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Environmental Technology & International Affairs

Effectively achieve the goal of the 2030 climate framework: A case of cooperation between Poland and Germany

A Master's Thesis submitted for the degree of
"Master of Science"

supervised by
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Vienna, 30.03.2015

Affidavit

I, **Tomasz Zaluska**, hereby declare

1. that I am the sole author of the present Master's Thesis, "Effectively achieve the goal of the 2030 framework: A case of Poland and Germany", 57 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
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ABSTRACT

The European Union has set ambitious goals in the field of energy. With the 2030 framework member states have to implement further more stringent policies. Although united by a common goal, member states pursue various strategies which may be contradictory. Germany decided to phase out nuclear energy, whereas Poland is expected to run a nuclear power plant by 2024. Therefore the question arises whether cooperation between these states could solve the current problems in the energy sector taking into account the goals set for the year 2030.

Today, Poland and Germany face various challenges in the electricity sector. Germany struggles with higher fluctuations in the electricity grid, inflexibility of the incumbent system, increasing prices for end consumers and difficulties of the big utility companies to adapt to the new market environment. Poland on the other hand is relying on outdated power plants which require extensive investment and face increasing electricity demand from end consumer and industry.

Therefore, this thesis aims at analyzing in depth these challenges faced by Germany and Poland. Based on these findings it will seek to find ways of cooperation which would allow both countries to reach more effectively the 2030 framework considering the economic and political perspective within the limits of technical constraints.

Key words: Polish Energy Policy; 2030 Framework; Cooperation Poland Germany; BEMIP; Transnational electricity exchange; Power plants in Poland; Electricity sector in Poland.

CONTENTS

1 INTRODUCTION

Energy is the founding basis of a growing economy and is therefore a major concern at the European and National level. Coupled with the need to combat climate change, the European Union set itself ambitious policies for the year 2020 (European Commission, 2008) and efforts to reach concrete legislative obligations for the period 2030 are progressing (European Commission, 2014a). Within these set of goals, member states define their respective national policies.

However, sometimes lack of coordination or cooperation between national policy makers of member states may lead to opposing outcomes. After the Fukushima nuclear reactor accident, Germany opted for the phase-out of nuclear energy under its “Energiewende” policy (Bundesregierung, 2011), whereas Poland announced the building of its first nuclear power plant until 2024 (Economist, 2014). Tighter cooperation between national policies can be of great importance, particularly in the field of electricity where due to its physical characteristics, the medium can not be stored on a large scale.

Among scholars, the problems of the energy policy of Poland and Germany have gained increasing awareness. Buchan analyzes the challenges that Germany faces due its ambitious “Energiewende” policy (Buchan, 2012), while Reuster and Küchler address the cost aspect of the policy decision (Reuster and Küchler, 2013), whereas Cwiek-Karpowicz analyzes the Polish and the German policy for comparability on a policy level (Ćwiek-Karpowicz et al., 2013). However, the question remains whether Poland and Germany could reach their policy objectives more effectively through means of cooperation.

This thesis will address this issue and analyze whether given the current problems in the electricity market, and the challenges faced by Poland and Germany to reach the 2030 framework goals, both countries could more effectively reach their goals.

1.1 Thesis Objective and research question

The objective of this thesis is to examine how Poland and Germany can achieve their energy targets proposed in the 2030 framework more effectively through means of cooperation, either in the policy arena or the private sector. Specifically, it is analyzed whether such cooperation is possible between the states, how it should be defined and what scope it should have. Further, the benefits and drawbacks of such cooperation will be addressed and weighed against each other, to draw a conclusion regarding the viability of such cooperation. Therefore, to reach the defined objective, the following hypothesis will be tested:

Through the exchange of electricity between Poland and Germany, in which Germany supplies Poland with Renewable Energy in peak hours and Poland provides coal power to Germany in off-peak hours, the goals of the 2030 Framework can be reached more effectively.

1.2 Methodology

In order to assess the viability of such cooperation the hypothesis is tested across three dimensions: technical, political and economic.

The economic implications are evaluated in **Chapter 2**. Before assessing the economic aspects of the agreement, current economic problems of the electricity sector are discussed. A comparison is made between Poland and Germany regarding electricity prices and price fluctuations.

In **Chapter 3** the technical aspects are examined. First and foremost it is crucial to understand whether such cooperation is technically feasible and implementable between the two states. Therefore, the available generation capacity and the flexibility of the power generation are scrutinized. Further the current transmission capacity and its development are analyzed in order to determine the potential scope of the agreement between the involved countries.

Chapter 4 addresses the political environment of the proposed cooperation. The chapter commences by outlining the current major political hurdles regarding the 2030 framework. First the 2030 framework introduced by the European Commission is analyzed, which shall help to identify possible scenarios for the member states' obligations until the year 2030. The following section examines whether the proposed agreement facilitates the achievement of the 2030 goal on the political level. Hence, national policies and the EU policy are scrutinized to understand if the agreement is consistent with and supportive of the respective policy goals. Understanding the political interests and interdependencies will allow to draw a conclusion regarding the design and stringency of the agreement in the last part of this chapter.

Finally, **Chapter 5** relates the findings of the technical, political and economic section to each other and draws conclusions as to whether such cooperation is possible and how it could look like. Subsequently the potential benefits of such a proposal are presented. This chapter subsequently expounds the potential effects of the agreement on the industry and its main players and shows how the cooperation would mitigate the countries' problems. Finally, Nordpool, the Nordic energy market is used as a referential case study.

2 ECONOMIC PART

The electricity sector in Poland and Germany has been evolving rapidly in the course of liberalization. With new policies and changing of international commodity markets Poland and Germany's electricity system face various economic challenges. This chapter thoroughly discusses these challenges which have to be addressed by the proposed cooperation between Germany and Poland.

2.1 Fluctuations in the German electricity grid

Non-dispatchable sources of energy such as wind or solar, although having numerous advantages also bring various challenges to the grid due to their intermittent nature. One important occurrence is the increasing fluctuation in the grid, having significant technical and economic impacts. Energy intensive industries report more occurring frequency fluctuations possibly since the shutdown of nuclear power stations in Germany (Renewables International, 2011). Particularly, industrial equipment which is sensitive to fluctuations in the grid is exposed to higher risks, forcing an increasing number of companies to install emergency energy sources. A survey by the association of German industrial energy companies (VIK) published that short interruptions have increased by 29 percent between 2008 and 2011 (Schröder, 2012). Figure 1 shows the variability of hourly onshore wind power output in Spain. The average output of around 20GWh can fluctuate within a day even up to 142% (Bahar and Sauvage, 2013).

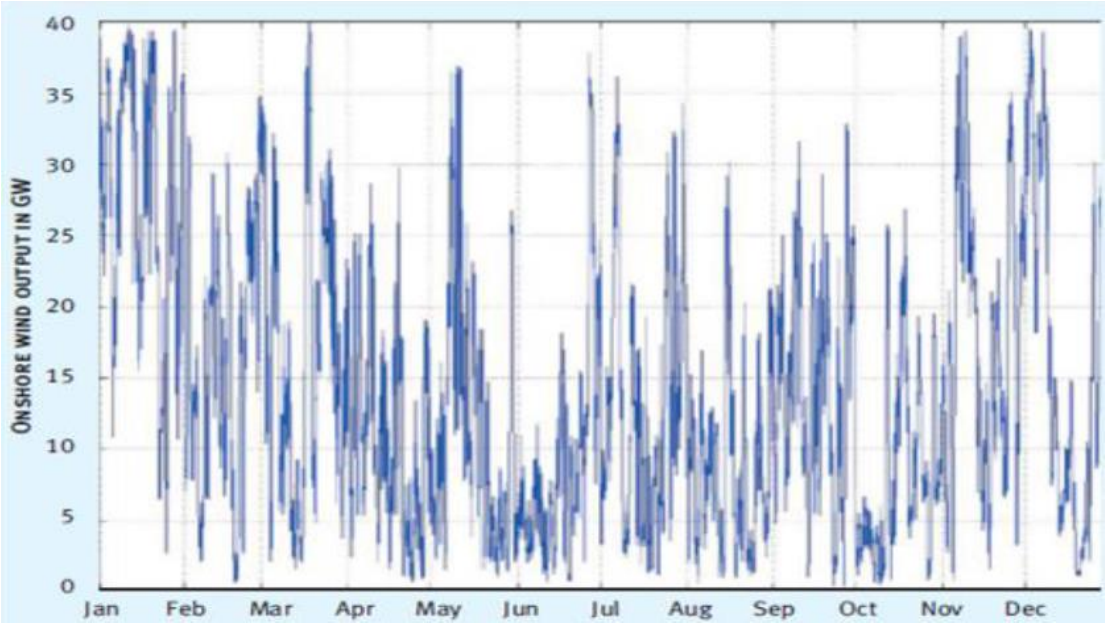

Figure 1: Hourly onshore wind power output in Spain (2009) (Bahar and Sauvage, 2013)

An important economic consequence of increased fluctuations comes with regards to the accuracy of prediction production models. The estimation of weather conditions which greatly influence the output of renewables, are difficult to predict in a precise manner. Due to lack of large scale storage capacity, the electricity market has the unique characteristic that demand requires to match supply. Therefore, high amount of renewables in the grid and in consequence any deviation from a projected capacity can have severe effects on demand and supply. The disproportion is then reflected in the price of electricity. Figure 2 shows the error in total projection stemming from various sources, whereas the graph on the right side depicts the effect on price as at 16. March 2013. It is interesting to observe the correlation between the total wind projection error (dark green area on the left graph) and the Day-Ahead electricity spot price (dark blue line on the right graph) between 0AM and 8AM. The total projection error leads to an oversupply of electricity in the market and therefore resulting in a negative electricity price (Mayer, 2014).

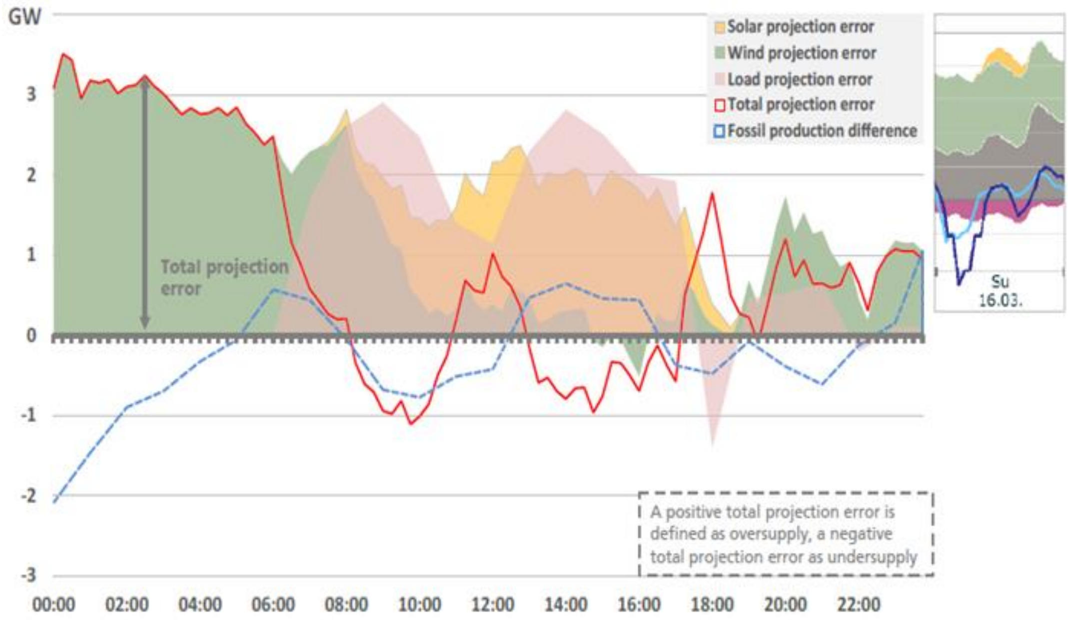

Figure 2: Actual production/load minus projected production/load (from day before) (Mayer, 2014)

2.2 Inflexibility of the incumbent system in Germany

Furthermore, renewable energies result not only in increased volatility but also push prices down due to oversupply. Figure 3 depicts the total electricity generation in Germany in week number twelve of 2013, including the day ahead and the intraday prices. It is clearly visible that where solar and wind energy was low, prices remained higher. On the contrary, on the weekend (23.3. - 24.03) more renewable energy was fed into the grid pushing prices to negative levels below EUR 50/MWh. This situation of oversupply is also confirmed by the levels of exports during that week (marked in light green below the X-axis). From Monday 18.3 to Thursday 23.3, exports remain under 10,000MW, whereas on the weekend they increase almost until 20,000MW (Mayer, 2014).

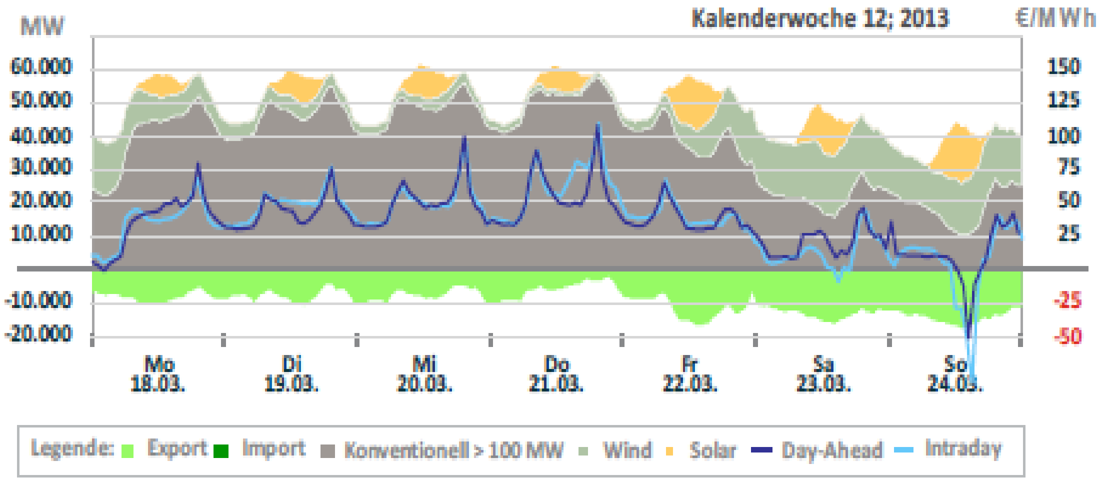

Figure 3: Example of a weekly development of electricity prices of conventional and renewable energy sources in March 2013 (Mayer, 2014)

This trend is confirmed by findings on the export/import balance levels at a yearly basis as shown in Figure 4 (Mayer, 2014).

Figure 4: Electricity export and import balance for Germany (2001-2014) (Mayer, 2014)

The "Energiewende" has not only changed Germany's energy mix in favour of renewable energies by a simple matter of proportion but it also disrupted the market by producing vast quantities of electricity only in particular hours of the day. A major hurdle is the inflexibility of the German power plant landscape and its difficulty to adapt to the current market dynamics. A study of the Fraunhofer institute shows this development by analyzing the production of electricity by power plants in Germany. As an example, production of various types of electricity during a chosen week is analyzed. Figure 5 demonstrates the weekly profile for generation of conventional and renewable energy sources in March 2013. Whereas Figure 6 shows the electricity spot price traded on the market for the same period of time (Mayer, 2014).

The generation profile makes visible the general functioning of the electricity market. Nuclear energy (marked red) and brown coal (marked brown) generate the base load electricity with a constant capacity over the entire week running around at a 56% to 77% load. Black coal and gas fueled power plants supply the system with medium load. However, since wind and solar energy are due to their nature dependent on atmospheric conditions; they do not cover the peak load in the classical sense and can either feed little or large quantities into the system. In the 12th calendar week in 2013, from Monday to Friday the wind conditions are unfavorable and peak and medium loads are supplied by black coal and gas fired power plants, with solar energy filling the peaks. However, on the weekend electricity demand is lower than during week days and in this case strong conditions generated more than 20GW of electricity. The high amount of wind forced to shut down almost all the black coal fired power plants. Due to technical constraints, brown coal power plants could not reduce their capacity significantly. The exports increased strongly to over 15GW but did not suffice to cover the entire oversupply. As a consequence the price on the electricity market fell down to over -50 EUR/MWh (Mayer et al., 2013).

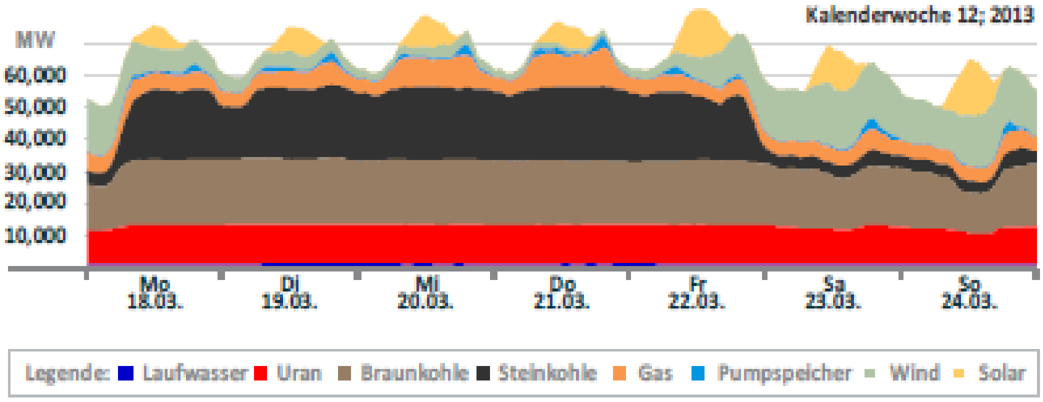

Figure 5: Actual production by generation type for a week in March 2013 (Mayer et al., 2013)

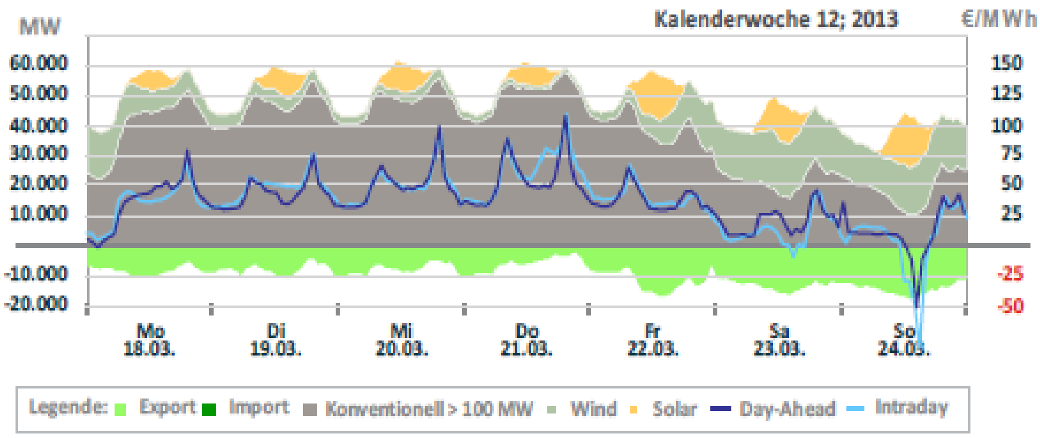

Figure 6: Example of weekly development of electricity prices of conventional and renewable energy sources in March 2013 (Mayer et al., 2013)

Negative prices are a sign of oversupply, where despite lack of demand, electricity producers feed in electricity into the grid and pay the consumer for taking it. To understand the reasons for this at a micro level, Figure 7 shows the load of conventional power plants benchmarked against the day ahead spot price of electricity. It is astonishing to note that despite negative prices, nuclear power plants run at high capacities and do not reduce their capacity below 50%. Brown coal fired power plants do not run below 45% even in situations of negative electricity prices. These dynamics clearly indicate that an increased number of renewable energy requires more flexible electricity generation capacity (Mayer et al., 2013).

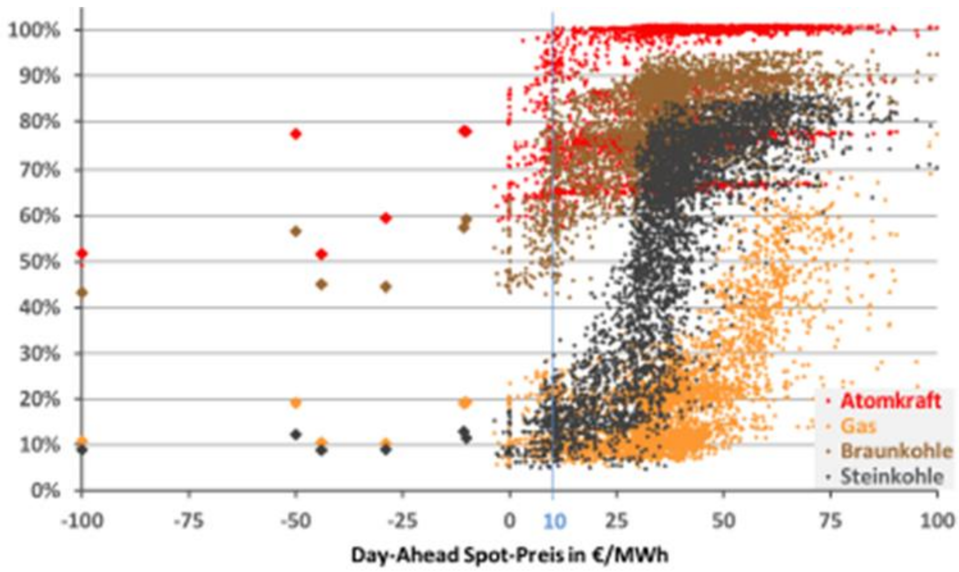

Figure 7: Power plant load at different price levels (1. half 2013) (Mayer et al., 2013)

This deterioration of energy prices is depicted in Figure 8, which depicts the number of hours with negative energy prices from the year 2000 until 2013. Whereas in the year 2000 not a single hour experienced negative prices, in the year 2013 the number rose to 60 hours (Götz et al., 2014).

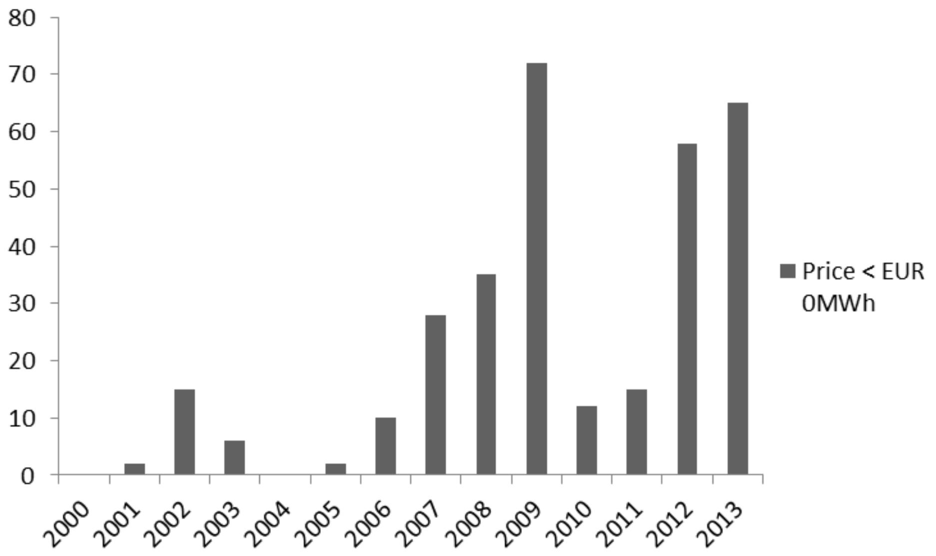

Figure 8: Frequency of negative prices at the EPEX Spot Day-Ahead-Market (Götz et al., 2014)

2.3 Increasing electricity prices for consumers in Germany

Contrary to popular belief which was falsely communicated in the media, high amounts of renewable energy that push down the cost of energy in the market do not lead to cheaper electricity for the final consumer. Although the electricity market produces free electricity due to sources such as wind and solar, this type of electricity is in support of the Germany state through a feed-in tariff system which guarantees a fixed payment for each unit of power produced. The energy is sold on the spot market and the difference between the received market price and the defined feed-in tariff is transferred to the final consumer. Therefore, the larger the spread between the spot price of electricity and the feed-in tariff, the higher the cost for the taxpayer (EUWID, 2013).

An important indicator is the development of the price of energy, which is an essential indicator for the economy, both for the industrial and household consumption. In the industry it is an important cost factor of production and can be decisive over its competitiveness. For households, affordable energy prices are essential for the low-income class. Figure 9 shows the development of the electricity price structure for the end consumer in the time period 2000 to 2013. The red area depicts the percentage due to feed-in costs and the remaining blue area aggregates other cost factors including energy generation, taxes etc. In the year 2000 only 1.4% of the electricity cost amounted for the feed-in tariff cost, whereas in the year 2013, already 19% of the electricity bill went to feed-in charges. This level of charges lies even above the price of electricity traded on the German energy market[4] (EUR Cents 5.28 Cents and EUR Cents 4.5 respectively) (Eurostat, 2014). To address this problem German´s Minister of Environment suggested to set a cap "Preisbremse" (=pricebrake) for the feed-in charge, to stop the increasing trend. He stated that, *"for me it is of utmost importance that the price for [the] ordinary consumer remains affordable"* (BMU, 2012).

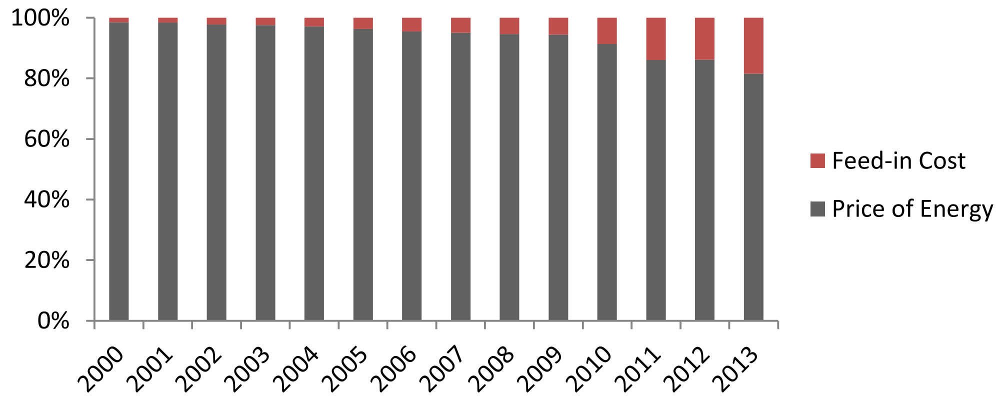

Figure 9: Energy prices distribution (2000-2013) (Eurostat, 2014)

Figure 10 provides energy prices (KWh) in selected EU countries in the year 2013. The chart depicts well that Germany and Denmark, both countries with a high level of renewable energies, have the highest prices in the ranking, almost 30 percent higher than the EURCent 20.01 European average (Eurostat, 2014). This confirms the argument of renewable energy critics that feed-in tariffs have indeed a significant effect on the price of energy and shifting the burden on the consumer. Hence a trade-off between renewable energy and high prices exist. However, on the commercial

[4] The price at the energy market excludes all possible surcharges, taxes and levies and reflects only Generation costs.

side, special treatment has been given to businesses with an extensive use for electricity[5], to preserve their competitiveness on the International Market (§ 40 EEG).

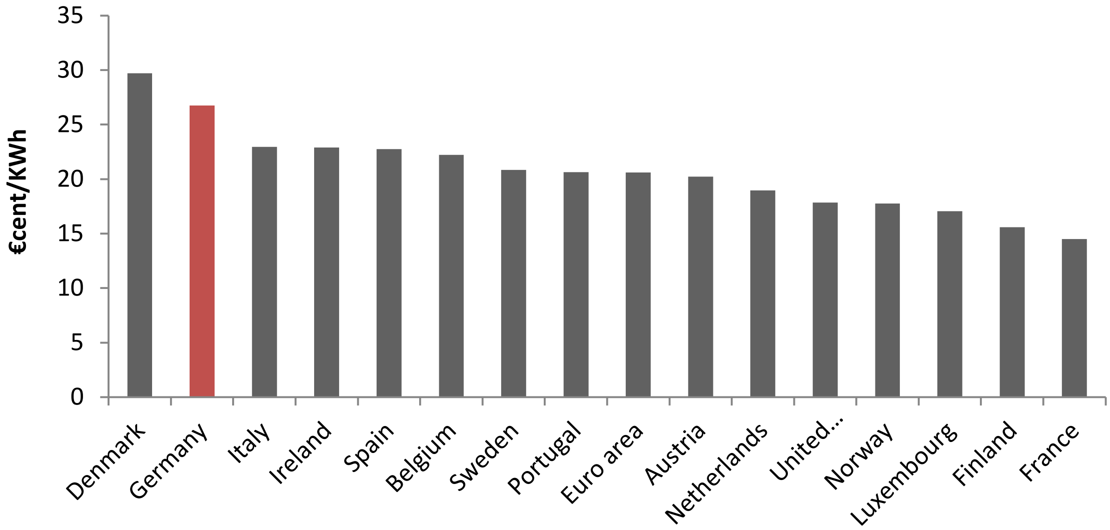

Figure 10: Electricity prices for end consumer for selected countries (2012) (Eurostat, 2014)

2.4 Conventional utilities need of change

Germany's electricity sector is dominated by the big 4 utility companies (E.ON, RWE, EnBW, Vattenfall) that have emerged after the liberalization of the energy market in Germany, which control around 80% of the electricity market (Seifert, 2009). Historically, Germany's electricity giants had only limited contribution to the expansion of renewable energy. In 2010 only 14% of the installed renewable energy capacity was owned by the big utility companies (Advisory House, 2013). The shift towards renewable energy and the decision to remove nuclear energy from the energy mix has put major utility companies under pressure. Figure 11 depicts the share price of publicly traded E.ON and RWE between 2008 and 2014. Both companies have lost significant 80% of their share price and their Market capitalization has fallen significantly. This clearly shows that utility companies struggle on the energy market. E.ON has sold a third of its German power stations and decreased their stake in Municipal utilities. RWE has shutdown various power

[5] Companies with an use of electricity over 10GWp are subject to minimal environmental charges (PWC, 2014)

plants and is taking 16GW of power generation off the grid and Vattenfall was forced to close down two nuclear power plants (Wetzel, 2013).

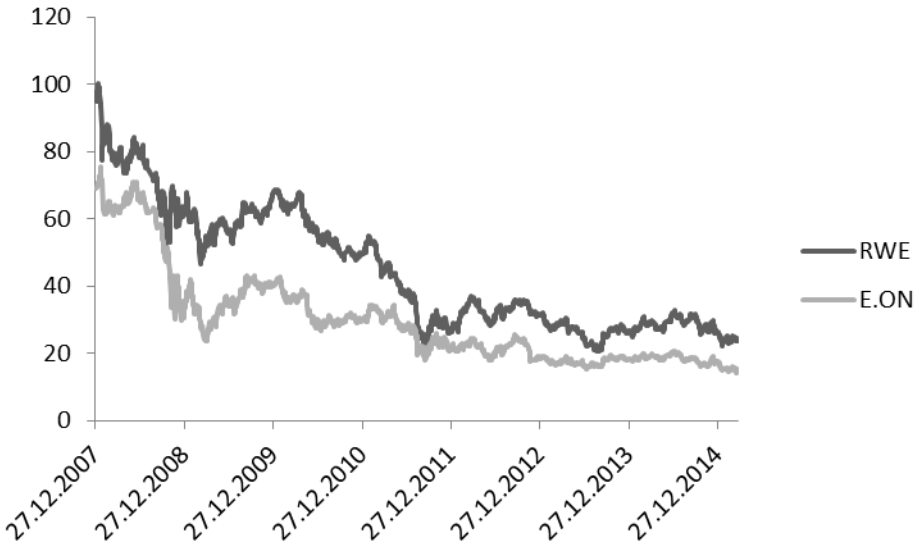

Figure 11: Share price of RWE and E.ON (2007-2015) (Yahoo Finance, 2015)

The strategic response has been quiet different between the four utility giants. For instance, E.ON, the largest company by assets, plans to outsource its current conventional power plant assets. Vattenfall is looking for disposal of its brown coal assets in Eastern Germany, whereas EnBW is expanding increasingly in renewable energy (Platts, 2015).

2.5 High cost of coal in the Polish commodity market

Poland faces many technical challenges in the electricity sector, Poland has an outdated power plant infrastructure (ARE, 2014), where a large capacity has to be shut down in the next years. The current infrastructure is based mainly on brown or black coal due to significant coal reserves in the area. In Poland, various scenarios have been considered on how the energy landscape should develop up to 2030, a topic which is discussed in the subsequent chapter regarding political challenges. In any case, due to the importance of the mining sector in Poland it is reasonable to assume that coal will remain an important part of the Polish electricity landscape (Forbes, 2014). Therefore a major economic impediment, current and future, will be the cost of using coal as a resource for electricity generation. According to the Ministry of Economy in Poland, the Polish mining sector made PLN 273.5m (EUR

66.7m[6]) losses. There is however, a wide range of profitability differences between polish mining companies. The Bogdanka mine had a net result of PLN 330m (EUR 80.5m), whereas the worst performing group Kompania Weglowa made a net loss of PLN 770m (EUR 187.8m) (Wysokie napiecie, 2014). The performance of the mining industry is heavily dependent on international market prices of coal. Figure 12 shows the average coal price in Europe and its development in recent years. Since 2011 the coal price has decreased substantially due to lower world energy prices as a result of cheap shale gas supply and due to slower economic growth of China, who fueled demand for coal in recent years. Figure 13 shows the net income from the Polish mining industry. It is clear to observe the relation between the fluctuation in the price of coal and the performance of the mining sector in Poland (BP, 2015).

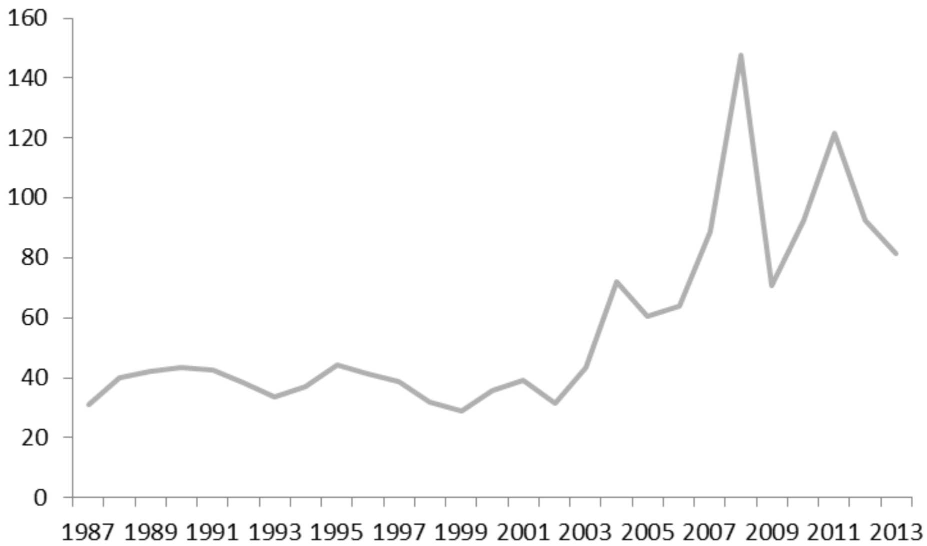

Figure 12: European coal price USD/t (1987-2013) (BP, 2015)

[6] PLN/EUR as at 31.12.2014: 4.15 PLN/EUR

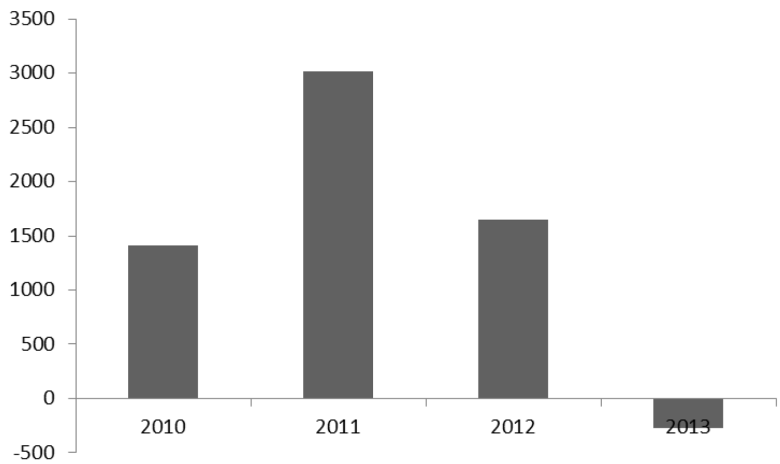

Figure 13: Net income Polish mining industry (PLN m, 2010-2013) (Forbes, 2014)

The average cost of coal production of PLN 302/ton (~ EUR 73/ton)7 has remained constant over the last years. Therefore, at an average European coal price of EUR 60/ton the average loss made by the electricity production in Poland in 2013 was around EUR 13/ton (Economist, 2015). Consequently, to remain competitive the mining industry has two possibilities; either cut costs or increase revenue from the sale of coal.

On the cost side, 51% of the total costs are associated to personnel. The historical importance of the industry and its political influence[8] has established a strong union since its inception. Job or pay cuts are therefore difficult to implement. In January 2015 Polish Prime Minister Ewa Kopacz due to strong resistance from the unions, once again, abandoned the plan of closing lossmaking mines (Financial Times, 2015).

In terms of revenue growth, mining companies are also restrained due to the low price of coal on the market. Inventory of 7 million tons of coal were accumulated in Polish mining companies due to lack of demand (PB, 2014). Many Polish power plants started buying increasingly cheaper imported coal from Eastern countries such as Russia. In 2013 the Polish industry imported more than 10 million tons of coal from abroad, 68% coming from Russia (Wyborcza, 2014).

The price of Polish coal is crucial for the electricity generators in Poland who are the main buyers of the commodity. The Polish state as an important shareholder of the

[7] PLN/EUR as at 31.12.2014: 4.15 PLN/EUR

[8] More than 100 thousand people are employed in the mining sector

biggest electricity producers (PGE, Tauron, Energa and ENEA), makes sure that these "national champions" supply their resources from their Polish counterparts. Therefore, if the price of Polish coal rises, the burden is shifted to the end consumer (Polish Ministry of Treasury, 2015).

2.6 Rise in domestic consumption for Poland

Table 1 depicts total consumption of electricity in 2013 for Poland and EU member states which joined in 2004 (Czech Republic, Hungary, Slovakia and Slovenia). In 2013 Poland had a consumption of electricity of 124 GWh. The demand for electricity has grown steadily from 2002 to 2013 with an average rate of 2,2% which is highest among its peers and also high significantly above the European average of 0,5% (Eurostat, 2014).

Table 1: Electricity consumption in GWh selected European countries (Eurostat, 2014)

	Total Consumption	Growth (CAGR 02-13)
Poland	124,059	2.2%
Czech Republic	56,691	1.0%
Hungary	34,856	0.9%
Slovakia	25,084	0.9%
Slovenia	12,590	0.7%
Euro area	1,991,872	0.6%
EU 28	2,780,189	0.5%

Electricity consumption can be further divided into household, industry and transport categories. As shown in Figure 14, households are the biggest category of electricity demand (73TWh) followed by industry (47 TWh) and transport (3TWh). The highest demand increase has come from the household sector with an average growth of 2.6% p.a., whereas the industrial demand grew by 2.0% and transport exhibited a decrease of 3.5% annually (Eurostat, 2014).

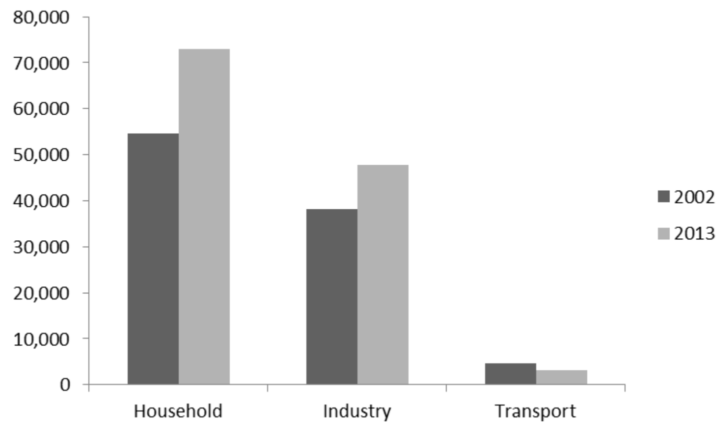

Figure 14: Distribution of consumption in Poland TWh (2002 / 2013) (ARE, 2014)

In order to allow comparability between household demands for electricity, Table 2 demonstrates household consumption per capita for Poland, its peer group and the European average. In Poland 1.9MWh per inhabitant per year are consumed in comparison to peers such as Slovakia and the Czech Republic. Therefore it is reasonable to assume that Poland has still plenty of upside potential to reach the European Union average at 3.4MWh per inhabitant (ARE, 2014).

Table 2: Household consumption per capita for Poland and selected peers MW/capita (2013) (Eurostat, 2014)

Country	MWh/capita
Hungary	1.90
Poland	1.90
Slovakia	2.35
Czech Republic	3.01
Slovenia	3.19
EU (28 countries)	3.39

Figure 15 depicts electricity prices per capita kw for end consumers and Figure 16 shows the energy efficiency measured as the Gross inland consumption of energy divided by GDP (kg of oil equivalent per 1 000 EUR). In both categories Poland remains in the average range of its peers, with average price of 0.22 EUR cent/kw and 295kg of oil equivalents (Eurostat, 2014).

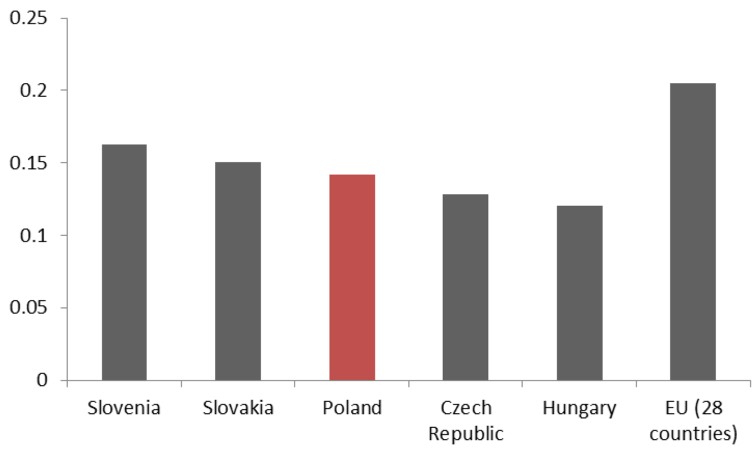

Figure 15: Household electricity prices EURcent/kwh (2014) (Eurostat, 2014)

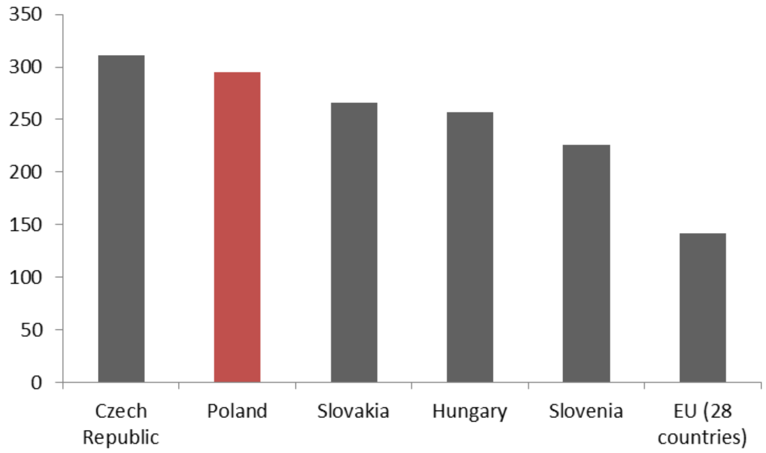

Figure 16: Energy efficiency kg oil equivalents (2013) (Eurostat, 2014)

3 TECHNICAL PART

3.1 Generation capacity

3.1.1 Historical development and current situation in Poland

After WWII, the Polish electricity system was rebuilt by the communist regime. After nationalizing the incumbent electricity grid and power plants the government initiated the modernization of the grid and construction of new power plants for the steel industry. The technology was mainly imported from the Soviet Union and was suffering from extreme inefficiencies. Many power plants of this era are still in operation today. In the 1990s, the Polish energy system underwent major restructuring. The electricity grid was connected to the European electricity system and many reforms for the liberalization of the energy market were initiated. After the accession of Poland to the European Union, further reforms were necessary and Poland had to implement various directives for further market liberalization such as unbundling and various transparency measures (Kwinta, 2012).

Figure 18 shows the development of the generation from 2004 until 2012. In the year 2012 Poland reached an annual gross production capacity of 165TWh and is growing at a modest rate of 0.7% per annum. Self-consumption of the generating units and losses due to inefficiencies in the grid reduce the amount of electricity that is delivered to the final customer by a significant portion. In 2004 this amounted to around 38TWh of electricity but due to investments in infrastructure and an increase in performance, this number was reduced to 36TWh and was therefore reduced from 25% (2004) of generation total to 22% (2012). The net export/import balance remains positive in 2012 and makes Poland a net exporter in the market. However, this position has changed and as of 2014 Poland has become a net importer of electricity (ARE, 2014).

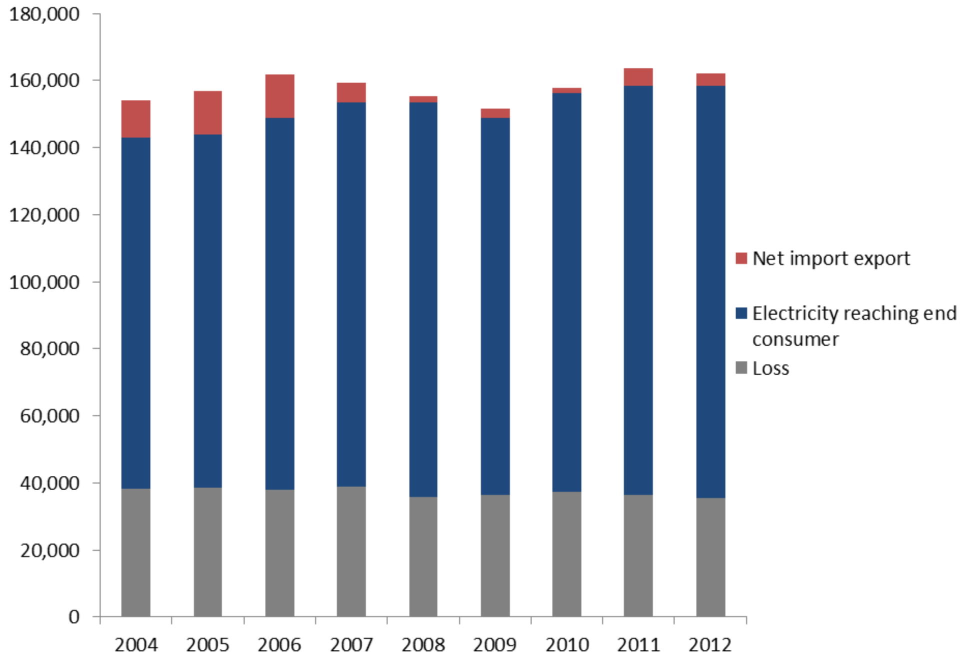

Figure 17: Gross generation in Poland TWh (2004-2012) (ARE, 2014)

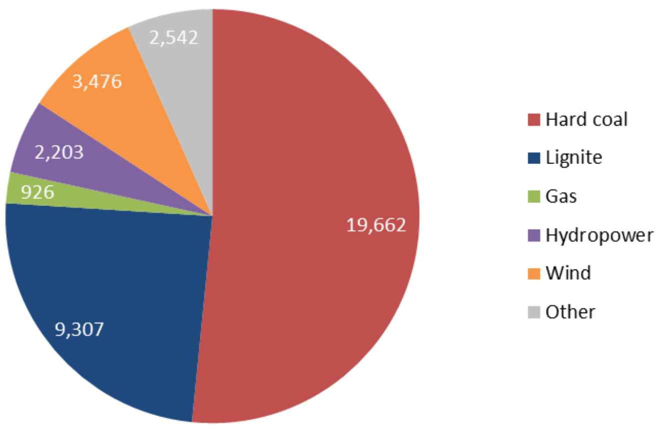

Figure 18: Total installed capacity by production type GW (2013) (ARE, 2014)

In terms of installed capacity in Poland fossil fuels dominate the electricity mix as demonstrated in Figure 18. Hard coal (20GW) is the most used resource, followed by lignite (9GW). Renewable energy, such as hydro and wind constitute only (6GW) of capacity.

The current age structure of the Polish electricity system still resembles the relict communism spirit. As depicted in Figure 19 176 from the 325 turbogenerators operated in 2013 are more than 30 years old. In terms of installed capacity 18GW of the 30GW are from this era constituting around 60% of total electricity generation (ARE, 2014).

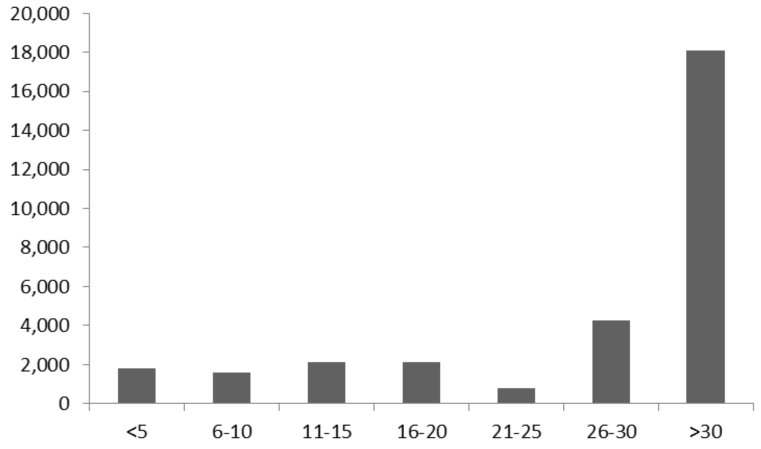

Figure 19: Age structure of powerplants in Poland MW (2014) (ARE, 2014)

Figure 20 maps all the power plants in operation in the year 2013 in accordance with the fuel used. The corresponding size of the bubble reflects the relative size of the capacity installed. The biggest power plant is the Belchatow power station with a 5.3GW installed capacity. It is the largest thermal power station in Europe, and third largest fossil fuel power station in the world. As second in terms of size follows the Kozienice black coal power station with 2.8GW installed capacity located south east of Warsaw and operating as the main electricity provider for the capital.

The map shows clearly the planning strategy of the communism system. A small number of large coal powered plants (either black or brown coal) located in the center of the country, with some power plants located in the coal mining region. For big and medium size cities (> 100 000 inhabitants) many smaller cogeneration plants were built (marked in red). The vast majority of these plants are fueled with black coal, in some cases adding biomass to fulfill tighter environmental regulations (ARE, 2014).

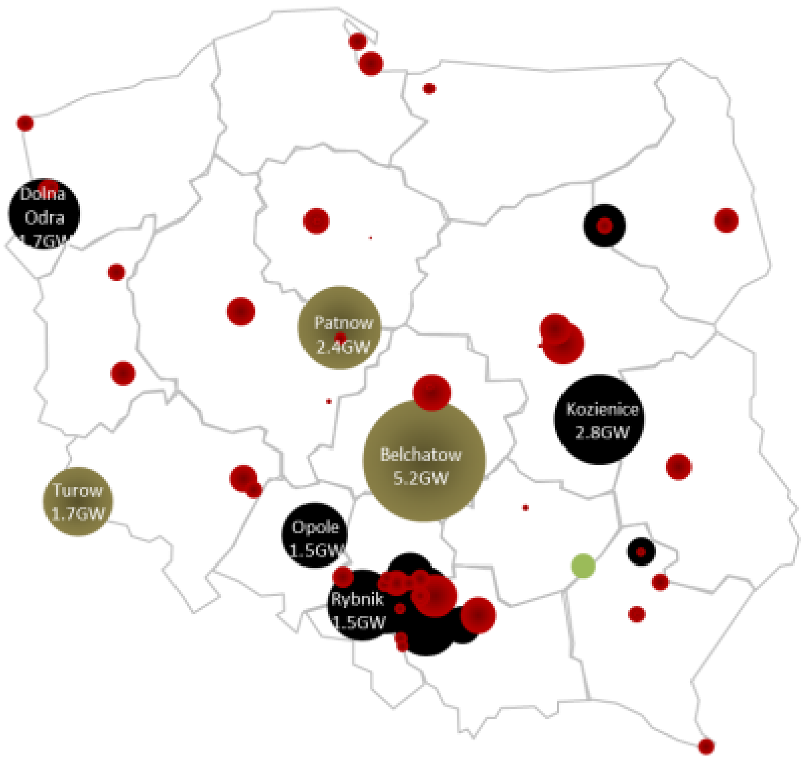

Figure 20: Map of Poland with Power plants (ARE, 2014)

Table 3 shows the 10 biggest power plants in Poland, their installed capacity, production and their average load. Only 3 out of 10 of the biggest power plants are fueled by brown coal. However, brown coal powered plants have higher loads during the year than black coal counterparts and are used mainly as base load electricity providers. Belchatow, as the biggest power plant, produces 35TWh of electricity accounting to around 25% of the electricity demand of the country (ARE, 2014).

Table 3: Biggest power plants by installed capacity in Poland MW (2013) (ARE, 2014)

	Type	Plan	Installed Capacity 2013	Production 2013	Load 2013
1	Brown Coal	Belchatow	5,298	34,832	75%
2	Black Coal	Kozienice	2,845	12,107	49%
3	Black Coal	EDF Rybnik	1,775	9,691	62%
4	Black Coal	Dolna Odra	1,772	5,447	35%
5	Brown Coal	Turow	1,698	10,425	70%
6	Brown Coal	Patnow	1,664	7,726	53%
7	Black Coal	Opole	1,492	7,157	55%
8	Black Coal	Polaniec WK	1,400	6,448	53%
9	Black Coal	Jaworzno 3	1,345	6,725	57%
10	Black Coal	Laziska	1,155	4,385	43%
		Total	38,646	164,557	49%

These findings are confirmed when analyzing average hours of power plants working at full capacity per type of fuel. Brown fueled power plants work almost 70% of the time on full capacity whereas black or gas fueled power plants only at around 50% throughout the year (Table 4).

Table 4: Power plant operation hours by type h (2013) (ARE, 2014)

Type	hours of working at maximum capacity	% of total hours in the year
Brown	6092	70%
Black	4333	49%
Gas	4285	49%

The gathered data clearly illustrates the current state of the Polish electricity system. Electricity production is centered upon outdated coal fueled power plants built by the communist regime. To keep up with increased electricity demand and fulfil environmental regulations, generation capacity has been increased and environmental systems (scrubbers, etc.) have been installed. Brown coal fired power plants are used as base load power plants running on higher load levels, whereas black coal power plants are used as support for peak demand. Most medium and large cities in Poland have cogeneration plants to supply heat and electricity.

3.1.2 Historical development and current situation in Germany

Electricity generation in Germany has risen particularly after WWII due to the rapid economic growth owing to reconstruction. Initially the rise in the demand of oil was covered by increasing the capacity of coal, gas and oil powered plants; however with time, alternative methods of electricity generation were emerging. In 1961 the first experimental nuclear reactor was constructed. Since then nuclear energy has become an important source of electricity accounting for more than 30% of electricity generation (Langhammer, 2014).

Today, the policy direction has changed dramatically. The German "Energiewende" envisages a transition from nuclear energy to renewable energy. To promote renewable highly beneficial financial schemes have been set up enabling a rapid development of the renewable energy sector. Figure 21 depicts the current electricity generation in Germany. Already more than 20% of electricity is produced by wind, solar, biomass or hydropower (EIA, 2015).

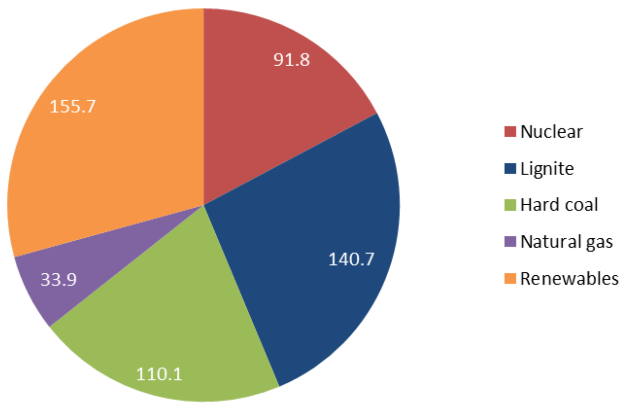

Figure 21: Total generation by type in Germany TWh (2014) (EIA, 2015)

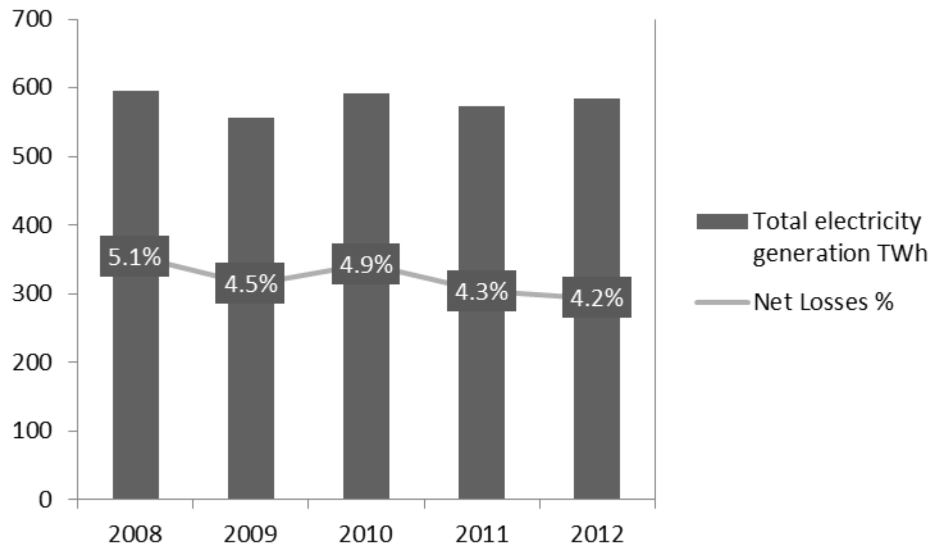

Figure 22: Total electricity generation in Germany TWh (2008-2012) (EIA, 2015)

Figure 22 shows the development of the net generation of electricity in Germany from 2008 until 2012. From a total generation of 595TWh the output has fallen to 585TWh in 2012. This development can be greatly attributed to the fall in demand due to rise in energy efficiency. This is also confirmed by the decrease in losses due to distribution in the electricity system which have fallen from 5.1% in 2008 to 4.2% in 2012 (ARE, 2014).

The age structure of conventional power plants is more recent than in the case of Poland. Figure 23 shows the age distribution of power plants with over 100MW installed capacity. The majority of power plants went online between 1980 and 1989, however they have been successively added to the grid (Destatis, 2015).

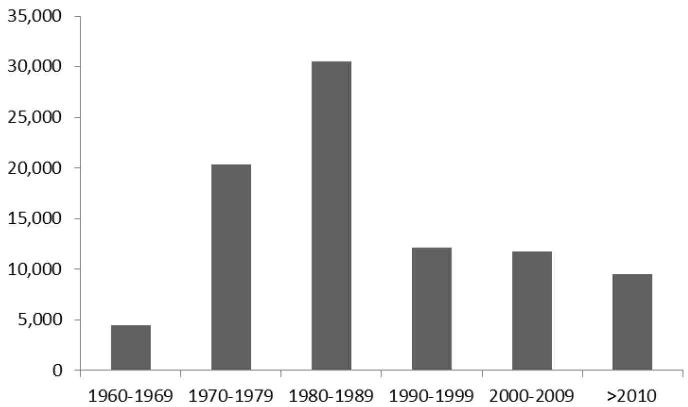

Figure 23: Age structure of conventional German power plants over 100MW (Destatis, 2015)

3.1.3 A comparison of Polish and German generation capacity

The brief background on both countries allowed evaluating their historical and current technical standpoint. This sub chapter will focus on the comparison between Poland and Germany to understand whether a cooperation is possible.

To allow for comparability between the countries, three different measures are displayed in Figure 24. The first is the total electricity production between Germany and Poland divided into electricity produced by conventional electricity sources and renewable energy in 2012. Secondly, it presents changes which are envisaged by the prospective governments in terms of electricity mix until the year 2030. Finally the estimated electricity production is shown for the year 2030 and the respective share of renewable and non-renewable sources (Polish Minister of Economy, 2009).

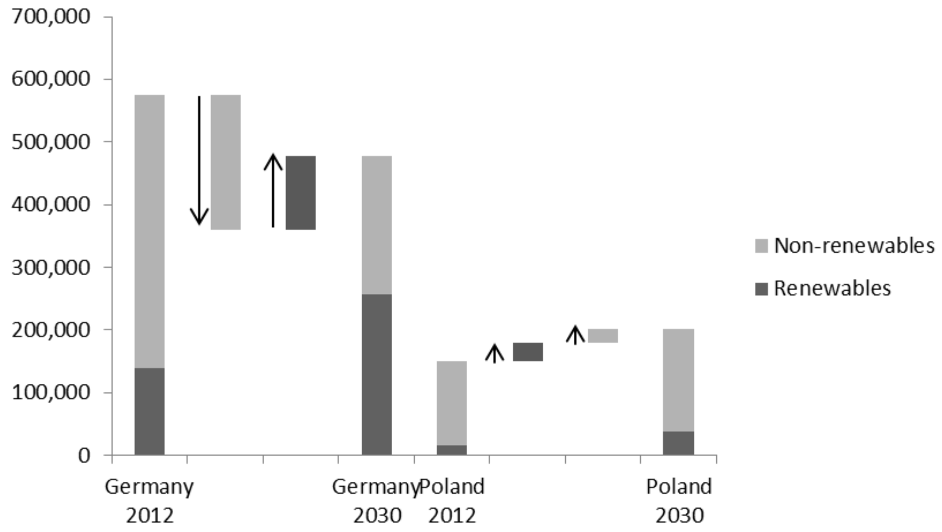

Figure 24: Total electricity production in Poland and Germany (2012/2030) (Destatis, 2015), (Polish Minister of Economy, 2009) and (Schlesinger, 2011)

The first important fact is the broad disparity between the German and Polish electricity system. In 2012, Poland with a total installed capacity of 35GW accounts only for 22% of the German total. Due to Germany's increased efforts in the field of renewable energy, the generation of green energy in Germany could already cover Poland's total annual energy demand. The forecasts of Electricity Generation for 2030 for Germany and Poland show two important trends. Until 2030 Germany will lower its electricity generation from 575 TWh to 477 TWh by decreasing conventional electricity generation by 216 TWh but increasing the renewable electricity production by 118 TWh (Schlesinger, 2011). Due to Poland's relativity low level of energy generation, electricity production will rise from 150 TWh to 202 TWh through an increase in conventional energy by 28 TWh and renewable energy production by 23 TWh. This scenario is based on the assumption of the current national energy policies, which may change due to various economic and political factors. However, in the long run it is reasonable to assume that in accordance with the European long term goals, Germany will seek to curb its electricity demand due to efficiency improvements and shift its energy mix towards renewable energies. Consequently, Poland's energy production will rise due to the current low level of consumption and outpacing efficiency improvements and relying more on conventional energy generation in 2030. Even in the year 2030 Germany's renewable energy production (258 TWh) would in terms of magnitude suffice to cover Poland's future entire electricity demand (202 TWh) (Polish Minister of Economy, 2009). This data leads to a crucial finding with regards to the future development of both national electricity systems and set a basis for a possible cooperation model. In the case of Germany, more than 220TWh of conventional electricity are planned to be dispatched, bringing enormous challenges to the power grid. A major obstacle is that many conventional power plants serve as base load plants and since renewable energies rely on meteorological conditions and therefore cannot guarantee a steady electricity flow, alternative solutions have to be provided (Bankwatch, 2013). Poland's challenge of the future demands various changes in the sector. As presented in the previous chapter Poland's power plants have a long life span and are not only less efficient but also raise environmental concerns. This requires shutting down various plants in the next decade. Therefore, not only the Polish electricity sector requires to install new generation capacity due to rising demand as depicted in Figure 25, but also exchange capacity that will go offline in the near future. As indicated in graph y in the period 2011-2018, 2.9GW have to be shutdown, whereas 4.2GW have to undergo deep modernization and therefore resulting in extensive need for new investment in generation capacity (PwC, 2011).

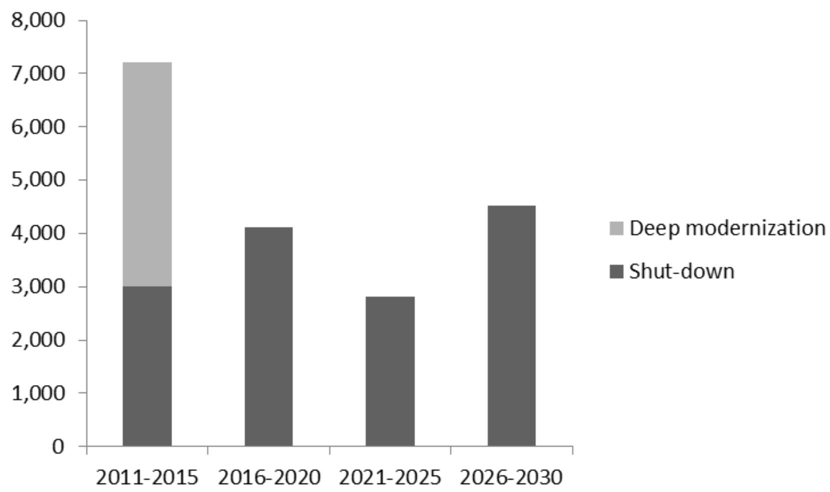

Figure 25: Projection of shutdown of blocks in Poland MW (PwC, 2011)

According to a report by the Ministry of the economy, the Polish electricity system will have a deficit 2017 of 1.1GW of electricity production, which it has to import from neighboring countries (Polish Ministry of Economy, 2013). Whereas according to estimates by the PSE, the Polish transmission operator, this figure will in 2020 amount to 6.4GW under the current business as usual scenario, taking into account that the plants have to be taken off grid due to age or due to not meeting environmental standards.

Figure 26 and Figure 27 give a deeper insight into the generation capacity by analyzing the actual generation of Poland and Germany on a monthly basis. The graphs depict clearly the different energy demand between these neighboring countries. An important finding is the discrepancy between the generation amounts between the winter and the summer. In Germany, highest generation occurs in winter with 49TWh of capacity, whereas in summer it falls to 38GWh. In Poland, the impact is far smaller with 14GWh of generation capacity in winter and 11TWh in summer (EIA, 2015).

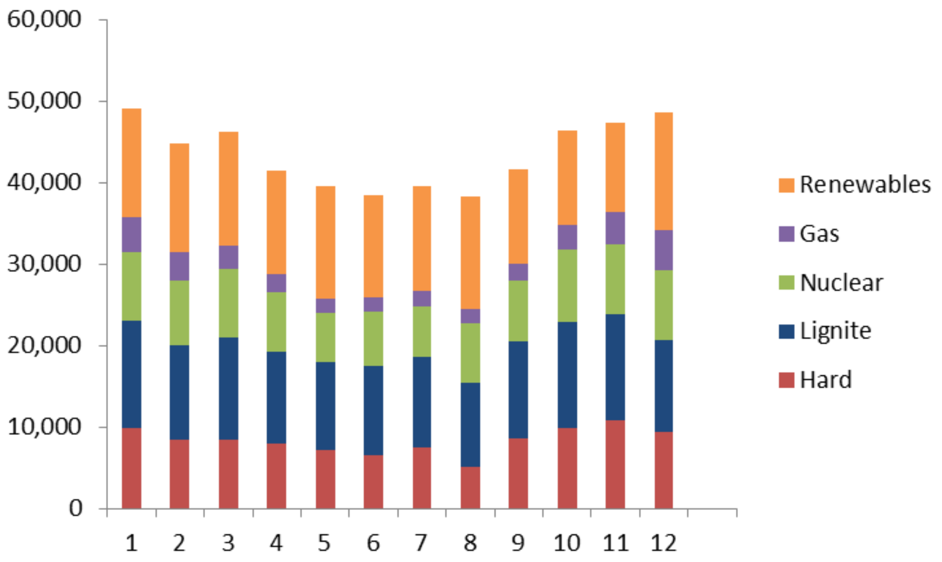

Figure 26: Total monthly generation in Germany GWh (2013) (EIA, 2015)

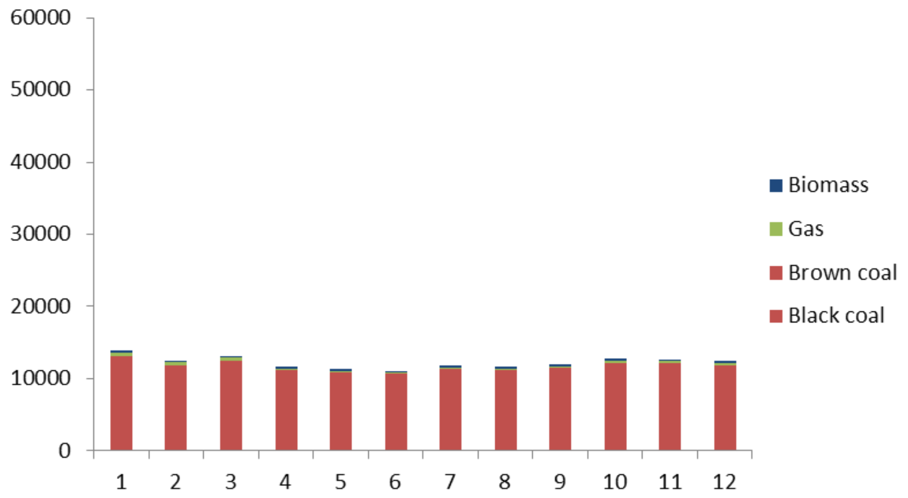

Figure 27: Total monthly generation in Poland GWh (2013) (ARE, 2014)

3.2 Conclusion

The current energy landscape in Poland and Germany allows to better understand which boundaries the proposed cooperation between both states can have in term of capacity. The first important fact is that Poland has an outdated power plant infrastructure that needs to be exchanged. Until the year 2030 almost 15GW of shutdowns are projected. Secondly, the demand for electricity will require additional 25% to the current generation capacity, whereas in Germany, the forecasts foresee a reduction in conventional power capacity and an increase in renewable energy. These developments require not only large investments in the following but also give broad possibilities for adjusting their strategic decision for better cooperation to achieve the long-term strategies defined in their national policies as well as agreed in the European 2030 framework.

3.3 Transmission Capacity

3.3.1 General background on the transmission capacity in Poland and Germany

For a robust analysis of the electricity system, after having discussed the generation possibilities of both countries, the transmission capacity is a crucial factor to be considered. Despite being neighbors, both countries operate in different settings even with regards to the transmission grid. Germany is conveniently situated between many developed European electricity markets and takes part in the North-Western, Central Eastern, Central Southern energy regions and transmits four times more electricity than Poland. Connections to neighboring countries such as Austria, Switzerland, France, Luxembourg, Belgium, Netherlands and Denmark are well established (Ćwiek-Karpowicz et al., 2013).

Poland in turn is situated at the eastern border of the European Union and is part of the Central Eastern region with only a limited connection to the North-Western region through a single link to Sweden. The links to Belarus and Ukraine consist of only a direct link to one power station each across the border (Puka and Szulecki, 2014). Various links are available to the Czech Republic and Slovakia and progress on market coupling is improving through a memorandum of understanding signed on 15. January 2014 between the TSOs, power exchanges and national regulators of the involved CEE countries.

The overall size of the grid of both countries is summarized in Table 5. Poland has a total circuit of 774 thousand km and Germany with 1773 thousand km. The stark difference between both can be partly explained by the higher number of electricity receivers in Germany than in Poland but also to weaker infrastructure in Poland. However, in both countries many lines are quiet aged and require retrofitting. (ARE, 2014).

Table 5: Total length of Transmission lines for Poland and Germany km (2013) (ARE, 2014)

Country	Overall circuit length (km)	> 100 kV (km)
Poland	774,141	32,671
Germany	1,772,696	133,887

A higher proportion of renewable energy fed into the grid requires an increasingly more flexible transmission system, both at the regional as well as the national level, designed to support flow of electricity in both directions. According to a survey by Accenture, the German grid requires 290 thousand km of expansion. Forecasts by the German Association of Energy and Water Industries (BDEW) and Association of local Utilities (VKU) foresee investments amounting to EUR 25bn. 69% of experts that have taken part in the survey doubt that investment in the grid will be sufficient to fulfill the plans in the roadmap until 2020. Poland's 5 biggest electricity distributing companies and the Polish national transmission operator (PSE) committed to invest over EUR 10bn in the Polish distributing and transmission system until 2019 (Forbes, 2014).

3.3.2 Transmission capacity between Poland and Germany

Historically, transnational trade of electricity was managed by vertically integrated companies who entered into long-term bilateral contracts. Main motivation behind trade was more of a technical nature in order to stabilize the electricity grid. With the ongoing liberalization of the energy market, divergence in prices became an incentive to trade electricity across borders (OECD, 2013).

The first connection between Poland and Germany was established in October 1995 as Poland's first step in the EU application, where Poland became part of the Union for the Coordination of Transmission of Electricity (Kasprzyk, 2006). Currently there are two interconnectors linking both countries with a 220kv line; one station between the German town of Vierraden and a Polish station in Krajnik in the northern part and in the south between Hagenwerder and Mikulowa. A third interconnector is currently under discussion since 2008 (between Eisenhüttenstadt and Plewiska), however without any concrete undertakings. In 2008 the EC initiated the Baltic Energy Market Interconnection Plan (BEMIP), a plan for the connection of Baltic states in the field of electricity and gas. One of the envisaged goals was strengthening the interconnectors between Poland and Germany, upgrading them from 220kV to 400kV. According to the 6th BEMIP report as of September 2014 the works are under construction (European Commission, 2014b) .

The interconnectors between Poland and Germany have gained increasing importance due to higher amounts of renewable energy fed into the grid, creating the so called “loop flows”. When renewable energy generation is at its peak levels in Northern Germany, this leads to unplanned flows to Germany’s CEE neighbours. As noted in a joint report by the Polish, Czech, Slovak and Hungarian Transmission system operators:

“When realized Schedules between DE and AT are in the range of 3 000 – 4 000 MW (about 17% of hourly samples in the period January 2011 – December 2012), the median of unplanned flows on the DE-PL border is at the level of 1 320 MW, i.e. about 900 MW higher than in the case of the “safe level” (450MW) of natural loop flows. Exchanges above 4 000 MW cause about 1 200 MW of unplanned power flows on top of natural loop flows of 450 MW, adding up to some 1 650 MW of unplanned power flows expressed in terms of a median value. “ (CEPS et al., 2013).

The consequence of loop flows has a negative effect on the stability of the grid and can cause cancellation of transmission capacity for cross boarder trade (Skånlund, 2013). The problem was acknowledged by the EC and resulted in the recognition of the third interconnector between Poland and Germany as a regional priority project in the Baltic energy market interconnection plan (European Commission, 2011). Initially PSE and 50 Hertz agreed on the installation of virtual phase shifters[10] and since this measure proved insufficient, both companies entered into an agreement for construction of physical phase shifters.

3.3.3 Technical possibilities of hard coal power plants

As proposed by this paper, the cooperation between Poland and Germany entails Polish electricity producers to generate electricity in off peak hours and fill the electricity gaps created by intermittent electricity sources. As described in the

[10] A Phase-Shifting Transformer is a device for controlling the power flow through specific lines in a complex power transmission network. The basic function of a Phase-Shifting Transformer is to change the effective phase displacement between the input voltage and the output voltage of a transmission line, thus controlling the amount of active power that can flow in the line (Siemens, 2014).

previous chapter, Poland's power plants are largely outdated and around 10GW of new hard coal capacity has to be installed. If new power plants will be installed, the question remains whether state of art technology will be sufficiently flexible to achieve the task.
According to a study by the association of electrical engineering the potential for improvement is significant. Table 6 show the technical characteristics of different generation of power plants of various types

Table 6: Potential of thermal power plants (Brauner, 2012)

Kraftwerkstyp		Steinkohle	Braunkohle	Gas- und Dampfkraft-werk (GuD)	Gasturbine solo
Lastgradient	$\%P_N$/min	1,5 / 4 / 6	1 / 2,5 / 4	2 / 4 / 8	8 / 12 / 15
im Bereich	$\%P_N$	40 – 90	50 - 90	40*) - 90	40*) - 90
Minimallast	$\%P_N$	40 / 25 / 20	60 / 50 / 40	50 / 40 / 30*)	50 / 40 / 20*)
Anfahrzeiten:					
Heiß (< 8 h)	h	3 / 2,5 / 2	6 / 4 / 2	1,5 / 1 / 0,5	< 0,1
Kalt (> 48 h)	h	10 / 5 / 4	10 / 8 / 6	4 / 3 / 2	< 0,1

Lesehinweis: heute üblich / Stand der Technik / Optimierungspotential

* bedingt durch die Emissionsgrenzwerte für NOX und CO bei Dauerbetrieb

Anforderungen:

Hohe Lastgradienten

Niedrige Minimallast

Kurze Anfahrzeiten

An important indicator for the flexibility of a power plant is the load gradient, which describes in percent per minute by how much the currently operating load can be changed. It is assumed that the Polish power plants that are currently in operation, that are largely outdated, have a current load gradient below 1.5%/min as in the case of hard coal fueled power plants. Technological advancement allows also for a decrease of the minimum load from 40% to a potential 20%. This is particularly important in situations where negative prices occur. Table 6 also shows major advancements in the area of ramp-up time. In the case of hard coal power plants this time can be reduced in the hot phase from 3 to potentially 2 hours and in the cold phase (not running for more than 48 hours) from 10 hours to 4 hours.
As currently analyzed, the improvement in the field of conventional technology has been significant including the case of hard coal power plants which are the most frequently used in Poland. Therefore, it is assumed that in the coming years state of

art technology will allow to install flexible power plants which will better adapt to a more volatile electricity system.
If Poland succeeds in installing 10GW of new hard coal power plant capacity, it will enable to be competitive among its neighboring states on the electricity market.
It is important to note that as described previously, hard coal power plants run on lower capacity than comparable lignite power stations such as the power plant in Kozienice 2.8 GW (49% average load in 2013), Dolna Odra 1.8 GW (35% average load in 2013) and Opole 1.5 GW (55% average load in 2013) and therefore have more flexibility in terms of adjusting their capacity (ARE, 2014).

3.3.4 Technical impediments

Interconnector
Interconnectors are the physical infrastructure (cables) that connects separate electricity markets. The connections initially were constructed as a technical safety measure and the markets that they linked developed independently with different designs and priorities. Therefore, mostly the transmission capacity between two markets was limited and constituted a bottleneck. The volume of electricity which can be transferred between such markets is denoted as rated capacity, which depends on various ambient factors. After discounting for various safety margins, TSOs inform market participants about the net transfer capacity of the interconnectors that is available for trade (ENTSOE, 2000). The net transfer capacity between Poland and Germany is shown in Table 7. With an average capacity of 1GW the capacity is comparably small and currently does not allow for trade of large volumes of electricity between both countries.

Table 7: Net transfer capacity between Poland and Germany MW (2011) (ARE, 2014)

	Winter 2011	Summer 2011
PL-> GER	1100	1200
Ger->PL	1200	800

Given the capacity, market participants can trade electricity if they are granted access to the grid by the involved TSOs. The so called TPA (“Third Party Access”) is most commonly granted either through implicit or explicit auction. In the case between Poland and Germany the implicit auctions are held. In contrast to the explicit auction the players in the market are not granted explicit cross boarder allocation but the allocation is included in the price of the energy bid in the market.

Due to its technical constraints the electricity market has very complex dynamics that have undergone manifold changes since its inception and has evolved differently in many countries. In a case of closer integration between two electricity markets, these differences have to be taken into account and overcome by streamlining various measures.

For instance one of such special market arrangements that can vary considerably in Europe is the design/possibility of intraday auctions[11]. Particularly for countries with vast amounts intermittent sources of energy this market is important, since the precise estimation of these sources of electricity can be hard to achieve early in advance. Gate closure time is the last occasion to inform the TSO before the physical trade of energy occurs. Table 8 shows the gate-closure times for various countries in Europe. The range reaches between 15 minutes in Austria/Germany to 6 hours in Spain/Portugal. The assimilation of the arrangements between Poland and Germany would facilitate the electricity trade between both countries (OECD, 2013).

Table 8: Gate-closure times before deliver of electricity (OECD, 2013)

Austria	15 minutes before delivery
Belgium	60 minutes before delivery
Czech Republic	3 hours before delivery
Denmark	45 minutes before delivery
Finland	60 minutes before delivery
France	60 minutes before delivery
Germany	15 minutes before delivery
Hungary	3 hours before delivery
Italy	4 gate closure times during the day
Netherlands	2 hours before delivery
Norway	60 minutes before delivery
Poland	60 minutes before delivery
Portugal	6 gate closure times during the day
Spain	6 gate closure times during the day
Sweden	60 minutes before delivery
Switzerland	45 minutes before delivery
United Kingdom	60 minutes before delivery

[11] Intraday auctions serve to give market participants to adjust their trade schedule.

3.4 Conclusion

With regards to the transmission capacity the current situation between Poland and Germany leads to many bottlenecks. Due to the increasing amount of renewable energy unwanted effects such loop flows occur. From the plans envisaged by the European Union through the BEMIP plan it is clear that these bottlenecks are of concern and that it can be expected that these problems will be eased (European Commission, 2014b). However, the question remains whether these plans will be put into practice, due to various stakeholders involved which can slow down the process significantly. If the plans will be implemented as scheduled an increasing electricity exchange between Poland and Germany as proposed by this paper the technical hurdle will be overcome in the long term.

4 POLITICAL PART

4.1 Energy Policy in the EU

4.1.1 The Legal Framework

Although evolving from the European Coal and Steel Community, the legal competence to legislate in the field of energy was only introduced with the EU Treaty of Lisbon in 2007. As of Article 4 TEU (European Union, 2007), energy is regarded as a matter of shared competences between the European Union and its member states, giving both national and European decision makers the power to legislate. Article 194 of the TFEU defines in more detail the main aims of EU energy policy (European Union, 2012). The phrase in Article 194 (2) *"need to preserve and improvement of environment"* emphasizes the link between energy and environmental policy.

4.1.2 The Legislative Procedure

In contrast to the creation of legislative acts, the procedure for setting strategic policies in the European Union is not strictly defined. Primarily, the European Council is the responsible body for giving general political direction under Art. 15 TEU (European Union, 2007). The Commission can initiate proposals and forward them to the European Council in the form of a communication, serving as a reference point, yet ultimately the member state governments are vested with the decision making powers. The form and scope of this decision is not defined in advance, but consists mainly of a policy framework with general statements regarding certain quantified goals (such as a renewable target expressed as a percentage of consumption). Further, an action plan can be included, which consists mainly of qualitative, strategic goals such as external policies. Negotiations are held behind hidden doors and decisions are taken unanimously. After the strategic decision by the council, the commission drafts a detailed legislative proposal, which subsequently follows the ordinary legislative procedure to be ultimately adopted via co-decision of Council and Parliament. The room for maneuver for the legislative proposal of the Commission is naturally determined by the level of detail provided by the policy framework of the European Council. Detailed and accurate guidelines leave only limited discretion for the legislative draft, whereas vague outcomes shift the decision-making to subordinate legislative bodies (Geden and Fischer, 2014).

4.1.3 Energy and Climate Package (2020 target)

The first milestone of the European energy policy was the climate and energy package, adopted in December 2008, consisting of a range of measures to fight climate change. The so called 20-20-20 targets envisaged three major policy measures: a reduction of greenhouse gases emission by 20 percent, an increase of energy efficiency in the EU by 20 percent and a target of 20 percent of renewables in the EU energy mix. (Directive 2003/54/EC, 2003)
Such ambitious policy was only possible due to various sociological, economic and political factors. The development on international energy markets created pressure for change in energy policy. Figure 28 depicts the Dow Jones UBS Commodity Index, a major commodity index.

Figure 28: Dow Jones UBS Commodity Index (Google Finance, 2014)

The steady rise of commodity prices (such as oil, gas or coal) in the period 2004 to 2008 urged states to seek alternative energy sources. On the political side, many Central Eastern European countries were concerned primarily with security of supply of oil and gas and sought to diversify their energy portfolio and their suppliers. Additionally, the United Nations *Intergovernmental Panel on Climate Change* (IPCC) issued it´s 4th assessment report in this time period, increasing public awareness of climate change and therefore bolstering public support. As a result, the 2020 energy and climate package sought a compromise by combining the security of supply issue of the CEE states and the climate goals of more ambitious countries (Geden and Fischer, 2014).

4.1.4 Paradigm Shift

However, since then, the economic and political environment has changed and naturally altered the political priorities of the member states, thereby creating a different starting position for the 2030 negotiation round. The financial and sovereign debt crisis that has burdened the European economies in recent years, has undoubtedly made European member states more cautious regarding energy prices, in particular in a situation in which the US market experiences low energy prices due to the rise of shale gas explorations. *"First of all, we aim to address the high cost of energy and the lack of a unified energy market. I believe that this is probably the most important priority,"* said Kostis Hatzidakis, the Greek minister for development and competitiveness, at the EU industry ministerial meeting in March 2014 (Gotev, 2014).

4.1.5 Proposal for 2030

Due to long investment cycles in the energy sector and the goal to reach an agreement before the UN climate negotiations in 2015, discussions regarding the time period 2020-2030 have already began. The green paper presented in March 2013 initiated the formal consultation process. In January 2014 the Commission issued a proposal for an agreement on the issue for the period 2020-2030. This proposal consisted of two main targets with a timeframe until 2030:

1. A greenhouse reduction of 40% compared to 1990 levels
2. A renewable energy target of 27 percent (however, only binding on EU level, without any national targets)

Support has come from the European Parliament, where members voted in favor and even included a binding national renewable energy target. However, despite the Commission´s proposal and a favorable vote from parliament, the European Council has the ultimate power to set up the strategic agenda and has yet to make a decision. (European Union, 2014)

4.1.6 Possible outcomes

The outcome of the negotiations, which will result in policy measures for the period 2020 until 2030, is difficult to predict from the current standpoint. However, it is possible to outline certain scenarios which can be expected to materialize. The debate among member states centers upon three major scenarios, which are outlined in Table 9. These three options are analyzed across two dimensions: target architecture and the design of the targets. The target architecture comprises the specific targets that would be incorporated in the framework, whereas the design of the targets specifies the exact obligations that the member state would incur. For all scenarios the assumption was made that the time horizon would be defined until the year 2030 (Geden and Fischer, 2014).

Table 9: Possible Outcomes for the 2030 Framework (Geden and Fischer, 2014)

Key elements of a negotiation compromise

Target architecture	Option 1 *Emissions reduction (“technology-neutral climate target”)*	Option 2 *Emissions reduction + expansion of renewable energy (“two-target model”)*	Option 3 *Emissions reduction + expansion of renewable energy + increase in efficiency (“three-target model”)*
Design of the “headline targets”	‣ Specific target level for emissions reduction ‣ “Domestic” or with offsets? ‣ Unilateral and/or conditional? ‣ Distribution over ETS and non-ETS sectors	All elements of Option 1 plus ‣ Specific target level for expansion of renewable energy ‣ National targets or EU-wide target? ‣ Share of renewables in total energy consumption or individual target for the electricity sector?	All elements of Options 1+2 plus ‣ Specific target level for increasing efficiency ‣ Reduction in energy consumption or improvement in energy intensity? ‣ Legally binding or indicative?
Time horizon	2025 or 2030?		
Basic structure of the negotiation outcome	Comprehensive package or series of individual decisions?		

4.1.7 Option 1: Emission reduction

The first scenario´s main provision entails an emission reduction target, based on technology neutrality. The need for an emission reduction policy has received broad approval among member states. (Geden and Fischer, 2014) However, more cautious member states have emphasized the need for technology neutrality. The argument relies on the idea that in the long run it is uncertain which technology will be the

most effective to achieve the target. A technology neutral approach means in political terms that renewable energies would lose importance in energy policy and favors countries which prefer to refrain from drastically restructuring their energy system.
More diverging positions are reflected in the design of the targets, where two issues are at the forefront: firstly, what the **specific level** should be, and secondly, whether the commitments should be **unilateral or conditional** with regards to the outcome of the UN negotiations.
Regarding the level of commitment for CO_2 reduction two main positions can be outlined as follows: ambitious countries, which support the commission´s suggested reduction of 40 percent and on the other spectrum, countries of the Visegrad Group[12], representing more conservative goals regarding climate policy, which did not name any specific target. The decision on the target level perhaps also depends on the European strategy for the UN negotiations in 2015 in Paris.
Regarding the question as to whether unilateral or conditional commitments should be pursued, opinions have similarly diverged. Some governments argue in favour of unilateral commitments, expecting other developing countries to follow. In turn, countries of the Visegrad Block ask for strict conditionality, holding that such steps require commitment from all major polluters and that unilateral action would create a disadvantage for domestic industries.

4.1.8 Option 2: Emission reduction + Renewable energy target

This option, in addition to the CO_2 goal, encompasses a **target for renewable energy consumption**. If such target would be included, the issue again remains as to what level of commitment would be required. The commission suggests a level of 27 percent until the year 2030, arguing in its last progress report that such target would be achievable simply by maintaining the current growth rate. Countries with national energy policies, which include ambitious goals on their own, such as Germany or Denmark, advocate that such goals would increase security of supply, support domestic industries and carry positive ramnifications for the climate issue. However countries that rely heavily on fossil fuels argue that this would endanger European industries. Another crucial factor worth consideration is the current progress of states

[12] Visegrad Group, also called the Visegrad Four is an alliance of four Central European states – Czech Republic, Hungary, Poland and Slovakia

regarding the 2020 renewable targets. States that are not able to keep up with current targets and fear infringement procedures will be discouraged of further commitments for the subsequent period. Further, the question remains whether the target should be applied only on EU level, as the commission suggests in its proposal, or also include national targets as it is included in the climate and energy package for the period until 2020. Additionally, the issue concerns the exemption of certain industries from the renewable target.

4.1.9 Option 3: Emission reduction + Renewable Energy target + Energy Efficiency target

Since only Denmark supports this option and it is not mentioned in the 2030 proposal by the Commission, it is disregarded.

4.2 Poland's vs Germany's energy policy

The current German energy policy is based on three main targets. First is the phase out of nuclear energy. In 2011 eight nuclear reactors have lost their license, whereas the remaining nine reactors will be shut down by 2022. The second important target is the expansion of renewables with ambitious targets set for the year 2020 (Ćwiek-Karpowicz, 2013). The last cornerstone is an efficiency target. Germany plans to cut its electricity consumption of 590TWh per year to 500TWh per year (Schlesinger, 2011)

Poland in turn has different political priorities with the major focus on energy security and therefore striving to diversify and decrease energy imports. The main tool for this strategy is the strong support for the domestic industry (Ćwiek-Karpowicz, 2013). The construction of the LNG terminal in Swinoujscie also confirms this strategy (ArcorMittal, 2015).

The different priorities between Germany and Poland are reflected in the current electricity mix and future development plans. Despite these differences, Poland's focus on the security aspect and Germany pursuing the sustainability strategy, cooperation is crucial to develop an economically viable system.

4.3 Conclusion

The future commitments for the 2020-2030 period are hard to predict due to widely divergent views of the member states. The last EU summit talks on climate change in March 2014 have not yielded any result to date. Since the EU suffers from high energy prices, whereas the United States benefits from cheap shale gas, ambitious climate goals can not be expected.

Based on the proposal by the commission, supplemented by the position ousted by the member states, two major outcomes seem likely: Firstly, given the general approval of greenhouse gas reduction, certain targets will be defined, yet neither a precise design nor a clear reduction level appear likely. Secondly, a binding agreement for a renewable target will be reached, however probably not on the national level (as suggested by the commission), therefore leaving more room for national decision-makers. This solution is based on the notion of technology neutrality, which does favor renewables as the sole technology for CO_2 reduction. For the purposes of this thesis the assumption will thus be made that EU member states **will have certain** CO_2 **emission reduction targets** for the period until 2030. With regards to renewable energy targets it is assumed that there will be **no legally binding** obligation for national states, even if on EU level some renewable goals may be defined.

5 A proposed solution

5.1 The proposition

The previous chapters have evaluated the technical, economic and political problems that Germany and Poland currently face. On these grounds, this chapter will analyze the hypothesis that is proposed by this thesis:
"Increase cooperation by exchanging electricity between Poland and Germany, in which Germany supplies Poland with Renewable Energy in Peak hours and Poland provides Coal Power to Germany in Off-Peak hours."

5.2 The scope

To determine the extent and scope of the cooperation the exchange between both countries, the installed capacities of Poland and Germany are displayed in Figure 29 that are forecast to be functional by the year 2030. Germany is forecasted to have a capacity of 220GW in the year 2030. The biggest part of in terms of type of generation is renewable energy (146 GW), followed by gas (30 GW), hard coal (25 GW) and lignite (19 GW). Due to the high variability of renewables it will remain a great challenge to balance the electricity stemming from renewable sources. The main balancing counterpart to electricity source from renewable energy will be gas and hard coal fired power plants with a total of 44GW of capacity. Brown coal will serve as the base load.

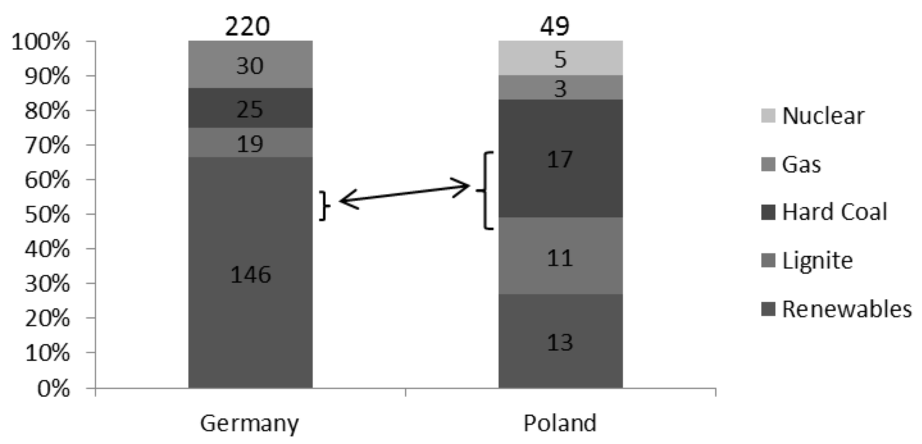

Figure 29: Installed capacity for Germany and Poland GW (2030) (EIA, 2015)

Poland which has a much smaller electricity market is expected to have around 50 GW of installed capacity, with hard coal as its largest source (17 GW), followed by renewables (13 GW), lignite (11 GW) and nuclear (5 GW). The ministry of Poland estimates that around 10GW of hard coal power plant capacity has to be either deeply modernized or requires shutdown and installment of new infrastructure. Hence, in order to satisfy the demand in 2030 62% of the total hard coal capacity has to be renewed. This will pose not only a tremendous challenge but also gives the opportunity for Poland to install new state of the art machinery that will be flexible and reduce CO_2 production. These 10 GW of new capacity are suitable for transnational exchange of electricity that are competitive on the electricity market. It is hard to estimate to what extent Germany might export renewable energy in the future due to the dependence on meteorological conditions. Due to such extensive capacity of 130 GW of renewable energy the main constraint of the trade between both countries will be the transmission capacity of the interconnector. However it is important to note that in the first half year of 2013 already 200h of trading on the market were trading below EUR 10/MWh (Mayer et al., 2013) (a level which is considered below the cost of any generating source in the electricity market). Already trading this capacity exchanged on the Polish market would have a benefit for both countries.

5.3 Example from the market

To show possible advantages between both countries Figure 30 and Figure 31 show the actual generation per production type on the 17.3.2015. An important finding is that generation is in general quiet stable, dominated by hard coal generation, followed by lignite generated electricity and complemented by modest amounts of onshore wind energy. To allow better understanding of the market dynamics, the day ahead spot price of electricity on the Polish energy market is inscribed (red line). The electricity price follows the general consumption pattern; at night when consumption is low the price trades at around EUR 25/MWh, later in the day consumption peaks during evening hours, at this time coal fired power plants increase their capacity and hydro pump storage is activated (TGE, 2015).

In Germany, the situation is slightly different due to the additional capacity of solar and wind energy installed. Demand peaks in the morning hours between 7 and 9 which puts pressure at prices. During midday 15 GW of solar energy is fed into the grid lowering the price electricity to around EUR 22/MWh. In the evening, two important factors occur. First demand increases due to fact that domestic increases by people that are returning from work, the second factor is the rapid decrease in solar energy, therefore pushing prices to a level of EUR 60/MWh (Mayer, 2014).

In order to allow for comparability, Figure 32 describes the relation between the German Day ahead EEX price and the day ahead spot price at the Polish energy exchange on the 17. March 2015. The Polish price remains constant in the range between EUR 22 MW/h and EUR 36 MW/h, whereas the German price is more volatile and ranges between EUR 20 MW/h and EUR 57 MW/h, with two peaks; one in the morning hours and the second in the evening around 20h. These spikes in prices can be partly attributed to the lack of flexible power plants in the German market.

Therefore in a future scenario Polish flexible coal energy could buffer spikes in the German electricity market on the intraday market, whereas German renewable energy could decrease the Polish energy price during midday between 10h and 14h. This situation would generally balance out the price differences between both countries.

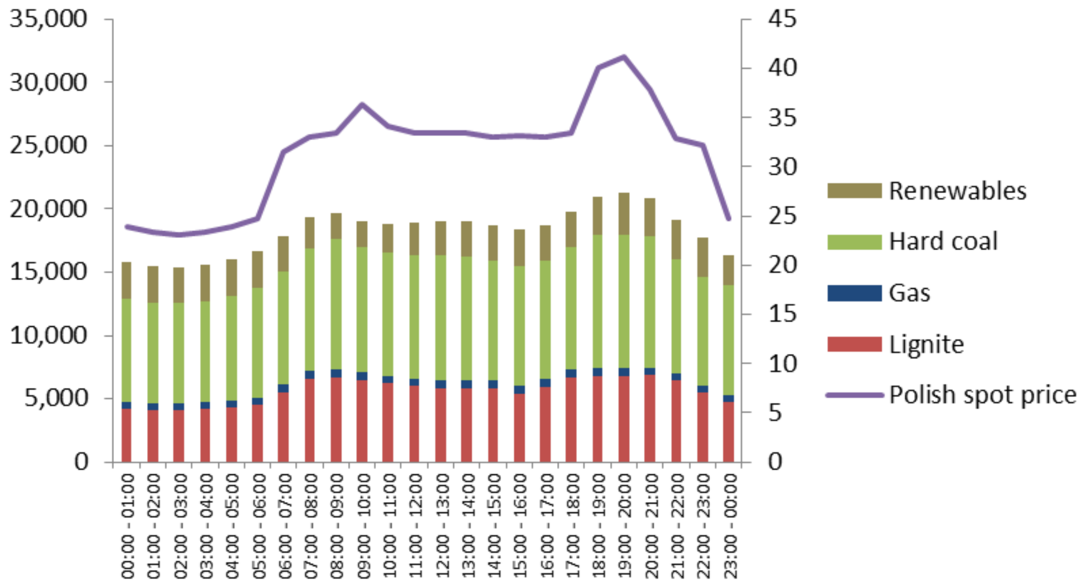

Figure 30: Electricity production by generation type in Poland (17. March 2015) (TGE, 2015)

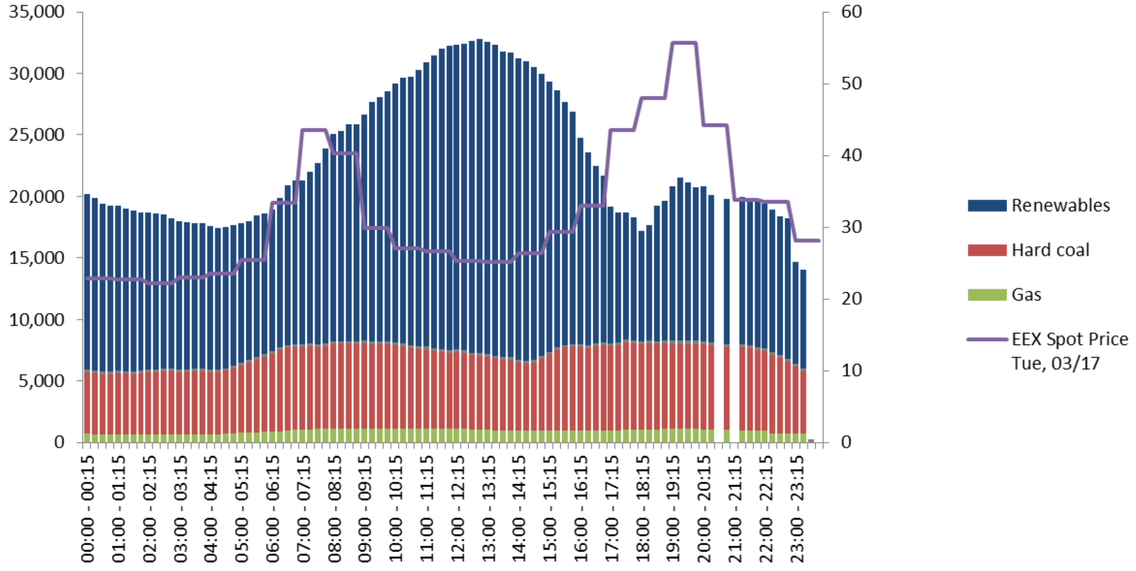

Figure 31: Electricity production by generation type in Germany (17. March 2015) (Mayer, 2014) [14]

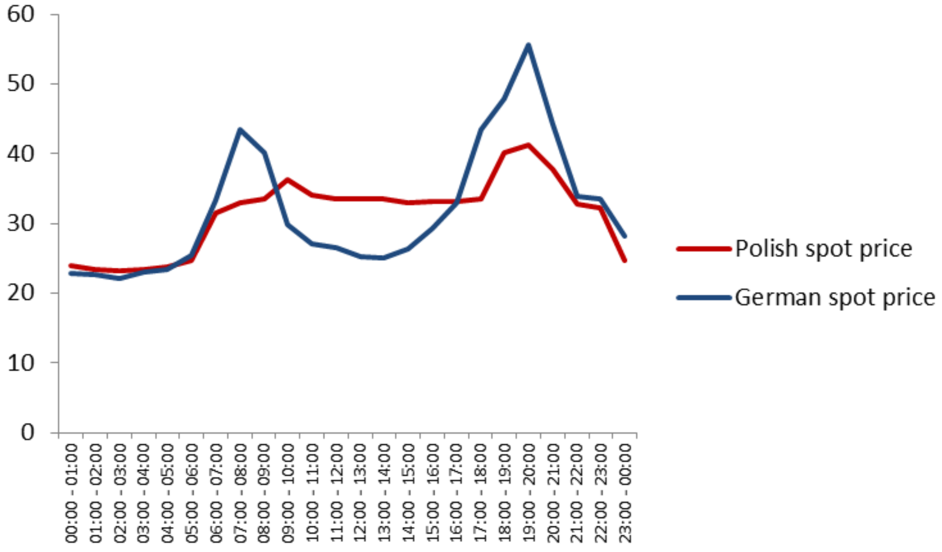

Figure 32: Comparison of Polish and German spot price (17. March 2015) (TGE, 2015) (Mayer, 2014)

[14] Generation capacity without base load (lignite and nuclear)

5.4 Advantages

5.4.1 Economic fundamentals

The basic economic notion of specialization of trade goes back to the great economist David Ricardo who proposed the theory of comparative advantage. Ricardo argues that it is mutually beneficial for both countries if that a nation should concentrate on industries where the countries have a comparative (Boudreax, 2008). If both countries concentrate on their unique resource and trade it actively on the market they are better off, as in a case where both countries produce both goods. In the case of Germany and Poland, an argument can be made that Germany has a an advantage in the field of renewable energy, due to the incumbent industry and the experience from installing vast amounts of wind and solar energy in their electricity system. For Poland, it can be assumed that Poland has a comparative advantage in the field of electricity generation from hard coal. Although it might not have an advantage in terms of technology, since many best available technology is usually acquired from abroad. Poland has the advantage of a abundant domestic coal resources and even more importantly has the social acceptance by the population.

In the context of energy, Karsten Neuhoff outlines four major advantage of international exchange of electricity. Primarily, exchanges allow to better use complementary resources. In the case of Poland and Germany the complements are clearly defined; on the one hand volatile renewable energy and on the other hand flexible fossil fuel generation. The economic rationale is based on economies of scale and diversity. The bigger a pool of assets, in the context of the electricity it is the generation capacity, brings larger diversification and therefore can better balance the system (Neuhoff, 2009).

The second advantage comes from the variability of demand during the year. Consumption patterns are similar between Poland and Germany, with higher demand up to 22% than in summer due to the rise in heating demand. However, higher irradiation in summer leads to higher solar energy output in Germany, which can be balanced out with energy demand in Poland.

Thirdly, transnational electricity long term imbalances can be overcome a situation of undersupply. As it is mentioned in the report by the Polish ministry of economy already in the year 2017 1.1 GW are missing in the Polish electricity system. A strong interconnection to its neighboring countries can mitigate the problem, such as in the case of Italy where demand growth was underestimated and lack of own generation could be balanced by imports from Italy.

The final aspect is the possibility of pooling reserves. Particularly in Germany reserves gained importance due to the increased amount of renewable energies, where the variability creates problems of grid stability. Although an introduction of capacity markets has been discussed in Germany, Minister for Economic Affairs and Energy Sigmar Gabriel declared that "no Hartz IV support will be given to utilities"[15], therefore it is not to be expected to see such market mechanism into force in the near future. The severity of the problem can be seen from the fact that many German gas fired power plants have already requested shutdown due to lack of profitability, the authorities have denied the request due to grid safety reasons (Frankfurter Allgemeine, 2015). Therefore pooling reserves with countries such as Poland could linger these problems in the long run.

5.4.2 Effect on Polish utilities

As required by the directive 2003/54/EC (Directive 2009/28/EC, 2009) Poland has unbundled the various stages of the supply chain of electricity. In 2006 Polish power companies have been formed into vertically state-owned companies (PGE, Tauron, Energa and Enea) as outlined in the strategic "Program for the electricity power sector". Today three out of the four companies are still majority-owned by the state treasury (Bayer, 2014). Therefore, the state as the biggest shareholder puts frequently pressure on the companies in pursuance of their political goals. This was evident in November 2013 when CEO Krzysztof Kilian of PGE resigned after the government demanded the construction of a 3600 MW power plant in Opole. The financial evaluation of the project was deemed risk with a low probability of positive returns on investments. However, the government argued that it is necessary due to security of supply (Forbes, 2014). This situation shows clearly that due to the influence of the state, the Polish energy sector will remain loyal to its coal resources. Therefore, if it is assumed that coal will remain an important part of the energy mix, the proposed cooperation with Germany will enable Polish electricity producer to sell their energy on the Intraday market, where they can sell their electricity for higher prices.

[15] Hartz IV is welfare reform program in Germany

5.4.3 Effect on German utilities

As described previously, German utility companies are under pressure in the current market environment. Since their currently inflexible electricity generation units can not cope with vast amounts of renewable energy. The proposed cooperation would stabilize the market in Germany and hence would have a positive effect on the German market participants, at least to the extent that would reduce very lower or negative electricity prices.

5.5 Design of the cooperation

A crucial question to define is how such cooperation could be implemented. A possible design of the framework requires the accommodation of the economic, technical and political constraint. Two main approaches have been identified: a policy driven and a market driven.

5.5.1 Policy driven

A policy driven approach would entail the state as an important stakeholder in the energy sector to promote cooperation. Poland and Germany could enter into an agreement to foster cooperation. Such an agreement could have various forms. It's severity could range from a concrete arrangements to take action to a lax intention letter. Whatever the severity of the agreement might be, the following are measures that could be undertaken to strengthen cooperation:

- Poland and Germany could agree on combining there balancing zones. Currently, electricity markets, vary greatly in their rules, design and functioning. It is outside of the scope of this thesis to analyze thoroughly the differences between the Polish and the German market, but market characteristics such as balancing groups, auxiliary mechanisms for renewables and their treatment in the grid differ significantly from each other. Therefore the two governments could agree on assimilating their standards to allow for better trade between both countries, that can be used as a role model for other countries to join. In the seventh framework program of the European Union, eBadge is exploring ways to introduce an EU wide intelligence balancing market (Svetina and Kramar, 2013). Also in the European gas market efforts are undergone to develop EU-wide balancing rules for the sector (European Commission, 2014). Although, combining the balancing zones would certainly lead to an very efficient market integration, however such approach might be considered to radical for both countries given the current differences between both countries.

- Poland and Germany could agree to increase investment in the interconnectors for electricity transmission to facilitate the exchange of energy. As noted in the chapter 3, the current technical capacity of the interconnector is small (1000 MW), creating bottlenecks between the two markets. This could prove necessary since the TSOs do not have the capacity to invest further financial means to support the system as stated in the 6th BEMIP report:

  "Based on a proposal made by PSE to concentrate first on internal reinforcements of the Polish grid, PSE and 50Hertz are currently discussing a possible postponement of the construction of the third interconnection line between Poland and Germany beyond 2025."

Therefore Poland and Germany could help to finance the interconnectors and greatly improve the cross boarder transmission capacity, which would enhance trade between both countries.

5.5.2 Market driven

In a market driven approach, private stakeholders such as electricity generation companies or trading companies from both countries could set up a structure that, given the right legal framework, could benefit from the exchange between Poland and Germany. This could be achieved through a creation of a fund, which would consist of renewable energy producers from Germany and hard coal fueled power plants from Poland. Since Poland and Germany have various market mechanisms and the balancing is separate in both countries, such fund would function as a unique balance group in Poland and Germany. However, such system would be possible only with an extensive upgrade of the electricity grid.

5.6 Example Nordpool

An important example which can serve as a reference point to the electricity trade between Germany and Poland is the analysis of the Nordpool electricity exchange. Nordpool is the largest market of its kind in Europe with active spot and futures trading (Skånberg, 2012). With more than 361 TWh traded on the day ahead spot market, the commodity exchange accounts for more than 80% of total consumption in the Nordic countries. Such high number of traded volume on the exchange gives liquidity to the market, facilitates trade and therefore strengthens competition between market players. The market consists of participants from Norway, Sweden, Denmark, Finland and the Baltic states (Estonia, Latvia and Lithuania), Germany and the UK with the respective TSOs as their main shareholders (Nordpool Spot, 2015). For this purpose of this thesis, the Nordpool market, is not only important due to its size and effective market mechanism, but due to the fact that the participating countries have a diverse spectrum of generation assets in which large quantities are traded over a long span of time such as due to seasonal variations but also in short term spans due to sudden variability or mismatch.

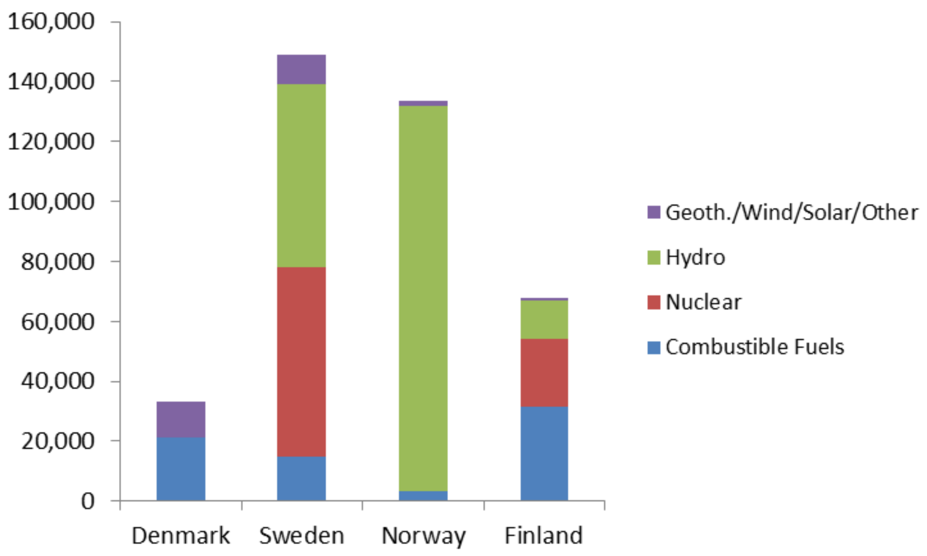

Figure 33: Electricity mix for Denmark, Sweden, Norway and Finland (Bahar and Sauvage, 2013)

Figure 33 depicts the total electricity generation for the four major Nordic countries participating in the Nordpool and underpins two important findings. First, participants vary distinctively in size; Denmark reaches only a production capacity of 35TWh per year, whereas Sweden, the largest producer has a capacity of around 150TWh. Further it is important to note that the countries differ significantly in their energy mix. Norway in this regard is fully dependent on hydropower, Sweden relies to a large extent in nuclear energy and hydropower, whereas Denmark generates 65% from combustion fuels such as coal and gas. Figure 34 and Figure 35 depict the appearance of seasonal flows between the Nordic countries. A comparison is made between electricity flows in the winter season 2013 (December – January) and the summer season in 2014 (June - July). Finland has an ongoing electricity deficit and is importing through its link to Sweden around 3.5TWh of electricity during December/January as well as between June/July. Due to a strong integration with its neighboring countries Finland can outbalance its electricity under supply. In the case of the connection between Denmark and Sweden the exchange due to seasonality can be observed. During the winter months Denmark supplies Sweden with fossil energy (1TWh December/January, whereas in June/July the electricity come back from Sweden to Denmark (1.4TWh). Seasonal variability due to meteorological conditions can be outbalance on a large scale at is shown in the case of the Nordic countries.

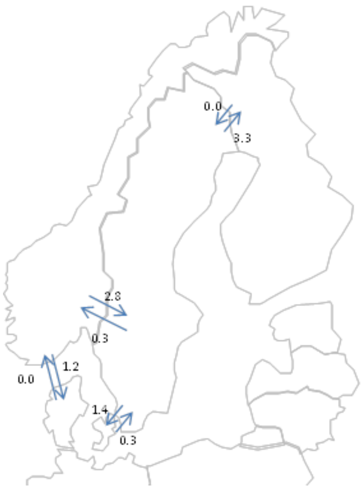

Figure 34: Electricity flows between Nordic countries in TWh (December 2013 /January 2014) (Nordpool Spot, 2015)

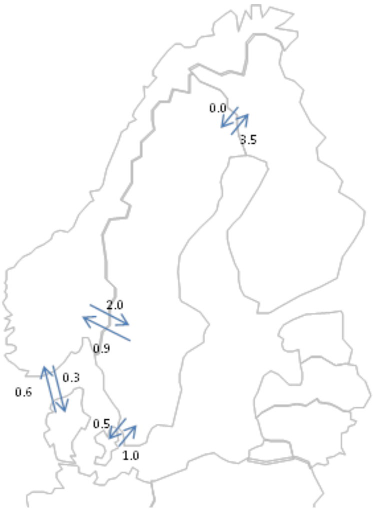

Figure 35: Electricity flows between Nordic countries in TWh (June 2014 / July 2014) (Nordpool Spot, 2015)

The electricity market in Nordic countries shows that transnational trade is also quiet flexible in short term variability. Figure 36 shows the electricity flows from Denmark to Norway. Due to the different capacities of both countries, a regular exchange between Denmark and Norway is regular is scheduled in order to make use of the complementary resources.

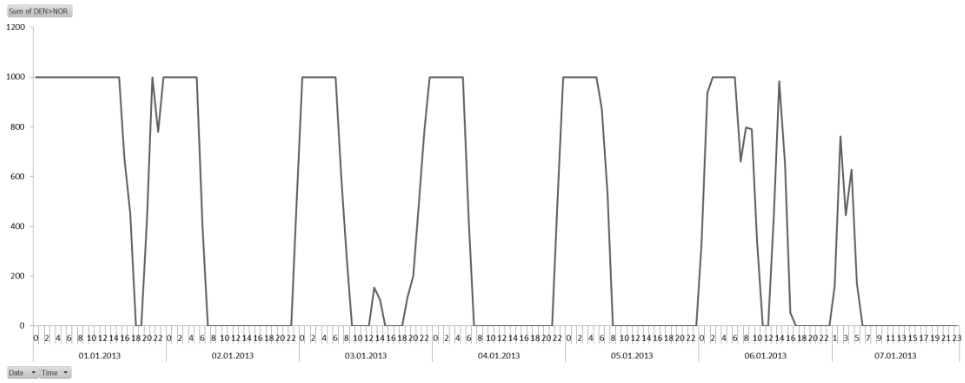

Figure 36: Electricity flows from Denmark to Norway MW (March 2015) (Nordpool Spot, 2015)

Although Nordic market differs greatly from the setting between Germany and Poland certain commonalities can be identified. Poland in 2030 will have a similar capacity in terms of fossil energy as does Denmark today. Poland plans to reduce its coal and gas fired power plants up to a level of 60%. Denmark electricity mix in 2013 was divided into 65% conventional energy sources and 35% of renewable energy. Although Denmark already advanced greatly in the development of renewable energy, conventional electricity are still vital and gives Denmark the possibility as a buffer to counter imbalances stemming from seasonality of hydropower.

6 Final conclusion

The aim of this thesis was to understand whether cooperation between Poland and Germany is possible based on technical, economic and political factors.

From the economic perspective the German electricity market is challenged by high electricity prices for end consumers, financial difficulties of large utilities, high variability of the electricity output and inflexibility of the incumbent electricity generation system. Whereas Poland's major problems are high cost of domestic coal and outdated infrastructure combined with rising demand. To overcome these challenges Poland has to upgrade its current hard coal power plants to a modern more flexible infrastructure which can adjust to the variable output of renewable energy generated in Germany. Thus, creating a win-win situation where Germany can sell its oversupply of electricity to Poland in peak hours and Poland can supply Germany with electricity when renewable output is low. The complementary use of the Polish generation capacity stabilizes prices for the German market participants and gives the Polish electricity producer better price for their products.

With regards to the technical capacity, the interconnectors between both countries have limited capacity and create bottlenecks. Therefore, current trade between both countries is only possible to a limited extent. However, with sufficient investment by both Poland and Germany, these bottlenecks can be overcome.

On the political level future commitments for the 2020-2030 period are hard to predict, since no binding legislation has been in place. The last EU summit talks on climate change in March 2014 have not yielded any result to date. Since the EU suffers from high energy prices, whereas the United States benefits from cheap shale gas, ambitious climate goals can not be expected. Therefore, it is fair to assume that both Poland and Germany can pursue their current political agenda. Poland's main policy concern is centered around energy security, whereas Germany is focused on the sustainability issue.

To conclude, there is fertile ground to enter into cooperation between Germany and Poland in the field of electricity trade, which would resolve many of the economic challenges faced by both countries and enable to reach the 2030 framework goals. However, current technical conditions would not allow for any significant exchange of electricity. Sufficient political commitment from Germany and Poland in this respect would allow overcoming this hurdle.

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Annex

German energy policy

Development of Renewable Legislation

Germany´s green legislation has a long tradition and established many research institutes in the field. In the 1980s it initiated small scale R&D programs and demonstration plants promoted by the Federal Ministry of Research and Technology. Consequently in 1989 a market stimulation program has been implemented which granted fixed access to the grid and a fixed price for the produced energy for a total of 250 MW installation.

The next legislative milestone was the Renewable Electricity Feed-in Act in 1991. It required utility companies to give preferential access to renewable energy generators at a certain minimum price[16]. This requirement was limited to only 5 percent of the energy generated. Due to the immature stage of photovoltaic energy production, the incentive was too low to stimulate the growth of the solar energy industry and only resulted in a limited development of wind energy plants.

The current Renewable Energy law was introduced in the year 2000 and since then was amended only in the year 2004, 2009 and 2012. These amendments brought only modest changes and merely redefined the regression level of remuneration. The Renewable Energy act had three important aspects. First of all, it guaranteed a fixed feed-in tariff payment, which was independent of the market price of energy and therefore hedged against market volatilities. The second important feature was that it defined the duration for payments. The energy generator was promised the tariff for a 20 year time period. The last crucial element was that for each technology a certain level of regression was set, meaning that every year new projects received a lower guaranteed tariff. This measure intended to stimulate improvements in technology through economies of learning, motivated companies to set up plants as quickly as possible, in order to increase efficiency through the learning process. The German legislators defined the yearly reduction between 2 and 6 percent.

The fixed rate of remuneration and the long term guarantee reduced the risk of investing dramatically and therefore created a favorable setting for the renewable

[16] The minimum price was set at 80% of the last two years average

energy sector. This is particularly important since renewable energy plants require a higher initial capital investment than conventional fossil plants and therefore the reduction of the cost of financing is crucial for renewable energy deployment.

Data background

Table 10: Operating power plants in Poland (ARE, 2014)

Type	Powerplant	Installed Capacity 2013	Installed Capacity 2012	Installed Capacity 2011	Yearly load
Brown Coal	Belchatow	5298	5298	5298	75%
Brown Coal	Turow	1698	1898	1898	70%
Brown Coal	Patnow	1200	1200	1200	48%
Brown Coal	Adamow	600	600	600	63%
Brown Coal	Patnow II	464	464	464	65%
Brown Coal	Konin KONK	143	193	143	33%
Black Coal	Kozienice	2845	2845	2845	49%
Black Coal	EDF Rybnik	1775	1775	1775	62%
Black Coal	Polaniec WK	1400	1600	1600	53%
Black Coal	Dolna Odra	1772	1772	1772	35%
Black Coal	Opole	1492	1492	1492	55%
Black Coal	Jaworzno 3	1345	1345	1345	57%
Black Coal	Laziska	1155	1155	1155	43%
Black Coal	Lagisza	820	1060	1060	48%
Black Coal	Siersza	666			34%
Black Coal	Ostroleka	647			63%
Black Coal	Skawina	490			32%
Black Coal	Stalowa Wola WK	300			38%
Black Coal	Blachownia	165			42%
Black Coal	Jaworzno 2 WK	140			69%
Biomass	Polaniec Zielony Blok	205			74%
Biomass	Konin KONG	55			50%

Biomass	Jaworzno 2 BM	50		42%
Biomass	Stalowa Wola BM	30		14%
Cogeneration	Siekierki	622		48%
Cogeneration	Krakow	460		43%
Cogeneration	Zeran	334		61%
Cogeneration	Poznan Karolin	283		39%
Cogeneration	Wroclaw	263		42%
Cogeneration	Lublin Wrotkow	246.5		21%
Cogeneration	Chorzow ELCHO 2	238.4		56%
Cogeneration	Gdanska	220.6		47%
Cogeneration	Lodz 3	205		36%
Cogeneration	Lodz 4	208		44%
Cogeneration	Zielona Gora	198		76%
Cogeneration	Bydgoszcz 2	227		29%
Cogeneration	Bialystok	203.5		26%
Cogeneration	Katowice	135.5		72%
Cogeneration	Pomorzany	134.2		47%
Cogeneration	Nowa Sarzyna	112.8		79%
Cogeneration	Nowa	125		39%
Cogeneration	Gdynska	110		55%
Cogeneration	Rzeszow	102		22%
Cogeneration	Czechnica	100		30%
Cogeneration	Gorzow	97.5		73%
Cogeneration	Lodz	82.5		40%
Cogeneration	Bedzin	81.5		57%
Cogeneration	Ostroleka	93.5		5%
Cogeneration	Fortum Zabrze	73.9		27%
Cogeneration	Szczecin	68.5		79%
Cogeneration	Bielsko Polnoc	55		67%
Cogeneration	Fortum Bytom	55		32%
Cogeneration	Bielsko Biala	50.8		24%
Cogeneration	Elblag	49		29%
Cogeneration	Tychy	40		57%

Cogeneration	Zgierz	16.7	14%
Cogeneration	Kielce	10.8	52%
Cogeneration	Pruszkow	7.1	47%
Cogeneration	Kalisz	8	26%
Cogeneration	Bydgoszcz	21.4	0%
Cogeneration	Przeworsk	10.9	0%
Cogeneration	Wschod Torun	3	57%