Barriers and drivers of new interconnections between EU and non-EU electricity systems

Economic and regulatory aspects

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ECN-C--06-006 May 2006

Acknowledgement

This report is the result of a study provided within task 2 of Work Package 1 (assessment of optimal electricity corridors between EU and neighbouring countries) of the ENCOURAGED project contract no 006588. Task 2 deals with the assessment of technical, economic and regulatory barriers for long distance transmission of electricity between the EU and its neighbouring countries. The European Commission under the sixth Framework Programme supports this research project. The study is conducted by ECN Policy Studies and is registered under project number 7.7670.

The authors thank Riccardo Vailati (CESI SpA), leader of WP1 for the pleasurable co-operation within Work Package 1. In addition, many thanks are owed to Jeroen de Joode of ECN for his comments as a co-reader of this report. For any questions regarding this report, please contact Mr. Frits van Oostvoorn, oostvoorn@ecn.nl, telephone +31.224.564438.

Abstract

Interconnection of different electricity systems offers several advantages and benefits. In the first place it provides reliability and increases the robustness of the system. Furthermore, it increases economic efficiency and reduces the possibility to abuse market power. Price differences are the signal that efficiency gains can be obtained. To make a sound decision whether to invest in new interconnection capacity, the causes behind the price differences should be well understood. Price differences must originate from structural, long-term causes. Differences in primary resources, fuel mix and load patterns are such causes. It is important to note that price differences that result from the difference between regulatory structures (lack of level playing field) may not be structural and therefore may not justify investment in interconnection capacity. Next to advantages and benefits, interconnection is faced with costs and barriers. Firstly, there are investment costs, which are high for building new interconnections, and there are energy losses that are caused by transporting electricity. A third possible barrier is congestion within the EU, which impedes the imported electricity to freely flow to demand areas (and hinders the export of electricity to neighbouring regions). Furthermore, interconnection may create loop flows. In addition, interconnection could lead to an increasing import dependency, which may create political resistance. And finally, there may be opposition from residents in the areas where the transmission and interconnection lines have to be built. Concerning regulatory issues, trade between markets is more likely to be impeded or distorted if market designs and rules between countries/regions differ substantially. Regulatory issues that are of relevance comprise rules concerning the timing of gate closure, imbalance arrangements, the firmness of transmission access rights, the type of tariff regulation, unbundling, the ownership of interconnectors, market structure, and security of supply measures. In conclusion, interconnection with neighbouring regions can definitively offer several advantages and benefits on a European (region) level, but they should be well compared with the integral costs and barriers that arise with it.

Contents

List of tables

List of figures

Summary

Task 2 of WP1 of the ENCOURAGED project analyses and assesses the main costs, barriers, benefits and drivers of new interconnection. In this report economic and regulatory drivers and barriers for interconnection of the EU at the one hand and adjoining regions on the other are identified and assessed. It gives a checklist of (qualitative and quantitative) drivers and barriers that are of importance when considering building new interconnection (or reinforcing existing interconnection) in general. It can be used to assess potential EU initiatives to build interconnection capacity and as a structured framework for answering the question whether (additional) interconnection with neighbouring electricity systems will lead to a more optimal electricity system in the EU and/or its border regions. Because the ENCOURAGED study is a European project, this report mainly focuses on whether and to what extent EU regions or the EU as a whole benefit from (additional) interconnection with neighbouring electricity systems.

Initially, the development of interconnectors was driven by system security requirements: the high-voltage interconnectors within the EU have been developed predominantly for short-term security reasons. However, the liberalisation of the electric power markets resulted in trading opportunities, and the cross-border interconnection lines are more and more used for trade reasons and price arbitrage. If an investment in interconnection capacity is made by the transmission system operator (TSO), which is a regulated actor, the interconnector is referred to as a 'regulated transmission line'. Merchant network investments, on the contrary, are facilities that are not built under the initiative of regulators or TSOs, and whose remuneration is determined by the market and not by regulation. However, the merchant model is not considered suitable as a general model for interconnector investment in Europe.

Interconnection can provide different advantages and benefits. In the first place it provides reliability and it increases the robustness of the system. Furthermore, it increases economic efficiency and reduces the possibility to abuse market power. Interconnection makes it feasible to select the cheapest generation available in the system. Price differences are the signal that efficiency gains can be obtained. To make a sound decision whether to invest in new interconnection capacity, the causes behind the price differences should be well understood. Price differences must originate from structural, long-term causes. Differences in primary resources, fuel mix and load patterns are such causes. In the long run, countries or regions that have cheap availability of specific primary resources are likely to concentrate on ('specialise' in) generating technologies that match with these resources. They will exploit specific comparative advantages. Furthermore, it is important to note that price differences that result from the difference between regulatory structures (lack of level playing field) may not be structural and therefore may not justify investment in interconnection capacity. It may be a 'false driver' for interconnection.

The advantages of interconnection come at a cost, and, partly due to the structure of the electricity system, they may not be fully exploited. Firstly, there are investment costs, which are high for building new interconnections. Next to the investment costs, there are energy losses that are caused by transporting electricity. Not only the length of the interconnection lines itself is of relevance, the transports that may be induced by interconnecting two systems (including loop flows) are of major importance as well. A third possible barrier results from the fact that the electricity grid in Europe cannot be considered a copper plate. Relatively small cross-border capacities and insufficient allocation of these capacities can lead to congestion within the EU, which impedes the imported electricity to freely flow to demand areas (and hinders the export of electricity to neighbouring regions). Whatever advantages there may be with interconnecting non-EU regions, these are unachievable if internal congestion occurs in an extent that it prevents them to be passed along across Member State borders in order to be beneficial at the EU level.

Furthermore, interconnecting non-EU regions can create the possibility of loop flows, which reduces the interconnection capacity that is available for the market and, therefore, reduces the possibility to make use of the advantages, causing the interconnector to become less efficient. In addition, because interconnection capacity competes with domestic generation, interconnection could lead to an increasing import dependency, which may create political resistance. And finally, there may be opposition from residents in the areas where the transmission and interconnection lines have to be built.

In addition to technical and operational standards, common market rules are needed to ensure a level playing field based on fair competition, cost-based pricing, access to the network, transparent and non-discriminatory network tariffs, proper cross-border-trade mechanisms, congestion management, and capacity allocation mechanisms. The more market designs and rules between countries/regions differ, the more likely it is that trade is impeded or distorted between markets. As a general rule, different designs and rules impede structural trade opportunities. Compatibility between key market rules therefore is important so that opportunities for trade can be fully realised. Regulatory issues that are of relevance comprise rules concerning the timing of gate closure, imbalance arrangements, the firmness of transmission access rights, the type of tariff regulation, unbundling, the ownership of interconnectors, market structure, and security of supply measures. However, full harmonisation of all trading rules and arrangements is not necessarily required for effective trade interaction between markets to occur. But regulatory arrangements need to be independent, with regulatory processes characterised by transparency, objectivity and consistency.

Concluding, interconnection with neighbouring regions can definitively offer several advantages and benefits on a European (region) level, but they should be well compared with the integral costs and barriers that arise with it, including regulatory issues. This report gives a broad overview of aspects that should be taken into account in this comparison.

1 Introduction

1.1 Background and objectives

An important objective of the European Commission, MS regulators, and other stakeholders, is to work towards the creation of an efficient and effectively competitive, single electricity market (ERGEG, 2005). The European Commission states (EC, 2004) that the overall objective of the internal electricity market is to create a competitive market for electricity for an enlarged European Union, not only where customers have choice of supplier, but also where all unnecessary impediments to cross-border exchanges are removed. Electricity should, as far as possible, flow between Member States as easily as it currently flows within Member States. Currently, Member States are not particularly well interconnected. However, certain countries within the EU have already adopted common harmonised rules. This development of regional markets, containing Member States between which interconnection is reasonably strong, can be considered as an interim stage to the creation of a single electricity market. Figure 1.1 gives an overview of regional electricity markets that may develop or already have been established within the EU.

A related issue that currently receives increasing attention, partly ensuing from the objective of creating an internal electricity market, is whether and to what extent the EU needs (additional) interconnection with its neighbouring electricity systems. The focus of Work Package 1 in the ENCOURAGED project is to identify optimal electricity corridors between EU and its neighbouring countries or regions.[1] For that insight, Task 2 of WP1 analyses and assesses the main barriers, advantages and drivers of new interconnections. In this report economic and regulatory drivers and barriers for long distance transmission[2] of electricity between the EU at the one hand and adjoining regions on the other are identified and assessed. The main non-EU regions that are considered in the ENCOURAGED project are northern Africa (Egypt, Libya, Tunisia, Algeria, Morocco), Turkey and IPS/UPS[3] (Russia, Belarus, Ukraine, Moldova). However, this report will not consider the connection options of these regions in detail, but will look at key advantages, drivers, barriers and costs for new (or additional) interconnections in general. It will answer the question which aspects play a role when considering building new or reinforcing existing interconnections. These aspects (or criteria) can be applied to possible future connections with specific non-EU regions. In a sense, this report will serve as a kind of ‘manual’ to evaluate and rank interconnection options (based on economic and regulatory aspects) and to assess if these are worthwhile to be supported by the EU. It gives a checklist of (qualitative and quantitative) drivers and barriers that are of importance when considering building new interconnection (or reinforcing existing interconnection) in general. It can be used to assess EU initiatives to build interconnection capacity and as a structured framework for answering the question whether (additional) interconnection with neighbouring electricity systems will lead to a more optimal electricity system in the EU and/or its border regions. Other tasks in WP1 are aimed at revealing the precise quantification and selection of optimal corridors.

Because the ENCOURAGED study is a European project, which is concerned with connections between the EU and neighbouring regions, this report mainly focuses on whether and to what extent EU regions or the EU as a whole benefit from (additional) interconnection with

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[1] See for more information on the ENCOURAGED project: www.encouraged.info.

[2] Transmission means the transport of electricity on the extra high-voltage and high-voltage interconnected system with a view to its delivery to final customers or to distributors, but not including supply (EC, 2003a; article 2).

[3] IPS: Integrated Power System. UPS: Unified Power System. The UPS interconnection includes almost all power systems of the former USSR (the CIS and the Baltic States).

neighbouring electricity systems.[4] However, the question whether to interconnect regions that are adjoining the EU, may have different outcomes depending on the chosen perspective. Interconnection with a non-EU country or region could be very well beneficial to a specific Member State, whereas, due to all kinds of reasons (such as internal congestion), from the perspective of the EU it is considered a local issue, which does not fall within the primary responsibility of the EU and the scope of this report.

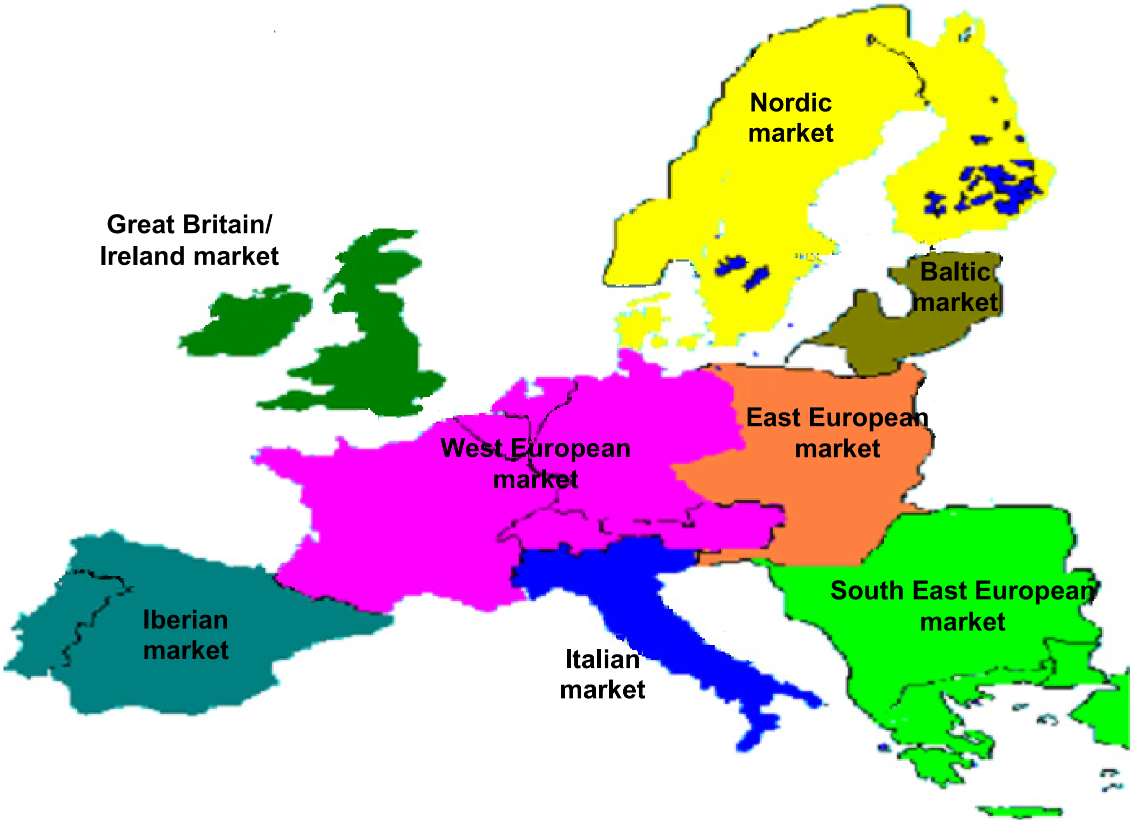

Figure 1.1 *Potential regional electricity markets within the EU*
Souce: EC, 2004.

1.2 Report structure

To place the interconnection issue into perspective, Chapter 2 begins with a general description of the historic development of the current European transmission network. Economies of scale and short-term security reasons were the most important drivers for the growing scale of network operation. Furthermore, the current operation of transmission networks will be discussed. As liberalised electricity markets cater to price differences, interconnection lines are more and more used for trade reasons and price arbitrage. Drivers, like price differences, and advantages of interconnection are the subject of Chapter 3. On the basis of a full list of advantages and drivers, the benefits of a specific new (or additional) interconnection with neighbouring electricity systems can be studied. From a EU perspective, it is important that Europe as a whole or at regional level benefits by interconnection and that, therefore, power from/to these neighbouring electricity systems can flow undisturbedly (to a certain extent) across Member State borders. However, this might raise a couple of potential problems. Internal bottlenecks within the EU may have effects on trade with neighbouring regions. Because the high-voltage interconnectors

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[4] In this report, the regional level is defined at the scale of several national systems and may exceed national boundaries. The local level refers to the national scale. Figure 1.1 gives an example of the order of magnitude of (European) regions.

within the EU had been developed predominantly for short-term security reasons, liberalisation of the electric power markets and the resulting trading opportunities that are fully exploited since quickly exhaust the capacities of the interconnectors (Brunekreeft, 2005). The resulting congestion within the EU can imply a barrier for expanding long distance transmission of electricity. Chapter 4 analyses this and other barriers and drawbacks of interconnection, which will lead to additional costs for the system in case they have to be removed. Chapter 5 will deal with regulatory issues. Regulatory arrangements may sometimes lead to distorted trade, creating advantages for one area and disadvantages for another, and may form (short-term) drivers as well as barriers for interconnection.[5] In addition, a lack of playing field between countries and regions may result in price differences, which form a main driver for interconnection. However, this lack of playing field may not be a structural basis for long-term trade. Because of the complexity and ambiguity, regulatory issues will be discussed in a separate chapter. Finally, Chapter 6 will give conclusions, summarising the most important aspects that should be taken into account when considering additional interconnection between the EU and neighbouring regions. In other tasks of the ENCOURAGED project, a more comprehensive cost-benefit assessment and evaluation of interconnection options will be performed. Thereby, it is of great importance to compare new interconnection with feasible alternatives, such as the building of new power plants. Appendix A gives an overview of recent, concrete approaches to connect non-UCTE areas.

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[5] However, appropriate regulation is of course indispensable for a well functioning and economically sound operation of the interconnected market and newly built connections.

2 Cross-border infrastructure

2.1 Historic development of electricity networks and transmission

The development of electricity networks begins in the late 19th and early 20th century.[6] Direct as well as alternating current were already generally known. Direct current (DC) was developed first, because it was easier to handle than alternating current (AC) and because dynamos could generate sufficient direct current. Furthermore, the first applications (lighting) and the distances that had to be covered fitted well with the relatively low voltage values. However, demand for electrical energy increased, and it became necessary to transmit larger loads. First, the voltage was raised to limit the losses, as these are proportional to the square of current intensity. But as the technical ability of generators at that time was too limited to generate sufficiently high voltage, electric current had to be raised. That caused voltage drops and huge energy losses, which resulted in conductors with larger diameters that were heavy, hard to handle, and expensive. This initiated the gradual switchover to alternating current. With the invention of the transformer (1881) and the development of the alternator, alternating current could be used to solve the problems that occurred with direct current. Instead of the current intensity, the voltage of the transmission grid could be raised by means of transformers, which have very high efficiencies.

As soon as the technical principles were fixed, the development of the electricity sector supported the industrial and economic developments. To meet the growing electricity demand, increasingly powerful generating units with better efficiencies were built. A distribution grid was needed to distribute the electricity to the final consumers. Local transformers made the power supply suitable for low-voltage users. Local entrepreneurs, followed later by municipal authorities, built their own generating stations and built an infrastructure to distribute the electricity across their city. As soon as the service was more or less established, issues of security of supply received more attention, and this led to connections between power stations within municipal areas, and later also between neighbouring cities, by means of a connecting grid.[7] If a generating unit experienced problems, other generating units could take over. The same happened within the distribution system and the first move from radial distribution to an actual network structure became visible (Overbeeke and Roberts, 2002). The increasing unit size of power stations improved fuel efficiency and reduced costs per kilowatt installed. Smaller units were removed and the former connecting network, which started off as an emergency backup system only, was used to transmit power from the larger stations to the distribution networks. However, distances were still reasonably short and the whole system was still managed by one vertically integrated utility.

Having optimised the costs of the power stations, the next step in the optimisation was to build them in locations where space was more affordable, bulk fuel (transport) was available, and where the environmental impact was acceptable. This meant that power had to travel over larger distances and a transmission network was needed to collect all the power generated and take it to the distribution networks. At this stage, the logical relationship between power generation and distribution was finished and many governments chose to concentrate generation and distribution in separate, specialised companies. Economies of scale and a greater technical reliability of the system were the most important drivers for the ever-growing scale of network operation (Künneke, 2003). Interconnecting the separate distribution networks and utilities via a high

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[6] This section is based on Elia (2003) and Overbeeke and Roberts (2002).

[7] ‘Connecting grid’ is referred to as the network that connects grids in order to increase reliability and efficiency. If a disturbance occurs in one grid, other grids can (temporarily) make power available via the connecting grid. Connecting grids are not meant to structurally transport large amounts of energy. That is the task of transmission grids.

voltage transmission system pooled both generation and demand. An interconnected transmission system also allowed for maintaining the quality of supply, e.g. frequency and voltage variations, across the system and offered economic and other benefits (Butler, 2001), which will be the subject of Chapter 3.

Later on, in the same way, the electricity grids of countries were connected to each other, by means of cross-border interconnection lines. Initially, analogue to the connecting network, the development of interconnectors was driven by system security requirements: the high-voltage interconnectors within the EU have been developed predominantly for short-term security reasons. But since liberalisation started, the European electricity network finds itself in exactly the same position as some national electricity grids in the sixties: in the middle of the transition from a connecting grid to a transmission grid (KEMA, 2004a). Although the development of interconnectors was initially driven by system security requirements, they were subsequently developed to take advantage of the efficient use of hydropower or imports from countries with large nuclear production (ICF, 2002). The liberalisation of the electric power markets resulted in trading opportunities that are fully exploited since (Brunekreeft, 2005). This transition means that the cross-border interconnection lines are more and more used for trade reasons and price arbitrage. The increasing integration of European economies and the introduction of the internal energy market have led to an increase of energy transports via the European grid. These transports are realised in a more complex and commercial environment within shorter timeframes.

Transmission terminology[8]

Because of the meshed network, electricity can find its way through several routes within the electricity grid. On the basis of electrical characteristics of the connections, the physical laws of Ohm and Kirchhoff determine the final distribution. Therefore, power flows can occur on places that are not directly involved with the contractual deliveries between two network points. Occurring power flows often do not correspond with the underlying exchange contracts and do not necessarily follow a contract path (between generator and customer), but may flow through parallel paths in other transmission systems.

Depending on the source and destination, these transports are referred to as ‘third party transmission’, ‘transit’, or ‘loop flow’. The energy exchange between two points in different control areas is called *exchange*.

- In case an exchange takes place between two control areas that are not adjoining, interconnectors of a third party are used. This third party takes care of a part of the energy transport, and its service is referred to as *third party transmission*.
- If the transport crosses an internal border of the European Union, this service is referred to as a *transit* (e.g. exchanges from France to Portugal).
- In case of energy transports within a control area or between adjoining control areas, it is possible that part of the energy flows through the system of third parties. These third parties then deliver a service that is referred to as *loop flow transmission* (e.g. the wind power from northern Germany to southern Germany that uses the Dutch, Belgian and French grids).

2.2 Current network operation: investment in cross-border connections

2.2.1 Regulated transmission lines

On a national level enhancements to transmission capacity, either through the construction of new transmission lines or the upgrading of existing ones, results from a process whereby each TSO undertakes system studies of their network.[9] The studies examine what changes need to be made to the transmission network in order for it to remain compliant with established technical

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[8] Based on KEMA (2004a).

[9] Section 2.2.1 is derived from ERGEG (2005).

standards against the background of likely future changes in generation and demand. The TSO has insight in the changes in the volume and location of generation and demand that affect the electricity flows over the network and consequently affect the need for network reinforcement. In return for making investments in the network to meet security standards, the TSO expects to receive a reasonable rate of return. In most countries, use of system charges provide this return and they are approved by the relevant regulatory authority. This is the fundamental 'regulatory contract' that exists between TSOs and regulators (ERGEG, 2005).

Investments in interconnection capacity, by definition, span TSO and usually member state boundaries, and therefore extend across regulatory borders. TSOs, however, are national bodies with national networks and investing to meet security standards is normally limited to investment to meet the needs of their own network in accordance with their national obligations. National obligations on TSOs (as their part of the 'regulatory contract') to maintain and develop their network to achieve technical standards, does not extend across national borders or to connections with other networks. Consequently, investment in cross-border infrastructure is typically driven by factors different to those used for in-country investment, such as local requirements to maintain system security or where TSOs and regulators agree that the construction of a particular line would be beneficial. However, the TSO has the technical knowledge as well as the expertise to evaluate cross-border transmission investments.

In addition to addressing issues associated with the triggering of cross-border investment, it is also necessary to consider the issue of funding of that investment. In order for cross-border investments by TSOs to occur, there needs to be an assured basis for future recovery of the costs of that investment. However, the 'regulatory contract', which forms the basis for domestic 'regulated' investment decisions by the TSO, does not, in all instances, apply in respect of cross-border investment. In some countries the issue of funding is addressed by government decision. For example, in Finland, Spain and Austria cross-border investment in infrastructure is approved by the government and the cost is automatically incorporated in the Regulated Asset Base (and recovered through network tariffs). However, in other instances, such as the arrangements in place in Great Britain, no such arrangements exist.

2.2.2 Merchant lines: investment and remuneration

Merchant network investments are facilities that are not built under the initiative of regulators or TSOs, and whose remuneration is determined by the market and not by regulation.[10] Its capital and operating costs are met from risk capital, without mandated guarantees of future traffic or other forms of bankable advance sales, other than those freely negotiated in the market (DKM, 2003). The merchant model is not considered suitable as a general model for interconnector investment in Europe (EC, 2004).[11] Under the existing EU Regulation, regulated investments are assumed to be the general rule. However, in some exceptional cases it might be envisaged that interconnectors could be constructed on a merchant basis. In that case, the remuneration of the transmission facility is unregulated and is determined by the market value that the transmission owner can obtain from arbitrage or from selling capacity on the line.

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[10] Section 2.2.2 is largely derived from CEER (2004).

[11] Next to various problems with the use of a merchant model that are discussed in this section, Joskow and Tirole (2003) give a more detailed overview.

Merchant transmission investment is only profitable if the discounted value of earnings from sales of new transmission capacity exceeds investment and operation costs (Keller and Wild, 2003).[12] Earnings from transmission will be higher if more congestion occurs. Since the income of the merchant investor is directly derived from the congestion rents, the investment that would maximise the profits of a merchant investor is typically of a lower capacity than the optimal investment that the regulator would have chosen, if it were able to assess the optimal investment (CEER, 2004). In general, the socially optimal network investment would reduce the remaining congestion rents too much, from the point of view of investors. In actual transmission networks of developed countries, congestion rents globally collect a small fraction of the total costs of the transmission network. This is why merchant investments can only contribute to the development of a transmission network in some specific instances, but they cannot be relied on as the main mechanism to develop the network.

The natural incentive for a merchant investor to invest in a transmission line is the appropriation of congestion rents, whenever they have a stable pattern and a significant volume, so that the expected income that is obtained exceeds the expected cost of the line. This is entirely normal in a business activity. But the implication should be noted: whenever a new line is economically justified, all other things being equal, it will be less expensive for the network users as a whole to pay the cost of the line than to pay the congestion rent. This is one of the reasons why a regulator might in principle look for the development of regulated network investments. Of course, things are rarely equal, and merchant investors will generally find options and opportunities that are missed in a more regulated setting.

The remuneration of the owner of a merchant network facility will not be regulated but, in principle, it will have to follow the same rules on access, transparency and non-discrimination that apply to regulated facilities. The existence of a merchant line cannot prevent the construction of an additional regulated or merchant line, even if it induces a decrease of the congestion rent levied by the merchant line. Equally, the conditions under which any such additional regulated line may be built need to be set out in advance in order to minimise regulatory risk for the merchant investor.

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[12] If the TSO invests in regulated transmission lines (discussed in the previous section), it can recover the costs by use of system charges. To get approval of the investment decision, the TSO can take (positive) external effects into account, such as increasing reliability and increasing competition, but this is impossible for merchant investors.

3 Advantages, drivers and benefits of interconnection

Interconnection lines can provide different advantages and benefits that play a role at the national level, but may be extended on a European scale too. The next sections briefly discuss the main advantages of and drivers for investments in interconnecting different power systems. These advantages and drivers can be valued and used for assessing the benefits of new or additional interconnection with non-EU regions. They have to be compared with the ensuing costs, and, therefore, Chapter 4 will discuss barriers and costs of interconnection.

3.1 Increasing reliability

As is already mentioned in Chapter 2, one of the most important advantages of interconnection is that it strongly contributes to the enhancement of the continuity and reliability of the electricity supply. Both short-term reliability and long-term adequacy of supply increase. Failures of generating units can immediately be compensated (temporarily) by neighbouring electricity systems and the meshed and interconnected grids make control of frequency stability and voltage levels easier. A large interconnected transmission grid, like in Europe, offers robustness. The effect of a (short-term) production or network failure in the interconnected system is in fact spread out over the whole of Europe. An integrated transmission and distribution system allows surplus generation capacity in one area to cover shortfalls elsewhere. In theory, the existing reserve capacity in the entire interconnected system can be shared among all constituent systems. This implies that in a larger (interconnected) system, the same reliability can be offered with a smaller reserve margin. In practice, however, the interconnected system is not a copper plate. Congestion issues, amongst other things, make this proposition only partly legitimate.[13]

In line with the short-term reliability benefits, interconnection can lead to a reduction in frequency response. System frequency varies continuously and depends on a careful balance between demand and generation. If system demand is greater than system generation, frequency will fall and if generation is greater than demand, frequency rises. To avoid an unacceptable fall in frequency should generating plants fail, additional generation or reductions in demand need to be available that can be called upon at very short notice. This is referred to as ‘frequency response’. Without transmission interconnection, each separate system would need to carry its own frequency response to meet demand variations, but with interconnection the net response requirement only needs to match the highest of the individual system requirements to cover for the largest potential loss of power (generation) rather than the sum of them all (NGC, 2005). Interconnection allows the frequency of the total system to be controlled without each separate system having to maintain its own frequency (Butler, 2001).

Concerning the long-term aspect of reliability, a firm interconnection of different markets promotes the working of the market as it increases liquidity, which results in a better price development, which in turn automatically contributes to adequacy of supply. A stable price development is, after all, an important indicator for investors in new generating capacity. A robust electricity network forms the basis of sound competition between large European electricity producers (TenneT, 2004).[14]

Finally, increased interconnection allows for the improvement of security of supply by allowing a more diverse mix of primary energy sources (EC, 2004).

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[13] Section 4.3 will discuss the congestion issue in more detail.

[14] However, as will be discussed in Section 4.5.2, interconnection capacity competes with domestic generating capacity and may, therefore, dispel domestic investments in new generating capacity.

3.2 Price differences

When interconnections are weak (or not existing at all), the gains in reliability that can be obtained in new interconnection links are quite important, but later on, when interconnections become stronger, the additional gains become progressively less important. Concerning reliability, the European system has reached such a size and has developed so detailed common standards that very few improvements can be expected from the interconnection of new systems (EURELECTRIC, 2005). At that moment, a second advantage may however appear which consists in the possibility of developing systematic exchanges of electricity in the presence of differences in electricity prices.

The existence of price differences between regions is one of the most important economic drivers for interconnection nowadays. Interconnectors are the vehicles for price arbitrage between markets. As long as there are structural price differences between countries, there is a need for interconnection capacity, for imports as well as exports. Partly, these price differences may result from the lack of a level playing field for generation in the different parts of the European electricity system. Other causes for price differences are differences in fuel mix and load patterns. In the below sub sections, these causes are shortly discussed.[15]

3.2.1 Differences in fuel mix and primary resources

Different countries have different generation mixes. These can vary from generation that almost solely exists of hydropower (like Norway), comprise 75 percent of nuclear power (France) or have an emphasis on gas (Netherlands) or coal (Germany). The different generation types have different characteristics and the characteristics of the generation park in each country can lead to prices for wholesale electricity that vary by a factor of two or three (EC, 2004). Nuclear power has relatively low variable costs, and is a typical baseload type of generation. Gas, on the other hand, especially with the current high oil prices, is relatively expensive, but can be flexibly used to meet peak load. The differences in fuel mixes between countries or regions are linked with the availability of primary resources.[16] Weather conditions and landscape in Norway are very suitable for hydropower, the Netherlands has lots of gas and Germany possesses much coal. Therefore, interconnection and trade can be used to exploit comparative advantages. There are gains to trade between e.g. nuclear and hydro (Nordpool region, France-Switzerland).

Specific baseload technologies (nuclear and coal) require different fuels than typical peak-load technologies (gas and hydro). In the long run, countries or regions that have cheap availability of specific primary resources are likely to concentrate on (‘specialise’ in) generating technologies that match with these resources. They will exploit specific comparative advantages. But as there is no preferred technology for peak load or for base load, the long-term trend of exchange will probably head in the direction of intra-day exchange: ‘base-load countries’ exporting during off-peak hours and importing during peak-hours[17], and ‘peak-load countries’ vice versa. Due to different availabilities of resources in countries or regions, there may arise possibilities for efficient exchange within a day.[18]

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[15] Other possible causes for price differences, which are not discussed in this section, concern the wielding of market power (discussed in Section 3.3) and the amount of scarceness of generating capacity. If the reserve margin in a country is structurally low, scarcity rents may be present (which is a natural incentive to provoke new investments in generating capacity). In that case, investment in interconnection might be fruitful, but it must be compared with other feasible alternatives, such as an investment in new generating capacity.

[16] The availability of domestic primary resources (e.g. coal) is often a driver for specific generation types (coal-fired power stations). But also excellent supply conditions (e.g. for gas) may be a driver. Furthermore, social acceptance plays a role, especially in the case of nuclear power.

[17] Or exporting less during peak-hours.

[18] Fuel prices are an important factor, as they affect the relative advantages of the different generating technologies. Furthermore, the internalisation of CO_2 costs may have a major impact. And finally, the penetration of (intermittent) renewable energy sources may change the picture considerably.

3.2.2 Differences in load patterns

There could be a structural need for exchange if peak demand falls on different times within a day (particularly of importance for geographically, east-west spread areas). Furthermore, different demand characteristics (energy intensive industry) can result in different load curves, which justify structural exchanges. By connecting regions with different load patterns, it may be possible to meet demand more efficiently, as the aggregated demand curve is flatter.

3.2.3 Differences from a lack of level playing field

The level playing field concerns (regulatory) aspects like tax regimes, subsidies, (environmental) legislation and market structure. Differences in these aspects can create price differences, which are a driver for interconnection. However, it is expected that these national differences will fade away in the longer term (TenneT, 2004) and consequently will not form a basis for structural exchange. It may be a 'false driver' for interconnection. It is of major importance to denude if price differences that are existent between different markets are solely the result of a lack of level playing field. In that case, investment in interconnection may not be efficient. Because of the complexity and ambiguity, regulatory issues are separately discussed in Chapter 5.

3.3 Interconnection promotes competition and efficiency

Another important benefit of interconnection is that it enlarges the relevant markets of generators. Interconnection makes it possible to deploy generating units more efficiently. Connecting together all participants across the interconnected transmission system makes it feasible to select the cheapest generation available in the system - taking into account transmission losses and transmission capacity limits - irrespective of the location of the plant (Butler, 2001). A firm interconnection of different markets promotes the working of the market as it increases liquidity and competition. It reduces the possibility to abuse market power and it suppresses the higher electricity prices that might have arisen from it. A robust interconnected electricity network forms the basis of sound competition between large electricity producers (TenneT, 2004).

3.4 Conclusion

Interconnection of different electricity systems offers different advantages and benefits. In the first place it provides reliability and increases the robustness of the system. The effect of a production or network failure can be compensated by neighbouring systems. Furthermore, it increases efficiency and reduces the possibility to abuse market power. Competition is promoted, as the relevant market of generators is enlarged. Interconnection makes it feasible to select the cheapest generation available in the system. Price differences are the signal that efficiency gains can be obtained. They are the primary driver for interconnection and international trade, as interconnection makes it possible to arbitrage price differences. To make a sound decision whether to invest in new interconnection capacity, the causes behind the price differences should therefore be well understood. As interconnection infrastructure is very capital-intensive and has a very long life span, price differences must originate from structural, long-term causes. Differences in primary resources, fuel mix and load patterns are such causes. However, price differences that occur due to the lack of level playing field may not be structural and therefore may not justify investment in interconnection capacity.

4 Barriers, costs and drawbacks of interconnection

In order to achieve benefits of connecting to neighbouring non-EU regions, for the EU and EU regions - as well as for the neighbouring regions themselves - it is important that power from/to these foreign electricity systems can flow undisturbedly (to a certain extent) across Member State borders. However, this condition might raise a number of potential problems. Internal bottlenecks within the EU may have effects on trade with neighbouring regions. Consequently, it may not be sufficient to increase capacity on the interconnectors (or build new capacity) but to increase the capacity of the transmission grid within the EU in order to improve the conditions for international trade (EC, 2004). As stated in Section 2.1, high-voltage interconnectors within the EU have been developed predominantly for short-term security reasons, while the liberalisation of the electric power markets resulted in trading opportunities that are fully exploited and that quickly exhaust the capacities of the interconnectors (Brunekreeft, 2005). The resulting congestion within the EU can be a barrier for long distance transmission of electricity (Section 4.3). Furthermore, important constraints are the huge investment costs of EHV-networks (the interconnection lines itself as well as for transporting the power through Europe; Section 4.1) and rising costs with increasing transmission distances (losses, Section 4.2). An analysis of these and other barriers and cost factors that hinder the well functioning of interconnection lines, is the subject of this chapter.

4.1 Investment costs

Investment in transmission capacity is characterised by significant fixed costs. The costs of the fixed assets of the transmission system include permits, feasibility studies, rights-of-way, ground and preparatory work, the pylons and conductors and other equipment and their assembly, engineering and labour and finance costs (ICF, 2002). The realisation time of new transmission capacity is ten years or longer (KEMA, 2004a). ICF (2002) has made an assessment of the costs in a number of countries to arrive at an estimated standard cost of construction. Table 4.1 shows the estimated costs for construction over flat land.

Table 4.1 *Costs for constructing transmission lines over flat land*

	k€/km
Single 380kV overhead line	251
Double 380kV overhead line	402
Single 220kV overhead line	168
Double 220kV overhead line	269
400kV DC underground cable	2,008

Source: ICF, 2002.

ICF estimates that 380/400kV underground cables cost between 5 and 25 times as much to install as overhead lines. Besides the additional insulation, extra land is needed for the sealing end where the cables need to be connected to overhead lines. The volume of spoil excavated is over 30 times that required for the equivalent overhead line route. Burial also results in the loss of part of the energy conveyed. To remedy this, substations are required every 15 to 20 km. Repair costs are also greater as the detection, identification and repair of the underground cables is far more complex. As a consequence, underground cabling of networks at 380/400kV is the exception rather than the rule in most countries around the world.

The high investment costs and the long lifetime of interconnection and transmission lines, cause market participants, including TSOs and regulators, to be very cautious with investment decisions.

4.2 Energy transmission losses

Electricity flows across the transmission system cause transmission power losses, primarily due to the heating of transmission lines, cables and transformers. The farer power is been transported, the more of it is lost as heat. Most of these power losses are a function of the square of the current flowing through the circuit or transformer windings (I^2R) and cause unwanted but inevitable heating of transmission lines, cables and transformers (NGC, 2005). Since such losses are variable they are often referred to as the ‘variable’ power losses.

In addition there are unavoidable ‘fixed’ losses associated with overhead lines and transformers. These include fixed losses on overhead transmission lines, referred to as corona losses, which are a function of voltage levels and weather conditions. Corona loss is the loss of power to the air and insulation surrounding high-voltage equipment (NGC, 2005).[19] Fixed losses in a transformer are iron losses that vary with the frequency of the electricity flow (Butler, 2001). They occur in the iron core of the transformer when subjected to an alternating magnetic field. The ‘variable’ transformer heating losses mentioned above are sometimes referred to as ‘copper’ losses in recognition of the material used for transformer windings, and therefore transformers have ‘variable’ copper losses and ‘fixed’ iron losses.

Although DC lines have a higher capital cost, they do have lower line losses. Its line losses amount to about five percent on a 1000 km journey, whereas AC lines can lose up to 20 percent over the same distance (ICF, 2002).

To give an idea of the magnitude of grid losses, Table 4.2 gives an overview of grid losses as a percentage of domestic demand. Note that these are total losses, including losses on medium and low voltage levels. Grid losses on the (extra) high voltage level are only a small part of these.

As stated before, from a EU perspective it is important that Europe as a whole or at the regional level benefits by interconnection with adjoining regions. But if electricity has to be transported over long distances, which might be the case with interconnecting regions that are neighbouring the EU, energy losses may be an important barrier to interconnection. Not only the length of the interconnection lines itself is of relevance[20], the distance over which the imported electricity has to be transported into the EU is of major importance as well, including the transports that may be induced by the imports. The same holds for electricity that is to be used for export: that has to be transported through the EU as well and may also induce additional transports and cause losses. In these respects, energy losses may form a barrier for interconnecting regions that are neighbouring the EU.[21]

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[19] Corona loss is generally visible in the dark as a luminous glow surrounding high-voltage conductors.

[20] After all, DC lines could be used to reduce losses.

[21] If, due to high energy losses, interconnection is not viable from a EU perspective, i.e. it is considered to offer benefits at a local (national) scale only, interconnection with a non-EU country could be very well beneficial to specific EU Member States.

Table 4.2 *International comparison of grid losses*

Country	1980 [%]	1990 [%]	2000 [%]
Finland	6.2	4.8	3.7
Netherlands	4.7	4.2	4.2
Belgium	6.5	6.0	4.8
Germany	5.3	5.2	5.1
Italy	10.4	7.5	7.0
Denmark	9.3	8.8	7.1
Switzerland	9.1	7.0	7.4
France	6.9	9.0	7.8
Austria	7.9	6.9	7.8
Sweden	9.8	7.6	9.1
Great Britain	9.2	8.9	9.4
Portugal	13.3	9.8	9.4
Norway	9.5	7.1	9.8
Ireland	12.8	10.9	9.9
Spain	11.1	11.1	10.6
European Union	7.9	7.3	7.3

Source: KEMA, 2004b.

4.3 Internal congestion

One could say that the European electricity network finds itself in the same position as the national electricity grids in the sixties: in the middle of the transition from a connecting grid to a transmission grid (KEMA, 2004a). The liberalisation of the electric power markets in Europe resulted in trading opportunities that are fully exploited, which quickly exhausted the capacities of the interconnectors (Brunekreeft, 2005).[22] Relatively small cross-border capacities and insufficient allocation of these capacities can lead to congestion within the EU. The reality of today's electricity network is that Member States are not particularly well interconnected (EC, 2004).

Some of the bottlenecks within the EU are given by natural barriers like the Alps, the Pyrenees, the Northern Sea and the Mediterranean Sea. Furthermore, increased transient electricity flows can result in bottlenecks, like the transient flows through Belgium and The Netherlands.[23] Between Eastern Europe and its Western neighbours congestion is enforced by the cost structure of electricity generation. Poland, the Czech Republic and Slovakia have inexpensive surplus capacities for which Germany, Hungary and Austria are potential markets. Because of business or political (nuclear power) reasons, these countries are successfully opposing the commissioning of new transmission lines that could resolve the above-described bottlenecks (EC, 2003b).[24] Thus the profitable exporting lines are almost always congested.

Internal congestion within the EU could be a major barrier for interconnecting non-EU regions. If, due to this internal congestion, electricity cannot sufficiently flow across national Member State borders, interconnection with non-EU regions can at the most offer benefits at a local (national) scale only. Whatever advantages for the EU or EU regions there may be with interconnecting non-EU regions, these are unachievable if internal congestion occurs in an extent that it prevents them to be passed along across Member State borders. Network reinforcements are then required to solve internal congestion, but these may have very high costs, which may de-

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[22] Besides, more effective regulation has led to a reduction in excess transmission capacity, which makes transmission systems become more stressed and prone to congestion (IEA, 2005a).

[23] See Section 4.4.

[24] Section 4.5.2 will discuss political resistance against new interconnection lines.

crease the overall profitability of the concerned interconnection substantially. Congestion within the EU or EU regions prevents the advantages of interconnection to be fully reaped.[25]

4.4 Increase of unidentified flows (loop flows)

Currently, due to the fluctuating wind power from northern Germany, strongly changing international flow patterns regularly create unsafe situations in the northwest European electricity grid (TenneT, 2005). A surplus of wind power in northern Germany, during windy periods, cannot be directly transported to the south of Germany, because the German electricity grid was not designed to transmit these electricity flows. The excess of power is transported to the south of Germany via the Dutch and Belgian grids, as the internal network in Germany cannot handle the flows itself. These spontaneous electricity flows not only deteriorate the stability of the network, but also require bigger reserve margins concerning the allocation of international and interregional transport capacity (UCTE, 2005a). It hampers an optimal working of the market, as less interconnection capacity is available to market participants. That reduces the possibility to make use of the advantages that are described in Chapter 3, causing the interconnector to become less efficient. The expected strong growth of wind power in the coming years increases the risk of large-scale disruptions in the electricity supply system in the near future, if internal transmission capacity remains insufficient.[26]

Next to an inadequate electricity grid, another important cause for loop flows resulting from interconnection is the inaccuracy of forecasts of TSOs. TSOs do not have exact knowledge of trade transactions outside their own areas, whereas the resulting transports do go through their networks. For a reliable forecast of the amounts of electricity that crosses the interconnections, TSOs are dependent on UCTE data. However, the control blocks and control coordinators[27] only check the balance of demand and supply. There are no forecasts of the total UCTE power flows, e.g. by means of load flow calculations (KEMA, 2004a).

Another reason for loop flows are contingencies. Disturbances in the European electricity grids, like short circuits, lightning strokes, or operating errors, which result in the fall out of connections or generating units, cause (sometimes huge) changes in power flows that are unforeseen.

Control blocks (source: www.ucte.org)
One or several *control areas* form a *control block* (a technically and geographically demarcated subsystem able to be operated independently in cases of emergency). The coordinator of such a control block maintains the exchange balance (control program) towards the neighbouring blocks, and is responsible for the respective *metering* and *accounting*. Differences between the scheduled energy exchange and real physical exchanges (inadvertent deviations) of control areas/blocks have to be collected and offset during the following week. In UCTE, coordination centres -Brauweiler (RWE Transportnetz Strom GmbH.) and Laufenburg (ETRANS) in the first zone and Beograd (EKC) in the second zone- organise the *accounting* process.

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[25] However, individual Member States may still benefit of interconnection with a non-EU country. But if it is considered to offer benefits at a local (national) scale only, it does not fall within the primary responsibility of the EU and the scope of this report.

[26] See also Section 4.3. Section 4.3 describes congestion problems *between* countries (at the borders; interconnection), while Section 4.4 aims at congestion *within* a country.

[27] See textbox *Control blocks*.

4.5 Resistance against new lines

4.5.1 Public resistance

The construction of new transmission lines can be almost impossible due to opposition from residents in the affected areas (Keller and Wild, 2003).[28] Since nobody wants to have electricity lines in his backyard, the installation of such lines causes negative externalities in terms of decreasing land value and disfiguring of landscape. An attempt to overcome the resistance against new lines is to take these externalities into account e.g. in offering financial compensations, which have to be considered as costs of the investment. The consultation and possible legal procedures can lead to delays and substantial costs.

4.5.2 Political resistance

As interconnection capacity competes with domestic generation, new interconnection capacity may impede investments in domestic generating capacity. Importing countries, where domestic electricity generation is relatively costly, may therefore become increasingly dependent on foreign countries. That may be experienced as a political undesirable development. Import dependency is a very important issue in many European countries already. Import of electricity has a number of specific uncertainties that do not exist for domestic generation. These concern the development of electricity generation in neighbouring countries, the capacity and reliability of interconnectors, including the administration of the interconnection lines, and the regulation that still diverge on a number of points.[29]

Another barrier of political nature can be the choice for nuclear power. Poland, the Czech Republic and Slovakia have inexpensive surplus capacities for which Germany, Hungary and Austria are potential markets.[30] However, because of political (nuclear power) reasons, these countries are successfully opposing the commissioning of new transmission lines that could resolve the congestion bottlenecks (EC, 2003b).

4.6 Conclusion

In Chapter 3 advantages and drivers of interconnection are discussed. But these advantages come at a cost, and, partly due to the structure of the electricity system, the advantages may not be fully exploited. Firstly, there are investment costs, which are high for building new interconnections. These high investment costs and the long lifetime of interconnection and transmission lines, cause market participants, including TSOs and regulators, to be very cautious with investment decisions. Next to the investment costs, there are energy losses that are caused by transporting electricity. Not only the length of the interconnection lines itself is of relevance, the distance over which the imported electricity has to be transported into the EU is of major importance as well, including the transports that may be induced by the imports. The same holds for electricity that is to be used for export: that has to be transported through the EU as well and may also induce additional transports and cause losses. A third possible barrier results from the fact that the electricity grid in Europe cannot be considered a copper plate. Relatively small cross-border capacities and insufficient allocation of these capacities can lead to congestion within the EU, which impedes the imported electricity to freely flow to demand areas (and hinders the export of electricity to neighbouring regions). A lack of certain trans-border network connections and elements of the internal networks, as well as transmission limitations of the existing connections, are concrete barriers to unrestricted electricity trade (EURELECTRIC, 2002). Whatever advantages there may be with interconnecting non-EU regions, these are un-

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[28] Note that resistance against new lines (public as well as political) is not a direct economic issue. However, it can be a major barrier for building new interconnection lines.

[29] Chapter 5 will deal with regulatory issues.

[30] See also Section 4.3.

achievable if internal congestion occurs in an extent that it prevents them to be passed along across Member State borders in order to be beneficial at the EU level. Furthermore, interconnecting non-EU regions can create the possibility of loop flows, due to e.g. an inadequate internal electricity grid, the inaccuracy of forecasts of TSOs or contingencies. That reduces the interconnection capacity that is available for the market and, therefore, reduces the possibility to make use of the advantages that are described in Chapter 3, causing the interconnector to become less efficient. In addition, because interconnection capacity competes with domestic generation, interconnection could lead to an increasing import dependency, which may create political resistance. And finally, there may be opposition from residents in the areas where the transmission and interconnection lines have to be built.

These barriers have to be seriously taken into account when considering the interconnection of non-EU regions. A fair distinction has to be made between interconnection leading to benefits for the EU as a whole, and benefits at a local (national) level only. Because of the costs and possibly reduced advantages of interconnection, it may not always be cost effective to increase interconnector capacity. It has to be compared carefully with other options, e.g. the option to build new power plants.

5 Regulatory issues

The more market designs and rules between countries/regions differ, the more likely it is that trade is impeded or distorted between markets (ERGEG, 2005). Market players will tend to transact with players in the same national market rather than expose themselves to risks and difficulties of dealing with the other market, which may tend to discourage trades that might otherwise have been efficient. On the other hand, a lack of level playing field could also be a driver for trade, in the sense that it may create price differences. It is of major importance to denude if price differences that are existent between different markets are solely the result of a lack of level playing field. In that case, investment in interconnection might not be efficient, as it is expected that these national differences will fade away in the longer term (TenneT, 2004). For EU Member States it is already expected that most rules will be standardised at EU level in any event and that any artificial partitioning of the EU market will be avoided (EC, 2004).[31]

As a general rule, different designs and rules impede structural trade opportunities. Compatibility between key market rules is important so that opportunities for trade can be fully realised. In the following sections, a number of relevant regulatory issues are discussed.[32, 33]

5.1 Timing of gate closure

'Gate closure' is the point in time when market participants notify the system operator of their intended final physical position (NGC, 2005). Physical notifications become fixed and in addition no further contract notification can be made to the central settlement systems. After that point a market participant will be considered to be out of balance if its physical position within the given trading period does not match with its contracted position. Up until this point, market participants are able to trade in order to let their contracted position reflect their expected physical position. To the extent that there are differences in the timing of gate closure across a border, e.g. where in country A the timing of gate closure is half an hour in advance and in country B one day, there will be little or no opportunity for short term trade to occur from country A to country B although opportunities will exist from country B to country A (ERGEG, 2005).

5.2 Imbalance arrangements

Differences in national arrangements for dealing with the costs of imbalance may affect the competitive position of market participants. For example, if in system A the imbalance costs imposed by a market participant are reflected back on to him fully (as in Great Britain and the Netherlands) this results in sharp price signals that stimulates market participants to stay in balance and exposes them to risks if they fall into imbalance (ERGEG, 2005). The risk of a market participant connected to an adjacent network (system B), where balancing costs are socialised across all users, means that his risk profile on that network is different and the consequence of having an imbalance position may be much less severe for any individual. This may have the effect that a generator in system B has an advantage over one in system A, who will face the

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[31] As stated in Section 1.1, certain countries within the EU have already adopted common harmonised rules. Within these regional markets a more developed harmonisation of the regulatory approach taken to most or all issues is expected, including the degree of market opening, determination of transmission tariffs, the rules for bilateral trading as well as congestion management methodologies involving standardised day ahead and intraday markets (EC, 2004). In some cases, the regulations governing balancing and ancillary services might also be harmonised to some degree.

[32] Most of the sections in this chapter are derived from ERGEG (2005).

[33] The chapter does not intend to give a full overview of all relevant regulatory issues. It gives an idea of issues that might play a role with interconnecting different electricity and regulatory systems. See e.g. IEA (2005a) for additional discussion on regulatory issues concerning transmission infrastructure.

costs of imbalance directly whilst the other will not. The way that balancing costs are passed on to market participants through imbalance charges can affect their competitive position and as such the extent of compatibility between national imbalance arrangements within interconnected markets.

5.3 Transmission access rights

The allocation of transmission access rights, which give access to the transmission network and the interconnection lines, may differ from network to network. An access right consists of a number of elements, such as the capacity and location(s) for which access applies, the duration of the capacity right, and the degree of firmness of the access right (including the compensation to apply in the event that the right is not available under any circumstance) (ILEX, 2002). Some transmission networks (such as Great Britain, Austria and Finland) provide financially firm transmission access rights. In such cases a market participant that has their physical access rights reduced as a result of constraints or a transmission disturbance, receives financial compensation for lost output or consumption (ERGEG, 2005).[34] The effect of these arrangements is to make individual market participants less sensitive to the commercial risks associated with their particular location on the transmission network or to changes in the physical availability of transmission capacity. This reduces commercial uncertainty for market participants. In other countries, access rights may be financially non-firm. In such cases market participants are not compensated for the withdrawal of access rights and bear the commercial risks associated with lost output and consumption. That results in additional costs compared with market participants that have firm transmission access rights.

5.4 Tariff regulation

The structure of tariff regulation (including terminology such as connection charges, use of system charges, transmission charges, network charges and congestion charges) may differ between control areas. For example the proportion of total network charges that is placed on generators and users by each TSO may create price differences. In some TSO areas generators pay an average of zero, while in others generators may pay up to forty per cent of total costs (ERGEG, 2005). Such differences can be a disadvantage to generators in one TSO area compared to another in competition for the same customer. Furthermore, in some countries the cost of network losses, system constraints, ancillary services and taxes are included in the capacity element of the transmission tariff, while in other countries, these costs are included in either the energy element of the use of system tariff or in congestion management charges (ICF, 2002). Some countries also include a charge for stranded costs whilst others include charges relating to the promotion of renewable energy or CHP. All these differences in (the structure of) tariffs between different networks may lead to significant price differences, but it does not form a strong basis for structural exchange and therefore, on its own, it does not justify interconnection.

5.5 Unbundling and ownership of interconnectors

Interconnectors have a special importance, since they are the vehicles for price arbitrage between markets. Ideally, the price signals on both sides of a congested transmission line should be used as a signal not only to invest in generation assets but also in transmission assets. This reinforces that control over interconnectors is one of the most powerful roles in an electricity market. This ‘gate keeper’ gets access to congestion rent and potentially controls the level of competition that is allowed in any particular market. At any given level of transmission capacity, the congestion rent will be reduced if the transmission capacity is increased. Therefore, an

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[34] The TSO would only be able to withdraw access rights by buying them back. This approach would automatically mean that participants would be compensated for a lack of access in the event of transmission failures.

owner of such capacity may not have the right incentives to invest. The independence of this 'gate keeper' is, as a consequence, essential to a competitive liberalised electricity market (IEA, 2005a).

In some cases ineffective unbundling can encourage transmission network owners to discriminate in favour of incumbent generators, at the expense of efficient network investments to maximise trade and competition. If, as expected, imports lower domestic prices, then vertically integrated generation/ transmission importers will lose and may block interconnector investment. Besides discouraging efficient network investment, such behaviour may have the potential to distort efficient operation and development of regional electricity markets. Therefore, unbundling transmission from generation on both sides of the border is an important step in reaching agreement to strengthen interconnection (Newbery, 2002).

5.6 Conclusion

The more market designs and rules between countries/regions differ, the more likely it is that trade is impeded or distorted between markets (ERGEG, 2005). The presence of differing national or regional approaches may impact upon cross border trade. As a general rule, different designs and rules impede structural trade opportunities. Compatibility between key market rules therefore is important so that opportunities for trade can be fully realised. Regulatory issues that are discussed in this chapter comprise rules concerning the timing of gate closure, imbalance arrangements, the firmness of transmission access rights, the type of tariff regulation, unbundling and the ownership of interconnectors. However, as stated before, this chapter does not pretend to give a full overview of all relevant regulatory issues. There may be a lot of other regulatory issues that are of importance when considering interconnection. For example the market structure (including the mechanism through which trade occurs) in adjacent countries/regions may take one of various forms and is of influence on trade.[35] And another factor that may need to be considered is the extent to which national measures for ensuring security of supply are compatible (ERGEG 2005).[36]

However, the above discussion does not necessarily mean that full harmonisation of all trading rules and arrangements is required for effective trade interaction between markets to occur. But regulatory arrangements need to be independent, with regulatory processes characterised by transparency, objectivity and consistency (IEA, 2005b).

Furthermore, it is important to note that price differences that result from different regulatory structures may not form a basis for structural exchange, as it is expected that these national differences will fade away in the longer term (TenneT, 2004). It may be a 'false driver' for interconnection. Therefore, it is of major importance to denude if price differences that are existent between different markets are the result of a lack of level playing field. In that case, investment in interconnection may not be justified.

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[35] A market could be a mandatory market (such as a Pool arrangement, like proposed for Ireland and Northern Ireland) through which trades must occur or could be through the existence of an 'over the counter' (OTC) bilateral market where market participants enter voluntarily into bilateral contracts (like the trading arrangements established in Great Britain). In some instances, it may be common for both types of market to be in existence in any given area (ERGEG, 2005).

[36] For example, a market with capacity payments may need to address how these payments would work in relation to energy imported from an adjacent market.

6 Conclusion

6.1 Introduction

When interconnections are weak (or not existing at all), the gains in reliability that can be obtained in new interconnection links are an important advantage. But later on, when interconnections become stronger, the additional gains become progressively less important. Concerning reliability, the UCTE system and its existing interconnections with UK, NORDEL and North Africa has reached such a size and such a level of quality that very few improvements can be expected from the connection of new systems (Eurelectric, 2005). The primary motivation for the growth of the system, which was the improvement of security, shifts to other reasons which can be political or commercial or both.[37] Advantages may appear by systematic exchanges and trade of electricity due to e.g. differences in generation costs. Especially the border regions of the EU may benefit from interconnections with neighbouring regions. This chapter summarises the relevant potential benefits (advantages) and cost factors (barriers) that have to be taken into account when considering and evaluating (additional) interconnection between the EU and neighbouring regions. Section 6.2 gives an overview of relevant information and criteria that can be used to assess possible interconnections. Section 6.4 will summarise the final conclusions of this report.

6.2 Required information and criteria to assess costs and benefits of interconnection

To assess investments in new cross-border facilities, the advantages and barriers that are (qualitatively) described in this report should be evaluated for the concerned interconnection. These comprise, amongst others, the impact of interconnection on reliability, the effect on competition and efficiency, the cause that underlies possible price differences, current and possible future (internal) congestion, investment costs, energy losses, import dependency, and regulatory design of the markets. To be able to evaluate the possible advantages and barriers (criteria), Table 6.1 summarises information elements regarding the electricity market that should be monitored and made available in the respective countries.[38] For all information elements, historical and current data as well as expected developments should be made available.

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[37] This report looks at economic (commercial) drivers and barriers for interconnection; political reasons are left out of consideration (except Section 4.5.2, which shortly discussed political barriers for interconnection).

[38] Some of this information is already available for neighbouring countries. See for instance: http://www.eurelectric.org/statistics/MedLatest.htm.

Table 6.1 *Required information for assessing drivers and barriers*

Criteria	Required information of the systems to be interconnected
Reliability[*]	• Magnitude of electricity system [GW] • The amount of interconnection capacity • Reserve margin • Age distribution of generating facilities • Fuel mix • Amount of distributed and intermittent generation • Quality of network; historical data about energy not supplied; number of interruptions; average duration of interruptions
Price differences	• Electricity prices, including spot, baseload, peak and forward prices • Underlying reason(s) for price difference – The demand for electricity (including load patterns and peak load) – Total generation capacity – Reserve margin (to indicate possible scarceness of generating capacity) – Fuel mix and primary resources, including fuel prices – Regulatory system ▪ Market structure (including level of unbundling) ▪ Tariff regulation ▪ Timing of gate closure ▪ Imbalance arrangements ▪ Transmission access rights ▪ Ownership of interconnector
Competition & efficiency	• Number and magnitude of relevant market participants • Part of interconnection capacity that is/will be effectively available to the market (e.g. loop flows may reduce the availability)
Investment costs	• Length of interconnection line • Costs of permits, feasibility studies, rights-of-way, ground, pylons, conductors, etc.
Energy losses	• Length of interconnection line • The distance over which imported electricity has to be transported into the EU or neighbouring system • The distance over which electricity that is to be used for export has to be transported • The transports that are induced by interconnecting (load-flow calculations), including loop-flows • Voltage level and type (AC/DC) of the interconnector and transmission lines
Internal congestion	• Data (e.g. on capacity, usage, the physical topology) of the transmission grids, including the cross-border facilities, and possibly the distribution grids • Capacity of individual plants • Load flows (e.g. by means of load flow calculations)
Public & political resistance	• Import dependency (in percentage of total installed capacity and total electricity demand) • Public and political attitude concerning nuclear power • Expected public resistance and type of area (urban/rural) in which the interconnector and supporting (transmission) lines should be built

[*] Note that, apart from increasing overall reliability, an event affecting a relatively distant part of a transmission system in a more integrated environment may also have greater potential to spread and severely disrupt the supply and operation of interconnected electricity markets (IEA, 2005b).

6.3 Cost benefit analysis

A cost benefit analysis may be a good tool to assess investments in interconnection capacity. Table 6.1 could be used as a starting point. Some barriers should be expressed in costs of solutions in order to make them compatible for the analysis (e.g. internal congestion could be expressed in the costs that have to be made to resolve it). But it may be difficult to obtain the required information. And even if all desired information is available, it may still be very hard to perform a proper cost benefit analysis in order to assess investments in interconnection. First, it can be problematic to exactly define the criteria (benefits and barriers) that are used. The criterion reliability is a good example of this. How can the additional reliability that may result from interconnection be measured? Which information is needed to get a good picture? There are lots of factors that influence it. The same holds for the criterion competition: how do you quantify the benefits that can be gained by increased competition? Furthermore, the relevant factors may be expressed in different units, which makes them hard to compare, or may sometimes be qualitative in nature (e.g. public and political resistance). And finally, the criteria should be weighted, which is a difficult issue as well and which makes the analysis susceptible to subjectivity. A proper cost benefit analysis is therefore not an easy thing to do.

Investments in interconnection and transmission network assets should only be made if the integral costs are smaller than the total benefits that arise from it. But even then, it may not always be cost effective to increase interconnector capacity, as it, for example, might in some situations be better to build new power plants (Brunekreeft, 2005). Interconnection must be compared with feasible alternatives (like maintaining the status quo or investing in generating capacity). Obviously, and expressed in simplified terms, when alternative investment possibilities exist, the network planner should choose those maximising the ratio of benefits to costs. The Australian regulatory authority has expressed this 'test' as follows: "*A new interconnector or transmission system augmentation satisfies this test if it maximises the net present value of the market benefit, having regard to a number of alternative projects, timings and market development scenarios*" (CEER, 2004). The term 'market benefit' is of course quite vague, but is defined as the total net benefits to all those who produce, distribute and consume electricity in the electricity market.

6.4 Final conclusions

It is of importance to make a clear distinction between interconnection leading to benefits for the EU as a whole or EU regions, and benefits at a local (national) level only. For valuating interconnection with neighbouring electricity systems from a EU perspective, it is important that benefits can be reaped at EU (region) level. As the European electricity system has already reached such a size, probably only few improvements from the connection of neighbouring systems can be expected for the EU as a whole. The potential benefits that are described in this report may especially be effective in the border regions of the EU. But internal network bottlenecks within EU regions may have constraining effects on trade with neighbouring regions. Additional network reinforcements may be necessary to mitigate or avoid internal congestion. Consequently, it may not be sufficient to increase capacity on the interconnectors (or build new capacity) but first to increase the capacity of the transmission grid within the EU in order to improve the conditions for international trade (EC, 2004). Only then, benefits can be reaped at EU (region) level.

Advantages, drivers and benefits of interconnection
Interconnection of different electricity systems offers several advantages and benefits. In the first place it provides reliability and increases the robustness of the system. Furthermore, it increases efficiency and reduces the possibility to abuse market power. Interconnection makes it feasible to select the cheapest generation available in the system. Price differences are the signal that efficiency gains can be obtained. To make a sound decision whether to invest in new interconnection capacity, the causes behind the price differences should be well understood. Price

differences must originate from structural, long-term causes. Differences in primary resources, fuel mix and load patterns are such causes. In the long run, countries or regions that have cheap availability of specific primary resources are likely to concentrate on (‘specialise’ in) generating technologies that match with these resources. They will exploit specific comparative advantages. It is important to note that price differences that result from the difference between regulatory structures (lack of level playing field) may not be structural and therefore may not justify investment in interconnection capacity. It may be a ‘false driver’ for interconnection.

Barriers, costs and drawbacks of interconnection
The advantages of interconnection come at a cost, and, partly due to the structure of the electricity system, they may not be fully exploited. Firstly, there are investment costs, which are high for building new interconnections. Next to the investment costs, there are energy losses that are caused by transporting electricity. Not only the length of the interconnection lines itself is of relevance, the transports that may be induced by interconnecting two systems (including loop flows) are of major importance as well. A third possible barrier results from the fact that the electricity grid in Europe cannot be considered a copper plate. Relatively small cross-border capacities and insufficient allocation of these capacities can lead to congestion within the EU, which impedes the imported electricity to freely flow to demand areas (and hinders the export of electricity to neighbouring regions). Whatever advantages there may be with interconnecting non-EU regions, these are unachievable if internal congestion occurs in an extent that it prevents them to be passed along across Member State borders in order to be beneficial at the EU level. Furthermore, interconnecting non-EU regions can create the possibility of loop flows, due to e.g. an inadequate internal electricity grid, the inaccuracy of forecasts of TSOs or contingencies. That reduces the interconnection capacity that is available for the market and, therefore, reduces the possibility to make use of the advantages, causing the interconnector to become less efficient. In addition, because interconnection capacity competes with domestic generation, interconnection could lead to an increasing import dependency, which may create political resistance. And finally, there may be opposition from residents in the areas where the transmission and interconnection lines have to be built.

Regulatory issues
When interconnecting with neighbouring regions, the stability of the interconnected system must be guaranteed. System reliability requirements demand the responsibility of all system operators to maintain and develop the system and make the necessary investment in the network infrastructure. In addition to technical and operational standards, common market rules are needed to ensure a level playing field based on fair competition, cost-based pricing, access to the network, transparent and non-discriminatory network tariffs, proper cross-border-trade mechanisms, congestion management, and capacity allocation mechanisms (EURELECTRIC, 2003b). The more market designs and rules between countries/regions differ, the more likely it is that trade is impeded or distorted between markets (ERGEG, 2005). As a general rule, different designs and rules impede structural trade opportunities. Compatibility between key market rules therefore is important so that opportunities for trade can be fully realised. Regulatory issues that are of relevance comprise rules concerning the timing of gate closure, imbalance arrangements, the firmness of transmission access rights, the type of tariff regulation, unbundling, the ownership of interconnectors, market structure, and security of supply measures. However, full harmonisation of all trading rules and arrangements is not necessarily required for effective trade interaction between markets to occur. But regulatory arrangements need to be independent, with regulatory processes characterised by transparency, objectivity and consistency (IEA, 2005b).

Concluding, interconnection with neighbouring regions can definitively offer several advantages and benefits on a European level, but they should be well compared with the integral costs and barriers that arise with it. This report gives a broad overview of aspects that should be taken into account in this comparison.

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Appendix A Concrete approaches to interconnect non-UCTE areas

UCTE adopts a case-by-case approach of the numerous requests to interconnect:[39]

- *Bulgaria* and *Romania* permanently interconnected (2003). After ten years of technical and organisational preparations resulting in compliance with all UCTE criteria, the permanent parallel operation of the Bulgarian and Romanian systems were approved and, in May 2003, the Transmission System Operators NEK and Transelectrica became full members of the association.

- *Western Ukraine* (Bursztyn Island) interconnected (2003). The western part of Ukraine, so called 'Burshtyn Island' upgraded its system according to UCTE requirements since the UKRENERGO applied for synchronous operation in 199X. The synchronisation took place on July 1, 2002, and, after successful one -year trial operation, the permanent synchronous connection was approved by UCTE in September 2003.

- Reconnection of two UCTE synchronous zones (2004). In 1991, the UCTE system was split into two separately operating synchronous zones following war events in ex-Yugoslavia. After the normalisation of political situation, UCTE makes much effort to encourage involved parties to reconstruct damaged infrastructure that is indispensable for physical interconnection. After commissioning of lines and substations constructed by HEP in Croatia in late 2003, and the completion of facilities in Bosnia - Herzegovina in 2004, the reconnection of two synchronous zones was successfully achieved on 10 November 2004. From this date on, the UCTE frequency beats from Portugal to Romania and from The Netherlands to Greece.

- Assessment of the procedure concerning the interconnection of *Maghreb* with *Libya* and *Eastern Mediterranean* (2004). Nowadays, the UCTE synchronous area comprises Morocco (linked by the AC cable with Spain), Algeria and Tunisia. The investigations on further interconnection of Tunisia with Libya (already forming a synchronous block with Egypt, Jordan and Syria) are under way. Special attention is given to inter-area oscillations, their damping (by installation and setting of Power System Stabilisers in certain units), and to defense plans, assuring that a disturbance does not propagate throughout the system.

- A major study on the possible electrical integration of *Turkey* into Europe was kicked-off on 28 September 2005 after several years of preparation of the project (UCTE, 2005b). The study will be performed by UCTE and is actively supported and financed by the European Commission. The Turkish power system is currently not set up for synchronous operations with other countries, but there are many interconnections such as to Azerbaijan, Armenia, Bulgaria, Georgia, Iran, Iraq and Syria. Turkey's rapid growth in electricity demand, which has led to almost a doubling of installed generating capacity over the past decade, is expected to continue for the foreseeable future. This could lead to building a total installed generating capacity of as much as 65 GW by 2010. In order to cover the future peak demand of electricity a synchronous operation of the Turkish and UCTE system would be helpful from a system adequacy point of view and would bring electrical Turkey into a market of over 500 million electricity consumers. The results of the study are foreseen to be available at the beginning of 2007.

- *CIS/Baltics* request for synchronous interconnection. It should be first kept in mind that no system extension of comparable size and complexity has ever been mastered before world-

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[39] This section is derived from www.ucte.org.

wide. In 2002, RAO EES Rossii and the Electric Power Council of Commonwealth of independent states asked UCTE to synchronously interconnect with the UCTE system. After consultations with stakeholders, the procedure of investigation of technical, organisational and legal conditions under which the requested synchronous interconnection would be feasible without negative impact on the reliability of the existing system(s) started. The preliminary load flow study completed in May 2003 revealed major limitations in future East-West transfers of electricity, as interconnectors in Central Europe are already now operating at their limits. The envisaged feasibility study will address number of technical, organisational and legal / contractual issues related to the physical interconnection of these two bulk systems. Environmental, market and nuclear safety issues are not tackled by the feasibility study. The study shall be performed as a joint project mastered by a UCTE consortium within a three years' period. The project kick-off was planned for early 2005 after signing a Cooperation Agreement between the Consortium of UCTE-transmission system operators (TSOs) and the IPS/UPS companies, but it has not yet started. The scope of the study (not exhaustive):

- Technical issues:
  - Coordination of control & reserve policies:
    - These policies determine the reliability of the whole synchronous area
    - Definition of transmission Reliability Margins (TRM) to be kept by TSOs
    - Main involved parties: TSOs and generation companies.
  - Dynamic analysis:
    - Mastering inter-area oscillations is crucial for reliability and needs extensive study work, resulting in investment in Power System Stabilisers (PSS) in generation units.
    - Transient stability: ability to withstand sudden incidents.
- Organisational issues:
  - The new unbundled environment shows that technical and operational coordination, necessary for interoperability of the control areas, must be embedded in appropriate organisational measures, involving not only TSOs but also generation companies.
  - Industry organisation (availability of spinning reserve a.s.o.),
  - Data exchange mechanisms & confidentiality clauses,
  - System operation policy,
  - Transmission capacity allocation mechanisms.
- Legal / contractual issues:
  - A binding legal/contractual framework is needed for ensuring the aforementioned organisational measures.
  - Other relevant market participants of newly interconnected area shall be bound by appropriate legal mechanisms: e.g: reserves to be guaranteed by generators shall be governed by national Grid Codes, etc.