EUROPEAN POWER MARKET INTEGRATION
POLAND & REGIONAL DEVELOPMENT IN THE BALTIC SEA

Final Report

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EXECUTIVE SUMMARY

The goal of this study is to show the impact of the energy transition (Energiewende) and of the market design change in Germany on the competitiveness of the Polish power market. The analysis discusses how to increase security of supply by strengthening the Polish market with low-cost, high-efficient and environmentally friendly solutions as well as qualifies the value of closer cooperation between the German and Polish power markets. The study describes the implications of this approach on the European power market integration and provides operational and strategic proposals for policy makers.

Germany's ambitious energy transition strategy goes alongside with the need to adapt its electricity market design, which does have an impact on its electricity neighbours and raises the question of competitive position of Poland's power sector. Having determined the risk or the opportunity for both countries, the study outlines three different scenarios for the Polish electricity market, including specific recommendations and implications.

The Polish power demand will increase by 50 percent from today's about 160 TWh to 240 TWh in 2040, while the Polish fossil power plant fleet is severely aged, which increases the possibility of unavailability and power shortages. At least 12 GW will be decommissioned in the next 10 years, while only 6.4 GW of new fossil capacity has been planned. Poland's electricity sector has been facing a substantial lack of investments over the last 1-2 decades and it will suffer on average 11 days of power shortages each year until 2020.

Given the current market conditions with low power prices, the urgently needed new capacities shall generate negative cash flows (missing money). Therefore, government's intervention is required to prevent power shortages. The Polish authorities should target short-, mid- and long-term measures with tailored mechanisms to secure generation adequacy in the short run and simultaneously set policies to trigger investments in clean, cost-effective and efficient power generation technologies keeping a close eye on the time lag between policy implementation, investment decision and start of electricity production.

Prompt implementation of policies that would release investments into national generation should be a key priority for this government. Strategies must be designed in such a way that eliminates the negative cash flow of clean, cost-effective and efficient power generation investments. The negative cash flow (missing money) to transform Poland to a low carbon electricity mix with a solid renewable energy share equals 0.3 to 2.3 Billion Euro per year or 0.22 to 0.96 EuroCt/kWh in 2020 and 2040.

Poland needs also a much stronger integration into the European electricity system with a strong build-out of interconnectors. An increased interconnection would allow Poland to take advantage of neighbouring capacities and save annually 3 Billion Euro instead of building in-house gas capacity and 6.5 Billion Euro per year compared to national coal capacity upgrade. Beyond that, Poland would be able to benefit from lower power prices e.g. from Germany, where electricity prices in 2030 are lower during 5294 hours (~60%) of the year.

1. INTRODUCTION: RESEARCH QUESTION

Germany's ambitious energy transition strategy goes alongside with need to adapt its electricity market design, which does have an impact on its electricity neighbours as the joint memorandum of the 12 countries and the EU Commission from July 2015 clearly proves it. The memorandum is backed by the EU's discussion paper on the new market design[1].

Poland has been historically hesitant to promote strong interconnection with neighbouring states. However, the EU energy market development policies and the growing domestic power demand make it inevitable that the Polish power system becomes an integral part of a regional power market.

Stronger interconnection and real market coupling will drive mutual impact of power systems. The question arises: what impact will the changes have on the competitiveness of Poland and the Polish power sector.

[1] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Launching the public consultation process on a new energy market design, COM(2015) 340 final

2. APPROACH

The focus of the analysis was to derive the impact of the Energiewende and the market design change in Germany on the competitiveness of the Polish power market. During the first stage of the project it became clear, that the Polish market is facing big challenges considering the security of power supply. If there will be no changes in the electricity system, the supply side will not cover the power demand in the near future already.

Accordingly, the approach of the study is to show a way that allows securing of supply and at the same time to strengthen the Polish market with low cost, high efficient and environmental friendly solutions. This approach leads to a closer cooperation of the German and Polish power market to gain efficiency environmental friendly and at low cost. The study points out the implications of this approach on European power market integration.

2.1 METHODOLOGY

The analysis is based on a 3-phased approach where the focus is on security of supply. Different scenarios are developed to examine which measures are necessary to avoid system shortages in the short and in the long run. The scenarios are based upon the following two principles:

- European integration with the enlargement of interconnection possibilities through transmission lines between Poland and Germany as well as the Baltic Sea region, Czech Republic and Slovakia.
- Provision of sufficient generation capacity in Poland by technologies with low cost, high efficiency, low carbon emissions and short project cycle time (that means the time required to generate the first kilowatt hour[2])

In the scenarios different combinations of the enlargement of cross border transmission capacities and development paths of wind, solar and gas power are presented.

2.2 WORKING GROUP STRUCTURE

The approach of the study is to analyse not only a single national energy market but looking at the cross border impacts of neighbouring energy market rules and policies. In order to consider a broad energy market knowledge base on German and Polish aspects as well as to have insights

[2] See Figure 10

on market development, challenges and opportunities correctly represented we created an advisory board with a number of outstanding energy experts in both countries.

The advisory board provided guidance on the actual situation of the energy sector in Poland and Germany and gave very valuable advice to the project team in developing and formulating solution driven scenarios. The advisory board has been an integral part of this study and has provided excellent input and review for this study. We would like to thank:

- Dr Joanna Pandera, Agora Energiewende, Germany/Poland
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- Adam Simonowicz, InfoEngine, Poland
- Prof. Dr. Dipl. Ing. T. Schneiders (Co-Author), Technical University of Cologne, Germany
- Izabela Kielichowska, Polish Wind Energy Association (PWEA), Poland

2.3 MODEL DESCRIPTION

The energy market model Power2Sim was applied to calculate the scenarios. Power2Sim is a fundamental software program produced by Energy Brainpool to simulate the development of electricity prices. It is based on a simulated merit order curve, by means of which the hourly wholesale electricity prices for all European countries are precisely calculated.

The short-term marginal costs of power plant electricity generation, the available generating capacity, and demand are the three main factors that determine the price of electricity. Power2Sim distinguishes between conventional and renewable power generation facilities. Electricity generation from renewables is taken into account before various conventional power plants, based on their short-term marginal costs, are included in the merit order model. The electricity generated from renewables is deducted from overall demand. Conventional power plants must therefore generate the remaining amount of electricity (residual load). In the model, renewable energies are taken into account differently, depending on the type of technology. Historical load data always serves as a basis to map the existing generation systems as precisely as possible. Power2Sim lists Europe's entire conventional power plant fleet and includes individual specifications such as fuel, efficiency and availability. This information is used to compute the merit order price.

The load model forecasts electricity demand in each country down to the hour based on specific day profiles, holiday and school holiday calendars as well as scenario trends.

The import and export model allows cross-border flows to be calculated for each border based on the cross border capacity. By including cross-border flows in the system, electricity prices in connected European electricity transmission grids can be calculated much more precisely.

All Power2Sim sub-models and their interaction are visualized in Figure 1.

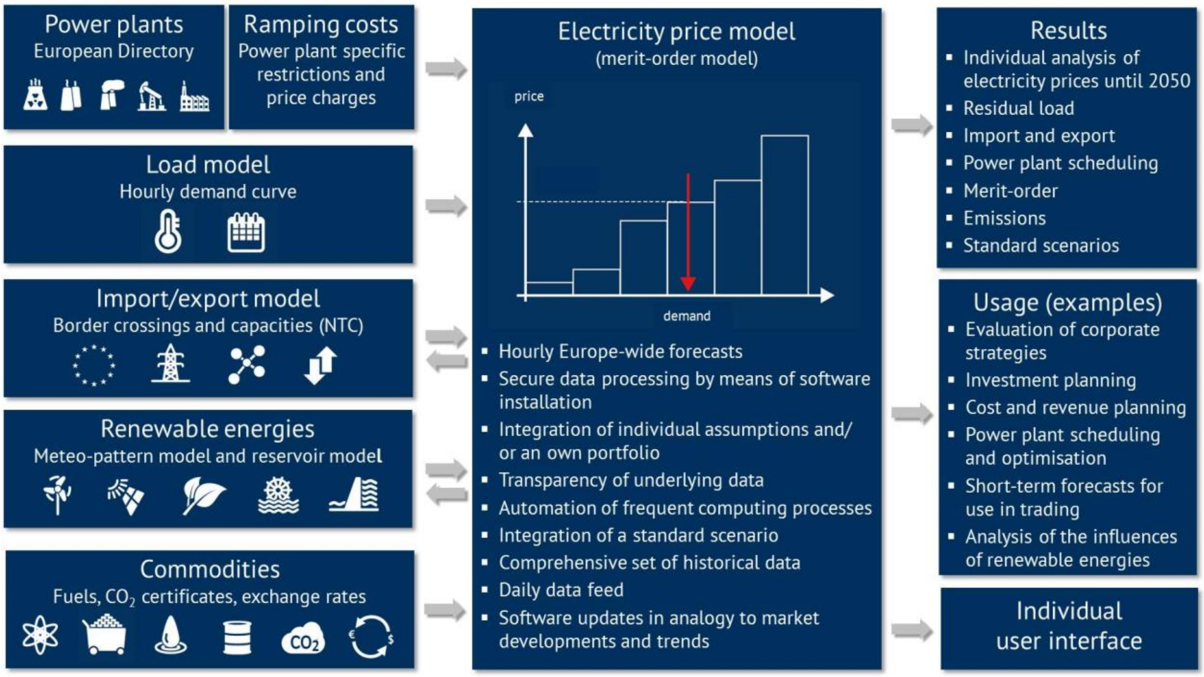

Figure 1: Structure of Power2Sim

The comprehensive set of historical data is compiled from information available from public sources such as Eurostat, ENTSO-E and IEA. The model is calibrated based on historical electricity prices, emissions, and volumes of generated and exchanged electricity.

The European power market scenarios are based on the study “EU Energy, Transport and GHG Emissions Trends to 2050” published by the European Commission in 2013. It shows a trend path to 2050 adapted to the country and to the European Union taking into account the specific initial conditions of every country in the EU 28. Moreover national plans published recently are used to react to adapted national planning and new market developments. This applies for France, United Kingdom and Germany. For Poland the “Development Plan for meeting the current and future electricity demand for 2016-2025” from grid operator PSE is taken into account in the scenario development.

The commodity prices in the scenarios are taken from the “World Energy Outlook 2015” of the International Energy Agency. The scenario “450 ppm” is applied to reflect the Paris climate conference decisions in 2015. It predicts a steep increase in CO_2-prices and a slight rise in fuel prices until 2040.

2.4 INDICATORS CONSIDERED

As the sources and assumptions shown in chapter 2.3 describe the German power system comprehensively (for more details of the German electricity market see chapter 3), the Polish power market needs further analysis. In the first step, the study analyses the amount of shortages in the Polish power system. The second step is to further investigate the measures that can be used to decrease the imbalance. Therefore, we have illustrated the costs of power generation on a total cost basis, where we take investment costs as well as operational costs into account. As wholesale markets are not always able to cover the power plant expenditures in the scenarios, a further analysis shows the financial consequences for Poland. In total, the cost for the system and consequently the cost for end costumers are displayed.

In brief: Indicators considered

- As the main market segment for short time energy trading **the day-ahead-market is simulated**. Further balancing mechanisms such as intraday trading, balancing market or special reserves are not taken into account. Therefore, possible short time flexibility e. g. demand side management is more likely underestimated.
- The sources and assumptions shown in chapter 2.3 describe the German power system comprehensively.
- When comparing power supply and peak demand the installed capacity has to be adjusted by the **availability of power plants**. The Power2Sim model takes this adjustment into account, which increases the situations with power shortages.
- Overcapacities in Germany ensure security of supply on the German power market in all scenarios analysed in terms of the fundamental model. If transport capacities are available, electricity from spare capacities can be exported to connected countries. The model ascertains the price for this exported electricity at the production cost (short run marginal cost) of the spare capacities.
- The **Polish power demand** is increasing by 50 percent from todays about 160 TWh to 240 TWh in 2040.
- The **Polish fossil power plant** fleet is severely aged, which increases the possibility of unavailability and power shortages. At least 12 GW of lignite and hard coal power plants being older than 50 years will leave the market to be decommissioned in the next 10 years.
- If Poland does not take measures to prevent **power shortages**, a few dozen hours are likely to have higher demand than supply in the years 2016 and 2017. Until 2040 this study analyses the effective management and the construction of new transmission capacities to neighbouring countries and the construction of new efficient, cost effective and environmental friendly capacities.

- For cost and power price analyses World Energy Outlook's 2015 "450 ppm scenario" is considered for the development of **commodity prices** with its assumption that climate change targets will be reached.
- For cost analyses of the respective technologies **levelized costs of electricity (LCOE)** were calculated based on comprehensive literature research.
- Due to low power prices the urgently needed new capacities could not operate economically. In the year 2030 for example the total costs of the entire power sector exceed the revenues from power sales by 2 Billion Euro (missing money). To meet the **investment needs** the regulators and governments need to design and implement policies to prevent this shortfall of revenues.
- As one of the results this study estimates the **cost of investment on consumers**. For cost estimation reasons a surcharge on the electricity bill is calculated.

2.4.1 DEMAND/SUPPLY BALANCE – TIME WITH 100 PERCENT SUPPLY GUARANTEED

To secure the functioning of the power system demand and supply need to be in balance at each point in time. Besides considering the total power plant capacities one has to pay close attention to the availability of the power plants during times of high demand. Another important factor is the availability of transmission lines to import power from abroad in situations where the demand cannot be covered solely by national power plants.

The model Power2Sim is simulating the day-ahead-market and therefore all calculations and analyses must be seen under this condition. In reality, an imbalance that occurs in the day-ahead-market might be compensated in the following intraday and balancing market. Furthermore, it is possible that there would be additional safety measures to ensure system stability. This study is focussing on balancing demand and supply only in the day-ahead-market.

Overcapacities in Germany ensure security of supply on the German power market in all scenarios analysed in terms of the model.

Basic assumptions for the Polish market in the short run are taken from the study from grid operator PSE "Development plan for meeting the current and future electricity demand for 2016-2025". Driven by continuous economic growth the Polish power demand is increasing by 50 percent from todays about 160 TWh to 240 TWh in 2040.

On the supply side, the Polish fossil power plant fleet is severely aged and – in comparison to other countries – less competitive. The biggest part with about 23 GW installed capacity of hard coal power plants counts on average almost 40 years. Lignite power plants are on average already operational for about 30 years. With a lifetime of about 50 years both power plants types comprise a number of power plants that will soon leave the market to be decommissioned. An overview of the power plant types and their age compared to Germany can be found in Figure 2.

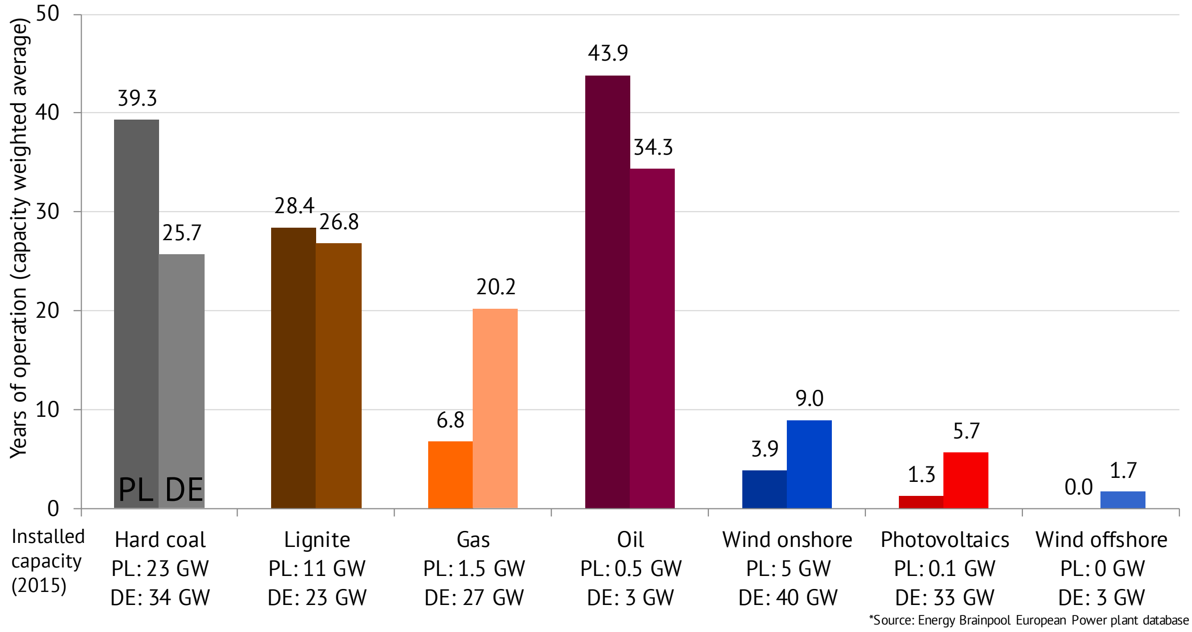

Figure 2: Average years of operation of Polish and German power plants, ordered by type

If supply will be able to cover the demand in the coming years depends mainly on the availability of the Polish power stations. On paper there is sufficient capacity installed today but as mentioned power plants are old and, although modernised, their reliability is decreasing and the risk of unscheduled outages is increasing. These circumstances make predictions and forecasts very difficult. At the same time, the old power plants are very emission intensive due to low power plant efficiencies. Some of the power plants will have to leave the market because of their high emissions do not comply with the IED[3] of the EU and their further modernisation to meet these requirements is not feasible.

Looking at the Polish power system in the Power2Sim scenarios the situation for the years 2016-2017 is very tight but supply is mostly able to cover the power demand. A few dozen hours are likely to have higher demand than supply. The individual day and time as well as plant availability will determine if a shortage situation takes place. In the following years, the possibility of shortfalls rises tremendously. The combination of increasing demand and the closure of power plants

[3] Industrial Emissions Directive

leads to a rising gap between demand and supply. In the short run, the possibilities to intervene in the power system are limited as investments in power plants or transmission lines have implementation periods of several years.

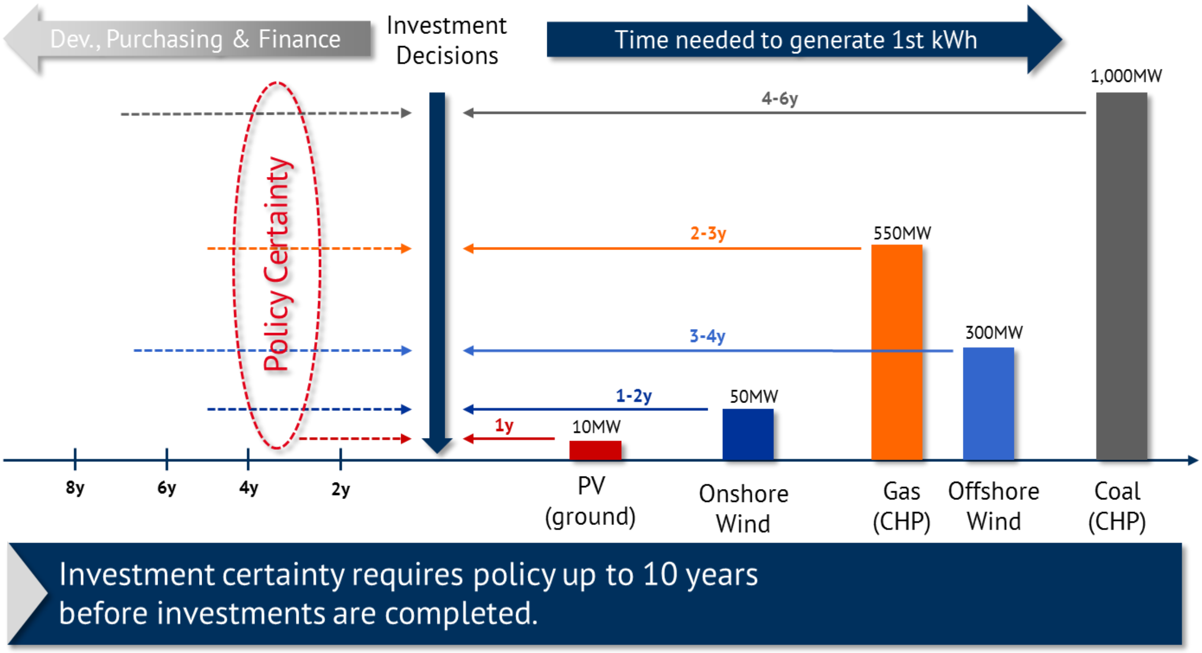

Figure 3: Energy sector investment cycle

To close the gap investment incentives or reserve mechanisms need to be implemented as soon as possible to allow generation capacities to be operational before the gap is too big to be handled.

Possible investments to equilibrate demand and supply analysed in this study are the construction of new or the effective management of existing transmission capacities to neighbouring countries and the construction of new power plant capacities. The security of supply in Poland shall be reached in an efficient, cost effective and environmental friendly manner.

2.4.2 COST OF ENERGY

The cost for the generation of electricity depends on the power plant type and energy source. The price setting factor in wholesale power markets are the cost for fuels and for emission compensation. To analyse the situation of Polish power plants in the future it is necessary to assume the cost development path of fossil fuels and emission certificates.

In the scenarios, the prices for fossil fuels and emission certificates follow in the short run the prices for future contracts in the specific products. For a long-term perspective (after 2020), the

"450 ppm" scenario of the "World energy outlook 2015" applies. Table 1 specifies the price paths of all relevant commodities until 2040.

DATE	HARD COAL $/T	OIL (BRENT) $/BBL	NATURAL GAS €/MWH	CO_2-CERTIFICATES €/T_{CO2}
01.07.2016	46.03	44.03	12.12	5.69
01.07.2020	48.01	55.58	15.88	8.27
01.07.2030	79.00	97.00	24.05	75.00
01.07.2040	77.00	95.00	22.78	105.00

Table 1: Price path used in the scenarios for fossil fuels and CO_2-emission certificates

Because of the Paris climate conference in December 2015 the abatement of climate change went up in political priorities. The "450 ppm" scenario describes a future where on a global scale the protection of the climate has a very high priority. Therefore, all states agree on the strengthening of emission certificate trading as a mechanism to reduce CO_2-emissions. Consequently, the price for emission certificates rises strongly over time.

At the same time with high emission certificates prices the costs for burning fossil fuels go up and thus the demand for the fuels decrease. This is why prices for fossil fuels only rise slowly in the "450 ppm" scenario compared to other commodity price scenarios in the "World Energy Outlook 2015".

2.4.3 LCOE NEEDED FOR POTENTIAL NEW INVESTMENT

The "Levelized Costs of Electricity" (LCOE) show the price of power generation in Euro per Megawatt hour (€/MWh) based on the total costs of the respective technology.[4]

In Figure 4 the different technologies considered in the study are compared. The costs differ in each year because of changes in the energy output and commodity prices.[5]

[4] The LCOE is calculated as follows: the sum of CAPEX, OPEX and short run marginal costs (SRMC) of the specific technology is divided by the amount of generated power. To operate break-even each technology needs power prices in the range of their LCOE.

The CAPEX and OPEX costs are based on current values. To derive the LCOE per year the CAPEX are distributed over the estimated lifetime of the power plant. The OPEX can be distinguished into fix and variable costs. The variable part of the OPEX is represented by the SRMC[4] of power generation. The SRMC comprise the costs for the fuel and the costs for compensating the emissions of CO_2 from that fuel by purchasing emission certificates.

[5] Fixed costs such as CAPEX and fixed OPEX and staying on current levels. This is due to the fact that in the scenario, the commodity prices are increasing over time based on the "450 Scenario" of the "World Energy Outlook 2015".

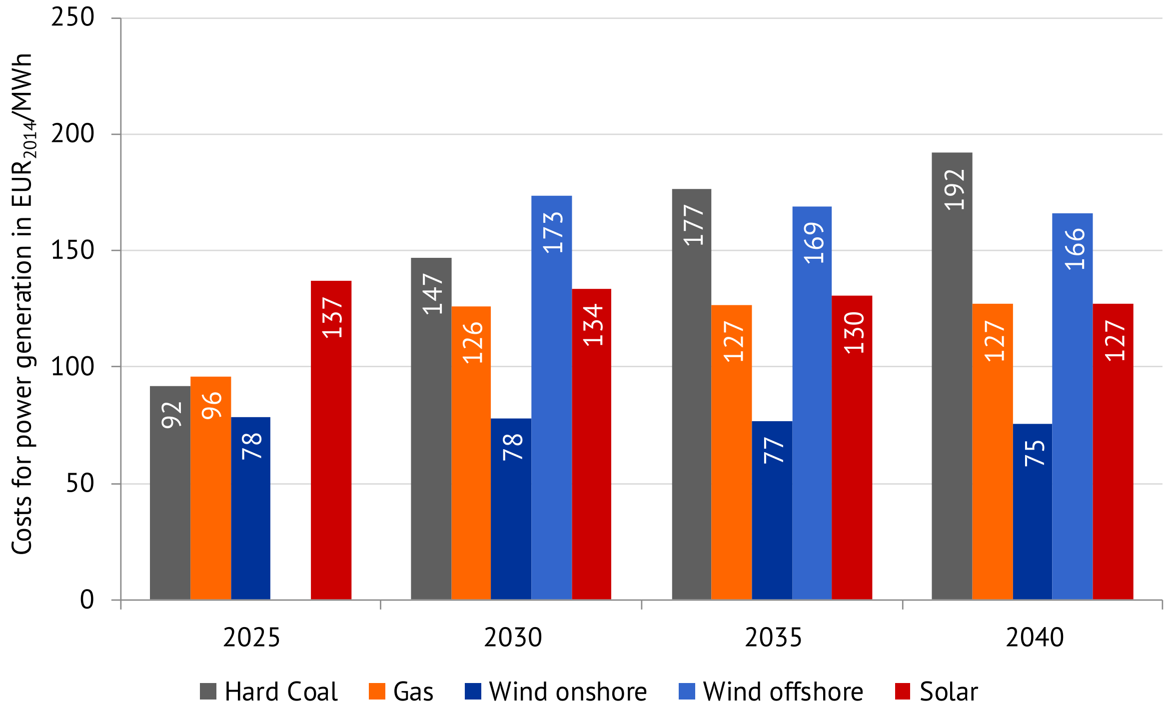

Figure 4: Levelized costs of electricity per technology 2025-2040

With increasing costs for gas and coal as well as the costs for emission certificates, the operational costs (short run marginal cost, SRMC) of these technologies increase as well. Because of the pricing for CO_2-certificates, the generation from gas power stations on a total cost basis is from 2030 on cheaper than the generation from coal. As coal power plants are more often shifted out of the market by gas, wind, solar power and imports, the power stations can produce only a smaller amount of power and the costs per produced megawatt hour is therefore increasing (CAPEX and fixed OPEX are divided by a smaller amount of generated electricity). The increase of gas prices and prices for emission certificates is from a LCOE view compensated by the higher full load hours of gas power stations. Therefore, the costs for gas power generation stay almost at the same level after 2030.

Wind and Solar become more efficient in the future (higher full load hours). This is why the costs per generated megawatt hour decrease over time.

2.4.4 INVESTMENT NEEDS

Today's electricity markets in Europe are seeing an extensive low price period because of decreased demand after the financial and economic crisis and a significant overcapacity of generation. Poland as growing economy is facing the opposite - aged generation capacity with insufficient renewal investments (except new capacity from wind power) during the last decades while having to supply an increasing demand. The electricity price today as well as in the forecasted period until 2040 is not sufficient to justify a renewal investment. The Figure 4 below illustrates the investment situation where the short run marginal cost (SRMC) per technology as well as their operation expenditures (OPEX) and capital expenditures (CAPEX) are shown for the complete year 2030 in Billion Euro. The total price (cost plus margin) of supplying electricity to all Polish consumers is 7.9 Billion Euro. The revenue from these electricity sales is equal to 5.9 Billion Euro leaving a negative cash flow of 2 Billion Euro (Missing Money).

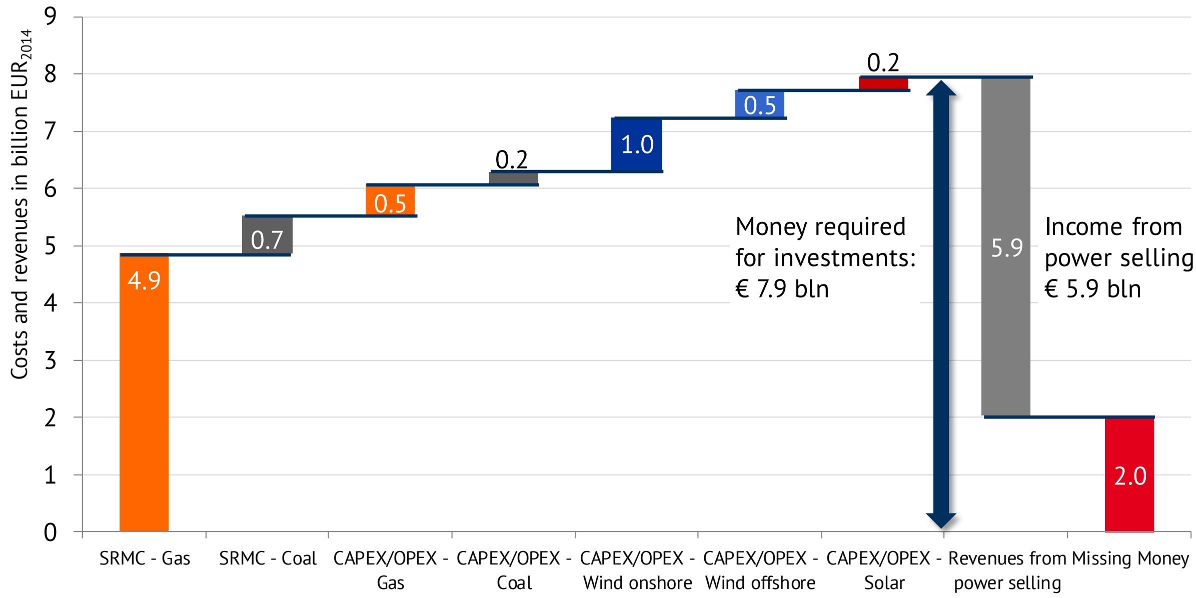

Figure 5: Negative cash flow (missing money) in 2030 for new power plants in Poland (Scenario Transformation)

This missing money has to be inserted into the energy sector in order to allow electricity generators to work profitable. In other words, the total electricity generation is missing ~25 percent of revenues in 2030. This is a main driver for ongoing postponement of very much needed generation capacity in Poland.

Regulators and governments need to design and implemented policies to meet this shortfall of revenues with a stable and long-term plan complying with European and national rules and regulations.

2.4.5 COST OF INVESTMENT ON CONSUMERS

The energy market has been and will be a highly regulated environment because of its long investment cycles as well as its importance for a prosperous development of a nation and a region. National and European policy makers therefore have to set the correct framework and fine tune the investment environment to create a secure supply of energy, which meets the environmental targets at an affordable price in order not to overburden the consumers and loose international competitiveness of the economy and region.

Achieving these targets is a societal challenge, as the cost of this task will have to be paid by all consumers. The cost allocation could be reached by regulatory adjustments of the energy market design or – as this analysis does for cost estimation reasons - via a surcharge on the electricity bill[6].

[6] The EU has set up a framework in order to have a common and non-discriminatory approach across Europe.

3. GERMAN ELECTRICITY MARKET

3.1 BACKGROUND

The German electricity sector has been experiencing a set of sector specific policies while the overall focus has only recently been provided after the Fukushima event resulting in the Energy Transition. The corner stones of the Energy Transition is an accelerated nuclear exit schedule which is paving the way power Europe's largest economy with renewables. The underlying convergence to a carbon free economy by 2050 relies strongly on the electricity sector with renewable energies taking a leading role in this transition process.

3.2 GENERATION CAPACITY DEVELOPMENT

Today's electricity market environment in Germany is seeing low whole sale prices and a declining demand. Currently, this situation will not lead to any market led capacity additions. In the long run, Germany will see a slightly increasing demand due to electricity consumption growth through more electric appliances, for heating and mobility diminished by efficiency efforts. On the supply side, the coal generation is declining and the gas share is increasing driven by higher CO_2 certificate prices. This trend will increase gas capacity from 25 percent today to about 60 percent with expected investments starting after the nuclear retirements have taken place in the 2020th.

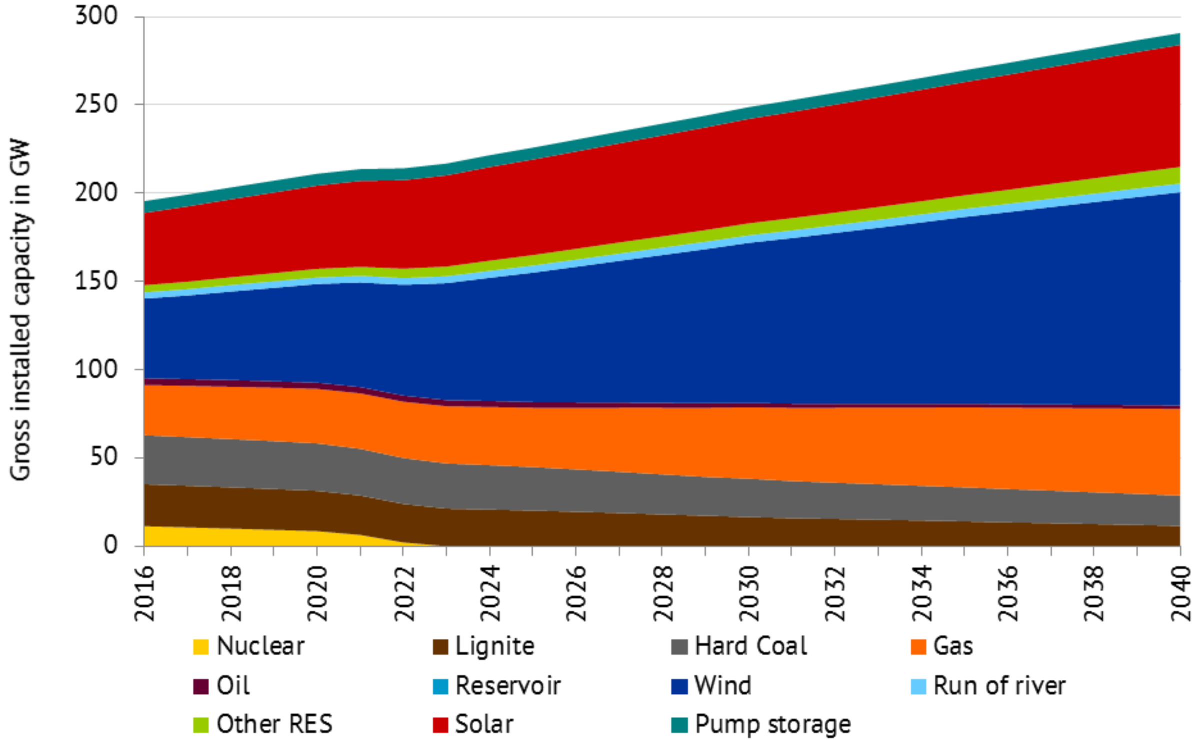

Figure 6: Development of installed capacities in Germany

Overall, the total capacity of demand driven technology will decrease by 20 percent in the period until 2040 while new investments into these power plants are mostly driven by security of supply aspects. These power plants are providing their capacity to the market in times when renewable energy cannot meet demand. The renewable build out is expected to follow the 2050 Energy Transition path to meet the minimum 80 percent consumption share target and is mostly fulfilled by wind energy.

3.3 DEMAND DEVELOPMENT

In order to forecast demand development in Germany for the period until 2040 it is important to judge if the demand increasing factors i.e. the increasing amount of appliances, e-mobility, etc. are outperforming the demand decreasing factors in the energy efficiency space. The graph below shows the Energy Brainpool's standard scenario for Germany based on the "EU Energy trends to 2050" (EC 2013) corrected by the actual demand figures of the past.

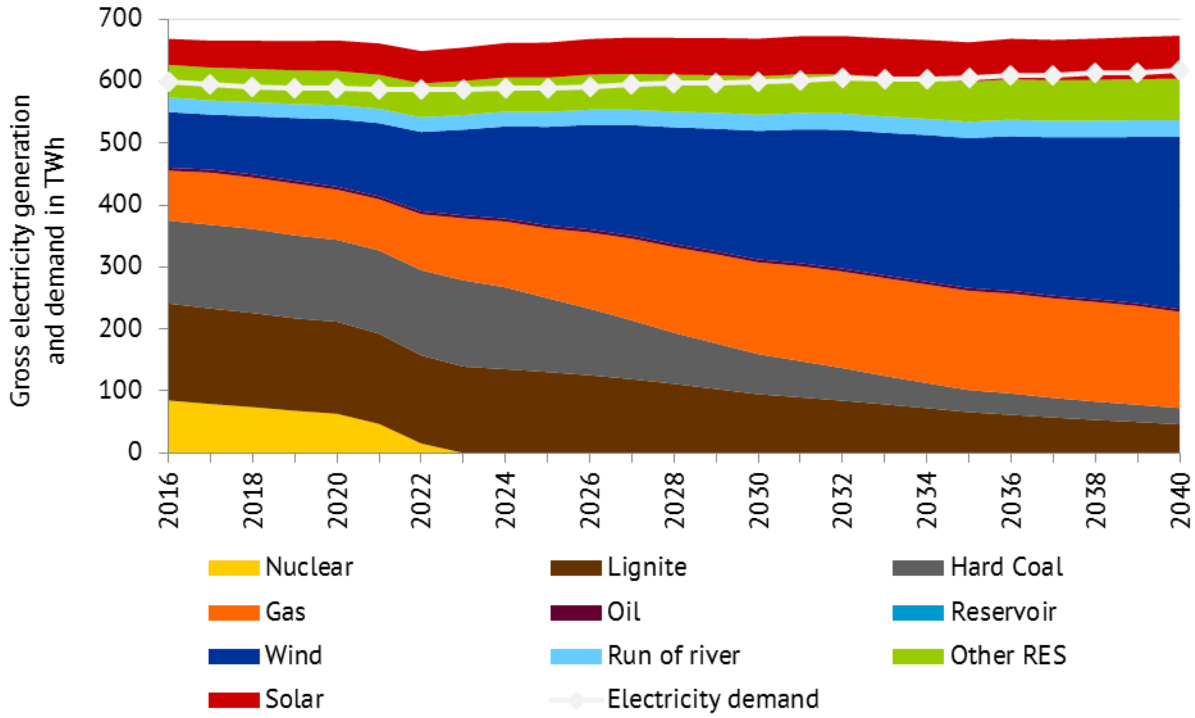

Figure 7: Development of electricity generation and demand in Germany

On the basis of a more prosperous outlook on the global economy and new electricity demand coming from power-to-heat, power-to-gas, heat pumps etc. as well as the fact that growing renewable penetration will increase the number of hours where electricity will be available at very low variable costs Germany expects a general increase in electricity demand starting in the 2020th.

In the meantime, Germany will see the opposite effect since efficiency gains are still significant and will reducing demand.

3.4 GERMAN ELECTRICITY MARKET REFORM

In 2015 Germany has started to reform its electricity market and has chosen not to create a wide spread capacity market to support market participants but more importantly to first reform the energy only market to allow this market to function properly with the intended increasing share of renewable energy. The Federal Ministry for Economic Affairs and Energy has published 20 measures in three different categories – stronger market mechanism, flexible and efficient energy supply and additional security – in their white paper in July 2015 (Figure 8).

Component		Measure
1	**"Stronger market mechanisms":** The measures packaged in component 1 strengthen the existing market mechanisms. The required capacities can thus refinance themselves and the electricity market can continue to ensure security of supply.	1. Guaranteeing **free price formation** 2. Increasing transparency in supervision of **dominant market position** 3. Strengthening **balancing group** commitments 4. Billing balancing groups for **each quarter hour**
2	**"Flexible and efficient electricity supply":** The measures of component 2 optimise the electricity supply at both European and national levels. They thus ensure a cost-efficient and environmentally compatible use of capacity.	5. Integrated **European development** of the electricity market 6. Opening up **balancing** markets for new providers 7. Developing a target model for **state-induced price components and grid charges** 8. Revising **special grid charges** for greater demand side flexibility 9. Continuing to develop **the grid charge system** 10. Clarifying rules for the **aggregation** of demand side flexibility 11. Supporting the wider use of **electric mobility** 12. Making it possible to market **back-up power systems** 13. Gradually introducing **smart meters** 14. Reducing grid expansion cost by **peak shaving fluctuating** RE 15. Evaluating **minimum generation** 16. Integrating **combined heat and power generation** 17. Creating more **transparency** concerning electricity market data
3	**"Additional security":** The measures of component 3 provide additional security of supply.	18. Monitoring **security of supply** 19. Introducing a **capacity reserve** 20. Continuing to develop the **grid reserve**

Figure 8: Specific measures for the German power market in the white paper of the Federal Ministry for Economic Affairs and Energy

These measures are currently going through the implementation process with some of them being already implemented.

4. CCEI (CLEAN, COST EFFECTIVE, EFFICIENT & INTEGRATED) APPROACH FOR THE POLISH POWER SECTOR

In brief: The CCEI approach for the Polish power sector

- Poland's electricity sector is facing a **substantial lack of investments** over the last 1-2 decades and will suffer 11 days on average of **power shortages** each year until 2020.
- Overcapacities in Germany ensure security of supply on the German power market in all hours and for all scenarios analysed in terms of the fundamental model Power2Sim.
- The target of our **3-phased approach** (chapter 4.1) **is to eliminate these massively distorting risks** on the Polish people and the economy and transform the Polish power sector into a clean, cost efficient and integrated (CCEI) system. Therefore, measures are needed, which...:

1. Scenario "Current Planning"

...prevents immediate brown outs but require instant actions.

Observation: The capacity additions, that are planned today, are not enough to balance the decommissioning of old power stations. A steadily increasing gap between the increasing demand and the changing supply can be observed.

2. Scenario "Fill the Gap"

...prevent brown outs around 2022 but also require immediate measures.

Observation: With the realization of the measures (4 GW additions of power plant and interconnection capacities), no shortfalls in the day-ahead-market appear until 2022. The lack of revenues from electricity sales (missing money) sums up to 0.3 to 0.4 Billion Euro per year in 2020 and 2021. These short-term measures are not sufficient to guarantee security of supply in the medium and long term

3. Scenario "Transformation"

...will transform the Polish electricity system into a modern renewable and gas based sector with low carbon emissions, high energy efficiency and well integrated into a regional power market.

Observation: Extensive investments of additional 43 GW capacity are needed to prevent power shortages until 2040. Due to comparatively high shares of renewable energies in Germany, in the year 2030 the electricity prices in Germany are in 5294 (~60 percent) hours lower than in Poland. Importing power saves up to 3 Billion Euro in 2040 compared to new gas power plants built in Poland and 6.5 Billion Euro compared to new coal fired power plants. 0.3 to 2.3 Billion Euro per year (which equals 0.22 to 0.96 EuroCt/kWh) are missing in 2020 and 2040 to transform the Polish power sector in accordance with the criteria of the CCEI approach.

4.1 3-PHASED APPROACH

Poland's electricity sector is in a very poor shape and marking a massive risk for the further prosperous development of the country driven by a substantial lack of investments over the last 1-2 decades. The power generation sector is overaged and out of date facing significant plant reliability issues increasing the probability of unscheduled outages which ultimately drives an immediate threat of controlled forced electricity demand reduction (brown outs) for large industrial consumers all the way up to uncontrolled system collapses (black out).

Figure 5 below shows the number of days where Poland does not have enough electricity generation capacity to meet the demand[7].

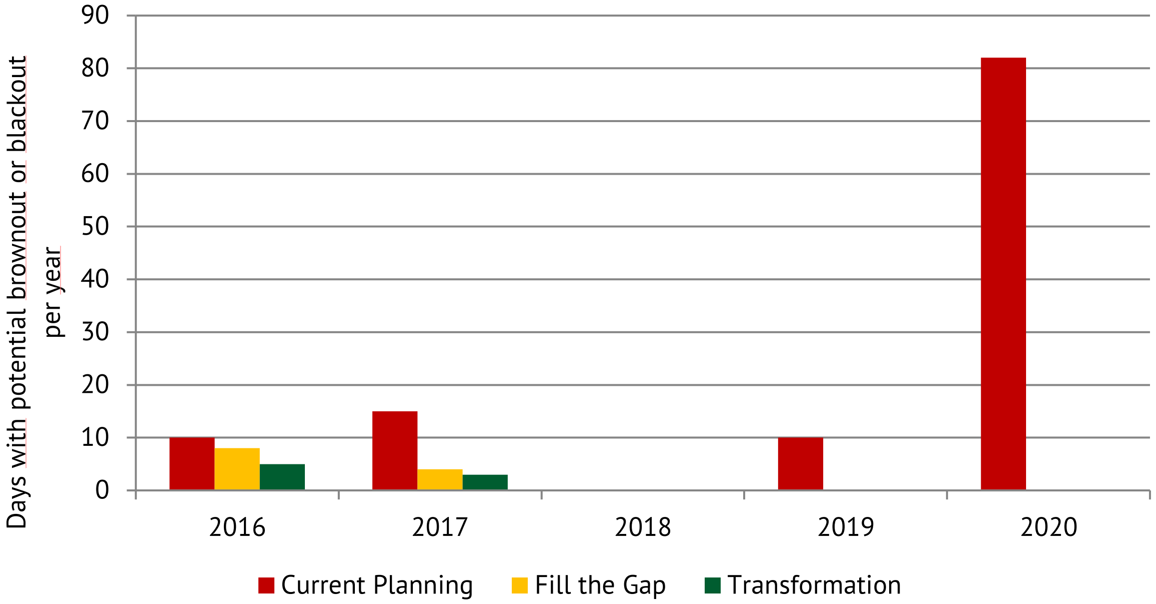

Figure 9: Number of complete days without electricity in Poland between 2016 and 2020 and the impact of the measures in the three scenarios

The target of our 3-phased approach is to eliminate these massively distorting risks on the Polish people and the economy and transform the Polish power sector into a clean, cost efficient and integrated (CCEI) system. In the 3 scenarios defined we are pairing required capacity additions with policy measures to counter the market short falls. This pairing will bring the Polish electricity system back in to a stable situation and avoid any brown outs and black outs as best as possible.

[7] In reality, these hours/days will not occur in one block but distributed over the year.

In a **first step,** we are describing measures, which **prevent immediate brown outs but require instant actions**. In other words these measure need to be in progress today to reduce the number of brown outs. We see that only an increase of the German interconnection capacity alongside with a lifetime extension of critical fossil plant and an enhanced renewable build out (accelerated commissioning) are the only remaining options due to very short time horizon.

In a **second step** we are describing measures which will **prevent brown outs around 2022 but also require immediate measures** to define clear technology support regulations because of the long cycle of the energy sector (period between project development and first kilowatt hour of electricity generated is up to 10 years for existing technology[8]). We recommend defining a clear growth path and aligned policy measures to continue the wind energy growth and also integrate photovoltaic incentives into the ready to go auctioning scheme. At the same time Poland has to capitalize on its energy efficiency potential by developing flexible gas based combined heat & power policies to replace existing coal based heat only plants. On top of that, Poland's interconnection capacities to neighbouring states have to be increased to take advantage of cost effective electricity import.

In a **third step** we are describing measures, which will **transform** the Polish electricity system into a **modern renewable and gas based sector** with low carbon emissions, high energy efficiency and well integrated into a regional power market. We recommend developing a national energy roadmap as a part of an integrated regional energy policy. We see significant benefit gains in leveraging the facilitation of the EU in the Baltic Energy Market Integration Policy (BEMIP) and understand the national energy roadmap as a part of regional approach. This is the right forum to align on topics of regional importance in the infrastructure space (enhanced gas infrastructure, increased cross border interconnections and joint offshore wind projects).

The stability of the electricity supply is vital for any country just as it is for Poland and distortions to this security of supply have far-reaching impact in multiples of the investment cost required and described in this study. The 3-phased approach shows that measures can be enacted to protect the country from severe issues while the time to implement them is right now.

[8] Nuclear energy generation is not considered in this figure.

4.2 CURRENT PLANNING

Scenario "Current planning" of the Polish power system is using an official plan to predict future developments. From the "Development Plan for meeting the current and future electricity demand for 2016-2025" the development of power plant capacities, demand and cross border capacities was derived. Following power stations will see partial or fully decommission:

Table 2: Decommission of existing power stations in Poland

UNTIL 2020	UNTIL 2025	UNTIL 2030
Adamów, Bełchatów, Dolna Odra, Jaworzno, Kozienice, Łagisza, Łaziska, Pątnów, Rybnik, Siersza, Stalowa Wola	Dolna Odra, Opole, Pątnów, Połaniec, Turów	Jaworzno, Kozienice, Laziska
6300 MW	5400 MW	1400 MW

At the same time, while demand is increasing this decommissioning cannot be fully replaced with new capacity additions:

Table 3: Commission of new power stations in Poland

UNTIL 2020	UNTIL 2025	UNTIL 2030
Włocławek, Gorzów, Jaworzno, Kozienice, Opole, Płock, Stalowa Wola, Turów	-	-
6400 MW	0 MW	0 MW

There are several other power stations in planning, but there are little information about these when and if they will be commissioned and be ready to produce power. The next table shows the development of interconnections. Because of investments and optimize operation, the connection to Germany will be opening for the market in 2018 with 500 MW.

Table 4: Capacity development of interconnection lines[9]

INTERCONNETION	2016-2017	2018-2020	2021-2030
Germany, Czech Republic, Slovakia	0 MW	500 MW	2000 MW
Sweden	600 MW	600 MW	600 MW
Lithuania	500 MW	500 MW	1000 MW

Observation: The capacity additions are not enough to balance the decommissioning of old power stations. A steadily increasing gap between the increasing demand and the changing supply can be observed.

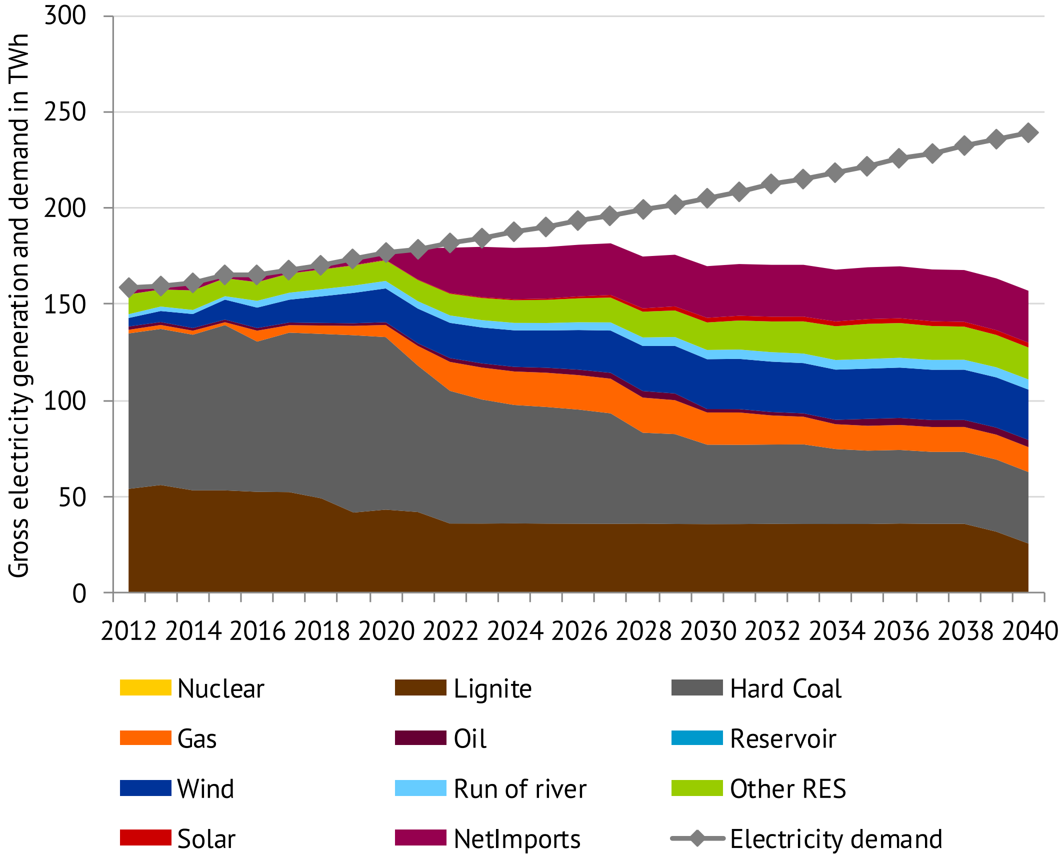

Figure 10: Generation, demand and imports in scenario "Current planning"

[9] The numbers must be interpreted as NTC (net transfer capacity) available for trading. The actual installed capacity can be significantly high.

4.3 FILL THE GAP

The scenario “Fill the gap” is using realistic assumptions about new technologies and power stations to close the gap between demand and supply seen in scenario “Current planning” by considering the situation of the Polish power system, planning types and feasibility of measures. The focus of the scenario is to avoid shortfalls in the short run (until 2021). Therefore, technologies and solutions with short realization times are chosen. Poland has many interconnections with neighbouring countries – especially with the German/Czech Republic/Slovakia area – that cannot be used totally at the moment because of existing network restrictions. One of the most important aspects is to solve the network issues and use the interconnections to trade power internationally.

Figure 11 illustrates the development of power generation, demand and imports over time.

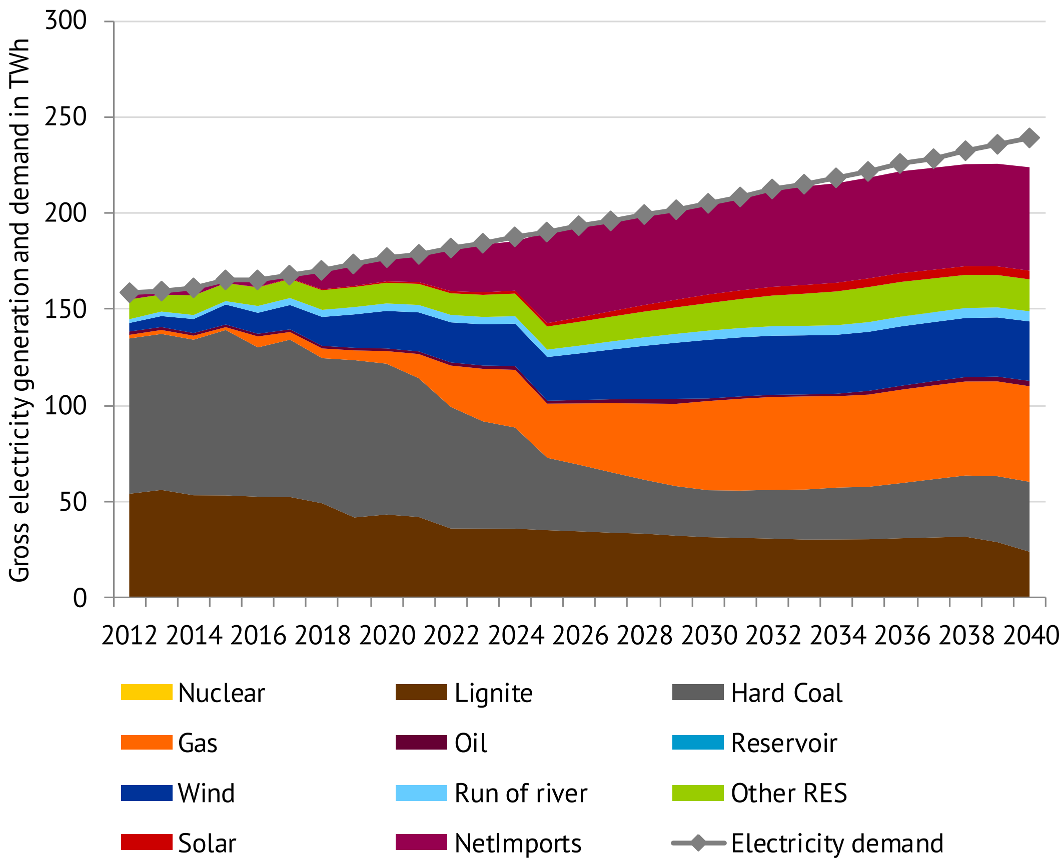

Figure 11: Generation, demand and imports in scenario „Fill the gap“

Due to the Industrial Emissions Directive (IED) and the high age, power plants with a total capacity of 6.5 GW will leave the market until 2022. These are mostly hard coal units. Gas, wind and solar power plants and an interconnector to Germany with a capacity of in sum 4 GW are implemented additionally compared to the scenario “Current planning” to counteract the shortfall risk. The commissioning dates and composition of the technologies can be found in Figure 12.

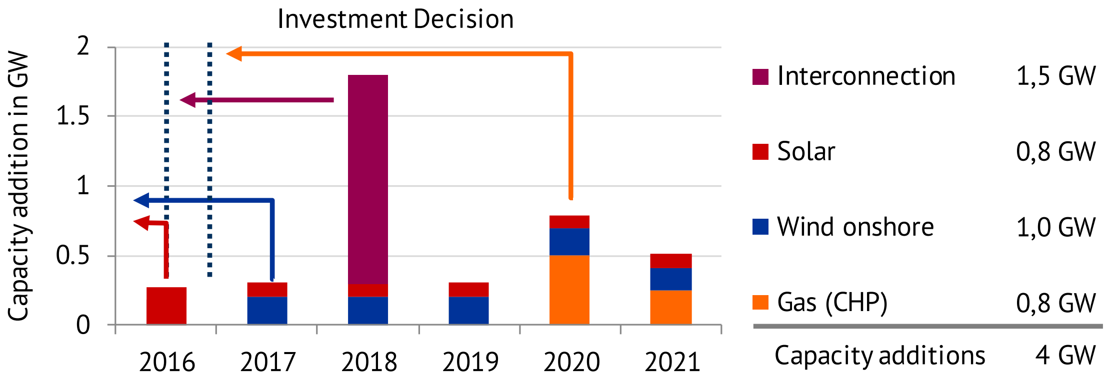

Figure 12: Capacity additions in scenario ”Fill the gap“ until 2021

Also illustrated in Figure 12 are the points in time when investment decisions need to be made. Obviously, there is immediate action necessary to follow the development path described in the scenario. With the realization of the measures, no shortfalls in the day-ahead-market appear until 2022.

Nevertheless, these short-term measures are not sufficient to guarantee security of supply in the medium and long term. After 2022, the balance of supply and demand will be very tight.

To sum up the scenario increases the security of supply of Poland but only in the short run shortages can be avoided completely. The replacement of coal power plants with imports, gas and renewables decreases the CO_2-emissions of the country. The opening of transmission capacities for cross border trading better integrates the Polish market into the European market, which also has economic benefits for end customers.

As power prices are not high enough to cover the expenditures of power producers, they realize a negative cash flow of € 0.3 to 0.4 bln per year in 2020 and 2021. Governmental incentives to invest nevertheless are necessary.[10]

[10] The calculation takes only to earnings from the day-ahead-market into consideration. Power plants can earn also money from e.g. forward and intraday trading, balancing and system services.

4.4 TRANSFORMATION

The scenario "Transformation" shows measures that are necessary to close the gap between supply and demand also in the long run, transform the energy system to be more climate friendly and decrease the dependency of coal. Gas and a more ambitious development path of renewables are therefore integrated into the system.

Figure 13 illustrates the development of power generation, demand and imports over time.

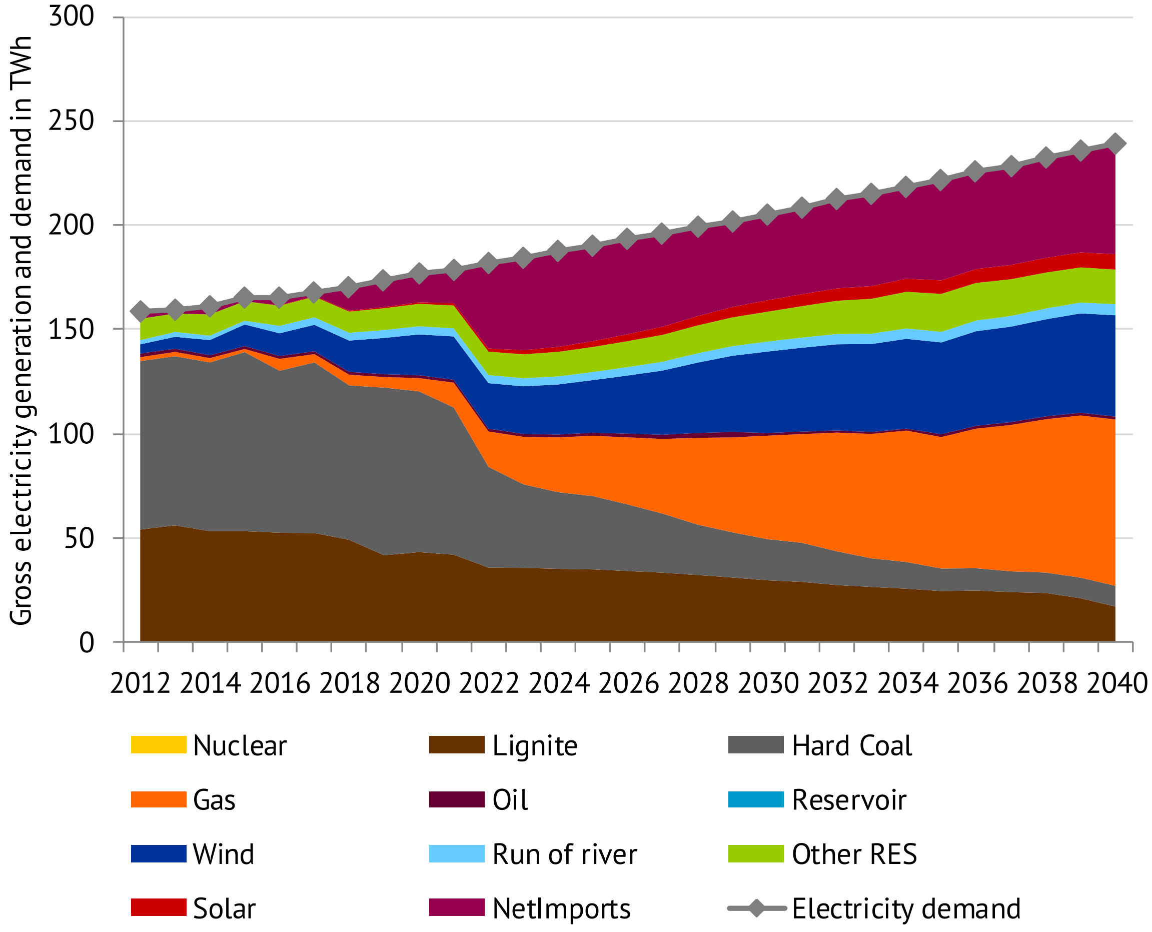

Figure 13: Generation, demand and imports in scenario „Transformation"

Due to their age, fossil-fired power plants with a total capacity of about 17 GW will leave the market until 2040. With additional 43 GW capacity additions compared to scenario "Current planning" supply can meet increasing demand in all years up to 2040. The long-term alternative to coal power stations are gas fired stations. In addition, the enlargement of interconnector capacities helps to reach security of supply. 16 GW of renewables are installed additionally until 2040, most of them wind power plants. To complete the new capacities from 2030 on Demand Side Management (DSM) is integrated into the scenario and the day-ahead-market. DSM means here the common participation of large customers in the power market.

All capacity additions can be found according to their commissioning year in Figure 14.

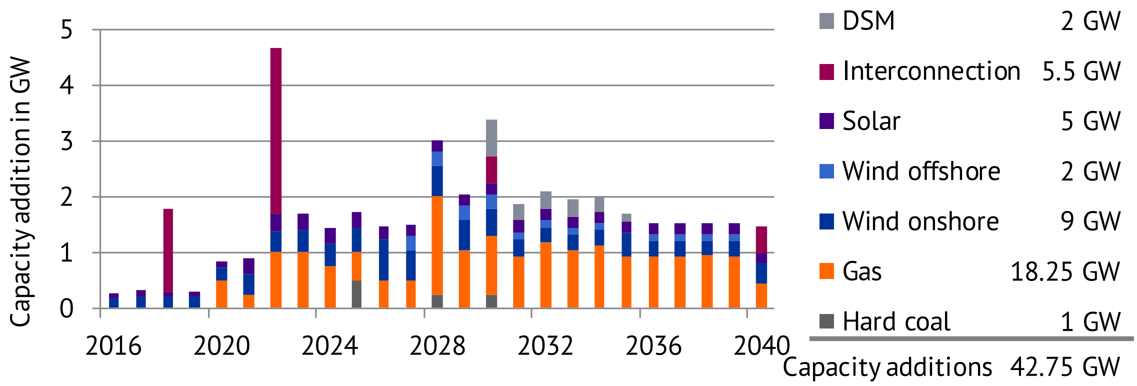

Figure 14: Capacity additions in scenario “Transformation“ until 2040

As in the scenario “Fill the gap” immediate action is necessary to cover demand in the short run. Also for the long-term perspective, planning needs to start as soon as possible to examine all possibilities in detail and to find appropriate investors.

To sum up the scenario “Transformation” is the only scenario that secures environmental requirements, covers demand and reaches security of supply over the whole scenario period. The replacement of coal power plants with imports, gas and renewables decreases the CO_2-emissions of the country. The renewable power producing capacities in Poland increase by more than 5 times from currently 5 GW to more than 30 GW in 2040. The construction of transmission capacities integrates the Polish market better into the European market, which also has economic benefits for end customers. Import of electricity is always cheaper than producing the same amount of imported electricity in the own country. Due to comparatively high shares of renewable energies in Germany, in the year 2030 the electricity prices in Germany are in in 5294 hours lower than in Poland. Therefore and as a further impact, the import of electricity reduces power prices in Poland. In the scenario “Transformation” importing power saves up to 3 Billion Euro in 2040 compared to new gas power plants built in Poland and 6.5 Billion Euro compared to new coal fired power plants.

As power prices are not high enough to cover the expenditures of power producers, they realize a negative cash flow of 0.3 to 2.3 Billion Euro per year in 2020 and 2040. Adjustments of the regulatory framework of the energy market or governmental incentives to invest nevertheless are necessary.

5. CONCLUSIONS FROM THE STUDY AND POLICY RECOMMENDATIONS

The major conclusions from the study are:

1. Maintaining the current energy policy will significantly increase the risk of brown-outs from estimated (at average weather conditions[11]) 240 hours per year in 2016 of no electricity to as much as 2000 hours per year in 2021 and resulting uncontrolled power peaks. This will have a **destructive impact on consumers**, especially in the energy intensive industrial production sectors, exposed to not only growing power prices but also uncontrolled breaches in production or need to invest in in fence energy generation.
2. The lack of bold decisions to actively re-shape the energy mix of Poland and the resulting insufficient investment in modern, cost effective and low-emission sources in the Polish power sector over the last 20 years has led to **a very serious situation of the power supply deficit**.
3. The Polish authorities will have no other option then to **miss the IED targets on SO_2 and NO_x emissions from large combustion sources** (by extending the lifetime of aged conventional power plants) **to secure supplies of energy** in the short- to mid-term.
4. Investments only in coal in the autarchic approach will significantly increase the overall cost of securing energy supplies. Coal is expected to become the most expensive technology by 2030. For comparison, energy imports from the Baltic Sea region may save up to 6.5 Billion EUR per year in 2040.
5. Given the overall dynamics in costs of power generation technologies and the need to secure cost-effective, clean and secure supplies of energy to the growing Polish economy, **bold changes in the energy mix and deep power market integration in the Baltic Sea region are needed**.
6. Investing in RES (mainly wind and PV) allows for **using vast domestic RES potential** and joint efforts for wind offshore in the Baltic Sea and will be a very **cost-effective approach**.
7. Interconnection alongside with regionalisation of power supplies within the Baltic Sea region will further increase security of supply in Poland in a cost effective manner where the Baltic Energy Market Integration Plan (BEMIP) should serve as a platform.

[11] Deviating weather patterns will further worsen the lack of stability of aged sources cooled with water from rivers.

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POLISH WIND ENERGY ASSOCIATION

The Polish Wind Energy Association (PWEA) is a non-governmental organisation established in 1999 supporting and promoting the development of wind energy. The Association brings together leading companies operating on the wind energy market in Poland: investors, developers, turbine and component manufacturers, both from Poland and abroad. PWEA is a member of the WindEurope and the Polish Member Committee of the World Energy Council.

PWEA's main areas of activity include: active participation in consultation of legal acts (laws and regulations), strategies, sectoral policies and programmes, and taking action for introduction of new legal solutions fostering the development of wind energy in Poland; close cooperation with ministries directly or indirectly linked to the energy sector and renewables; cooperation with the European Commission's Directorate-General for Energy, Directorate-General for the Environment, Directorate-General for Research and Innovation, cooperation with Members of the European Parliament and Members of Parliament from committees of both houses of the Polish Parliament, as well as promotion of knowledge on wind energy and organization and participation in events gathering industry representatives from Poland and abroad.

Polish Wind Energy Association is very active in the innovative energy solutions, driving the policy discussion in the area of regional power markets, ancillary services from wind power or impact of the energy sector on the environment and human health.

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MARTIN BERKENKAMP

As a German national, with more than 16 years of experience in the energy sector, Mr Berkenkamp started his career with US corporation Enron and then move to GE where he has held different roles in product- and market development, government affairs and business intelligence During his 15 years with General Electric he led various investment, growth and market entry initiatives in the EU and other European states, Russia, Asia North Africa, South Africa as well as in the Middle East. Mr Berkenkamp held several key roles in industry associations in Europe and Germany and is a recognized advisor to various governments.

In September 2015 Mr Berkenkamp founded advise2energy – a boutique consulting firm bridging investor requirements and project development needs as well delivering growth advisory to world-class technology companies.

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