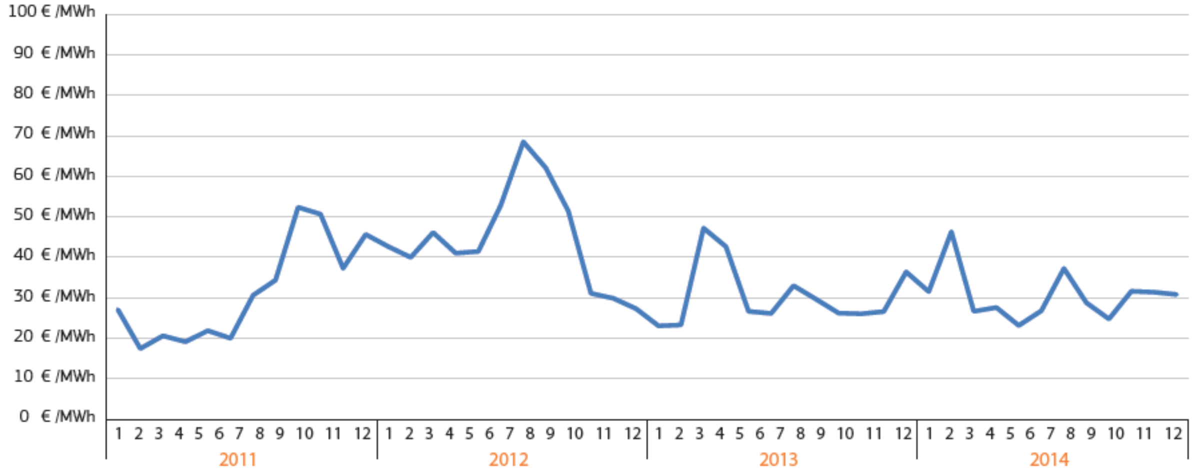


Source: European Commission, *Trends and Developments in European Energy Markets 2014*, Annex to the Communication dated 13 October 2014, SWD (2014) 310 final, page 33.

The graph in figure 2.4 represents the difference in the electricity wholesale market price between the cheapest region and the most expensive region. Despite a still high volatility, it is noted that this difference has tended to decrease, from approximately 40 €/MWh between 2011 and 2012 to 30 €/MWh since 2013.

Figure 2.4

Difference in the wholesale market price between the most expensive region and the cheapest region:



Source: European Commission, Quarterly report on European electricity market, 4th quarter of 2014, page 12.

Considering the results based on the two criteria above, it appears that the measures taken in continuation with the third directive on the internal electricity market are delivering results.

However, the European Commission reports that since the opening of the markets, the physical border exchange capacities have hardly increased[21]. It considers that an increase in these capacities is essential to achieve further progress. The additional interconnection requirements between two countries may be assessed by considering the price differences in their respective markets. The map shown in figure 2.5 shows these differences.

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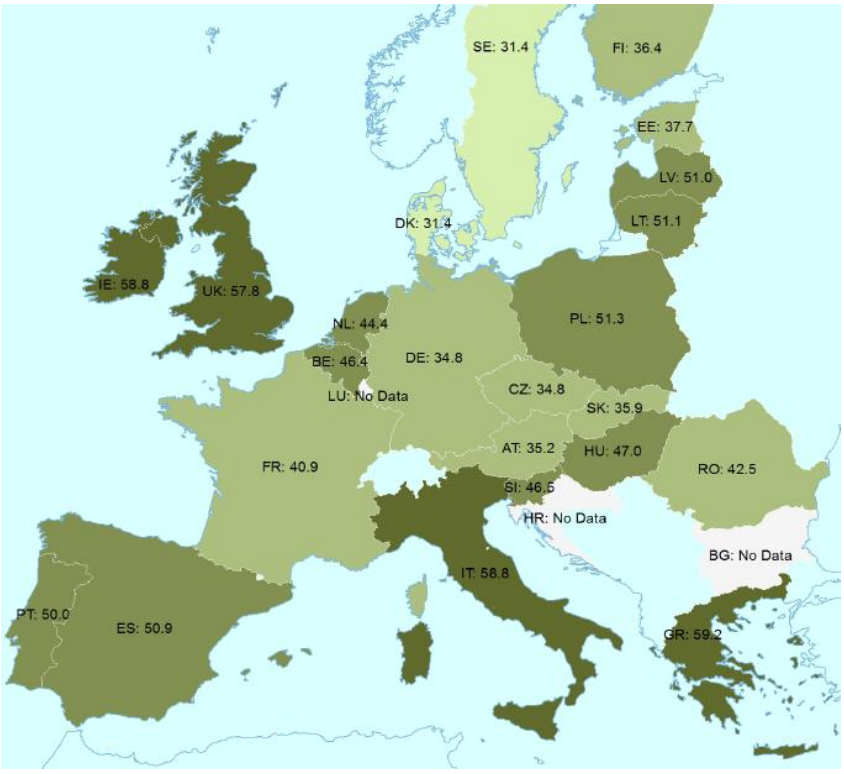
21. In the case of France, they have remained stable at around 15 GW throughout the last decade. Only the new connection with Spain will provide a significant increase. The power of this line (1.4 GW) is equivalent to an adjoining addition of 10 % to the capacities available at the borders of France (and a doubling of the electricity capacity connecting Spain and France). However, the characteristics of a line crossing the border are not sufficient to determine the transit potential. Indeed, the latter depends on the availability of infrastructure in each country on both sides of the connection, and this availability varies depending on the local conditions (for example, consumption peak or off peak). Thus, the average commercial capacity available for exchanges at the French borders is 12 GW at export and 8 GW at import (CRE, *Echanges d'électricité aux frontières*, June 2013, page 15).

Figure 2.5

Average prices observed on the wholesale markets in the fourth quarter of 2014



Source: European Commission, Quarterly Report on European Electricity Markets, fourth quarter of 2014, page 10.

However, cross-border connections alone are not enough: in some cases, it will also be necessary to develop the domestic network on both sides of the border. For example, a memorandum from the German TSO Tennet indicates that the export capacity to the Netherlands is approximately 2.5 GW when there is no wind; during peak wind, this falls to 1.5 GW because of network saturation upstream of the border[22]. Therefore, it would be pointless to reinforce the interconnection capacity between the two countries if the network in Germany were not strengthened. Another example is provided by the maps of the ENTSO-E organisation[23], referring to a "virtual borderline" along a Bordeaux-Marseilles axis, which would be a new bottleneck restricting the exchange opportunities between Spain and France if the trans-Pyrenean capacity increased. Currently, ENTSO-E believes that this virtual barrier already obstructs the proper operation of the French domestic market.

22. Tennet, Bestimmungen der Übertragungskapazität an auktionierten Grenzkuppelstellen der TenneT, 30 July 2012, page 7.
23. ENTSO-E, Ten Year Network Development Plan (TYNDP), 2014, page 59.

The Requirements Created by Renewable Energies and New Uses

The Treaty of Lisbon ("Treaty on the Functioning of the European Union"), which was adopted in December 2007, supports the development of renewable energies among the objectives of the Union's energy policy (article 194). A common framework was approved in 2009 to comply with this guideline. It sets a target of achieving on average 20 % from renewable energies in consumption in 2020. Each Member State has established a national plan to achieve this. Analysis of the 27 plans carried out in 2011[24] shows a general preference for renewable electricity, which should represent 34.5 % of the total electricity consumption in 2020. Hydroelectric, biomass, and biogas resources are limited, and most of the Member States are relying on wind and solar generation to fulfil their obligations. The European Council of 23rd and 24th October 2014 endorsed the European Commission's recommendation which advocated aiming for a target of 27 % from renewable energy in 2030[25]. According to the Commission's analysis, this level is equivalent to 45 % from renewable electricity[26], and in all likelihood, wind and solar power will dominate the new supplies.

Requirements relating to the transmission networks

Well before 2009, several Member States had committed to ambitious development programmes for these power generation sources, in particular Denmark, Germany and Spain. Their experience highlights that the development of wind and solar energy requires both an extension of their domestic transmission network and an increase in cross-border exchange capacity. Denmark, a leading country for wind energy, has been able to develop electricity generation from this source due to its very high level of interconnection: the lines connecting it to neighbouring countries allow imports or exports equivalent to 37 % of its total generation capacity. On favourable windy days, but with a low domestic consumption, the country can discharge the surplus to neighbouring countries; it can import without restriction on windless days but with a high local demand. The case of Germany demonstrates the opposite situation. On the one hand, the country lacks domestic lines capable of transmitting wind power from the north of the country, where the largest capacities are installed, to the south, where the large consumption centres are located, and on the other hand, the level of interconnection between Germany and its neighbours remains modest (around 10 % of its total

24. Croatia had not yet joined the European Union.
25. European Council, Conclusions adopted by the European Council (23 and 24 October 2014), EUCO 169/14, page 6.
26. European Commission, A policy framework for climate and energy in the period from 2020 to 2030, COM (2014) 015 dated 22 January 2014, page 7.

generation capacity)[27]. The inadequacy of the transmission network, domestic and external, results in curtailments of wind power generation or negative market prices.

At European level, ENTSO-E clearly states that the integration of renewable sources is the major determining factor of the 150 billion euros that it advocates investing in transmission networks by 2030. The target selected by the European Council, or 45 % from renewable electricity in 2030, represents the lowest scenario envisaged by ENTSO-E ("Vision 1"), while its highest scenario places the share of these sources at 60 % ("Vision 4"). It will be noted that the network configuration proposed by ENTSO-E in the 2014 10-year development plan does not mediate between these two perspectives. It is designed for the second, therefore 60 % from renewable electricity in 2030, but the writers state that the return on investments required would be lowered if this rate "only" reached 45 %.

Thus, the 2030 plan is a step towards a network in 2050 to accommodate an even higher share of renewable sources using the "electricity highways", whose characteristics will be revealed at the end of 2015, at the end of the *e-Highway 2050* groups study[28]. Furthermore, it should be noted that the plan aggregates the forecasts from the Member States, without making a selection under the criteria specified by the European Commission. Each Member State may therefore influence the joint plan by its national choices.

Basically, the economic benefit of interconnections previously lay in observing that the consumption peaks did not occur at the same time in neighbouring countries. The peak of country A could therefore be satisfied by available power stations in country B at a lower cost than the peak resources of country A. Can this logic be transposed to renewable energies? Its advocates claim that the wind does not blow at the same time in A and B; when it blows in A, it becomes legitimate to export the surplus from country A to country B. The data sets produced for Europe are still too short to confirm or deny this assumption; intuitively it seems plausible for the wind, but questionable for sunshine, as all the countries located on the same meridian may reach their peak solar generation at the same time. Yet, countries cannot all be exporters at the same time... In periods of complementarity, this type of export would be justified by a legal obligation giving priority to the injection of renewable electricity and no longer necessarily for economic reasons, since country B could have conventional generation at a lower cost than that of wind energy. In this situation, the cost difference would be filled by a financial support mechanism for wind power, borne by the consumer in country A. Thus, in order to meet a binding objective (27 % from renewable energy in 2030), the community would incur the expense

27. Idem source as figure 2.1.
28. ENTSO-E, Ten Year Network Development Plan (TYNDP), 2014, pages 9, 10 and 95.

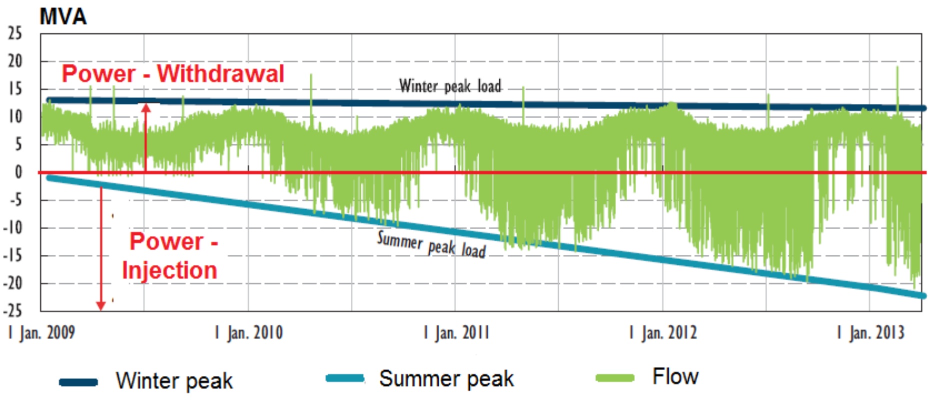
corresponding to this cost difference and that of the construction of lines to avoid shutting down intermittent capacity.

Requirements relating to distribution networks

Most of the wind or solar power generation sites are connected to the distribution network. Its infrastructure has been calibrated depending on consumption; yet the new sources are injecting much higher power to that which consumers are withdrawing, as is shown in figure 2.6. Moreover, the DSOs apply a maximum utilisation factor to consumption, since it has been proven that clients never all withdraw the maximum power simultaneously. There is no maximum utilisation with decentralised power generation: on the same electric line, all the solar or wind generation plants reach maximum power simultaneously.

Figure 2.6

Development of flows on distribution infrastructure



Up to 2010, the calibration of this infrastructure corresponded to the maximum withdrawn power (winter peak). The connection of solar power generation plants now leads to it being calibrated according to the maximum injected power (summer peak). The MVA unit reflects the power in MW.

Source: International Energy Agency, *The power of transformation*, 2014, page 42.

The effort required to increase the injection capacity on the networks varies between countries. Those which have the highest population density, generally have a high density of existing electricity lines, thereby providing a greater reception capacity. So, the German (5 km of line per km^2) or Italian (3.6 km/km^2) distribution networks require fewer reinforcements than their French (2.5 km/km^2) or Spanish counterparts (1.3 km/km^2)[29].

29. Eurelectric, Power Distribution in Europe – Facts and figures, 2013, page 17.

On the other hand, regardless of their density, when they receive additional generated power, all distribution networks require additional equipment to ensure the quality of power distributed (stable frequency and voltage), as well as the protection of devices and safety of staff working on the facilities. The existing devices, designed for one-way power flow (from the high voltage power station to the end consumer), no longer fulfil their role in the case of downstream injection. The additional equipment requires a specific design for the addition of a solar or wind generation plant in order to take the intermittent nature of these two sources into account.

Distribution networks are also affected by transfers of use to the advantage of electricity, which are instigated by mobility policies (generally encouraging electric vehicles) and heating (often favouring the heat pump). The European Directive 2014-94 on the use of infrastructure for alternative fuels has very detailed indications about the charging points for electric vehicles. No numerical objective has been set for the Member States, but these are required to equip their cities, and roads if required, with a number of charging points proportional to the number of electric vehicles in circulation at the latest by 2020 (Article 4 of the Directive). The Commission will draw up recommendations on this proportionality. In other words, if the manufacturers manage to sell these vehicles, the Member States will be required to follow by introducing a suitable charging infrastructure.

These charging stations pose a thorny problem for the DSOs. The total consumption for the vehicle load remains moderate: ERDF estimates that 2 million electric vehicles would only total 2 % of additional consumption per year in France, indeed a modest increase. However, the demand at the time of charging could destabilise the network. So, 2 million vehicles charging simultaneously would require 10 % of the installed capacity in France if it was performed in slow mode and 88 GW, or two-thirds of the total capacity of the French power generation facilities if it occurred in fast mode[30] ! Transmitting a signal to the user of these stations, carrying an incentive effect (if power generation available) or deterrent (in a peak consumption period) therefore appears essential.

This type of signal will come from communicating devices, which DSOs are gradually equipping their infrastructure with. At the end points of the networks, "smart meters" will be able to provide customers with all the information, allowing them to instantly monitor their consumption and possibly to move part of it to get the best price offers from their supplier. Online, "smart grids" will facilitate control of the infrastructure depending on injections, withdrawals, and potential incidents, a new task for most of the DSOs.

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30. ERDF, *La mobilité électrique : un nouveau défi*, 2012, page 9. Slow mode permits a full charge in around 8 hours and fast charge in 30 minutes.

Lessons learned from early experiences were used to assess the requirements at European level for 2020 and beyond, as well as for the reinforcement of the distribution networks for additional equipment. The number commonly selected puts the necessary investment at 400 billion euros between 2012 and 2020[31]. This sum includes the installation of 200 million smart meters by 2020, or a service of 80 % of established consumers in the 14 Member States which have chosen general deployment. Spain, France, Italy, and the United Kingdom are among them. Germany has restricted the installation of these meters to large clients, or only 15 % of all consumers.

Regulatory Framework and Community Subsidies

Article 170 of the Treaty on the Functioning of the European Union stipulates that "The Union shall contribute to the establishment and development of trans-European networks [...] in energy infrastructures". The decision to award, by virtue of this article, a subsidy from the community funds has taken various forms since 2006. The selected projects firstly received a contribution from the "Trans European Network Electricity" (TEN-E) programme, and then the "European Energy Program for Recovery" (EEPR)[32].

In 2013, a new regulation was adopted[33]. For electricity, the following summary can be made:

The regulation specifies four priority "corridors"; contrary to their name, they do not designate corridors for the passage of lines, but geographical areas within which renewable electricity generated is to be integrated and cross-border exchanges facilitated. For example, "corridor 1" brings together all the countries bordering the North Sea and aims to discharge power from offshore wind farms. The regulation also provides for a subsidy of experiments implementing smart grids.

The projects included in these corridors and fulfilling certain conditions have the title "Projects of Common Interest". They can compete for the award of a financial subsidy from the "Connecting Europe Facility" (CEF-Energy) special fund, provided with 5.8 billion euros for the period 2014-2020 (or 3 % of investment requirements)[34].

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31. Eurelectric, Power Distribution in Europe – Facts and figures, 2013, page 6.
32. The France-Spain trans-Pyrenean link, which came into operation in 2015, received a subsidy of 225 million euros from the EEPR programme.
33. Regulation 347/2013, On guidelines for trans-European energy infrastructure, dated 17 April 2013.
34. European Commission, *Implementation of TEN-E, EEPR and PCI Projects,* SWD (2014) 314 final, 13 October 2014, pages 19 and 20.

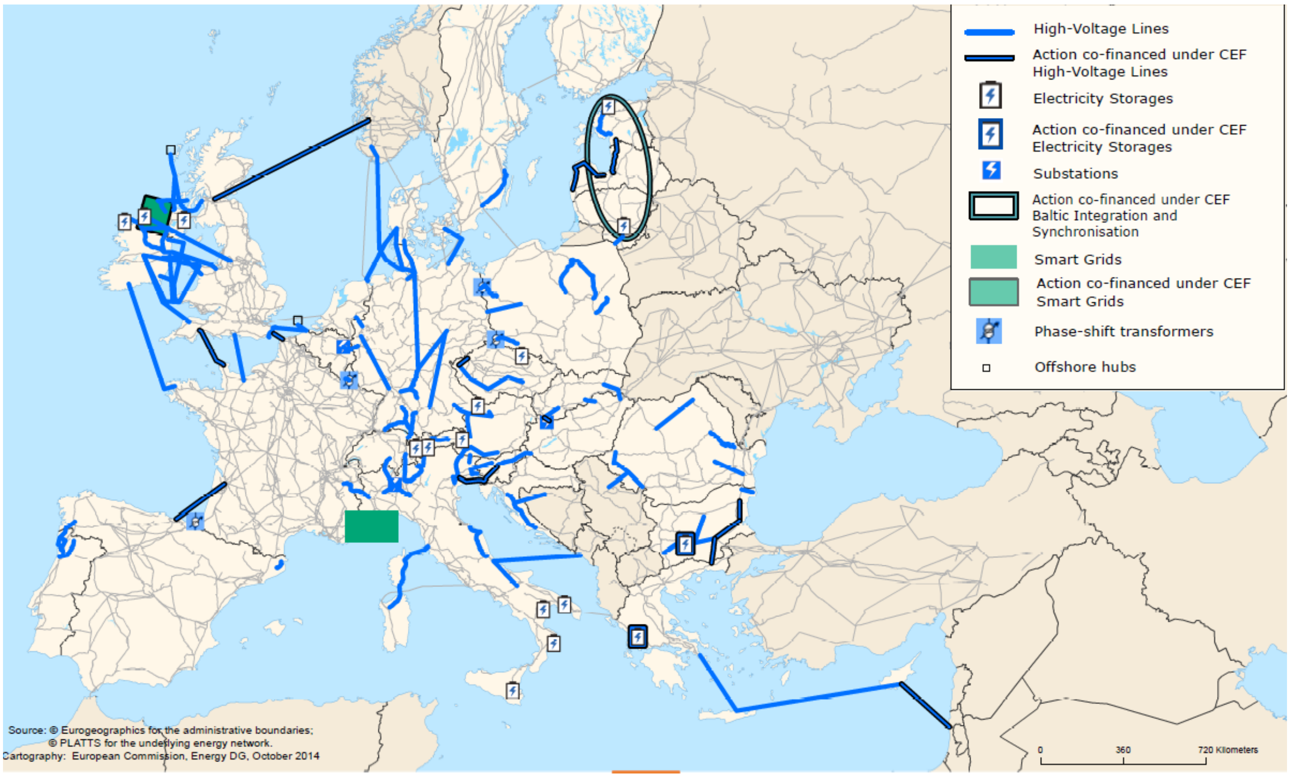
The tenders take place every year. At the end of 2014, the number of eligible projects amounted to 132. They were entitled to a total contribution of 646 million euros. They appear on the map shown below (figure 2.7). At the end of April 2015, only 17 of them have reached the final stage, resulting in the granting of a subsidy.

Among the criteria to be fulfilled are compliance with a completion timetable, application of a specific authorisation procedure, whose implementation must not exceed 42 months, as well as the preparation of a cost/benefit analysis according to a methodology published by ENTSO-E. When this study shows insufficient profitability, the Member States may be authorised to pay further contribution in derogation to the principle of financing by the network users.

It should be noted that Spain only appears in one of the four corridors decreed by the regulation of 2013; France, Italy, and the United Kingdom appear in two corridors; Germany is part of the four corridors. This specific characteristic is probably explained by Germany having been able to register domestic routes between the north and south of the country among the Projects of Common Interest, while most of the other projects selected consist of cross-border facilities.

Figure 2.7

Map of the facilities selected for the "Projects of Common Interest" at the end of 2014:



The 17 infrastructures selected for the award of a financial subsidy are outlined with a black border (the legend describes them under the name "*Action co-financed under CEF High-Voltage Line*"). France is benefiting for three underwater cable projects which it is associated with: one link through the Bay of Biscay with Spain and two under the English Channel with Great Britain.

Sources:

▪ European Commission, *List of actions selected for receiving financial assistance under CEF-Energy as of 21 November 2014.* [CEF: Connecting Europe Facility].

▪ European Commission website, DG Energy, visited on 26 April 2015: `https://ec.europa.eu/energy/node/22`

Uncertainties

The EU is committed to a vast expansion and reinforcement programme of its electricity networks, requiring the investment of several hundreds of billions of euros by 2030. Around two-thirds of these amounts will be assigned to the distribution networks and a third to transmission facilities with specific emphasis on cross-border connections. The primary objective of this effort concerns the absorption of increasing volumes of electricity from renewable sources; however the construction of the new transmission lines also aims to improve the security of supply and to facilitate permanent access to cheaper power generation. So, planned investments should provide an economic benefit. Without questioning the quality of the studies which assessed this benefit, this chapter discusses the assumptions underlying their results, and highlights the remaining uncertainties.

Uncertainties Related to Energy Efficiency and to Technical Developments

While the networks are being developed, the Member States are required to increase their energy efficiency efforts within the framework specified by the European directive of October 2012[35]. The national action plans developed by the Member States in accordance with this directive do not specify the share of electricity in the overall energy consumption, so that the TSOs retain their own assumptions. These demonstrate the uncertainty about electricity consumption: from 3 610 TWh (Vision 1) to 4 327 TWh (Vision 4) for ENTSO-E in 2030 (or a difference of approximately 20 %)[36]. This result aggregates countries likely to experience contrasting developments; in some cases the difference may be greater. For instance, by adopting the same assumptions as ENTSO-E, the difference between the foreseeable low or high consumptions in Italy

35. Directive 2012/27 relating to energy efficiency, dated 25 October 2012.
36. ENTSO-E, Ten Year Network Development Plan (TYNDP), 2014, page 9.

would reach 30 % in 2030[37]. In France, the difference is at 22 % according to RTE (difference between scenarios A and B in 2030)[38].

Consumption is not the determining criterion for the construction of infrastructure: its design depends either on the peak power demand or the power to be received from power generation facilities. With facilities receiving an increasing share from renewable sources, capable of providing 45% of European power generation in 2030, this second criterion becomes overriding. The infrastructure making up the networks is not modular: when installing a line or transformer, capacity is immediately increased by a factor of 50-100%, even if the requirement which the new facilities meet is much lower. Therefore, the uncertainty about consumption generates a significant financial risk, because the investment amount depends primarily on the installed capacity, but its profitability largely depends on consumption. Figure 3.1 shows that the length of the high voltage network is changing significantly like the installed capacity, and not like consumption. For its part, installed capacity sets the stage for the addition of capacities from renewable sources.

Figure 3.1

Developments in high voltage networks in the ENTSO-E area

	Cons. TWh	Growth	Installed Capacity GW	Growth	E-RES Installed Capacity GW	Growth	HV Lines x 1000 km	Growth
2009	3231	2,4 %	881	14,1%	101	107,8%	270	12,1%
2013	3308		1005		210		302	

The years 2009 and 2013 were selected since they represent the two extremes of a series of homogeneous data set. The scope of ENTSO-E extends beyond the EU (it includes Iceland, Norway, Serbia, Switzerland, etc.) The extension of lines only represents a part of the developments; recalibrations to levels of greater power and the installation of "smart" devices should be taken into account.

Source: ENTSO-E, *Statistical factsheet*, 2009 & 2013.

Consumption projections resulting in the figures quoted in the first paragraph are generally based on the macro-economic assumptions prepared at national level by the Member States: demographics, GDP growth rates, and energy intensity. They do not properly take the effect of technological developments into account. Yet, the considerable work in research and development undertaken in most of the major countries in the world could lead to significant progress in some applications influencing the network use. The simplest example is the decentralised storage of electricity. Improved

37. TERNA, *Piano di svilupo* 2014, page 29.
38. RTE, *Schéma décennal de développement du réseau* – Edition 2014, final version dated January 2015, page 44.

technical performance of batteries, accompanied by a decrease in their costs, would certainly stimulate self-consumption. This would result in a different availability from wind, and especially for solar power generation.

Therefore, networks receiving these facilities, calibrated nowadays according to their maximum injection capacity, would become oversized. Moreover, the average consumption withdrawn from these networks could decrease, despite the introduction of new demands like those for electric vehicles, which would further extend the time of return on investments made in order to reinforce them. Combined with the advent of smart devices enabling the consumer to finely control their consumption, the economic equation of system operators would be significantly changed.

Economic Uncertainties

Uncertainties about the costs and tariffs

The construction of major infrastructure, such as high tension lines, comes up against strong local opposition. Residents' associations have a considerable legal arsenal to obstruct sites which the EU and the Member States opened up for them by signing the Aarhus Convention[39] and by imposing stringent environmental constraints on large-scale works. Two recent examples demonstrate the strength of local associations:

The trans-Pyrenean connection between Spain and France only came into being after more than a decade of negotiations and the decision to place a part of the infrastructure underground.

In Germany, despite a legislative framework intended to accelerate the construction of lines, which restricts the obstructive power of the Länder (federal states), the construction of the high voltage infrastructure provided for in the law has been considerably delayed. In 2013, only 52 km of the transmission network were commissioned, which brought the completed work to 268 km, for 1 855 km planned[40].

39. The Aarhus Convention requires detailed information made available to the public and its involvement in decisions. It guarantees opponents the right to appeal in court.
40. French-German Office for Renewable Energies, Développement du réseau de transport en Allemagne – cadre réglementaire et état des lieux, February 2014, page 10.

In both cases, it resulted in a significant increase in the implementation cost. Hence, RTE estimates that the selection of underground infrastructure rather than aerial for the France-Spain line has increased its cost sevenfold[41].

It is possible that some lines will only encounter slight opposition that is quickly overcome. However we cannot exclude that other projects will find themselves facing an extreme alternative: accept significant additional cost with underground technology or give up. In both cases, the consumer will suffer. In the absence of infrastructure, they will not always be able to access the cheapest power generation source on the market. With expensive infrastructure, the additional costs on the "transmission" component of their bill will lessen the advantage that access to a cheaper power generation source gives them.

The reinforcement of the distribution network rarely encounters hostility. However, the cost of operations to be carried out will vary according to the network's choice to achieve the objective of 45 % from renewable electricity in 2030. Among the assessments available, a very detailed study[42] (cited below under the acronym DIN) provides some interesting conclusions. Its simulations are based on three scenarios, respectively including 68 %, 59 % and 51 % from renewable energies in the electric mix in 2030. The authors firstly consider that the investments to be made to the distribution networks vary slightly from one scenario to another, totalling approximately 215 billion euros in 2025 for the scenario at 68 % from renewable sources and 205 billion euros for the one at 51 %.

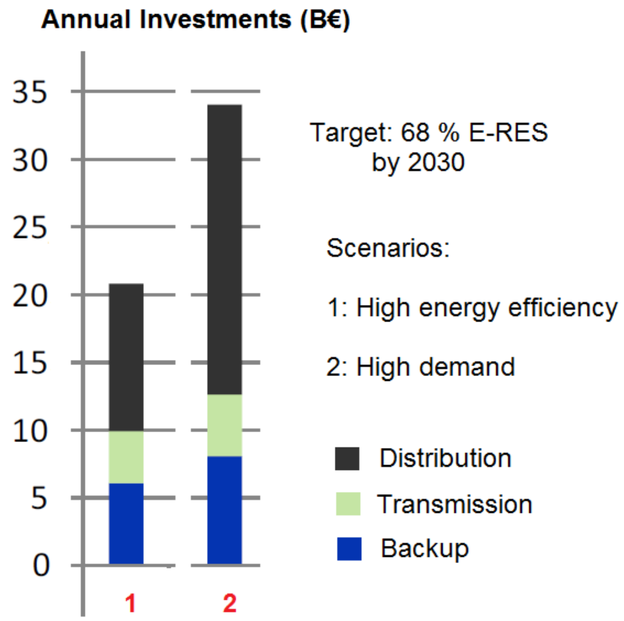
However, the study shows that the investment amount to be made increases considerably with the level of demand. In the scenario with high energy efficiency (1 in the graph below), they are almost halved compared to the scenario with high electricity demand. It will be noticed that the most significant investments are those which affect the distribution network, and to a lesser extent, those relating to the conventional power stations held in reserve (*backup*). A special simulation involved replacing around 70 GW of centralised power generation (offshore wind power) with an equivalent share of decentralised power generation (solar power). There is no significant saving on the networks; the additional cost comes from the increased need for backup units, following the low load factor of the solar plants compared to the offshore wind farms. The stability of transmission and distribution expenses at European level, however, masks their

41. Interview with M. Dominique Maillard, Chairman of RTE, by the special Commission for the review of the bill on energy transition for green growth in the National Assembly on 18 September 2014.
42. Joint study DNV-GL, Imperial College – London et NERA, *Integration of renewable energy in Europe*, final report, 12 June 2014. The results cited are extracted from page XII.

great variability at local level, depending on the nature of the renewable sources connected to the network and their location.

Figure 3.2

Sensitivity of investments to demand and to decentralisation of power generation



Source: DIN study cited in report 42, page XV.

The amount of the expected investments in the networks could therefore undergo a significant variation depending on the requirements put forward by the residents and the collective choices in terms of energy efficiency, whether these choices result from a public policy (for example via tenders) or private initiatives. Yet, this amount is high: about 20 billion euros per year for the distribution networks and up to 10 billion euros per year for transmission by 2030, according to some estimates, which represents an increase of 70-80 % in comparison to the sums invested up to 2010[43]. The operators do not have a treasury enabling them to self-finance their investments. They will seek capital contributions, but their often public nature will limit the volumes available, so that use of borrowing is necessary. Despite the low level of current interest rates, the payment of considerable sums to be borrowed will certainly require an upward revision of tariffs.

It should be emphasised again that the investments to be made are not meant to increase consumption; on the contrary, this should drop. They are intended to accommodate new generation

43. Transport: Roland Berger Consultants, The structuring and financing of energy infrastructure projects, July 2011, page 5.
Distribution: Eurelectric, Electricity Distribution Investments – What regulatory framework do we need? May 2014, page 5.

production from renewable sources, which will partially replace the old ones without being situated at the same locations and with having features requiring a greater capacity from the facilities. In classical economic theory, an investment represents either the renewal of existing equipment that has become obsolete, and it is then financed by previous depreciation, or the means of satisfying increasing demand, and it is then financed by additional sales. Here, the new investments far exceed the renewal requirements and the system operators will hardly derive extra revenue from their additional investments. Their main gains will come from a reduction in maintenance expenses due to renewed production facilities, but this benefit remains insufficient to balance the expense. Under these conditions, an increase in transmission tariffs seems inevitable.

This increase will in all likelihood be accompanied by a structural change. Indeed, as the table in figure 3.1 shows, the networks have surplus capacity on average at EU level (the line capacities increase more quickly than the power transmitted), and the phenomenon is expected to develop with the increase in the share of renewable sources in the production mix in most Member States. It appears highly likely that a simple increase in the current tariff settings will not be sufficient to stabilise the system operators' income. Ideally, a tariff reflects the structure of expenditure; yet the reinforcement of the networks will increase the operators' fixed costs by raising the capital costs which are indifferent to the power transmitted: their design increasingly depends on the power to be received, while their payment nowadays mainly comes from the energy transmitted. An amendment of the scales seems inevitable, leading to an increase in (or creation of, for some countries) the fixed component of the transmission contract, known as "subscription" for private households, which varies depending on the contract power. This development would reflect that of the role performed by the distribution and transmission networks, both of them playing an increasing role of insurance, but some facilities will only be used sporadically to their full potential.

Increasing the fixed component of the invoice has two consequences. Firstly, the increase will lessen the advantage currently enjoyed by self-consumers, whose behaviour is similar to that of the "free riders", who benefit from the security provided by the network, but do not pay a fair price, as payment of the facilities is still mainly based on the power consumed. Secondly, it reduces the gain that the network extensions are expected to provide by drawing on cheaper power generation facilities.

Uncertainties about the expected benefits

Mention is rarely made of the above considerations in studies evaluating the "social welfare benefit" of an integrated market. The term here refers to the gain obtained by the community when a product or service sees its cost decreasing without deterioration in the production factors, regardless of the cause: technical progress, regulatory adjustment, learning effect[44]… The calculation does not prejudice the recipient (consumer, producer, taxpayer, etc.); and generally it does not take into account the potential loss of income for some stakeholders.

In most of the cases, the studies compare electricity wholesale market prices between a situation with restricted cross-border exchanges and an unlimited situation. The gain represents the saving made by the systematic use of cheaper power generation units to meet demand, which is currently impossible due to bottlenecks at some borders and incomplete market instruments. Examples of assessments:

ACER considers that full market coupling in the European Union will generate a social welfare benefit of around 1 billion euros per year. It already provided an annual gain of 600 million euros in 2013[45].

The consultancy Booz & Co arrives at much higher amounts, between 12.5 and 40 billion euros in 2030, if all of the transmission network extensions recommended by ENTSO-E are carried out, compared to the situation prior to market coupling[46].

ENTSO-E assesses the gain between 2 and 5 euros per MWh consumed (€/MWh) that the recommended extensions in its development plan will provide in 2030, or if we take up the consumption assumptions reproduced in section 1 above (from 3 610 TWh to 4 327 TWh), between 7 and 22 billion euros per year for the EU[47].

These results need to be considered with caution. Unfortunately, the models used to perform the economic simulations do not show their parameters, but despite this

opacity, several qualifications can be made. Firstly, the cost of network extensions should be deducted. ENTSO-E places it between 1.5 and 2 €/MWh for transmission only, or therefore between 5.4 and 8.7 billion euros per year. A no less equivalent amount corresponds to the reinforcement of the distribution network. Secondly, the gain is calculated with questionable assumptions; for example, ENTSO-E selects a CO_2 price between 31 and 93 €/t (it is traded in 2015 at less

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44. The expression "social welfare benefit" is translated in English differently depending on the authors: *gross welfare benefit, social economic welfare, social welfare*.
45. Agency for Co-operation of Energy Regulators, Annual Report on the Results of Monitoring the Internal Electricity and Natural Gas Markets in 2013, October 2014, page 122.
46. Booz & Co, Benefits of an integrated European energy market, July 2013, page 90.
47. ENTSO-E, *Ten Year Network Development Plan (TYNDP),* 2014, pages 73, then 12 and 38 for the figures quoted in the following paragraph.

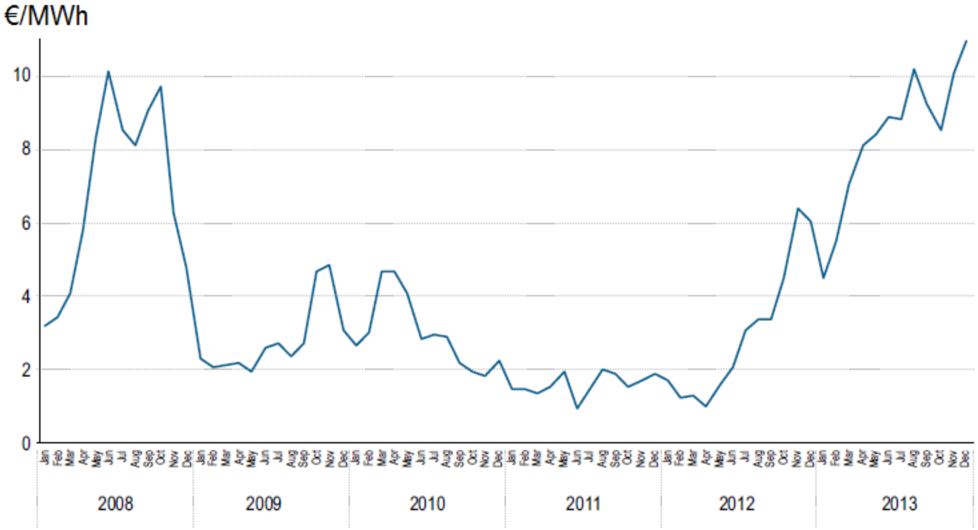
than 7 €/t) and adopts fuel prices provided by the International Energy Agency in 2011 (they have fallen sharply since 2014). Lastly, the gains are generally calculated with a simulation on market prices "all other things being equal"; yet it seems unlikely that the price set by the cheapest power station will remain stable if demand sent to it increases.

It should be noted that the studies mentioned above report social welfare benefits comparable with the spread of demand management practices (*demand response*), authorised by smart equipment on distribution networks and by control devices on the clients' appliances, in the range of 3-5 billion euros per year for the Booz & Co study, and between 10 and 20 billion euros per year for the DIN study.

Beyond the social welfare benefit, the development of interconnections between countries aims to achieve an alignment of EU wholesale market prices. Figure 2.4 (Chapter 2) suggests that a convergence between areas effectively starts due to market coupling; however ACER qualifies this finding by observing divergences within the same area. Thus, ACER has been observing an increasing difference within the "Central Western Europe" (CWE) area, bringing together the four countries bordering Germany (Austria, Belgium, France, and the Netherlands), since 2012. It attributes this on the one hand to the rapid development of wind and solar energy sources in Germany, whose power is put on the market at a price close to zero, and on the other to the large pool of coal power stations in Germany that can take advantage of the low international prices for this fuel. The graph in figure 3.3 shows this development.

Figure 3.3

Price differential on the futures market (Y+1) in the CWE area



The curve reproduces the difference between the lowest and highest price in the area. The prices observed correspond to a supply on the basis of maturity within a year. The lowest price is generally found in Germany and the highest in the Netherlands.

Source: ACER, Annual Report on the Results of Monitoring the Internal Electricity and Natural Gas Markets in 2013, October 2014, page 113.

But assuming it is increasing, the convergence of wholesale prices could not conceal the disparity in prices paid by the end consumer. They pay extra for:

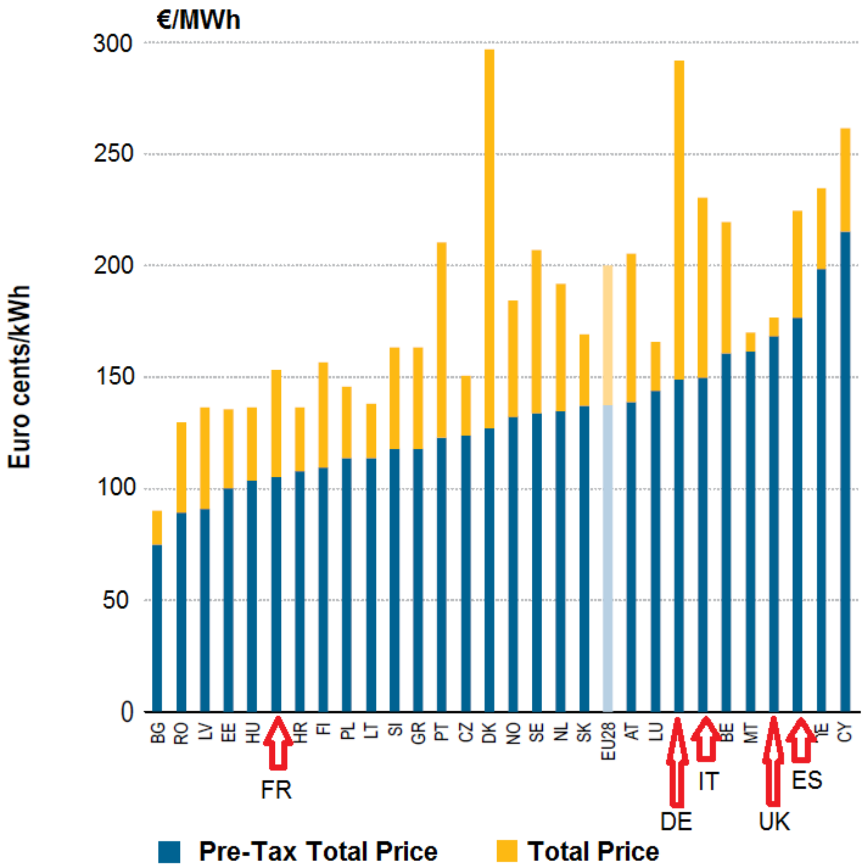
The transmission of electricity, according to the transmission scales highlighted in Chapter 1, which vary significantly from one country to another. Similar variations also exist for the distribution scales.

Costs and taxes imposed by the public authorities, including for example, concession fees, excise duties, compensation for the expenses from public policies (like the CSPE, a contribution to the public service charges for electricity in France, or the EEG-Umlage, a renewable energy levy in Germany), and finally VAT. The amount of these costs and taxes vary considerably from one Member State to another.

Figure 3.4 highlights the impact of the costs and taxes on the final bill for a domestic consumer.

Figure 3.4

Impact of costs and taxes on a domestic consumer's bill



Source: ACER, *Annual Report on the Results of Monitoring the Internal Electricity and Natural Gas Markets in 2013*, October 2014, page 27. Price of MWh for consumption between 2.5 and 5 MWh per year.

Therefore, the domestic consumer will benefit little from the convergence of market prices. Among the four countries in the same price area before costs and taxes (Germany, Spain, Italy, and the United Kingdom), the final price differs immensely.

For many industrial consumers, the convergence of market prices is an even less significant criterion because of the numerous specific provisions which affect them. The most typical case involves Germany: in 2014, for a consumption of 100 GWh per year, the total price was between 145.6 and 155.6 €/MWh. It fell between 41.4 and 46.4 €/MWh when all the exemptions were applied. The official tariff applicable for network use, still for an industrial client using 100 GWh per year, was established between 20 and 25 €/MWh. It was reduced to between 0.7 and 1 €/MWh due to the exemptions, or a discount of

96 %[48]. Their French competitors will only benefit from an exceptional discount of 50 % on their transmission invoice between 1 August 2014 and 31 July 2015[49]. A German manufacturer consuming 45 GWh per year only paid 3.1 €/MWh as costs for renewable energies (EEG-Umlage), while the full amount of the cost reached 62.4 €/MWh, or again an exemption of 95 %. For the manufacturer, the expense corresponding to this cost was equivalent to 141 070 € for the year. As for their French counterpart, the CSPE was only worth 16.5 €/MWh in 2014, but the exemption only applies above 0.5 % of its added value or from a ceiling of 598 000 € per year and per site, and therefore they may have paid the latter amount, more than four times higher than that required in Germany[50].

It is understood that stakeholders in industry would not be satisfied with a better convergence of wholesale prices as long as such differences will persist in various forms in favour of their competitors on the other side of the border.

If the social welfare benefit remains uncertain, can the EU hope for an industrial advantage? Two very different courses open up to initiatives likely to obtain a competitive advantage for European companies: on the one hand, electricity transmission equipment implementing high voltage and direct current technologies, and on the other, the processing of data from communicating devices expected to increase on the networks and among customers. In both areas, the advantage will be achieved more easily if governments work in close collaboration with industry to adjust the regulatory framework, stimulate research, innovation, and standardisation. Clearly, it is a question of conducting a true industrial policy to give any opportunities to groups of European companies, sometimes handicapped dealing with international competitors with a reserved market in their country of origin or with huge cash reserves. The application of a clause intended to protect infant industries is worth considering.

Political Uncertainties

Chapter 1 summarises the mutual assistance role played by interconnections in the history of electricity in Europe. This role takes on new interest when concerns about the security of electricity supply return to the foreground, mainly because of the increasing share of renewable sources of an intermittent nature (wind and solar energy) in the electricity mix. Their development increases the requirements

48. BDEW, *Strompreisanalyse*, June 2014, page 20.
49. CRE, *Communiqué*, 27 May 2014.
50. CRE, Délibération de la Commission de régulation de l'énergie du 15 octobre 2014 portant proposition relative aux charges de service public de l'électricité et à la contribution unitaire pour 2015.

for supplementary power generation (*backup*) or quick reduction of consumption, as a momentary failure can lead to load-shedding; yet it seems that the sustainability of the units dedicated to backup is not guaranteed and their income is becoming insufficient.

The EU has assigned the responsibility of security of electricity supply to its Member States[51]. The governments undertake this task by taking three restrictions into account:

Continuity of power supply: In the short term it applies to avoiding an unforeseen event that will result in a failure (*blackout* following, for example, a sudden rise in consumption or damage at a major plant).

Adequate capacity to demand: It intends in the mid to long term, and through an incentive for investment, for the necessary generation capacities to follow the development of consumption.

Control of the production mix: Member States still seek to set the choice of primary energy sources used in the power stations, which determines their energy dependency and commitments made elsewhere, particularly to reduce greenhouse gas emissions.

These restrictions have political consequences which will vary according to the degree of confidence in the markets to cope with it.

Consequences for the continuity of supply:

The nature of failure criteria and instructions for operators are different according to the countries. Specifically, as described in Chapter 1, the Member States have made the TSOs responsible for ensuring the correct balance between supply and demand. However in some countries, the market stakeholders (suppliers, traders, consumers) have tools enabling them to intervene up to the last moment before delivery and withdrawal; these are known as intraday markets. Marketplaces also vary nowadays by rating intervals, sometimes reduced to 15 minutes, so that the transactions can best follow a very fluctuating wind or solar power generation.

Market coupling on the European scene quite naturally leads to considering the broadening of the intraday markets and the standardisation of rating intervals. An increase in the capacity of cross-border connections would then allow suppliers the adjustment (quickly mobilised complementary power generation or transit interruption) to act in a vast regional group, even throughout the whole of Europe. The Booz & Co study evaluates the social welfare benefit that the EU would derive in 2030 at between 300 and 500 million euros per year.

51. Directive 2005/89, concerning measures to safeguard security of electricity supply and infrastructure investment, 18 January 2006.

However, because the failure criteria are established at Member State level, the possibility for operators to act at very short notice could aggravate distortions which already exist with current markets. Two examples include:

Some countries have introduced a price cap on the wholesale market in case of exceptional events, such as particularly high demand or the sudden unavailability of a part of the power generation facilities. Let us assume that a country that has introduced a cap at 3 000 €/MWh is in competition with a country without a cap on a day of emergency, it is obvious that operators will prefer to supply the latter where the price could reach 10 000 €/MWh or even more. Without dedicated domestic resources, the first country would face a temporary shortage.

In order to stimulate investments so that the domestic resources always fulfil peak demand, some countries have introduced capacity mechanisms consisting of paying for available power which ensures the viability of facilities not operating in regular periods, but essential in times of emergency. Although, it is too early to analyse the implementation of these complex instruments, it seems that the use of an interconnection between a country with a capacity mechanism and a neighbouring country without one benefits the latter: this would be the case between Ireland (with mechanism) and Great Britain (without) or between France (with) and Germany (without). Great Britain and Germany would benefit from it[52].

In more direct terms, if an exceptional event strikes several Member States simultaneously (breakdown of a large power station during a cold spell, or the lack of wind or solar for example), it is hard to imagine a government explaining to its voters that local load-shedding is necessary, because the national resources are supplying neighbouring countries due to the market model adopted by the EU. Still put another way, the pooling of emergency resources between several countries requires political agreement, approved by the people, setting out the rules according to which these resources will be distributed on the assumption that they could not fulfil the entire demand.

Long-term consequences:

A high-capacity, cross-border network could promote a gradual migration of power generation resources to the most favourable geographical areas. Such a development was described in an article

52. The case of Ireland and the United Kingdom is referred to in the DNV-GL study, Imperial College – London and NERA, *Integration of renewable energy in Europe*, final report, 12 June 2014, page 156. The case of Germany and France was the subject of a publication by Agora Energiewende, *Potential Interactions between Capacity Mechanisms in France and Germany*, March 2015.

posted on the Mines Paris-Tech Grande Ecole's blog[53], according to the following argument:

With the development of intermittent energy sources, countries with flexible production, for example, will take advantage of those that do not have them, and whose industries will therefore be weakened. For these countries, a lower cost of power will hence entail greater dependency.

With a high objective for renewable energies, the favourable areas will also have an advantage and those lacking natural resources (biomass, wind, sunshine) will experience a disadvantage.

By way of illustration, it cannot be excluded that the countries surrounding the North Sea, whose offshore wind resources are vast and which have conventional facilities adapted to backup, will gain influence over those who are far from these shores. How will the latter react faced with a loss of a part of their electricity generation appliances and business which is associated with it (suppliers, sub-contractors, etc.)?

It can certainly be considered that this potential situation would be comparable to that of a deprived area in a well-equipped country. In France, Brittany for example, remains largely dependent on other regions for its electricity supply. This parallel traces the answer to the question raised: for such a situation to become acceptable, politically the governance of the system needs to provide all the guarantees of transparency and decision-making, and economically it needs the solidarity mechanisms to compensate, at least partially, for the depletion created locally. At EU level, the density of the cross-border connections consequently requires new governance principles and a better consideration of the disparities. The conclusions of the European Council of 19 and 20 March 2015 regarding "the energy union" open the door to a development in this direction, but it still remains to be confirmed.

Impact on the production mix:

The above-mentioned Council conclusions do not remove the ambiguity about the compatibility between the free choice of the national energy mix (article 194 of the Treaty of Lisbon) and an internal market made stronger by reinforcing the interconnections.

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53. Mines Paris-Tech, EU Energy Policy Blog – Daniel Scholten, Thomas Sattich and Inga Margrete Ydersbond, *Power Struggles: The Intra-Community Implications of EU Energy Policy*, 30 November 2014: <www.energypolicyblog.com/2014/11/30/power-struggles-the-intra-community-implications-of-eu-energy-policy/>.

In this respect, the situation in France is a case study of the difficulties that emerge for this free choice. The country could fulfil the objective allocated to it for 2020 in terms of renewable energies by promoting its agricultural and forestry resources, as it has a significant potential of solid biomass for use in heating and biomethane injection in gas networks. This focus would maintain the nuclear option for the national electricity power generation. However, France is required to receive excess renewable electricity generated by its neighbours. The volumes currently received are still modest, but given their funding outside the market laws, these volumes are already sufficient to result in wholesale prices below the break-even point of the existing nuclear facilities during certain periods. Yet, the planned reinforcement of connections with Spain will increase exports of electricity generated in the Iberian Peninsula (reinforcements with Italy and then Germany will probably follow later). With a community objective of 45 % renewable electricity in 2030, imports and domestic generation would reach such a level that the nuclear plant would only have a more significantly reduced range of economic relevance, as the burden of fixed costs in nuclear technology requires almost permanent operation to ensure return on investment[54].

It can be argued that the interconnections also enable France to export electricity from nuclear power; indeed, its contractual track record is largely positive (92.4 TWh exported against 27.3 TWh imported in 2014) despite the penetration of renewable electricity[55]. Increased cross-border capacities would also stimulate competition between conventional sectors generating at base-load, and in this field, the existing French nuclear facilities is well positioned, and will further improve its position if the CO_2 allowance market recovers. Hence, new interconnections would in all likelihood increase exports and recover volumes lost in France at European level. The economic equilibrium appears maintained for the existing nuclear facilities, but proves more vulnerable for a potential renewal. The technical uncertainties mentioned at the start of this chapter, particularly the uncertainties about the development of consumption, generate a risk for the investor which seems nowadays only to be overcome by resorting to guarantees of the type the British government has granted to the developers of the future Hinkley Point C nuclear power station. In future, the risk will decrease if the cost of new reactors drops, due to learning effect on third-generation models.

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54. These findings appear in the Nuclear Energy Agency (OECD) study, *Nuclear energy and renewables,* 2012, pages 136 and following, which are continued by those of Professor William D'Haeseleer for the European Commission, *Synthesis on the economics of nuclear energy*, November 2013, chapter 9. These findings do not reflect an inadequacy faced with the variable nature of the residual load, which is not covered by the intermittent energy sources, since the new models of reactors allow for relatively fine monitoring of the load.
55. RTE, *Bilan électrique 2014*, edition dated 29 January 2015, page 33.

The European Commission approved the British guarantees, like it accepted that the German government is paying subsidies to the fossil fuel power stations placed in "network reserves" to safeguard security of electricity supply, while their profitability is no longer guaranteed by the market[56]. Although the Commission defends itself for having acted according to political considerations, both decisions foreshadow trade-offs which will become essential in a largely interconnected electricity system, but which supplies countries very diverse in natural resources, industrial bases or population demands.

56. The Commission provisionally authorised the payments intended to maintain the economic equilibrium of some power stations which are necessary to the security of supply in a worsened situation, but do not operate in normal conditions and will no longer be used when the German domestic network is completed. Methods for calculating the payments for these "network reserves" are unknown. At the end of the network reinforcements, the German government plans to switch to "strategic reserves" and the payments will then be determined after tendering.

Conclusion and Recommendations

While several of its Member States are experiencing a difficult economic situation, marked by weak growth, the EU has committed to an energy transition aiming to moderate its consumption and favour the most environmentally-friendly sources. The attempt at moderation relates to all forms of energy, but the development of new sources mainly affects electricity. The experience of countries which have taken the initiative shows that the development raises serious problems. Renewable sources are more costly than conventional sources for each kWh generated, and when added to generating facilities that were adequate, they generate over capacities, and additional expense. It is indeed necessary to pay conventional power plants even when they are not running to safeguard their availability, since they remain essential during periods where the lack of wind or sun deprives us of wind and solar input, which form the bulk of new power generation.

An acute need for reinforcing the electricity networks is now emerging. In each country, the choice in favour of multiple small renewable sources requires the national networks to be expanded, also in capacity, in order to receive considerable wind or solar power generation during certain periods, as quality and the intermittent nature of the latter require specific monitoring devices. The reinforcements firstly affect the distribution networks which most of the wind and solar facilities are connected to, and which will receive demand from electric vehicles in the future. However extending the long-distance transmission network also appears inevitable in order to deliver the renewable power generated to all consumers and to receive power generation from large sources such as offshore wind farms. A significant risk now is that the extension and reinforcements lead to networks with large overcapacity and each section is both necessary on some days, but rarely used on average. Such a phenomenon would in its turn create an additional cost, since it will be necessary to pay facilities providing increased capacity without consumption having increased in proportion, since the energy efficiency efforts are specifically intended to control it.

The EU hopes to offset the additional expenses on the networks by eliminating bottlenecks at the borders, which currently prevent a Member State from calling on power stations in neighbouring countries generating at a better price than its own plants. Several studies show a consequent gain and argue that the security of supply would be improved, with each geographical area being able to use a larger number of power stations to ensure continuity of its supply. In order to eliminate these bottlenecks, an overall interconnection objective was selected. It sets the export or import capacity of each Member State at 10 % in 2020 and 15 % in 2030 in terms of its installed capacity. For some countries, particularly in Western Europe, such an objective seems ambitious and invokes at least three reactions. Firstly, the calculation of economic gains is based on weak assumptions; in particular it presumes proper functioning of the markets, yet numerous distortions are currently allowed. Secondly, increased competition in terms of power generation will lead to winners and losers; the opportunities in the competition are not equal; it may result in resentment among the weakest towards this European energy policy. Lastly, the models implemented conclude that security of supply improves due to an increased role of the markets, which will deprive the Member States of their means of intervention, while they retain responsibility for this security as well according to the European legislation in force as vis-à-vis their general public.

The energy transition remains desirable and the networks play a crucial role in performing it properly. The uncertainties expressed here could not therefore serve as an excuse for inaction. But they suggest action with caution, so that the investments made in the networks do not penalise economic growth, or even stimulate it, in a period where the EU is faced with very dynamic competitors globally. Our recommendations are largely consistent with those that have been made by M. Michel Derdevet in the report he submitted to the French President in January 2015[57] ; they are based on four themes:

Controlling expenditure. This requirement appears paramount. Locally, it requires regulatory alterations to encourage renewable energy stakeholders to favour sites where the network is already dense, and a remote command of the injections to avoid calibrating facilities at a power level very rarely achieved. At European level, the control of expenditure is based on a regular review of the cost/benefit analysis according to the technical or social developments, such as the development of electricity storage or the general pressure to bury infrastructure. Broadly, the costs could be reduced by developing dedicated funds possibly under the auspices of the European Investment Bank, making capital available at the best market rates to all system operators.

Adopting an industrial policy. Electricity networks are expected to develop everywhere in the world. The European energy transition offers companies on our continent the opportunity to use the most recent technologies and to acquire skills that are transferable in other latitudes, for new equipment (high voltage direct current), as well as

57. Michel Derdevet, *Énergie, l'Europe en réseaux*, La Documentation Française, January 2015.

for processing data from "smart" systems. Their progress deserves to be strengthened by a community framework encouraging more research and development efforts, accelerating the standardisation processes of equipment, and promoting the most innovative European groups of companies through tenders.

Improving governance. The increased electrical interdependence of EU Member States, nowadays because of market coupling and in the future because of reinforcing the interconnections, argues for a kind of command post having an overview and facilitating interaction. Currently, there are only some sector bodies (ACER, ENTSO-E, etc.) as well as industry associations; meanwhile, the European Commission is centralising a considerable amount of information, but its initiatives are defined by the role assigned to it by the treaties. The chapter dedicated to governance in its recent communication on the "energy union" opens up innovative perspectives in the institutional field for further development.

Promoting co-operation. Although this idea is found in each of the first three themes, the usefulness of information exchanges cannot be overemphasised. In a period marked by deep uncertainties and rapid technological, economic, and social developments, the sharing of experiences forms an extremely powerful instrument for overcoming obstacles. The electricity networks will develop more easily if intangible networks support them, facilitating sharing of achievements and their access by interested parties.

These measures seem likely both to reduce the effort required of European citizens and to obtain their adherence to the intended purpose: a new electricity model.