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Energy Integration in European Power Sector

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ABSTRACT: This paper provides essential background of European power sector and discusses the theoretical background for its integration. Our work employs real-life statistics on the state of integration in order to find out what future development might be in place for this key sector of European economy. It can be shown that while some interest groups are losing on integration, others win. This issue enables us to discuss the delegation of control over the power market delegated to European entities. Our results demonstrate that there are considerable economic gains stemming from integration that are subjected to price variations and efficiency in using the power. Moreover, we explain how the power market on the EU-level implements reforms that might lead to the more integrated European power network.

Keywords: economic integration; energy economics; European Union; national power exchange
JEL Classifications: F40; Q20; Q47

1. Introduction

This paper introduces the basics of the European power sector as well as the current state of integration efforts in this sector in the specific case of Northern Europe. Further, it outlines the future steps towards a unified European power system. Both issues constitute an important problem in the context of the energy integration in Europe and beyond (see e.g. Convery and Redmond, 2007; Zachmann, 2008; Solarin, 2011; Romano and Scandurra, 2011; or Boluk, 2013).

Competitive, secure and sustainable energy is vital for enhancing the European economy and the development of the EU as such. With regard to these ambitious, European Commission set a goal for 2030 which envisages a high-level round table addressing the current fragmentation challenges and the promises of innovative technologies that will place the policy targets on the path of implementation.

It becomes obvious that EU needs novel, high performance low-cost, low-carbon sustainable energy technologies that can be bought and sold on the market. However, the main importance of these technologies, both in terms of delivery on in terms of policy goals, competitiveness and efficiency can be achieved through an integrated strategy for innovation in the European energy area that includes effective energy integration.

In January 2007, the European Commission published the third energy package report which represented a set of roadmaps, progress reports and the final results of the energy sector inquiry. The package also proposed future objectives, targets and actions report of the energy sector inquiry. The report concluded that there was a lack of electricity market integration on the European power market and this was mainly caused by the insufficient interconnecting infrastructure between national electricity systems, insufficient incentives to improve cross border infrastructure, inefficient allocation of existing capacities, and incompatible market design between TSOs and/or spot market operators.

Therefore, it seems that there are still obstacles in the way of power and energy sector integration in Europe that have to be tackled and removed in order to achieve the smooth functioning and competition on the European energy markets.

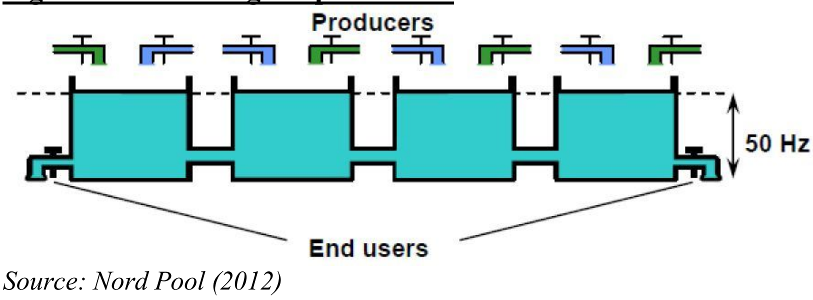
The paper is structured as follows: In the first part we introduce the basic pricing scheme and the different ways to handle the distribution of electricity that are employed in the European power sector. Next, we explain the organizational structure on the national markets and the players that operate on the European level.In the second part we will focus on the theory underlying increasing integration and take a more detailed look on the state of integration in the Nordic countries and especially on the border between Germany and Western Denmark. In the third part of the paper we explain how the European power markets are set to evolve in the future and what effects this might have on the integration in the sector.

2. European Power Sector: A Brief Overview

In order to provide power to human habitats, there is an intricate system that ensures the production of power, transmission through high-voltage lines, conversion to lower voltage lines and consumption of power, at precisely the same time a consumer turns on the power switch. In many ways it is helpful to visualize the power system as water flowing in a series of containers as shown in Figure 1.

Producers pour electricity into the system and power is tapped by consumers. But the system always has to balance. If there is produced more than there is consumed the frequency in the system rise from the base of 50 Hz (risk overflow in the tanks). If this is allowed to continue system components gets damaged (or shut down to prevent damage) and we experience a blackout (see e.g. Laurikka and Koljonen, 2006; Østergaard, 2009; or Križanič and Oplotnik, 2013). Similarly, if there is consumed more than there is produced the frequency falls below 50 Hz and there is again a risk of blackout. The single most important goal for the national regulators is to prevent conditions where the system might go into the risk of the power overload (Nagayama, 2009).

Figure 1. Visualising the power flow



Source: Nord Pool (2012)

When the operational security is ensured, the next issue is how to efficiently set prices on the markets that equalize supply and demand in every hour (Zachmann, 2008). In the liberalized European system this is handled by bilateral contracts between counterparties and anonymously trade on national power exchanges (Balagopalan et al., 2011). The terms of the bilateral exchanges are unknown, but significant volumes are traded on the exchanges (in the Nordic countries 72.7% was traded on exchange in April 2012) so the exchange prices must be representative of the general price level - otherwise there would be arbitrage opportunities between the exchange market and bilateral market (Oettinger, 2012).

Figure 2. Production/Consumption bids on the German/Austrian market

Source: Epex (2012)

In practice the total trade for hours occurs the following way: Part of the power consumption is sold bilaterally in day/months/years/hours before delivery of power. On the day before delivery of power, the national power exchange holds a day-ahead auction. In this auction producers/consumers submit bids for sale/purchase of power in every hour of the following day. The power exchange aggregates all submitted bids and finds the crossing price for every hour. This process is illustrated in Figure 2 for the German and Austrian markets (see Neubert and Böttcher, 2009).

The benefit of this marginal price setting is that if everyone bids their reservation price they will gain in welfare if their bid is accepted, and their bid is not accepted if they would lose welfare. Furthermore, the clearing price corresponds to the marginal costs of the last traded MW and thus provides a guide for future investment decisions. Most volume is traded before the delivery day, but because of renewable energy sources (RES) it is increasingly necessary to balance the positions in an intraday market. The intraday market is a classic continuous auction with bid/ask and an order book.

For operational reasons all consumers/producers have to balance their position (so that for example a producer feed all the power that was sold to other counterparties into the grid). If there is an imbalance it is eliminated by an automatic trade with the transmission system operator (TSO), usually for a disadvantageous price. The TSO obtains this balance-power supply/demand from operational reserves (see Lund, 2005; Lund and Kempton, 2008).

In the perfect world any power produced could be freely transmitted to the consumers. This is not the case. Because power lines are very costly, bottlenecks appear in the European transmission network. To counter bottlenecks the TSO's can do two things:

First they can set a different price on each site of the bottleneck that equates the supply and demand, taking into account the power that can flow from the cheap to the expensive region. These price regions mostly run along border lines, but some countries are also internally divided into price regions. In the Nordic system Sweden and Norway currently consist of 4 regions and Denmark of the two price regions East and West (Finland and Estonia both have one price region).

A second option the TSO can utilize when capacity between two regions are limited, is to intervene in the market to limit the actual power transmitted on the congested line. This is executed by the TSO buying power from additional producers at a higher than market price in the importing area, and the TSO selling back power to the producers in the exporting area at below market price.

The first model is generally preferred. It ensures that grid limitations are priced correctly. The market prices will then reflect the true economic value of production/consumption in different price regions. It also gives the market the true pricing signal for use in decisions on future investments and is costless for the TSO.

The second model can generally be very costly for the TSO. This cost is an externality that is not priced and thus the pricing is not economically efficient. Furthermore it gives wrong pricing signals for decisions on future investment. On the upside this model maintains a larger pricing area which limits the market power of larger participants.

The last point on power transmission between price regions is how the allocation of capacity on congested transmission lines is been handled. Historically the capacity has been sold in auctions and then the winner of the auction determined if they wanted to use the capacity. This is not the most efficient way, because an owner might transport power from a high price area to a low price area (which results in an adverse flow). Alternatively the capacity can be allocated automatically in the trading process. Then power always run from low-price area to high-price area and the owner receives the price differential between the two areas. This is the vision for the future European network.

The organization of the electricity market serves two purposes. First, it is to regulate and ensure the physical flow of power and to produce and consume the power most efficiently. These two purposes have spawned a number of institutions on the National level:

- Producers. The producers are the first link in the power chain. They both optimize production in the current power system and make huge investment decision based on their perception of any economic profit in the future power sector.
- Exchange. The power exchanges like any marketplace exist to match the lowest cost producers with consumers' willingness to pay. They also develop different products in demand by participants (i.e. intra-day trading).
- Traders and brokers facilitate trading on the exchanges. They serve many functions. By exploiting arbitrage they can connect different markets and make prices more informative (i.e. if a trader observes that the day-ahead auction and intraday on average differs significantly, they utilize this and the difference disappears). They can perform market making by supplying liquidity to the market and thereby connect producers and consumers through time.
- Retailers. Has a commitment to sell power to their end-users. They forecast the need and buy this power.
- End users. Consume power.
- Transmission System Operator. The TSO controls the operational security of the power grid. They usually operate the high voltage parts of the grid and transmission lines between countries.
- National Regulatory Agency - makes the national laws that are the base of the network and oversee the participants' action in the system.

The participants on the European level are mostly organizations of national participants. They control and debate the future development of the network. The main participants are:

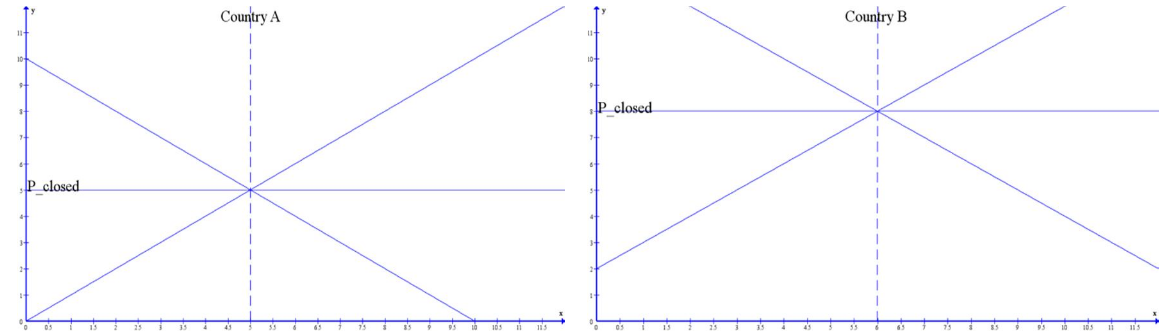
- The European Commission and European Union: The arguably most influential organization. As the agent of the national/European politicians they set both midterm and longer term goals for the energy sector. One of the currently most influential, the 3rd energy package that has many goals, one of which is that European market price coupling is to be completed by 2014. The Commission also sets emission reduction goals that are hugely influential in the power system development. On longer term the Commission promotes the idea that the European power generation is low carbon by 2050.
- Agency for the Cooperation of Energy Regulators (ACER) - one of the agencies formed by the EU Commission. As the interest organization of NRA's they oversee the implementation of reforms aimed at completing the goals set by the Commission.
- European Network of Transmission System Operators (ENTSO-E) - coordinates and controls the power network development in the European Union. Implements the infrastructure investments necessary to implement commission.
- Association of European energy exchanges (Europex) participate when reform decisions influence the power exchanges.

3. Integration of European Power Sector

In this section we will look at the economic value and distributional effects created by improving grid capacities and how this affects the national incentives to develop the grid. Then we take a closer look on the state of integration in the northern part of the power grid and briefly touch upon the state of integration in Central and Western Europe.

In Figure 3 one can observe the case where there is no transmission capacity and no equalization of prices. The supply/demand conditions in each country uniquely determine the price and production levels.

Figure 3. No transmission capacity between the two countries

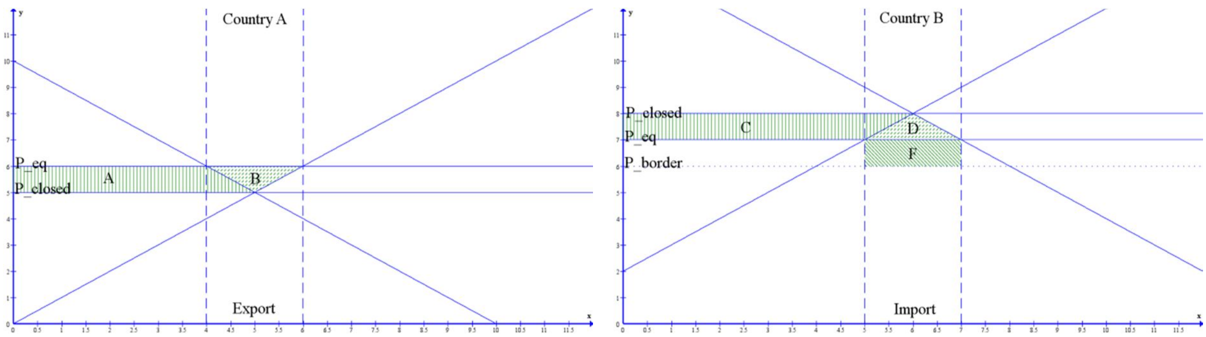


Source: Own results

In Figure 4 one can observe the case where the transmission capacity is lower than the demand of capacity, so that power is transported from the low-price country A to the high-price country B. This lowers the price in country B and raise prices in country A. Furthermore, it has the following welfare effects:

In country A, producers benefit from higher prices. They obtain area A from consumers in the country and area B is created by the trading. In country B the consumers benefit from lower prices. They obtain area C from producers and area D is created by the trade. The area F is the congestion rent that is obtained by the owner of transmission capacity.

Figure 4. Congestion between the two countries

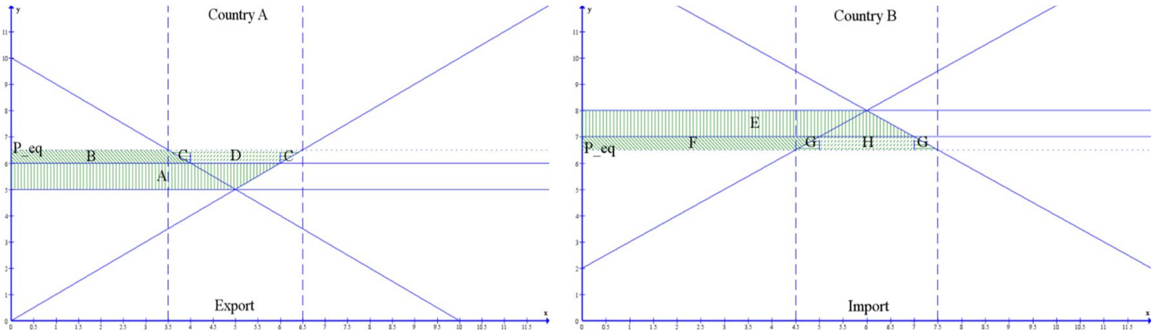


Source: Own results

In Figure 5 A, B we observe the case where the transmission capacity is higher than the demand, so there is a total equalization of prices. Compared to the situation in figure we observe the following:

In country A the producers still obtain area A as before, but now they also obtain area B from consumers, area D from the transmission capacity (TC) owner and the two areas labeled C area created by trade. In country B the consumers still obtain area E, but now also obtain area F from producers, H from the TC owner and the two G areas created by trade.

Figrue 5. No congestion between the two countries



Source: Own results

We are now in a position to see who benefits and who are hurt by increased integration. We see that consumers in high-price countries benefit and producers in low-price countries. For the TC owner it is ambivalent. When the price differential is high she obtains a large congestion fee per MW of additional capacity, but as he increase the capacity this causes the price differential to decrease and the congestion fee falls. This is situation is similar to a monopolist, who compares marginal revenue (MR) to marginal costs (MC):

$$\frac{MR}{MC} = \frac{\Delta Q \times PD}{Q \times PD_{eq} + \Delta P} = 1 \qquad (1)$$

where ΔQ - additional capacity quantity built, PD - price differential, Q - total capacity owned, PD_{eq} - price differential change, ΔP - price additional capacity built.

This leads to sub-optimal transmission capacity if the investment decision is taken by only comparing congestion fees to costs. This is in fact not the case in Europe. Total welfare analysis as in Figures 4 to 6 is used to determine the optimality of the investments, without regard to distributional effects. The construction costs are borne by all electricity producers/consumers through taxes. But the above analysis does pose questions when developing an international network. Who should be taxed for the development of a transmission network?

Denmark is an electricity highway between Norwegian and Swedish hydro power and German consumers. But that means that if prices are low in Norway and high in Germany the effect of additional grid investments are: German consumers receive lower prices. Norwegian producers receive higher prices. Danish consumers receive lower congestion fees. But who should then pay the construction and operation costs!? The fair pricing of international "grid service" and those responsible for the investments are therefore one of the many energy issues that needs to be solved on a supranational level.

This theoretical framework makes it apparent why integration is not exactly straightforward and the investment decisions require welfare analysis and the taxation of actual users. Therefore, the decisions on integration benefit by being deferred to the European level.

To put numbers on some of the issues discussed in the previous section, we will focus on the countries having grid connections with Denmark. As seen in Table 2 the average daily congestion rents are more than € 544,000. A major contributor is the trade running from the low-price Norway/Sweden through DK-West to high-price Germany (see Table 1). This emphasizes the note from before, that there is merit to thinking of the power sector as a European issue rather than national issue.

Table 1. Average Price differentials

Transmission	Price Differentials
DK-West – Norway	€ 4.86
DK-West – Sweden	€ 1.75
DK-West – Nordic System Price	€ 3.36
DK-West – DE	€ -4.95

Source: Own results

Table 2. Congestion Rents between DK and other countries (1/1/2011 - 14/12/2012).

Transmission	Congestion Rent
DK-West – Norway	€ 122 481 673
DK-West – Sweden	€ 46 157 910
DK-West – Germany	€ 85 972 154
DK-West – DK-East	€ 7 927 977
DK-East – Sweden	€ 75 846 700
DK-East – Germany	€ 50 646 085
Total	**€ 389 032 499**
Daily Average	**€ 544 863**

Source: Own results

If ones take a closer look on the trade between DK-West and Germany in Table 3, we also see that the trade runs into Denmark around 21% of the transmission hours. This illustrates another important function of the transmission capacity. It can act as a relief valve when national production is high and consumption low. This is specifically the case for Northern Germany, where high wind power production sometimes depresses the prices and leads to maximum out of North Germany. This additional capacity increases the revenue of renewable energy production and thus makes investment into RES more profitable. To a large extend the biggest contribution to renewables is in fact the integration of consumption areas that can consume power when production is high.

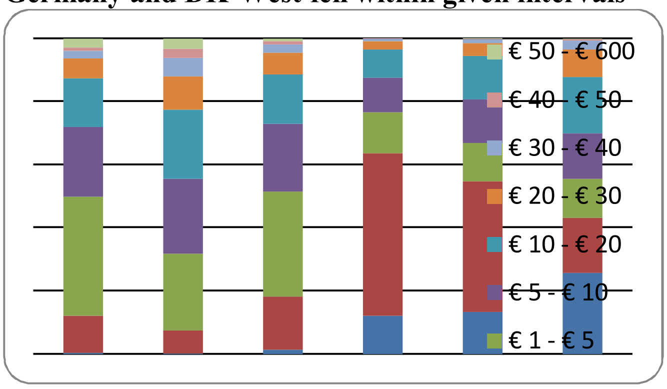
Table 3. Details on DK-West/Germany trade (1/1/2011 - 14/12/2012).

Parameters	Value
Hours	17 134
Days	714
Average Available DE -> DK	779,1 MW
Average Available DK -> DE	778,9 MW
Total transmission DE -> DK	2 138 057 MWh
Total transmission DK -> DE	7 836 759 MWh
Total Congestion rent	€ 85 972 154,15
Average Congestion rent/MWh	€ 8,62
Average daily congestion rent	€ 120 423,23
Average Hourly congestion rent	€ 5 017,63

Source: Own results

Last we take a look at the percentage of time when congestion was present and the level of congestion between DK-West and Germany. Figure 6 shows that the congestion level does seem to have gone down in the last five years.

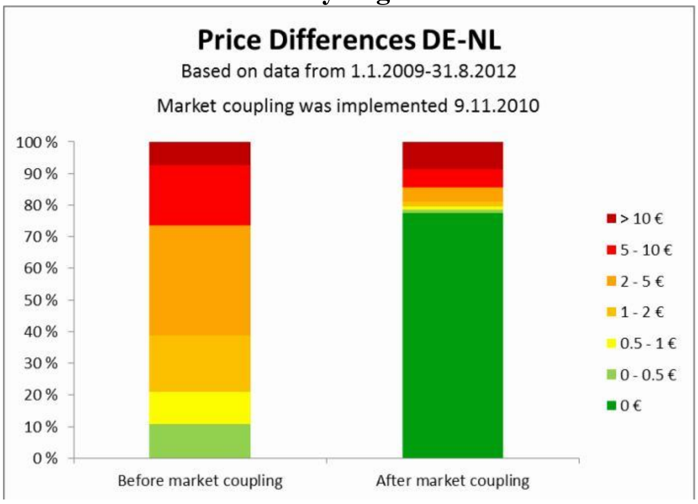
Figure 6. Percentage of hours where the price difference between Germany and DK-West fell within given intervals



Source: Own results

But it is not a significant trend in the highest congestion categories above €10. The two markets have employed market coupling from November 2009 and it does seem to have affected the markets in a positive way. Market coupling is the procedure of implicitly locating the capacity on the transmission line in the day-ahead market is auction.

Figure 7. Percentage of hours where the price difference between Netherlands and Germany in given intervals

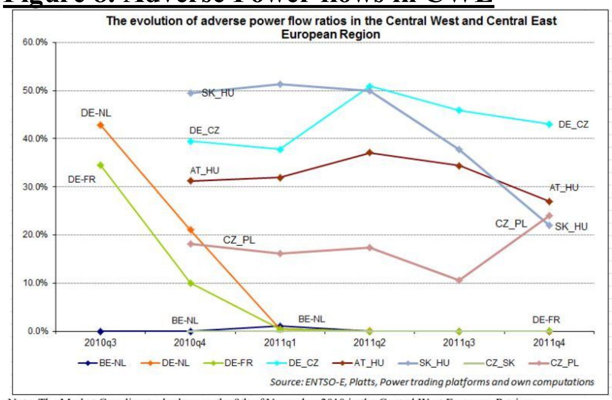


Source: Own results

When we compare the DK-West - Germany experience from last chapter to the experience between Germany and Netherlands (Figure 7) we note two things. First, the market coupling had a very positive effect on the time and amount of congestion. Second, the price differentials are of much lower than in the DK-De situation. This does imply that transmission capacity is more urgently needed to the northern part.

The success of market coupling can be measured by the reduction in adverse (economically inefficient) power flows. In Figure 8 one can see how the introduction of price-coupling in the CWE area (DE-NL-FR-BE) virtually eliminated adverse power flows.

Figure 8. Adverse Power flows in CWE



Note: The Market Coupling took place on the 9th of November 2010 in the Central West European Region

Source: Own results

4. Novel Trends in European Power Sector

The projects currently underway in the European power system are of two kinds. Investments into grid and generation capacity and investments fall into a more appropriate organizational structure. We will not focus much on investments in generation capacity. This decision is undertaken by private entities and ultimately affects the markets in all of Europe through € 1 trillion investments in the next ten years for energy There are several schemes in place in different countries to promote different types of generation capacity (i.e. solar power, wind-energy) and Europe-wide schemes (Carbon emission trading). A thorough evaluation of all these projects/schemes affecting the power market is beyond the scope of this paper. Here, we will look at selected projects being implemented by the parties introduced on the European level (see e.g. Söderholm, 2000; or Veith et al., 2009).

The grid investments are controlled by ENTSO-E. They operate with a Ten Year Network Development Plan, where projects necessary for European energy markets are decided. The current TYNDP from 2012-2022 contains investments of € 104 billion that are estimated to reduce Europe-wide generation costs by 5%, and facilitate integration of large quantities of renewable energy sources ENTSO-E (2012). There are also discussions on how the power market should evolve (especially the amount of Renewable energy and how to integrate these sources). These are currently published in Energy Roadmap 2050.

As already noted in Figures 5-8 market coupling has been a tremendous success where it has been introduced. The European Commission has put up a target of a single European price market coupling model by 2014. In September 2012 the coupling of Czech, Slovak and Hungarian markets was started and by now (Nordic-DE-NL-BE-FR-A-GB) markets should be price coupled. This should end up in an efficient single European market.

5. Conclusions

In this paper we have introduced some of the important concepts of the European power system. Then we showed how the integration between power markets worked in theory. We have seen that some interest groups lose by this integration, others win and it is not always politically straightforward how to achieve the most economical efficient provision of transmission capacity. This enables us to explain why so much control over the power market has been delegated to European entities (even though power generation capabilities are a very strategic reserve - no modern society can run without power). We have seen that there are large economic gains by integration, especially when the price variation within a country is large and other countries could have used the power more efficiently. Last we have seen how the power market on the EU-level is implementing reforms that aims to make the European power network more integrated, efficient and able to further the goal of less reliance on fossil fuel.

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