

DESIGN OF THE ELECTRICITY SYSTEM

PROVIDING GRID STABILITY IN THE FACE
OF A HIGHER SHARE OF FLUCTUATING
ENERGY GENERATION

FACTSHEET



Bundesministerium
für Umwelt, Naturschutz,
Bau und Reaktorsicherheit



INSTYTUT
JAGIELŁOŃSKI

ECOFYS

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This project is funded by the German Federal Environment Ministry's Advisory Assistance Programme (AAP) for environmental protection in the countries of Central and Eastern Europe, the Caucasus and Central Asia and other countries neighbouring the European Union. The responsibility for the content of this publication lies with the authors



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**Design
of the electricity system**
**Providing grid stability in the face of a higher share
of fluctuating energy generation**

FACTSHEET

Part I: **Design of the electricity system:
Experiences from Germany**
By: Dr. Christian Nabe and Jenny Cherkasky (Ecofys)

Part II: **Design of the energy system:
Assumptions in Poland**
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Key messages

Part I

**By: Dr. Christian Nabe,
Jenny Cherkasky (Ecofys)**

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With around 90% of all installed capacity of renewable energy in Germany being connected to the distribution grid, the distribution grid operators are assuming an additional 'energy collecting' role with increased responsibilities. As the renewable capacities and technologies are distributed very heterogeneously across Germany, the network operators are impacted very differently.

There are many different technologies available to network operators to provide system balancing services. In the last years, it could be observed that the higher competition of flexibility options in the reserve markets led to a strong cost decrease for the operating reserve. Further measures are discussed to enhance the flexibility of the system.

Furthermore structural changes in the bidding zones are currently discussed at European level. For instance, an adjustment of the common bid-

ding zone between Northern Germany and Southern Germany are brought forward as a way to cope with the challenges of temporary limited transmission capacity.

Curtailment of renewable energies due to network congestion has increased in the last years. The necessary investments into grid development can be decreased significantly with the application of innovative equipment (adjustable stationary grid transformer, active control technologies, flexibility options) and temporary curtailment of up to 3% of the total renewable power generation.

New decentralised market mechanisms ("smart markets") are in the development. Distribution system operators will forecast local grid congestions. Smart markets provide a coordination mechanism to optimise the use of flexibility options for local grid management to avoid renewable energy curtailment.

Part II

**By: Christian Schnell PhD,
(Instytut Jagielloński)**

The current energy mix in Poland still determines an energy system which is managed in centralized way. Large combustion power plants with a relatively high greenhouse gas emissions, mostly owned by state owned utilities are still the basis for the Polish energy system to secure supply – including mostly domestic fuel supply of hard coal and lignite by Polish coal mines. The share of decentralized RES power is still small, although in windy days wind power delivers up to 30 percent of demand. However, wind power is hardly balanced by other RES, i.e. mainly sun power, biogas plants, hydro power plants or smaller biomass units, so it has to be balanced by combustion power plants. Therefore a decentralized management of the energy system has not been implemented although distribution grid infrastructure has been modernized during the last few years. Furthermore, import capacities until 2016 have been substantially blocked by loopflows within the Phelix trading zone, i.e. Germany and Austria. Also the potential of demand-side-response management amounting to substantially more than 1 GW has been only partially exploited.

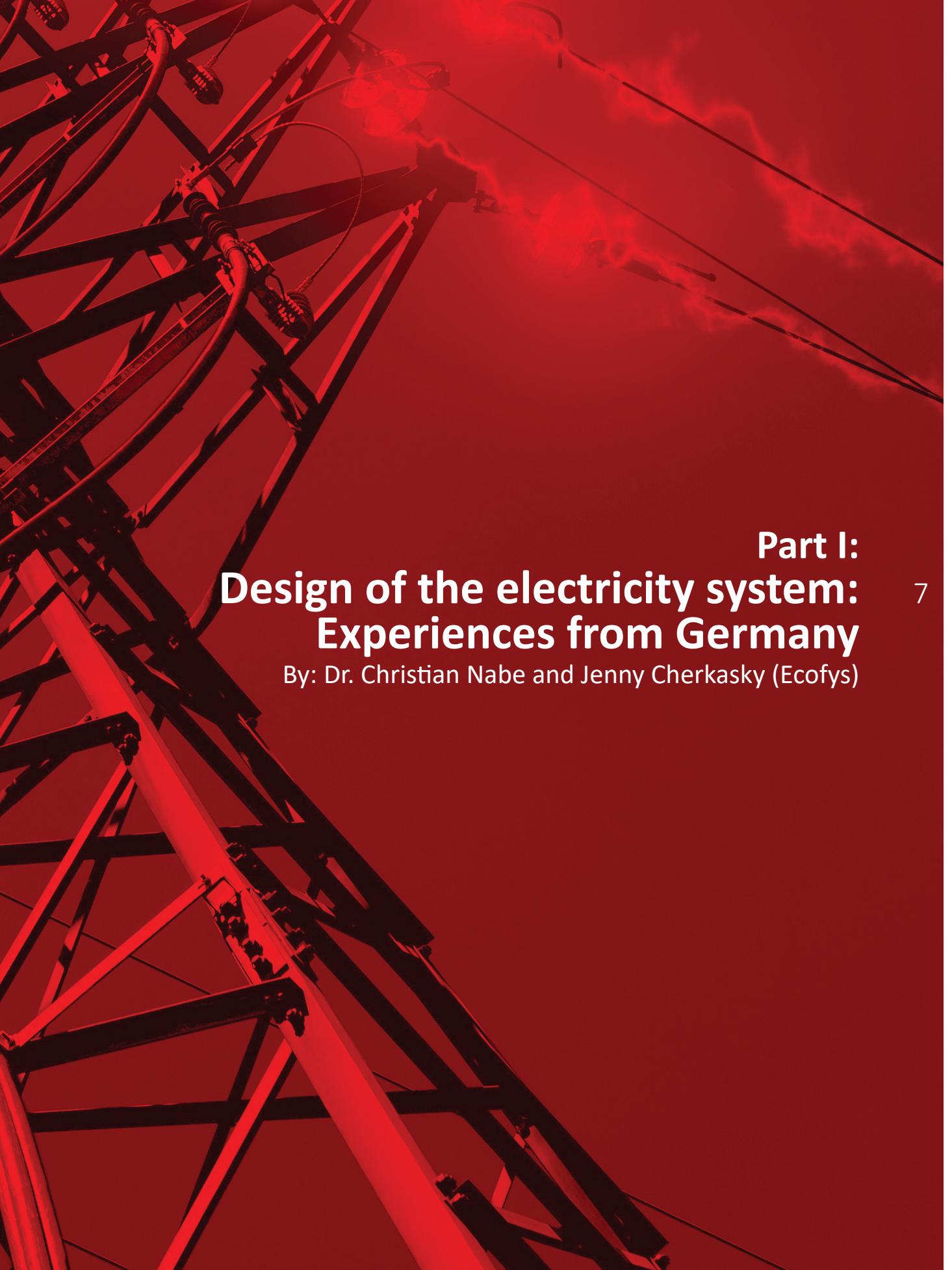
With this market environment the requirements of the winter package are a serious challenge for the Polish energy sector. With an obligation to

decrease greenhouse gas emissions steadily until 2030 to 500 kg CO₂/MWh – and, consequently a shutdown of coal power plants including a closure of Polish coal mines – the Polish energy mix has to change substantially in a relatively tighten time schedule. Therefore, Poland is currently re-thinking its energy mix, and until the winter package legislation is enacted it is hard to present a specific proposal of an energy mix until 2030 with a perspective for 2050.

Furthermore, the obligation to strengthen the management of distribution grids and to empower customers with smart meters, dynamic tariffs etc. provides to further economic risks for integrated state-owned utilities, as currently power transmission and distribution is still a profitable business- opposite to power production with new large combustion power plants, which face even further risk of increasing prices for greenhouse gas emission and increasing competition through power imports from neighbouring markets with lower wholesale prices. In this market environment a well-planned transition is inevitable to avoid bankruptcy of state owned utilities, sudden loss of many thousands of jobs and, eventually, hostile take-over of market assets by non-EU players risking the high energy security of the country.

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Part I:

Design of the electricity system: Experiences from Germany

By: Dr. Christian Nabe and Jenny Cherkasky (Ecofys)

The role of network operators and the costs for the electricity network are a major part of the political discussion around the Energiewende. Historically, the power production was located close to the power demand. With the Energiewende the power production has become resource-oriented which raises the questions of how this power can be transported and balanced with the power demand. This factsheet serves to illustrate the roles and challenges for the transmission and distribution network operators. It is a critical analysis of their tools (e.g. redispatch) and the suggestions for changes (bidding zone split). All in all, this factsheet attempts to derive suggestions for the integration of renewable energy generation into the electrical grid.

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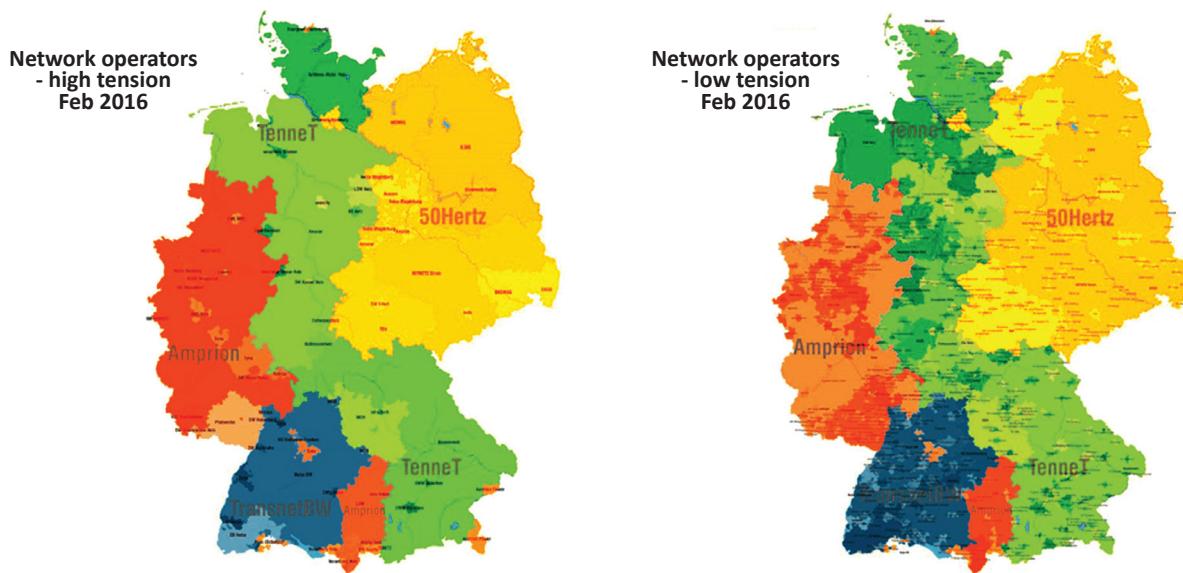
1.1 Impact of the Energiewende on the tasks of network operators in Germany

In the electricity market, the transmission system operators (TSOs) are entities responsible for the transport of electrical power from power plants through an electric grid. In Germany, the transmission grid voltage is between 220 kV and 380 kV. Due to the high cost of building and maintaining the infrastructure, the networks are natural oligopolies. The German transmission grid is divided into four control areas between the four

TSO Amprion, Transnet BW, Tennet and 50 Hertz (Figure 1), and has a length of 35,000 km. The TSOs transport the electric power to distribution network operators as well as abroad. One of their main obligations is to guarantee system stability. In system critical situations such as network congestion or deviations in frequency or voltage, the network operators must interfere. For this purpose, they have access to several ancillary services¹ such as redispatch, curtailment, or the balancing reserves, which will be discussed in the following chapters.

1. Ancillary services: Services that are provided by network operators to guarantee grid stability and security.

Figure 1

GEOGRAPHIC OVERVIEW OF TSO, THE NETWORK OPERATORS AT HIGH-VOLTAGE GRID LEVEL (LEFT) AND AT LOW-VOLTAGE LEVEL (RIGHT)
SOURCE: ENE'T, 2017

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In contrast to the small number of TSOs, there are around 888 distribution system operators (DSOs). They receive the electrical power from the TSOs and transport it further to the consumers. The distribution network is nearly 49 times as long as the transmission grid. Although the highest proportion of the network consists of low and middle voltage networks, some DSOs are also responsible for high voltage networks at 110 kV. Figure 1 above shows the DSOs operating at a 110 kV level on the left and the subordinated DSOs at lower voltage levels on the right.

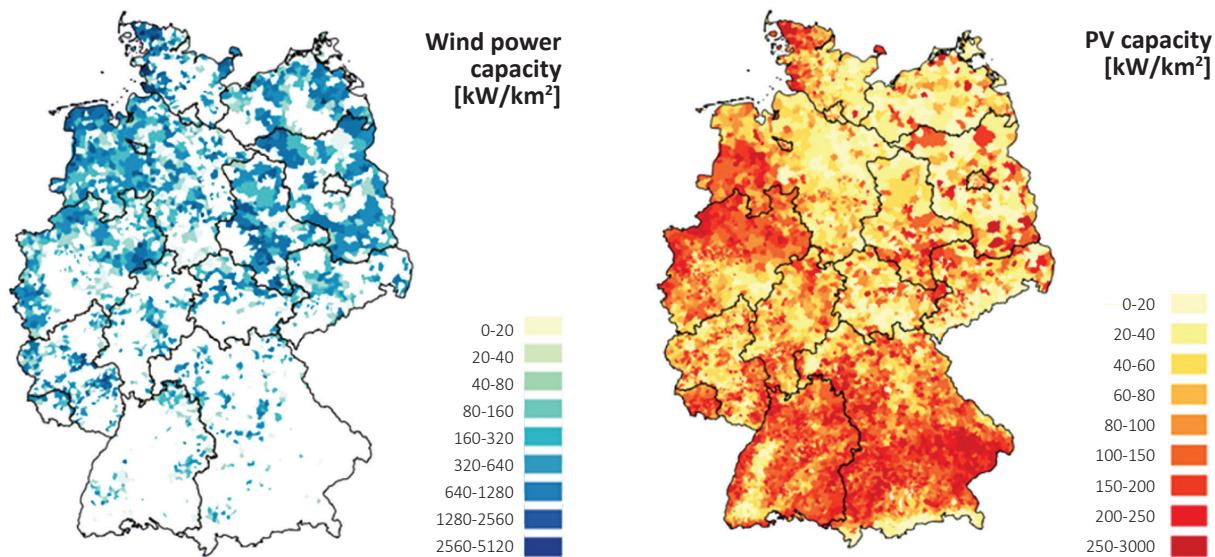
In the historic, unidirectional network system, most of the electricity production was fed into the transmission lines and then transported to the consumers at distribution grid level. With the increase in renewable power production, the network system has become increasingly bidirectional. 90% of all installed capacity of renewable energy is connected to the distribution grid, which amounts to around 98% of all installations. The renewable capacity is distributed very heterogeneously among the DSOs. For around 5% of the DSOs the installed renewable capacity even exceeds the maximum electrical load (Büchner,

et al., 2014). An increasing amount of electricity production from renewable energies must be fed back into the transmission grid from the distribution grid. As a result, the DSOs also have to cope with a 'collecting' rather than simply a 'distributing' role. The current network design was not intended for these additional challenges and thus causes network congestions at the distribution and transmission levels. (BNetzA, 2016)

As can be seen in Figure 2, most of the wind capacity has been installed in the north of Germany whereas most of the PV has been installed in the south. In 2016, the electricity production from PV and wind amounted to 20.3% and 42.2% of the total renewable electricity generation respectively (Burger, 2017). Given the fact that most of Germany's industry is based in the south, the distance between electricity production and consumption represents an additional challenge for the electricity networks.

Figure 2

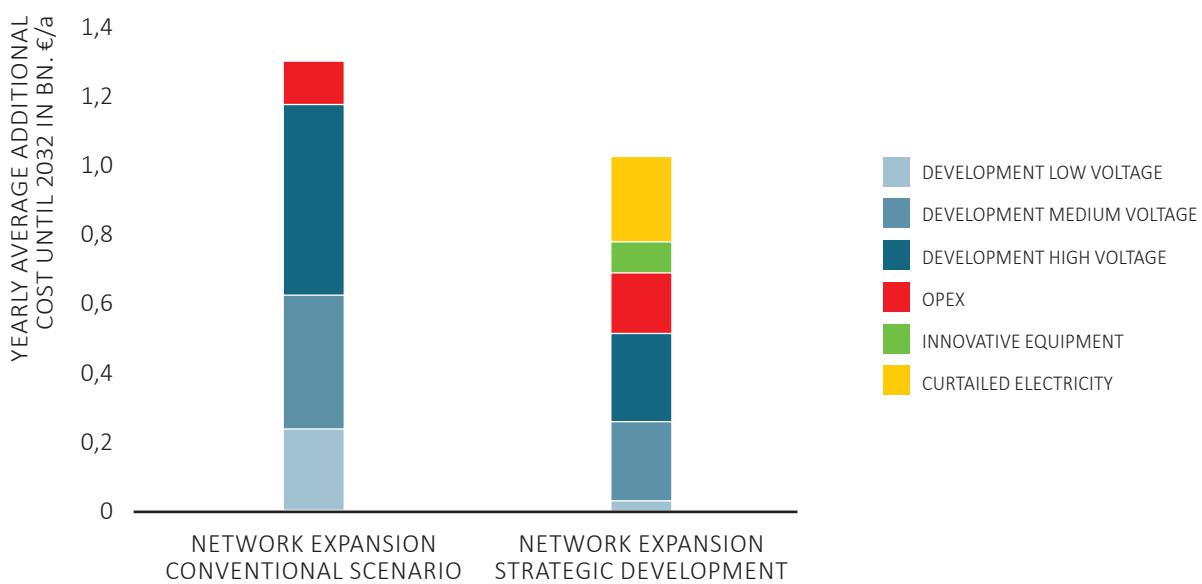
DENSITY OF INSTALLED WIND POWER (LEFT)
AND PV CAPACITIES IN GERMANY (RIGHT) IN JULY 2014
SOURCE: ECOFYS, FRAUNHOFER IWES



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Figure 3

CONVENTIONAL NETWORK DEVELOPMENT (LEFT) IN COMPARISON TO A COST MINIMAL
NETWORK DEVELOPMENT (RIGHT) FOR THE DISTRIBUTION GRID
SOURCE: BÜCHNER, ET AL., 2014



The high share of renewable energy generation makes additional grid development at all voltage levels necessary, but the required investments can be decreased through the use of innovative equipment (smart meter, virtual power plants, etc.) and acceptance of a certain

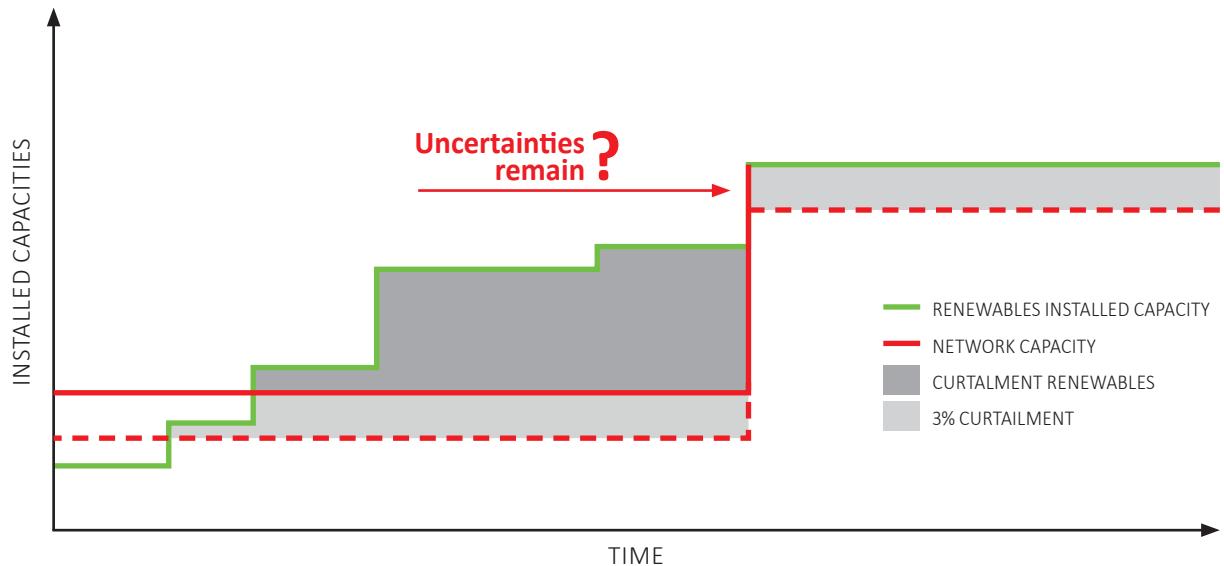
curtailment level. Until last year, the network operators were supposed to draft their development plans in such a way that no curtailment would be necessary. Such a grid development increases the need for investments to an unreasonably high value. Therefore, the legislator permitted the network operators to include curtailment of up to 3% of the total renewable power generation ('Spitzenkappung') (§ 11 (2) EnWG 2016). As illustrated in Figure 3, the new regulation decreases the necessary investments for the distribution grid (up to 110 kV) significantly. The comparatively higher number of system interferences causes additional operational costs (OPEX) and requires additional investments in innovative equipment.

As indicated in Figure 4, the regulation regarding the 3% curtailment is designed as a long-term measure. In the long term the network capacity should be developed in such a way that 3% of the renewable energy output from wind and PV would be curtailed. However, given the manifold uncertainties, it is yet unclear when the network development will reach that stage.

Figure 4

RENEWABLE ENERGY CURTAILMENT AND NETWORK CAPACITY OVER TIME

SOURCE: ECOFYS



One technology, which is seen as the foundation for flexible demand side management and which could therefore decrease the costs of integrating renewable energy into the grid, are smart meters. Price incentives could lead the power consumers to a network and resource-oriented power demand and decrease peak consumption (Agricola, et al., 2014). In a directive from 2009, the European Union suggests to roll out smart meters for 80% of the customers by 2020 (EC, Smart grids and Meters, n.d.). With the Law for the Digitalisation of the "Energiewende" the German government obliges energy consumers (with a minimal energy consumption of 7 MWh/a) and decentralised generators to install smart meters as long as the investment cost are below a determined cap (§ 31). However, the grid benefits can only be realised in the longer term. In the short term, the smart meter rollout is intended to lead to higher transparency and therefore energy efficiency. (Agricola, et al., 2014).

1.2 Congestion management by TSO on transmission level

The distance between the wind power production in the north and the high-power consumption in the south leads to congestion and makes additional north-south-transmission lines necessary. Nevertheless, the planned grid development is proceeding slowly. In the third quarter of 2016, only 700 km of the planned 8,000 km of additional transmission lines were realised. (Bundesnetzagentur, 2016). Overall, the German TSOs estimate the required investment from 2015 until 2025 to be in the range of €22 billion to €36 billion (Netzentwicklungsplan Strom, 2015; Nabe & Neuhoff, 2015).

Currently, TSOs can limit the volume of interconnection capacity to other countries to cope with congestions within their bidding zone. However, with one of the suggestions by the European Commission in the Winter Package, this measure might be prohibited (Coibion, et al., 2016).

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Transmission limitations are not mirrored in the German-Austrian bidding zone, which has spurred discussion about splitting up bidding zones.

1.2.1 Discussion on bidding areas in Germany

Per Article 2 (3) Commission Regulation (EU) No 543/2013, bidding zone or area describes the largest geographical area within which market participants are able to exchange energy without capacity allocation. Within one bidding zone there is only one wholesale price as electricity trading is unlimited. In contrast, trades from one bidding zone to another have to take into account transfer capacity constraints, which may result in price spreads between different zones (Entso-e, 2016). The cross-zonal capacity is determined in a calculation and allocation process by the TSOs. According to the EU legal framework, bidding zones should be defined in a manner to ensure efficient congestion management and overall market efficiency. However, some of

the bidding zones developed historically out of country borders and are not representative of transmission constraints.

In conclusion, the physical transmission constraints are not mirrored in the wholesale price. The TSOs manage congestion within a bidding zone through measures such as redispatch, which will be discussed in the next chapter. In large bidding zones, a single price might fail to provide an adequate indication of the demand-supply balance. Redispatch becomes necessary to increase the power generation in areas with higher demand and vice versa (EC, Interim Report of the Sector Inquiry on Capacity Mechanisms, 2016). Redispatch is an 'out-of-market' measure and comes at higher cost for electricity consumers. The lack of right price signals might further undermine the appropriate investment incentives and distort electricity prices (EC, Final Report of the Sector Inquiry on Capacity Mechanisms, 2016).

The common bidding zone of Germany and Austria is a highly liquid power market and has decreased the wholesale prices in Austria significantly. On the other hand, the congestion between the north of Germany with its high wind power production and Austria has made additional redispatching measures necessary and resulted in additional loop flows through its Eastern European neighbours (particularly Poland and Czech Republic). As the transmission capacity is not sufficient to transport the electricity production to the south, a part of the physical flows goes through Poland and the Czech Republic, putting additional pressure on their grids. At the same time the flows are only physical and no trades are concluded that would directly benefit the Eastern European countries. Therefore, the Agency for the Co-operation of Energy Regulator's (ACER's) decided in favour of a split between Germany and Austria by summer 2018. The German grid regulator, Bundesnetzagentur, which is also in favour of this split, has asked the German TSOs to initiate measures (ICIS, 2016). In addition to that, the European Commission reiterated in the Winter Package that bidding zone borders should be subject to review by all involved stakeholders (Coibion, et al., 2016).

Austria is benefiting from the low wholesale prices resulting from the German Energiewende and is challenging the decision in European courts. Austria brings forward the following points to defend the common bidding zone with Germany:

- The split goes against a further electricity market integration in Europe.
- The congestion does not originate at the German-Austrian border but within Germany (ICIS, 2016).
- The recommendation from a regulatory assessment by the group of European electricity grid operators is only expected in the second quarter of 2017 and any measures before that would be premature (Zha, 2016).
- Per a report that is backed by general energy directorate (DG Energy) of the European Commission and EU courts, a division of bidding zones must be done within a 'bidding zone review process' which can only be initiated by the TSOs and member states but not by the regulatory agency itself (ACER) (Industriemagazin, 2016; Thalmayr, 2015; ICIS, 2016)

Despite the resistance from Austria, proponents argue that the split is conform with EU rules.

As a further step, the disintegration of the German bidding zone into a northern and southern one was also discussed. The borders between the two bidding zones could represent the congestion zone and provide the right incentives for investments. In the north the electricity prices would be lower, which might be attractive for the industry. Additionally, a higher demand in the North would reduce the need for additional transmission lines. Nonetheless, the German government opposes such a measure and brings the following arguments forward:

- A split would decrease the market liquidity which might result in higher transaction costs, higher risk and therefore less investment (FrontierEconomics, 2013).
- Price difference (€1.70/MWh or 5% of the wholesale price) is too low to decrease the cost for redispatch.
- Long lead times are necessary so delivery agreements are not jeopardized.
- Negative experiences abroad where different price zones led to strategic bidding and erratic variations (PJM- Pennsylvania-New Jersey-Maryland in 1997).
- Different feed-in tariffs 'EEG-Umlage' in result of different wholesale prices.
- Increasing market power of players within the smaller bidding zones.
- High market transformation cost (BMWi, 2014).

Moreover, it is questionable whether investors would rely on the fact that the price discrepancy stays that way given the fact that investment decisions have a long-term impact and that the network development is seen as an important measure to integrate renewable energy generation.

Instead of creating two bidding zones within Germany, there are some calls to evaluate the potential effects of a nodal price system. In a nodal price system, the different 'nodes' or parts of the transmission grid can have different wholesale prices which capture the availability of transmission and production capacities. After the failure of the zonal system in PJM, a nodal price system was introduced including around 2,000 different nodes (Egerer, von Hirschhausen, Weibezahn, & Kemfert, 2015); however, the counter-arguments against deviating from the current arrangements remain.

1.3 The redispatch and curtailment process and the roles of renewables and CHP

According to Art. 2 (26) Commission Regulation (EU) No 543/2013, 'redispatching' describes a measure activated by one or several system operators by altering the generation and/or load pattern in order to change physical flows in the transmission system and relieve a physical congestion. Redispatch focusses on regional bottlenecks by decreasing the power production before and increasing the power production after the bottleneck (BNetzA, 2016). The regulatory basis for redispatching is set in §13 Abs. 1 EnWG. Redispatching could be only realised with conventional power capacities from 10 MW onwards which were connected to the voltage level of 110 kV and above. These limitations regarding the voltage level were abandoned with the EnWG 2016. Nevertheless, this option is rarely used at present.

Two days before delivery, the power plant operators provide operation and unavailability plans to the TSOs (ERRP-data). Based on this information, the TSOs can estimate the capacity potentially available for redispatch. The TSOs evaluate the load flow calculations and evaluate whether limits might be exceeded. By bringing this information together, they decide on the necessary redispatching measures and announce them not earlier than at 2:30 pm for the following day (BDEW, 2014).

Units that made a redispatching contract with the TSOs are obligated to adjust their power production. Once the generation units are called for redispatch, they are not allowed to engage in any intraday activities (Nabe & Neuhoff, 2015). Power plant operators are compensated for the incurred costs and profit losses by the TSOs (BNetzA, 2012).

The Winter Package suggests a market-based redispatching or curtailment (Coibion, et al., 2016). In a market-based design generators would bid for being redispatched and be selected by the network operator based on the lowest bid. This suggestion is controversial as generators have a different leverage on the grid depending on their distance to the bottleneck. One concern is that generators might use their advantageous position to maximise the returns. Another suggestion from the Winter Package is to limit priority dispatch only for small re-

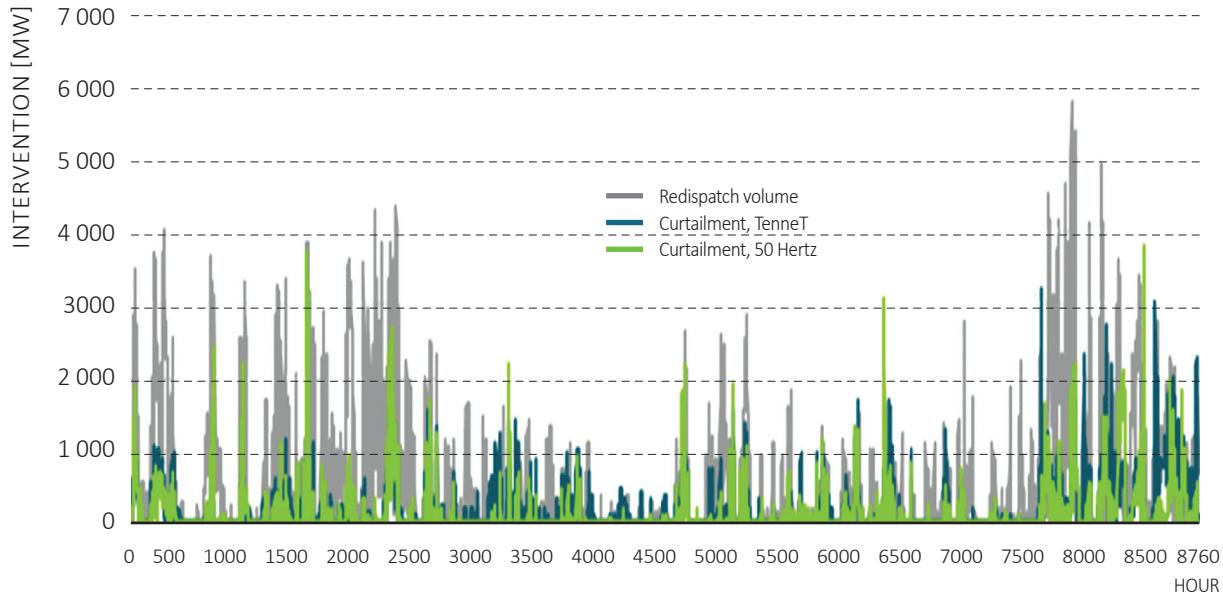
newables and high-efficiency cogeneration installations (<500 kW) as well as early-stage technologies (Coibion, et al., 2016). At the moment, renewable power generation is always prioritised compared to conventional power generation to be fed into the grid and should only be curtailed as a measure of last resort.

An additional instrument for congestion management was created in 2016 and includes the combination of Power-to-Heat-plants (PtH-plants) with conventional CHPs. In the case of network congestion, CHPs can be turned off and the required heat is then produced through the PtH-plants. Thus, the TSOs gain additional access to connectible load for their redispatch (ZuLaV- 'Zuschaltbare Lasten Verordnung'). The CHPs must have been constructed before 2017 and be located in regions with high volumes of wind energy feed-in to be eligible for this instrument.

The last option for coping with grid congestion is the curtailment of renewable energy generation. Curtailment means that the generation from renewables and CHPs is decreased. Generally, renewables and CHPs are prioritised for feed-in into the grid, but their production can be decreased to ensure network stability. The generators are compensated with 95% of what they would have produced or 100% if the curtailment decreases their yearly earnings by at least 1%. Due to the efficiency losses incurred as well as the principle of priority dispatch for renewables, this is an option of last resort.

Figure 5 below illustrates the magnitude and frequency of redispatch and curtailment measures in 2015. As the biggest share of curtailment takes place in the operating region of 50Hertz and TenneT (95% of the capacity curtailed), only these two network zones are considered for the visualisation of curtailment measures. It becomes evident, that most of the network adjustments take place during the winter months with particularly high wind power production. As redispatching measures have priority over curtailment, their volumes exceed the electrical power curtailed.

Figure 5 | **REDISPATCH AND CURTAILMENT OVER 2015**
SOURCE: ECOFYS

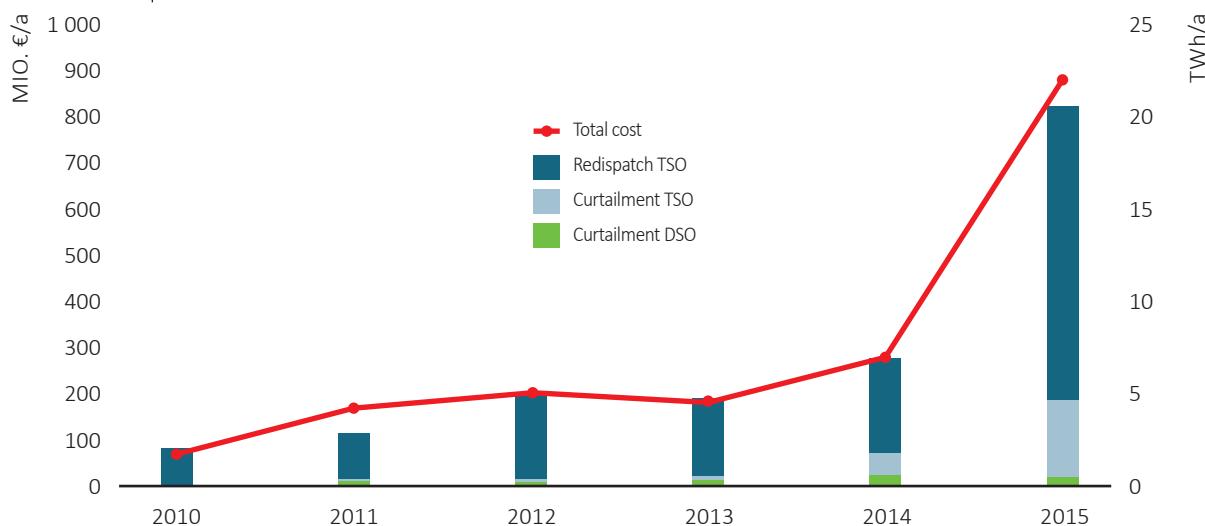


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Must-run capacities and inflexible power generation from conventional power plants also restrict the flexibility of the network operators (Götz, Henkel, Lenck, & Lenz, 2014). One of the reasons for must-run capacities is heat production from CHPs and participation in the balancing market, which requires fast reaction times.

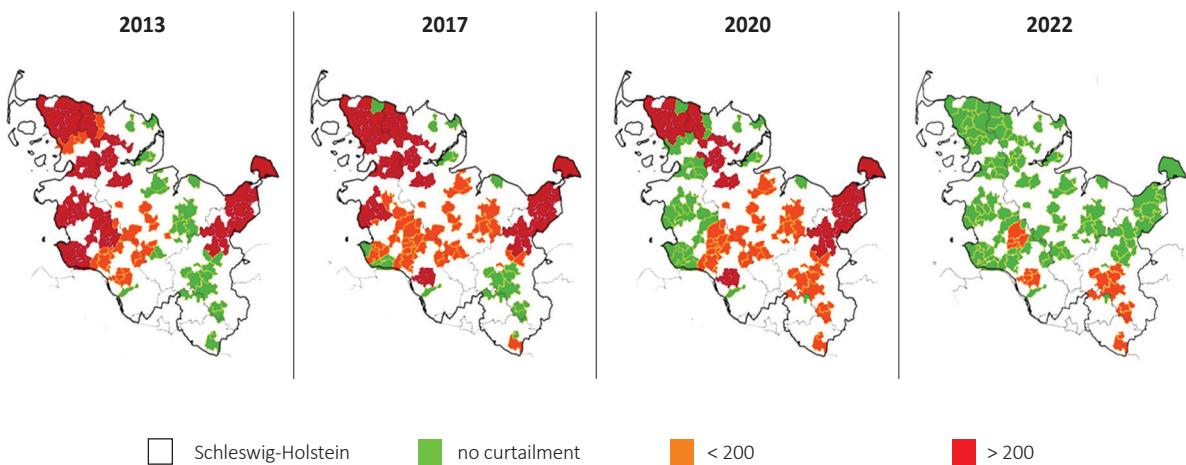
As can be seen in the next figure, the cost for redispatching and curtailment increased steadily until 2014 and jumped then to nearly €1 billion in 2015. The costs are expected to stay in the same magnitude over the next years.

Figure 6 | **DEVELOPMENT OF ANCILLARY SERVICES OVER TIME (COSTS AND ACTIVATED VOLUMES)
ACCORDING TO § 13 ENWG, DIFFERENTIATION ACCORDING TO § 13 (1) ENWG (REDISPATCH)
CONGESTION DUE TO TRANSMISSION NETWORK, ACCORDING TO § 13 (2) ENWG
(CURTAILMENT) DUE TO CONGESTION IN TRANSMISSION AND DISTRIBUTION NETWORK**
SOURCE: BASED ON (MELUR, 2015; BNETZA, MONITORINGBERICHT 2014; BNETZA, 2015; BNETZA, 2016;
ECOFYS, 2012; ECOFYS, 2013; ECOFYS, 2015)



The distribution grid expansion can proceed faster than transmission expansion since permit processes are easier and public resistance is lower. One example for that is Schleswig-Holstein, a region with particularly high wind power production in Northern Germany. Through the expected expansion of the distribution grid, the interventions can be decreased to only a few hours per year by 2022 (Burges, et al., 2014; Schleswig-Holstein Netz AG, 2017).

Figure 7

**ESTIMATION OF CONGESTION AT DISTRIBUTION GRID LEVEL
IN SCHLESWIG-HOLSTEIN FROM 2013 TO 2022**
SOURCE: ECOFYS, SCHLESWIG-HOLSTEIN NETZ AG, 2017

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Another congestion instrument is the regulation for the disengagement of load (AbLaV-'Abschaltverordnung') which has been prolonged until 2022. Within a bilateral contract between a TSO and an industrial company, the industrial company is obligated to decrease the electricity demand in critical network situations. It is compensated for the provision of the flexible capacity and additionally for activated energy. As the minimal capacity is 10 MW, the number of eligible companies is limited.

1.4 Balancing market

The balancing market serves to balance electricity supply and demand to keep the network frequency around 50 Hz. The balance can be achieved either through an adjustment of the supply or demand side (positive and negative balancing energy). In contrast to redispatch the adjustment takes place on a system as opposed to regional level and targets the balance of the system rather than regional congestion (BNetzA, 2013). Moreover, it is a market-based measure in contrast to system-based measures such as redispatch.

The four TSOs contract the operating reserves² on a common platform (www.regelleistung.net) as a single buyer. The operating reserve can be further differentiated into three segments:

Table 1

TYPES OF OPERATING RESERVE

SOURCE: REGELLEISTUNG.NET, HIRTH & ZIEGENHAGEN, 2015; PROF. STERNER, ET AL., 2014

RESERVE TYPE	MINIMUM QUANTITY [MW]	CONTRACTING PERIOD	MAXIMUM ACTIVATION TIME	REMUNERATION	CONTROL VARIABLE	MARKET SIZE [MW]
PRIMARY RESERVE (PR)	1	WEEKLY	30 SECONDS	CAPACITY	FREQUENCY DEVIATION	600
SECONDARY RESERVE (SR)	5	WEEKLY	5 MINUTES	CAPACITY AND ACTIVATED ENERGY	BALANCE OF CONTROL ARE, FREQUENCY DEVIATION	± 2000 AND MRL
TERTIARY RESERVE (TR)	5	DAILY	15 MINUTES	CAPACITY AND ACTIVATED	SR ACTIVATED	+ 2500 / - 2800

The bids are sorted until the necessary capacity has been met and the provider of the operating reserve receives their remuneration per the 'pay-as-bid' principle. To participate in the auction all participants must prequalify and prove that they will be able to deliver the operating reserve.

One proposal from the EU winter package is to move the bids closer to potential delivery by giving the opportunity to provide balancing power intraday ("Regelarbeitsmarkt"). Thus, renewable energies, particularly wind power, could more easily participate in the balancing market. The bidder would be remunerated for activating the balancing energy but not for the provision of capacity.

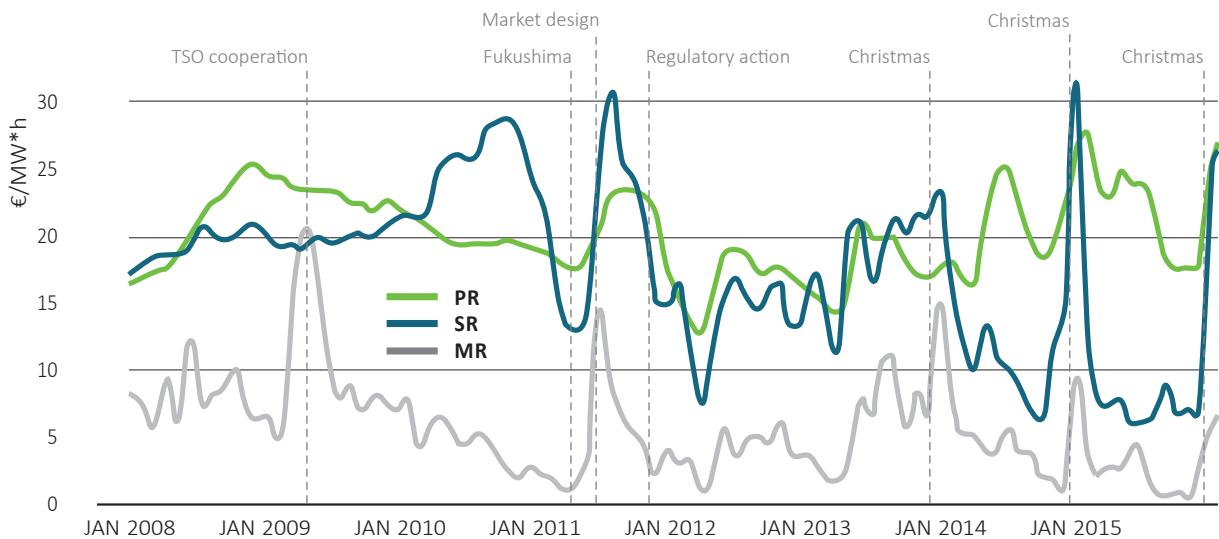
As can be seen in the next figure, the operating reserve prices decreased over time but can peak in days with particularly low market liquidity (such as Christmas). The facilitation of cooperation between the TSOs ('Netzregelverbund', NRV), the phasing out from nuclear energy after Fukushima, and regulatory changes had different impacts on the prices of the different operating reserve types. At the same time, the amount of the activated reserve has steadily decreased (Figure 9). Some of the reasons for this development might be stronger incentives for a system balance through higher prices for compensation energy, better production forecasts, and hindrance of strategic behaviour of power plant operators. As a result, the aggregated cost for the balancing power provision declined by 50% (Hirth & Ziegenhagen, 2015).

2. Operating reserve: Generation capacity available to the network operator for a short period of time to balance power demand and supply.

Figure 8

PRICE DEVELOPMENT OF OPERATING RESERVE OVER TIME

SOURCE: HIRTH & ZIEGENHAGEN, 2015

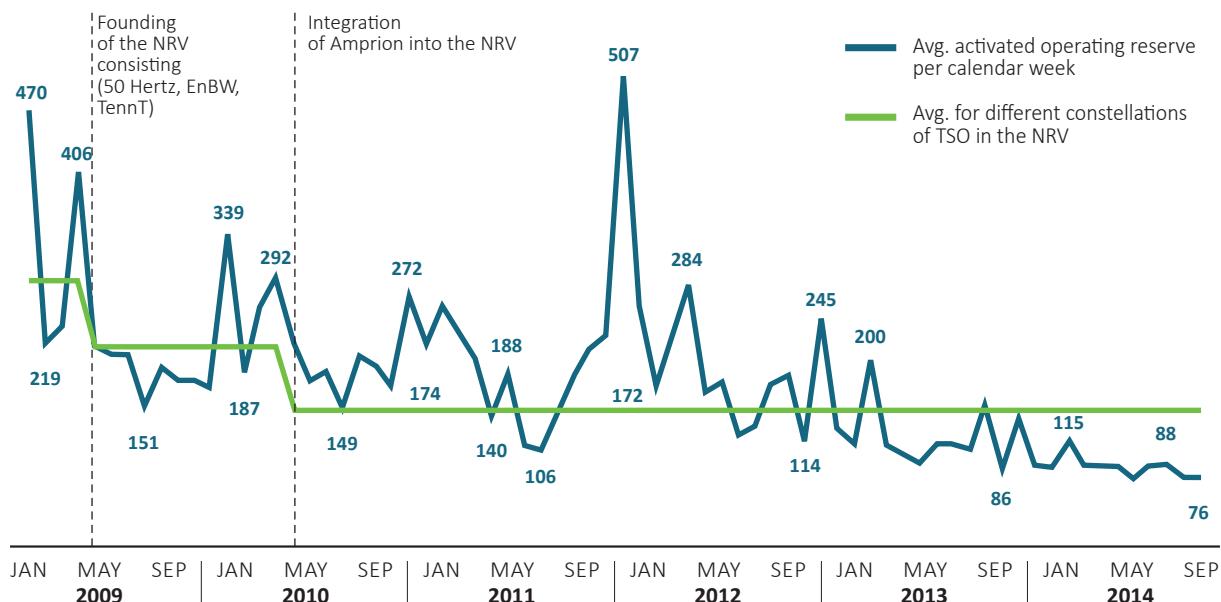


Neon analysis. Based on data from Bundesnetzagentur, Regelleistung.net, TSO websites. Monthly volume-weighted averages of all products (peak / off-peak, negative / positive) per segment.

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Figure 9

ACTIVATED OPERATING RESERVE



The prices on the primary reserve market dropped even further in the last year. This was caused mainly by the high supply of batteries that participated in the primary reserve market.

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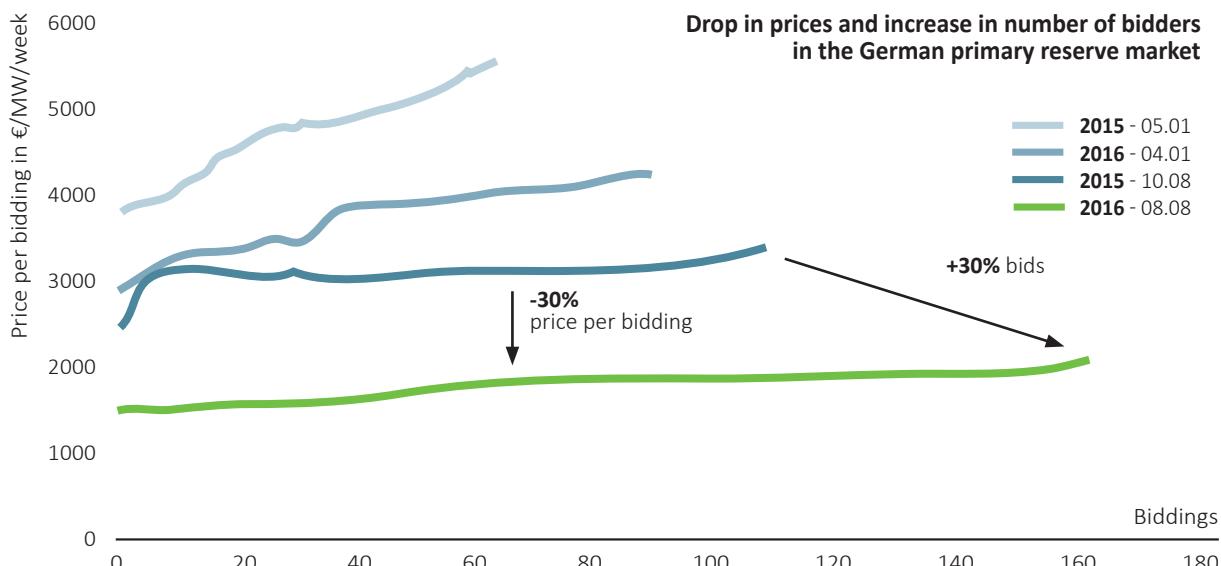
The prices on the primary reserve market dropped even further in the last year. This was caused mainly by the high supply of batteries that participated in the primary reserve market (see Figure 10). Electric batteries are very well suited for the application in the primary reserve market due to their fast reaction times and steep power gradients. With decreasing costs for batteries (Figure 11), they will be competing even more with the classical primary reserve suppliers in the future. The classical suppliers are conventional power stations, but the frequency response leads to losses in efficiency and/or lifetime. In Germany the market size of the primary reserve is limited with 600 MW and no significant increase is expected in the coming years. Nonetheless, should the requirements in market size or activation time increase, as in the case of a lower availability of rotating masses, the battery systems would be very well equipped to fulfil these requirements (Prof. Rehtanz, et al., 2014; Prof. Sterner, et al., 2014).

In the secondary and tertiary reserve markets, battery systems are less competitive with other technologies. Only the use within a pool with other technologies could provide an economic solution in the next years. Aggregators such as Next Kraftwerke already use virtual power plants³ to participate in the balancing market. The pooling of generating capacities allows a higher share of renewables in the provision of ancillary services. In a later stage, smaller consumers could also be pooled and provide balancing services through the use of smart meters and smart appliances.

3. Virtual power plants: It is a system which aggregates several generation units and could also include consumption units. In contrast to conventional power plants, virtual power plants can consist out of many different, distributed generation units such as micro CHPs, wind turbines, photovoltaic and others.

Figure 10

**PRICE EROSION DUE TO THE HIGH AMOUNT OF BATTERIES
IN THE PRIMARY RESERVE MARKET**
SOURCE: SAUER, 2016

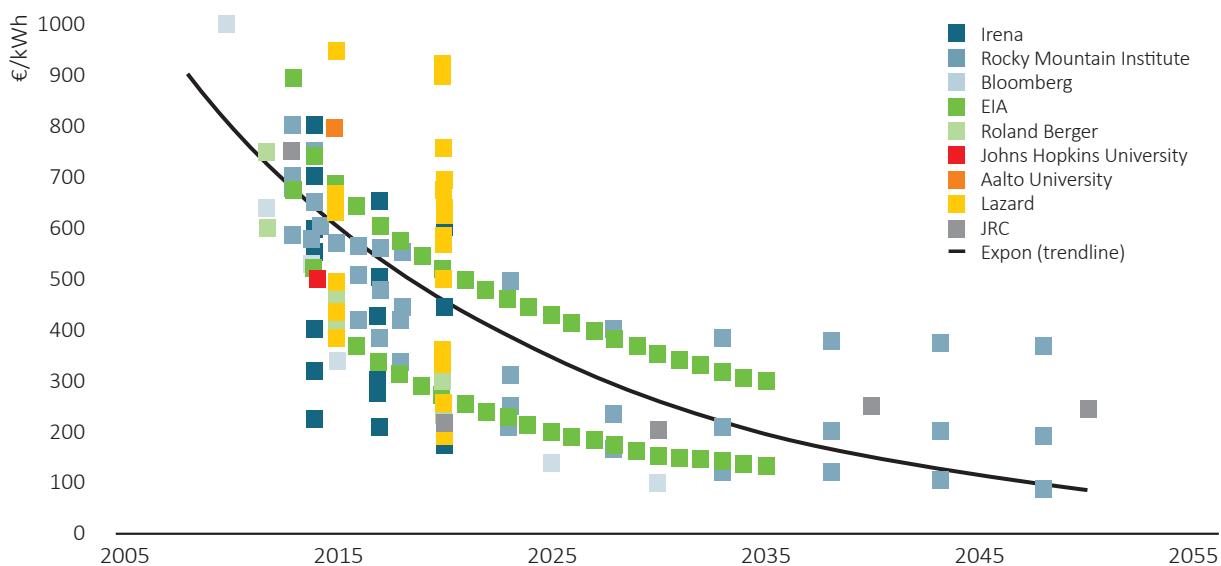


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Figure 11

**CURRENT, PASSED AND PROJECTED BATTERY SYSTEM COSTS (DATA POINTS < 1000 €/KWH)
FOR LITHIUM-ION BATTERIES**

SOURCE: IRENA, 2015; RMI, 2014; BLOOMBERG, 2016; EIA, 2012; ROLAND BERGER, 2012; CASTILLO & GAYME, 2014; JRC, 2014; LAZARD, 2015; ZAKERI & SYRI, 2015



In Europe, Germany is by far the largest market for batteries, particularly for lithium-ion batteries. The first wave of large-scale battery pilots was installed between 2012 and 2014. Most of them are intended to participate on the primary market and are located in regions with a high share of wind power production (burof, 2017).

Figure 12

OVERVIEW HIGH-SCALE BATTERY SYSTEMS IN GERMANY

SOURCE: DOE GLOBAL ENERGY STORAGE DATABASE, 2017; GTAI, 2015; BUROF, 2017

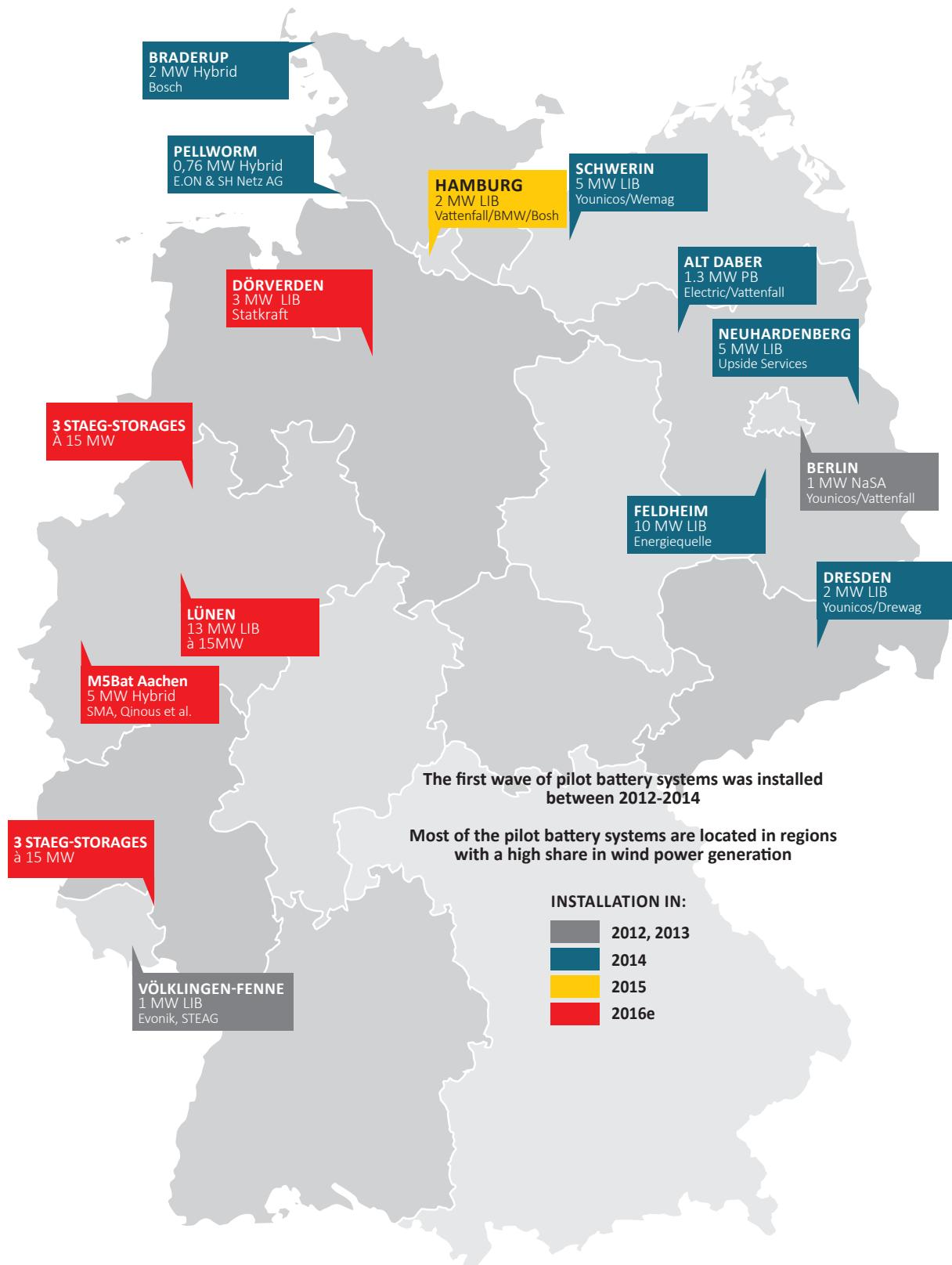
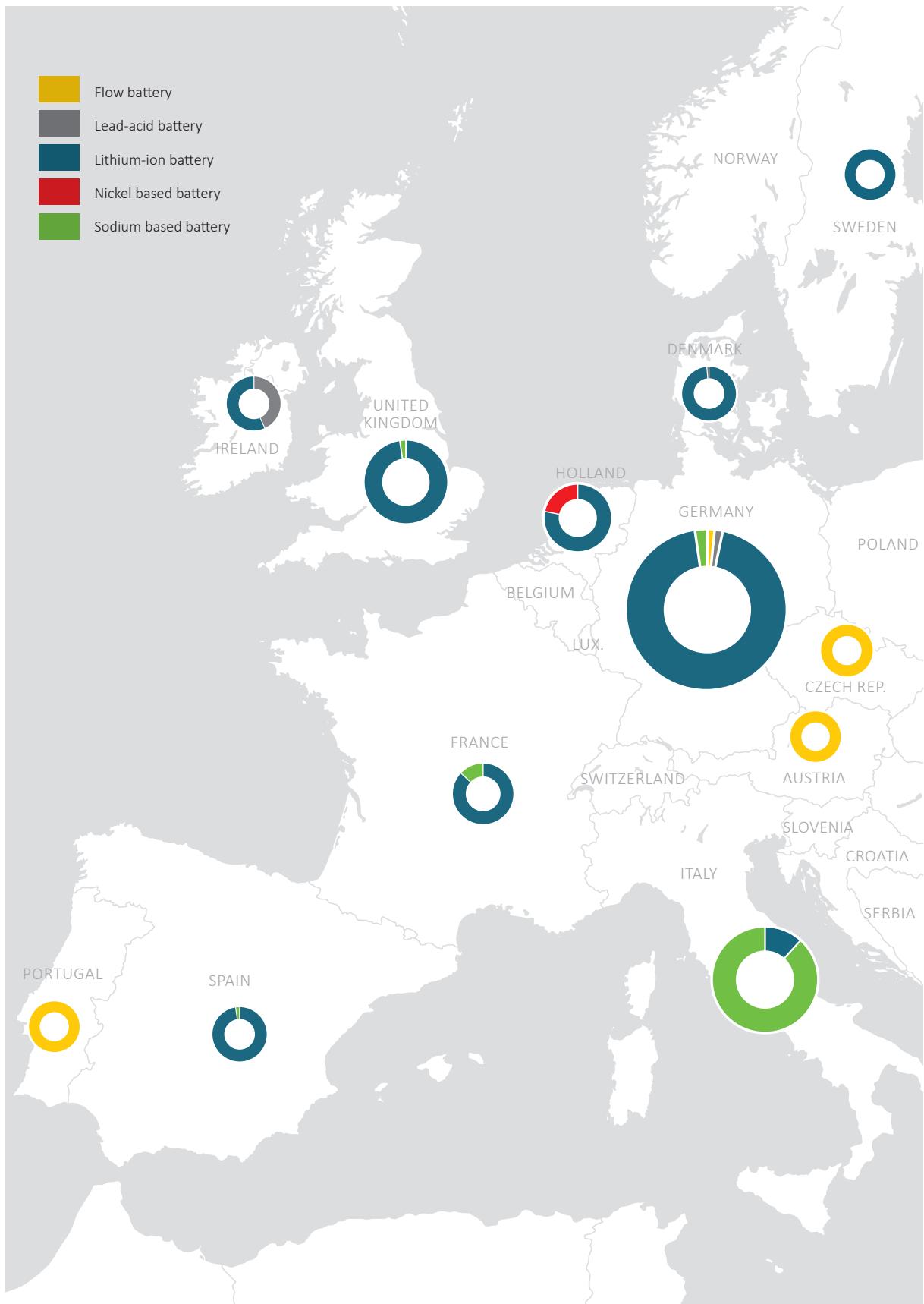
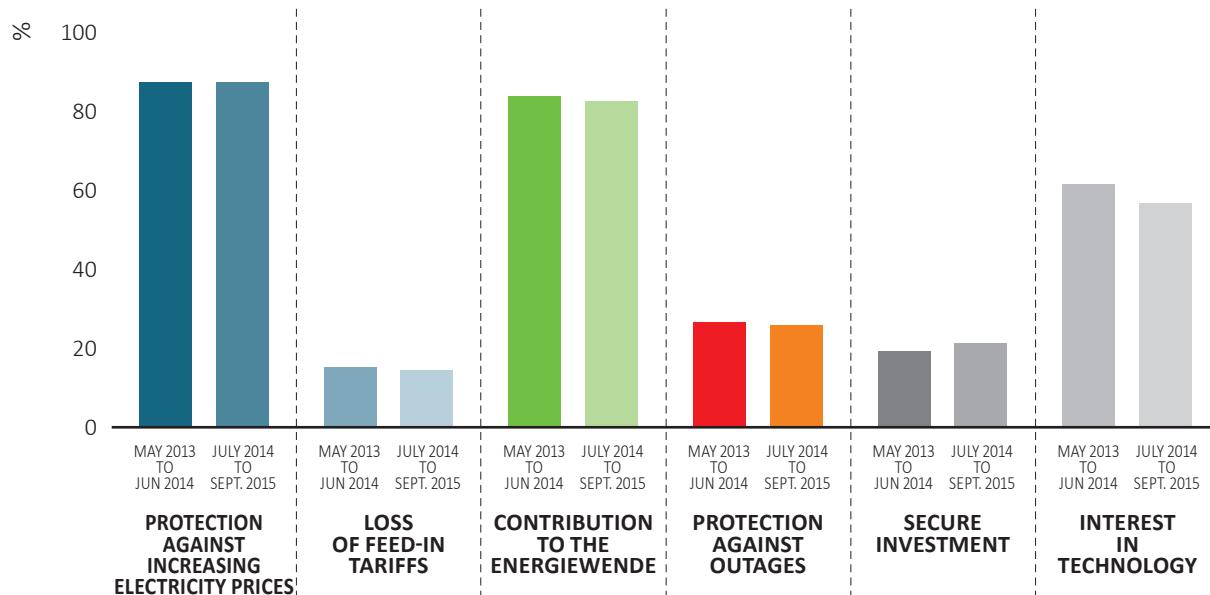


Figure 13 | **DEMAND FOR BATTERY TECHNOLOGIES IN EUROPE**
SOURCE: DOE, 2016

In UK, frequency response is also the main market for battery-storage in the UK. Additionally, last year National Grid tendered 200 MW for Enhanced Frequency Response (EFR), a new service which aims to develop technology to provide frequency response in 1 second or less. The tender was dominated by lithium-ion storage. (National Grid 2017) Besides the balancing power market, there are two other applications for batteries which are particularly interesting for Germany:

- Self-consumption in combination with PV (residential storage)
- Storage for businesses and industries (e.g. support scheme in North Rhine-Westphalia for batteries that have a load profile that has the exact opposite profile than PV)

Figure 14 | **MOTIVATION FOR INVESTMENTS IN PV-BATTERY STORAGE SYSTEMS**
SOURCE: ISEA, 2016



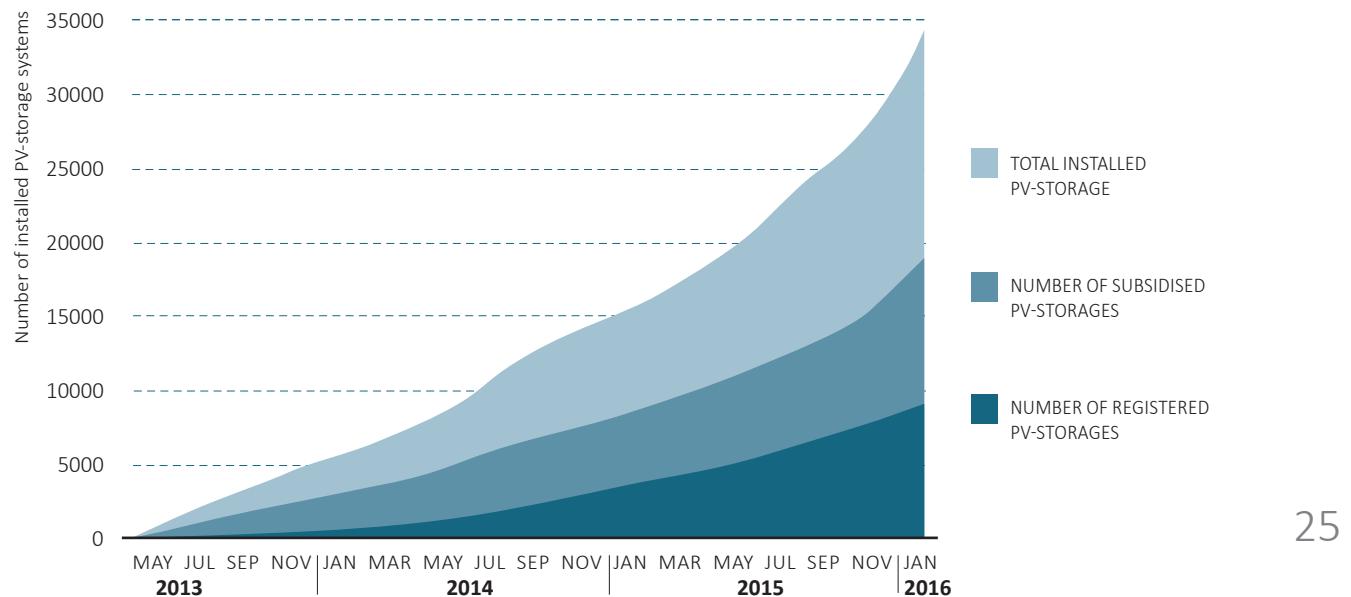
A PV panel in combination with a battery storage allows for increasing the self-consumption share. Once the feed-in tariffs drop below retail power rates or expire, this combination becomes particularly interesting from an energy cost perspective. In recent years, the main drivers for residential self-consumption (with PV-battery systems) have been 'protection against rising electricity cost' and the wish to contribute to the Energiewende (Figure 14). Nevertheless, with the elimination of the German feed-in tariffs ('EEG-Umlage'), the economic attractiveness of PV-battery systems will further increase.

In Germany, the growth in installed capacity of PV-battery solutions has been substantial in the last years (Figure 15). The installed capacity increased fivefold from the end of 2013 to the end of 2015.

Figure 15

CUMULATIVE INSTALLED CAPACITY IN PV-BATTERY STORAGE SYSTEMS

SOURCE: ISEA, 2016



There are some risk which might hamper the broad deployment and profitability of batteries in energy systems (Ecofys et. Al. 2015):

- Potential supply bottlenecks due to large demand (e.g. for e-mobility)
- Political risk as biggest share of cell production outside of Germany/Europe
- Regulatory challenges (non-harmonised standards, uncertainty about future regulations, double taxation for production and consumption)
- Public acceptance (safety, data security)
- Technical challenges (high system costs and low lifetime, little experience with grid integration)
- Market-related risks (market design changes necessary)

1.5 Future role of DSO

As discussed before, the DSOs play increasingly a more active role in the grid management and face several challenges:

- More flexible demand: prosumers, batteries, e-mobility, heat pumps, etc.
- More volatile supply: PV and wind power
- Higher interaction of market actors: virtual networks, new energy supply companies
- Steeper gradients on demand and supply side (simultaneous activation)

- increased requirements regarding transparency and flexibility of distribution grid (smart grids, smart meter)

These challenges can be managed through the implementation of a Smart Market. Such a market allows the flexible operation of the electricity system and contributes to an optimal utilisation of the network through the availability and use of information and coordination options (Neuhoff 2011). It coordinates between market and network level and creates a market result by taking both into account.

Figure 16

ILLUSTRATIVE MAPPING OF MECHANISMS IN THE GERMAN POWER MARKET

SOURCE: ECOFYS

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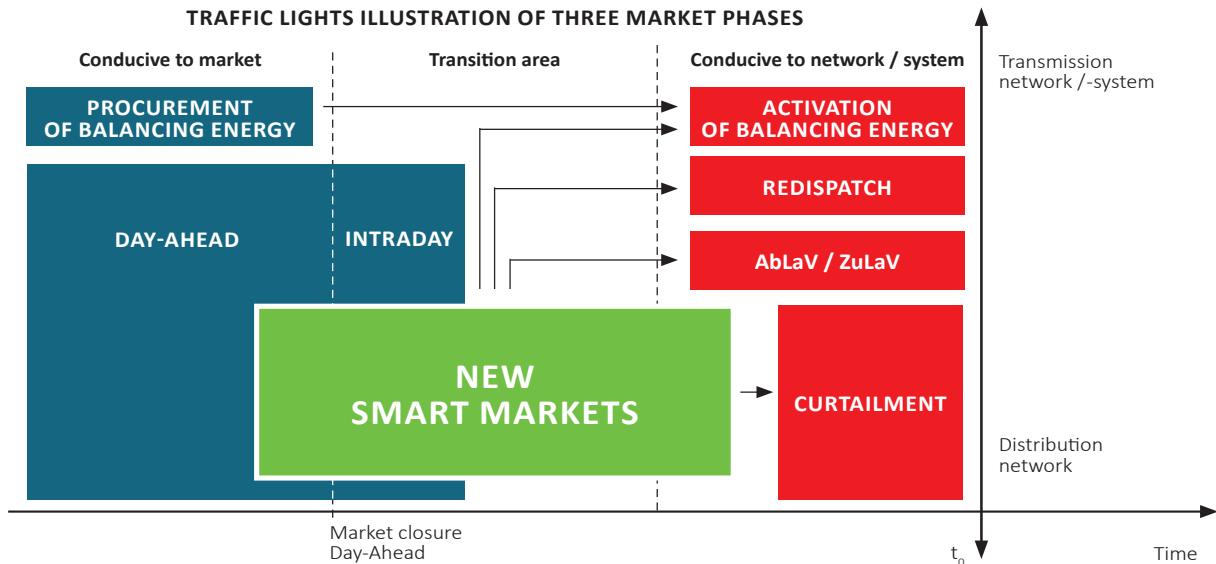


Figure 16 illustrates and categorises the different instruments in the power market. In the green zone the spatial component is insignificant. Trade in the Spot market and the procurement of operating reserve can be assigned to this zone.

The red zone is located just before delivery where system operators can activate the aforementioned measures to guarantee a stable system operation. Both zones are interwoven as market actors could

make adjustments in the Intraday market which serve to balance the energy system or grid (e.g. countertrading). It is only a simplistic illustration that neglects some of the details. For example, it is important to keep in mind that curtailment (EinsMan) can be initiated and realised by TSOs and DSOs.

Smart markets could play an intermediary role between these two zones and limit the need for the emergency procedures in the red phase and decrease system costs through a more efficient allocation of resources.



Part II: **Design of the electricity system:** **Assumptions in Poland**

By: Christian Schnell PhD (Instytut Jagielloński)

2.1 Introduction

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Following obligations at the EU level, Poland deployed a fast development of wind power through recent years with negligible marginal running costs, and private investments went chiefly to areas that benefit from public support. A few years ago, the Polish government decided how to avoid blackouts after decommissioning the old coal power plant capacity and forced state-controlled utilities to invest in a 4.2 GW fleet of new coal power plants. However, the more deployed the wind energy is, the more it lowers the wholesale prices – whether by electricity generated by Polish wind farms or wind power imported from neighbouring countries - and the load hours of conventional power plants. Therefore, the Polish government decided in 2014 to use “capacity payments” to support conventional power generation. However, such public support requires notification with the EU Commission, which does not favor providing long-term support for coal power capacity due to high greenhouse gas emissions.

So, Polish government mid of 2016 practically curtailed further wind farm project development through the so-called distance act, which implemented a rule that the minimum distance for new wind farm projects from residential areas and protected forests and nature areas amounts to 10 times tip height of the wind turbine – subject to an appropriate master plan. This generally excludes most competitive tip heights of wind turbines exceeding 150 meters. Furthermore, more than 2 GW of ready-to-build wind farm projects have to connect and achieve permit of use until mid of 2019, otherwise already achieved building permit becomes invalid. Furthermore, it is planned that the volume of the respective auction basket – practically the last auction which includes above ready-to-build onshore wind farm projects not complying with the new minimum distance rule-, which takes part at the end of 2017/beginning of 2018 auction shall provide to only 120–150 MW installed capacity, so that underbidding may provide to a situation where succeeding projects will not be constructed.

Other competitive RES, such as solar power have not yet been developed, although the Polish transmission system operator PSE recommends investments in 2-3 GW PV, as in the summer most areas in Poland lack of water, so cooling water for coal power plants is hardly available. In this fact sheet, we first present an overview of the current market environment for the Polish state-controlled utilities, which do not only have a major share in power production, but also in transmission and distribution grids.

Secondly, it needs mentioning that the Polish energy system is still at the beginning of its transition, and it requires, e.g. upgrading of pylons and wires that bring intermittent renewable energy to the customers or implementation of full-scale demand-side-response management mechanism. For the last few years, Polish distribution system operators undertook a lot of effort to modernize distribution grids, but transmission grids are yet to be modernized. However, as in many other EU member states, extension of transmission grids faces local protests, which substantially delay the extension of the grid. A modernized grid infrastructure is essential for rolling-out smart meters and motivating customers to a demand-side-response management. Redesigned consumer markets should adjust prices more frequently in order to reflect the fluctuations of the weather. Markets that sell commoditised per kilowatt-hours should be transformed into markets where consumers pay for guaranteed services. They should adjust prices more frequently in order to reflect the fluctuations of the weather. Therefore, intraday markets have to be strengthened in order to educate consumers and enhance appropriate behaviour, such as consuming power when it is cheap, or paying a higher tariff for guaranteed energy. A lot more storage will be needed, and smart grids bolstered by big data will do more to keep the demand in line with the supply. At times of extreme scarcity, a high fixed price could kick in to prevent blackouts. Markets should reward those willing to use less electricity to balance the grid, just as they reward those who generate more of it. Bills could be structured to be higher or lower depending on how strongly a given customer wished to have guaranteed power all the time.

2.2 Market environment for power production in Poland

Due to its energy mix and its historical development, the Polish energy sector is unique in Central Europe, and its transition towards low emission economy is at a significantly different stadium than in Germany. Firstly, it is recommended to be introduced in the general market environment of Polish utilities, which are state-controlled, as this has a major impact on energy policy of transmission system and distribution system operators which are controlled by the same utilities.

Installed capacity and load requirements

The current Polish power plant park is characterised by a large share of fossil fuel generation

with the highest capacity dedicated to hard-coal and lignite generation. Renewable power sources currently represent only a smaller share of the installed capacity. Wind-onshore installations amount to less than 6 GW and PV to less than 200 MW of the installed capacity. Total installed net generation capacity adds up to 41 GW, however, only 25 GW of thermal power units are centrally managed for the purpose of the balancing market and capacity market mechanisms by the Polish TSO – so called JWCD.

Figure 17 | **INSTALLED CAPACITY 2013 -2015 IN MW INCLUDING CENTRALLY MANAGED UNITS JWCD**
SOURCE: URE

	31.12.2013 r.	31.12.2014 r.	31.12.2015 r.
Total	38 406	38 121	40 445
Public power plants	32 341	31 631	31 927
Public hydroelectric power plants	2 221	2 369	2 290
Public heat and power plants, Including:	30 120	29 262	29 637
Hard coal-fired	19 812	18 995	19 348
Brown coal-fired	9 374	9 268	9 290
Gas-fired	934	999	999
Wind farms and other RES	3 504	3 877	5 687
Industrial power plants	2 561	2 613	2 831
JWCD	25 094	24 663	24 782
nJWCD	13 312	13 458	15 664

A share of 84% of the Polish power production is based on baseload power plants, mostly hard-coal and lignite-fired, and additionally 6% of power production comes from industrial power plants which are also mostly coal-fired, totalling to almost 90% of power production from coal with an average emission of 920 kg CO₂/MWh of produced power. However, a part of this production is based on a solid biomass firing, amounting in total to almost 6% of production. Gas power plants do not play a remarkable role with 3% production and are currently less competitive than coal power plants which squeeze-out gas power plants due to merit order-principle. In the recent years Poland observed a fast development of wind power doubling within the last three years, and currently onshore wind capacity provides for a maximum of 30% of Polish power consumption in windy days with low consumption e.g. at Christmas.

The required load in 2015 varied between 20.5 GW during the summer months and 24.5 GW in December which could in theory be covered by centrally managed thermal units.

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The required load in 2015 varied between 20.5 GW during the summer months and 24.5 GW in December which could in theory be covered by centrally managed thermal units. The capacity reserves are generally higher in the winter months. In the summer months, the planned maintenance and modernisation works of thermal power plants cover up to 5.4 GW of the capacity, whereas after the 2015 close-to-blackout scenario during July and August, PSE decided to move those works from July/August to May, June and September. Unplanned maintenance works cover up to 2 GW capacity. Furthermore, up to 8.4 GW capacity are power sources not centrally managed such as units below the installed capacity of 50 MW and not plannable units such as wind farms.

Figure 18 | **2015 POWER PRODUCTION BY SOURCES**
SOURCE: 2015 POWER PRODUCTION BY SOURCES

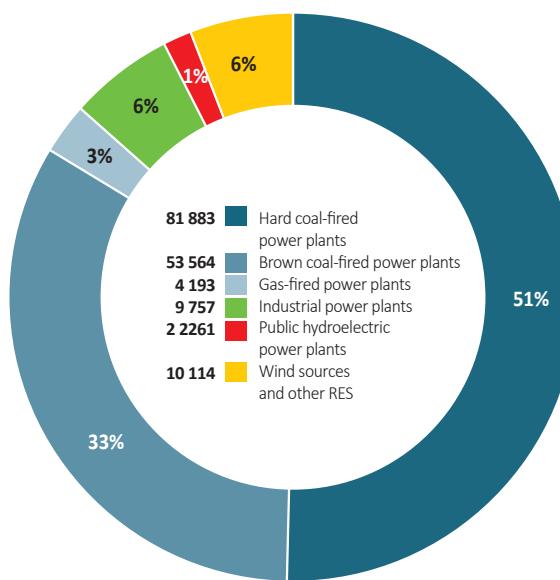
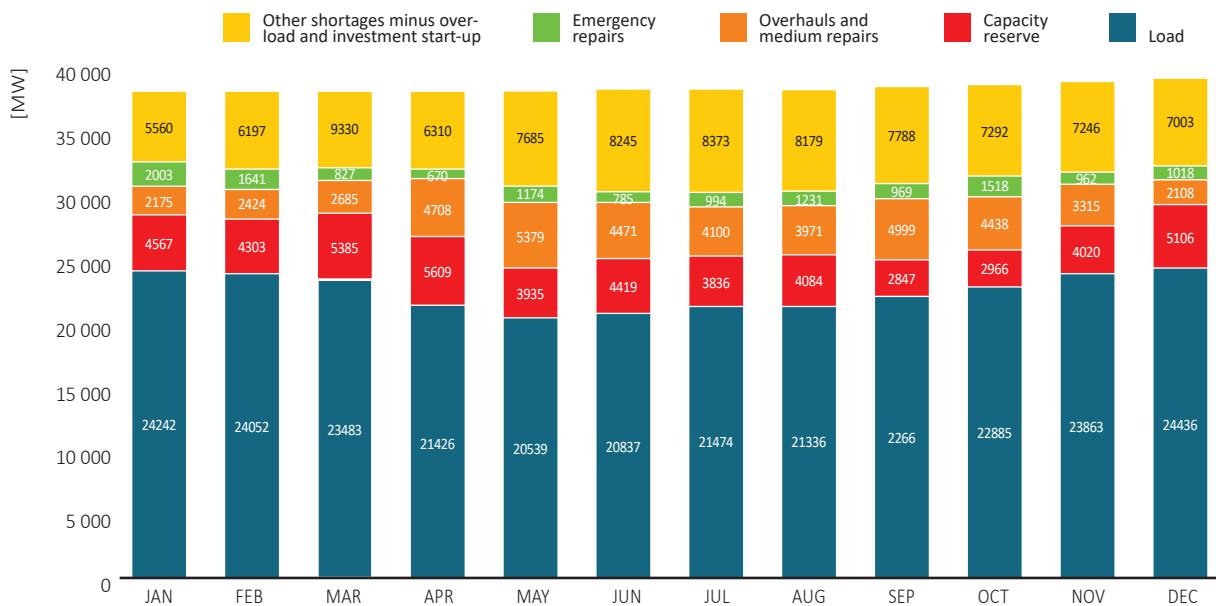


Figure 19

MONTHLY DEVELOPMENT OF AVAILABILITY OF INSTALLED CAPACITY IN 2015

SOURCE: PSE



Historical data shows the development of the available capacity. Generally, the peak load slowly increases, whereas the required reserve capacity slowly decreases – mainly due to partly introduced demand-supply-management of large industrial consumers. The planned maintenance and modernisation works of thermal power plants

significantly increase – due to the age of the thermal power plant park – and, consequently, also the unplanned maintenance works increase. The capacity of power sources not centrally managed also increased significantly – mainly due to the increase of installed capacity of wind farms.

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Figure 20

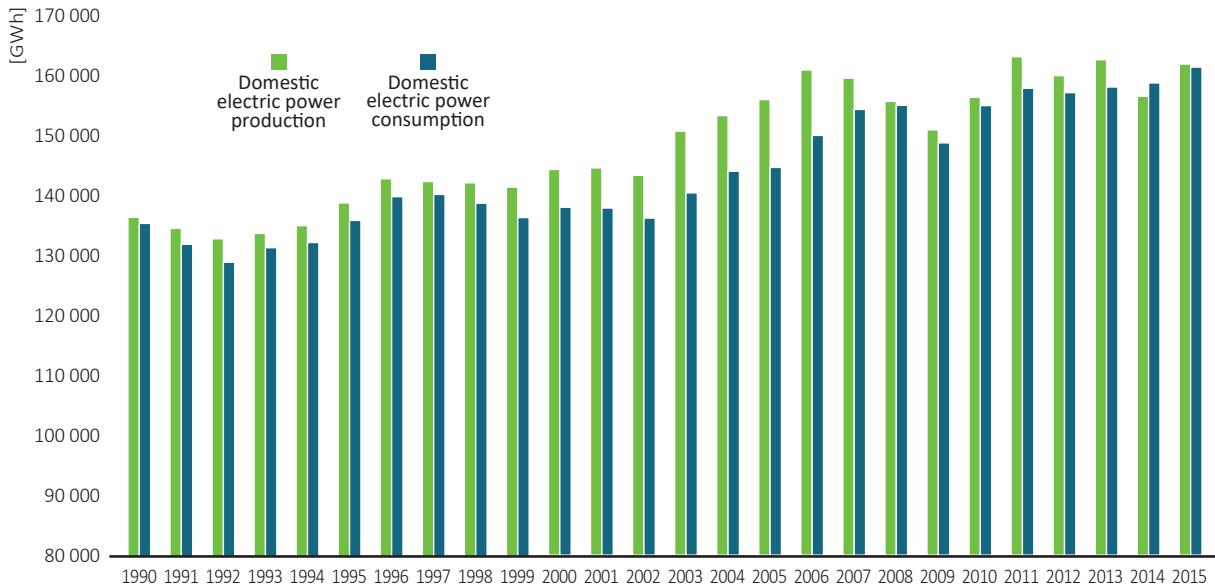
DEVELOPMENT OF AVAILABLE INSTALLED CAPACITY 2006 - 2015

SOURCE: PSE

SPECIFICATION	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Power available	34 623	35 232	34 830	35 075	35 538	36 276	37 264	37 749	38 216	38 891
Load	21 916	22 371	21 453	21 371	21 618	22 356	22 349	22 587	21 937	22 541
Power reserve	5 197	4 815	4 376	5 496	4 508	4 308	4 349	4 064	4 446	4 241
Overhauls										
and medium repairs	2 690	3 225	3 022	2 930	3 166	3 631	3 563	3 321	3 697	3 760
Emergency repairs	780	1 081	1 130	912	1 443	980	954	1 114	1 163	1 138
Other shortages minus										
overloads and investment start-up	4 038	3 741	4 849	4 367	4 802	5 001	6 048	6 663	6 972	7 211

Power consumption in Poland has been growing continuously for the last decades, with a decrease in 2009 due to a financial crisis.

Figure 21 | **GROWTH IN POWER CONSUMPTION 1990 - 2015**
SOURCE: PSE



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The following graph shows how the installed capacity is used to cover power consumption. The centrally managed units provide between 15 and 18 GW of the power consumption, however, in the summer months their production is higher than in the winter months, whereas the units which are not centrally managed, i.e. wind farms and smaller CHP plants having priority access take over their share. Spinning reserves amount between 0.9 and 1.7 GW and are generally higher in the winter months – those units are mainly depreciated coal power plants - and also so-called “cold reserves” (i.e. requiring a cold-start of coal power plants which usually takes days or even weeks) with a capacity between 1.4 and 3.8 GW show a similar load profile. Both types of reserves are so-called capacity market mechanisms, however, the EU Commission generally questions cold reserve capacity mechanisms due to missing flexibility in an event of scarcity of power. Due to the impact of climate change, i.e. hotter summers, it is expected that in the coming years the summer peak will almost converge with the winter peak amounting to currently 25 GW.

Figure 22

MONTHLY DEVELOPMENT OF INSTALLED CAPACITY USED IN 2015

SOURCE: PSE



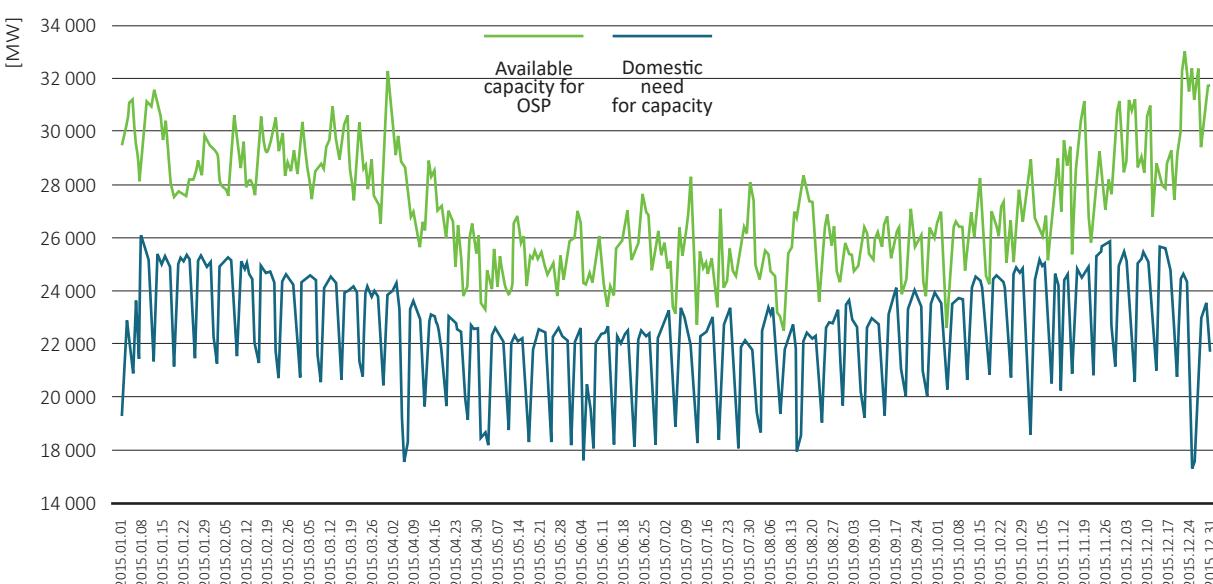
The following graph provides an overview of the available capacity and consumption in 2015. Low reserves during summer months are remarkable. It also demonstrates that the above mentioned cold reserves are generally not used due to its reaction time, and the existing installed capacity including spinning reserves is sufficient to cover the need for power. Therefore, so-called cold-reserve-mechanisms have been generally criticised by the EU Commission as an ineffective state aid.

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Figure 23

AVAILABLE CAPACITY AND CONSUMPTION IN 2015

SOURCE: PSE



Development of conventional thermal capacity until 2025

The conventional thermal capacity is determined by known new entry and decommissioning of capacity. According to power plants under construction, an increase in the new conventional thermal capacity in the period from 2014 until 2025 by 7 GW can be assumed by:

- 2.5 GW gas-fired capacities (part of the investments in gas power plants are currently stopped);
- 0.5 GW lignite capacities; and
- 4 GW hard coal capacities (not including currently tendered Ostroleka 1 GW power plant).

The new entries include (hard) coal power plants in Opole (PGE) with a 1.8 GW installed capacity, in Kozienice (ENEA) with a 1.0 GW installed capacity, Jaworzno (TAURON) with a 0.9 GW installed capacity and Turow (PGE/lignite) with a 0.5 GW installed capacity. The political decision to build these power plants was made by the previous government determined by energy security. Currently, for another 1 GW power plant in Ostroleka (ENEA/ENERGA) a tender for construction is organized, however, the financial model has not yet been finally prepared.

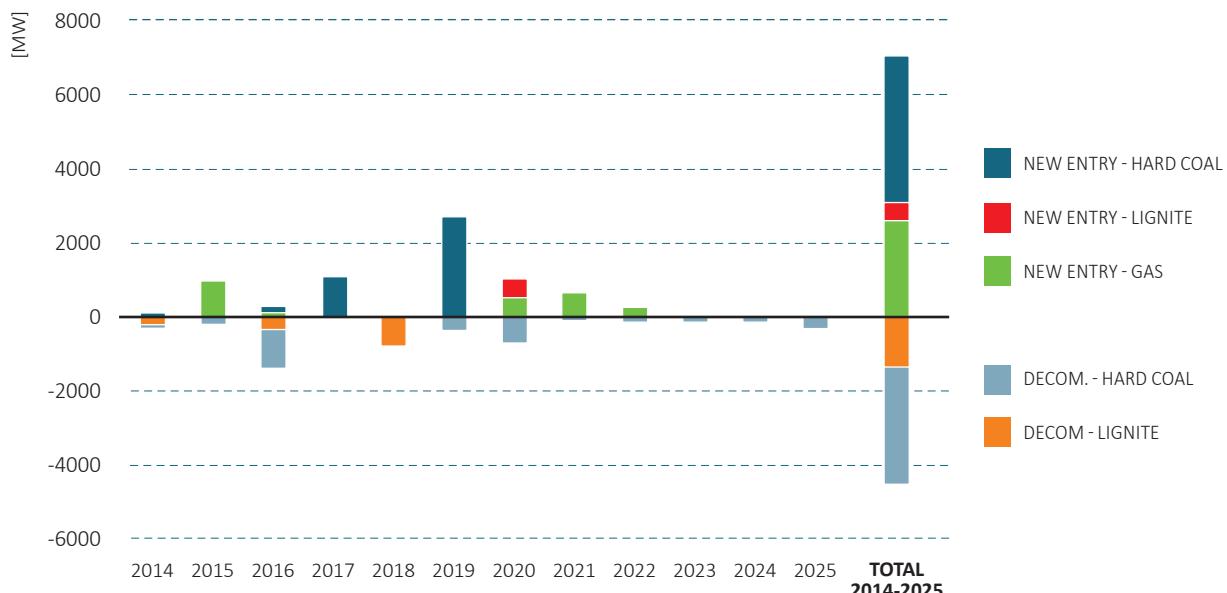
At the same time, decommissioning of at least 4.5 GW power plant capacity can be expected by 2025, which does not include parallel decommissioning of CHP plants (26 GW of installed heat capacity has to be decommissioned by end of 2022/2023):

- 3 GW of currently existing hard coal capacities; and
- 1.4 GW of lignite coal capacity.

In total, conventional generation capacity of thermal power plants increases by 2.5 GW until 2025. The table below shows the distribution of known new entries and planned decommissioning of power plant capacity (installed capacity) – without CHP.

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Figure 24 | **DEVELOPMENT OF CONVENTIONAL CAPACITY UNTIL 2025**
SOURCE: WYSOKIENAPIECIE.PL



Electricity exchange capacity

Poland's electricity system has been for a long time rather isolated from other EU member states, although Poland has theoretically a high level of interconnection capacity to its neighbouring countries.

Figure 25

CURRENT POWER EXCHANGE CAPACITIES

SOURCE: PSE

POLAND	LOCATION	TECHNICAL LINE	REMARKS
WESTERN BORDER / GERMANY	Krajnik – Vierraden	400 kV AC double circuit line	Phase shifter installed and operating since 2016
WESTERN BORDER / GERMANY	Mikułowa – Hagenwerder	400 kV AC two single circuit lines	Phase shifter installed and operating since 2016
NORTHERN BORDER / SWEDEN	Słupsk Wierzbicino – Stärnö	400 kV DC cable line	
NORTHERN BORDER / LITHUANIA	Ełk – Alytus	400 kV AC double circuit line	LitPol-Link operating since 12/2015, limited import during night hours
EASTERN BORDER / BELARUS	Białystok – Roś	220 kV AC single circuit line	Not operating, high investments required
EASTERN BORDER / UKRAINE	Rzeszów – Chmielnicka	750 kV AC single circuit line	Not operating, high investments required
EASTERN BORDER / UKRAINE	Zamość – Dobrotwór	220 kV AC single circuit line	Only import capacity, high investments required
SOUTHERN BORDER / CZECH REPUBLIC	Wielopole–Nošovice/ Dobrzení – Albrechtice	400 kV AC double circuit line	
SOUTHERN BORDER / CZECH REPUBLIC	Kopanina/Bujaków – Liskovec	220 kV AC double circuit line	
SOUTHERN BORDER / SLOVAKIA	Krosno Iskrzynia – Lemešany	400 kV AC double circuit line	

Generally, for the last years import capacities have been very low at a level of 2%, i.e. 3-4 TWh of electricity consumption, mainly due to technical limitation by loop flows within the Phelix trading area, i.e. between Germany and Austria through Poland, the Czech Republic and Slovakia.

Figure 26

**HISTORICAL DEVELOPMENT OF INTERCONNECTION CAPACITIES
IN NEIGHBOURING EU MEMBER STATES**

SOURCE: EC 2ND REPORT STATE OF THE ENERGY UNION

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In 2015, the balance of cash flow closed at a level close to zero. Data shows that 14.8 TWh was sent abroad while import amounted to 14.5 TWh. Each of these volumes constitutes approximately 8% of the total energy demand.

Figure 27

POWER EXCHANGE IN 2015/REAL BY COUNTRIES

SOURCE: PSE

	IMPORT	EXPORT	SUM
BELARUS	0,0	0,0	0,0
CZECH REPUBLIC	208,0	9 764,7	-9 556,7
LITHUANIA	13,8	64,5	-50,7
GERMANY	10 658,9	17,4	10,641,5
SLOVAKIA	0,1	4 925,8	-4 925,7
SWEDEN	3 511,7	20,2	3 491,5
UKRAINE	66,5	0,0	66,5
TOTAL	14 459,0	14 792 5	-333,5

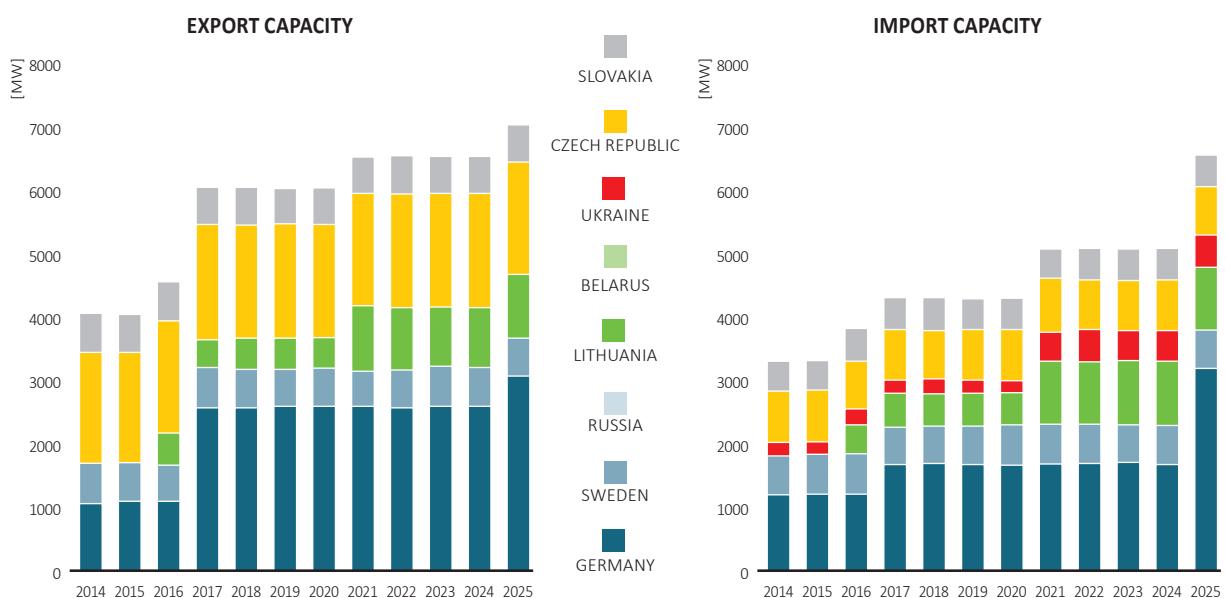
Due to the installation of phase shifters at Krajnik-Vierraden and Mikułowa – Hagenwerder interconnectors, the new LitPol-Link and the planned market split between Germany and Austria (Austria is a net-importer of 10 TWh power yearly, mainly of wind power from Germany and nuclear power from the Czech Republic which leads to low wholesale market prices in Austria) a significant increase of physical power import capacity will be observed soon in Poland.

A further increase in the interconnection capacity until 2025 is expected:

- The import capacity from neighbouring countries to Poland increases to 6.6 GW covering more than 25% of the production units centrally managed by PSE (so-called JWCD units amounting to approx. 25 GW); however, the second LitPol-Link interconnector is currently questioned by PSE, which prefers to construct a sea cable between Klaipeda in Lithuania and Władysławowo at Polish Baltic Coast for the benefit of future Polish offshore windfarms;
- The export capacity to neighbouring countries increases to 7.1 GW in 2025.

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Figure 28 | **INTERCONNECTION CAPACITIES**
SOURCE: ENTSO-E, PSE



Neighbouring wholesale markets

Consequently, lower wholesale prices in the neighbouring countries may lead to a sharp increase of power imports. In 2015, the Polish wholesale base market average was at a level of EUR 37.8 per MWh, which is below 2015 EU average of EUR 40.6 per MWh, but significantly higher than the base market average in Sweden – EUR 22.1, Germany – EUR 31.7, the Czech Republic – 32.4 and even Slovakia – 33.6 per MWh. Historically, wholesale market prices in Poland have been since 2013 at a level comparable with Germany.

Figure 29 | **WHOLESALE PRICES IN NEIGHBOURING EU MEMBER STATES**
SOURCE: EC 2ND REPORT STATE OF THE ENERGY UNION

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WHOLESALE PRICES AT POWER EXCHANGE		
	[EUR/MWH] 2015	RELATIVE CHANGE 2013-2015 [PP]
CZECH REPUBLIC	34,4	-11,9%
GERMANY	31,7	-16,3%
LITHUANIA	41,8	-14,7%
POLAND	37,8	2,2%
SLOVAKIA	33,6	-9,7%
SWEDEN	22,1	-44,0%

As Poland has substantially higher wholesale prices than its main neighbouring countries, power import may take over a higher market share in case of a higher interconnection capacity.

Energy security

According to the second state of the Energy Union report, due to its energy mix Poland has a by far higher energy security than any other neighbouring EU member state, i.e. is less dependent on import of all types of energy carriers. Poland is only in 28.6% dependent on energy imports, compared to the Czech Republic with a coefficient of 30.4%, Sweden with 32.1%, Slovakia with 60.9% and Germany with 61.6%. However, the energy security coefficient has sharply decreased for the last 10 years, e.g. by lacking international competitiveness of the Polish coal mining sector.

Figure 30 | **NET IMPORT DEPENDENCY**
SOURCE: EC 2ND REPORT STATE OF THE ENERGY UNION

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	NET IMPORT DEPENDENCY [%]	
	NET IMPORTS [% OF GROSS INLAND CONSUMPTIONS + INTERNATIONAL BUNKERS]	ABSOLUTE CHANGE 2005 - 2014 [PP]
CZECH REPUBLIC	30,4%	2,4%
GERMANY	61,6%	1,2%
LITHUANIA	77,9%	21,1%
POLAND	28,6%	11,0%
SLOVAKIA	60,9%	-4,4%
SWEDEN	32,1%	-4,7%

Due to this market environment, the EU winter package causes a few serious threats for coal dependent Polish utilities in a mid-term perspective.

Capacity markets

Capacity markets, i.e. additional payments for reserve capacity are generally permitted, and Poland currently implemented two types of capacity markets. However, future implementation of capacity markets requires a European-level annual assessment by ENTSO-E of “the overall adequacy of the electricity system to supply current and projected demands for electricity ten years ahead”. This assessment will evaluate the adequacy of national proposals to introduce a capacity mechanism. Even if this first hurdle is taken, the interconnected Member States should be consulted, and other approaches, such as interconnection and storage, should be considered first. Capacity mechanisms must be open to providers in the interconnected Member States- unless they take the form of strategic reserves like the mechanism currently implemented in Poland, however, a strategic reserve mechanism is not capable of stimulating any new investments. According to the Revised Market Regulation, national authorities must not prevent the capacity located in their territory from participating in other countries’ capacity mechanisms. Those generators participating simultaneously in more than one capacity mechanism “shall be subject to two or more penalties if there is concurrent scarcity in two or more bidding zones that the capacity provider is contracted in”.

Additionally, the draft Regulation sets an emission limit of 550 g CO₂/kWh for a combustion plant on which a final investment decision, i.e. final tender for construction works is made after the Revised Market Regulation enters into force to be eligible for capacity mechanism support. Taking into account the current stage of coal power plant project development in Poland, in case a new environmental impact assessment is required, any new coal power plant cannot qualify anymore for a capacity mechanism support – BAT coal power plants emit 750 g CO₂/kWh (technically challenging coal-to-gas power plants with gasification in coal mines might produce electricity below this emission threshold, and also coal-dust heat/cogeneration

plants may produce below the threshold). The only exception is the fully permitted 1000 MW Ostroleka coal power plant which may meet the required timeline, however, this plant would not be on-grid before 2024. Furthermore, for all the existing power plants exceeding an emission limit of 550 g CO₂/kWh, the capacity market mechanism (as strategic reserves) can provide support only until end of 2025.

Contribution of the National Energy and Climate Plan

The Governance Regulation is a framework legislation aiming to give credible underpinning to the commitments on climate change that the EU as a whole has made under the Paris Agreement and to bridge the gap left by having an EU level 2030 renewables target but no correspondingly increased Member State level targets. It also gives legislative expression to the EU’s Union-level energy and climate targets to be achieved by 2030, which are (i) a binding target of at least 40% domestic reduction in economy-wide greenhouse gas emissions as compared with 1990, (ii) a binding target of at least 27% for the share of renewable energy consumed in the EU, (iii) a target of at least 27% (increased to 30%) for improving energy efficiency in 2030, to be revised by 2020, (iv) having in mind an EU level of 30% and a 15% electricity interconnection target for 2030. Poland is obliged to reduce its emissions till 2030 by 7% as compared with 2005, which implements a reduction of the average emission intensity of electricity production to 500 g CO₂/kWh by 2030. However the domestic data provides an GHG average emission for coal power plants being responsible for almost 90% power production amounting to 920 g CO₂/kW. According to EU data, in 2000 the GHG emissions in Poland amounted to 710 g CO₂/kWh, in 2005 to 690 g CO₂/kWh and in 2010 to 670 g CO₂/kWh, whereas the projection for 2020 is 590 g CO₂/kWh and for 2025 560 g CO₂/kWh. Therefore, the reduction of the average emission intensity of electricity production should speed up, still, the government substantially hampered a further development of renewable energy.

Every 10 years, starting in 2019, each Member State is to enact an integrated national energy and climate plan covering a period of ten years,

starting from 2021-2030 period. The plan is to set out in considerable detail the information which is required by the relevant Member State, i.e. national objectives and targets, additional policies and measures they have adopted, and finally their emissions projections are going forward to another 10-year period. The achievements have to be reported every two years, and every five years an update is required. The plans are first to be submitted to the Commission for comment one year in advance, in draft, i.e. the first draft by 1 January

2018, and the Ministry of Energy is fully aware of this challenge. Practically, a low emission scenario is inevitable for successful notification of any support mechanism, including capacity mechanism support.

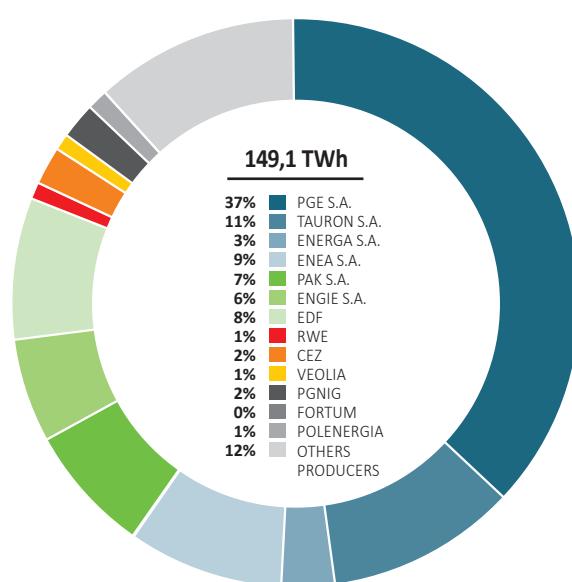
Market share of Polish (partly) state-owned utilities

For the last 10 years Poland has implemented a strategy to create five large state-controlled utilities in the electricity and gas sector and continuously takes over assets of foreign (state-owned) utilities which had been previously privatised, e.g. the purchase of the Silesian distribution grid operator GZE in 2011 from Vattenfall by Tauron or the initiated take-over of coal/biomass power assets from ENGIE and EdF by a group of Polish state-controlled utilities.

Five partially state-owned utilities PGE, TAURON, ENEA, ENERGA and PGNiG Termika (all the companies are listed on the Warsaw Stock Exchange) currently control 62% of the power production capacities, and after the planned take-over of coal/biomass power assets from ENGIE and EdF may control 76% of the power production facilities.

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Figure 31

SHARE OF UTILITIES IN NET ELECTRICITY PRODUCTION 2015
SOURCE: URE

Risk matrix of the Polish state-controlled utilities

Poland's state-owned utilities try to find their way to operate in a very challenging market environment for power production:

- increasing CO₂ prices for the energy sector under the improved ETS trading scheme,
- auctioning free allowances of emission certificates from 2021 for new investments in technologies which emit maximum 450 kg CO₂ per produced MWh (decision by European Parliament from 15/02/2017),
- introduction of capacity market support schemes only for technologies which emit maximum 550 kg CO₂ per produced MWh

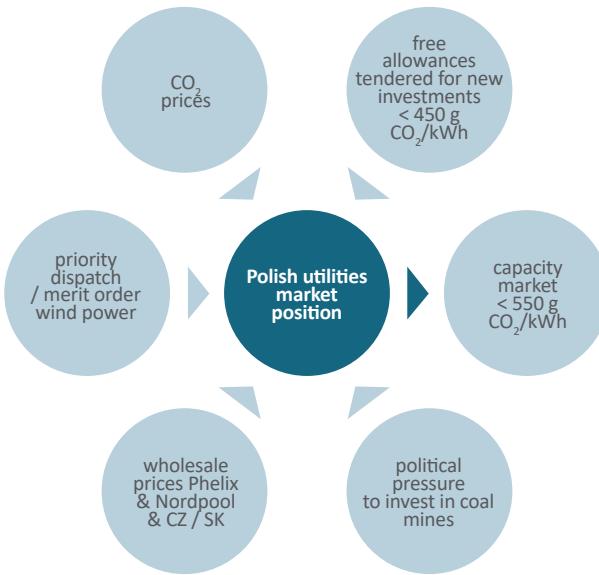
(draft electricity market regulation as published by the EU Commission on 30/11/2016 as part of the “winter package”),

- priority dispatch for electricity produced by renewable energy sources in Poland and further extension of RES-E sources,
- import of cheaper RES power from Germany and Sweden (directly or indirectly through Lithuania) and cheaper nuclear power from the Czech Republic and Slovakia,
- and last-but-not-least politically stimulated investments in (hard) coal mines to provide required cash flow for operation, which has been initiated by the previous and continued by the current government and blocks urgently needed investments in low-emission generators.

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Figure 32 | MARKET RISKS FOR POLISH UTILITIES

SOURCE: INSTYTUT JAGIELLOŃSKI



The Polish energy policy as determined by the Ministry of Energy due to its mixed shareholder and political perspective has severe difficulties to align the European approach of creating the Energy Union regarding inner electricity market and decarbonization of the EU, not to providing to bankruptcy of state-owned utilities and, consequently, risking hostile take-overs of Polish utilities. This approach also determines the role of grid operators.

2.3 Market environment for power transmission and distribution by Polish utilities or production in Poland

Poland's transmission system operator PSE, but even more its large distribution system operators PGE Dystrybucja, TAURON Dystrybucja, ENEA Operator and ENERGA Operator are technically and legally unbundled, however, controlled by Polish state-controlled utilities.

Grid infrastructure

Grid infrastructure, especially distribution grids have been modernised during the last years. Due to grid modernisation transmission losses substantially decreased during the last five years, mainly in the distribution grids.

Figure 33

PRODUCTION AND TRANSMISSION LOSSES IN POLAND 2010-2015

SOURCE: PSE

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		2010	2011	2012	2013	2014	2015
EPROD	TWh	157,7	163,5	162,1	164,4	159,1	161,4
ΔE	TWh	12,0	10,6	10,7	10,5	10,1	10,2
ΔE%	%	7,58	6,47	6,61	6,37	6,33	6,33

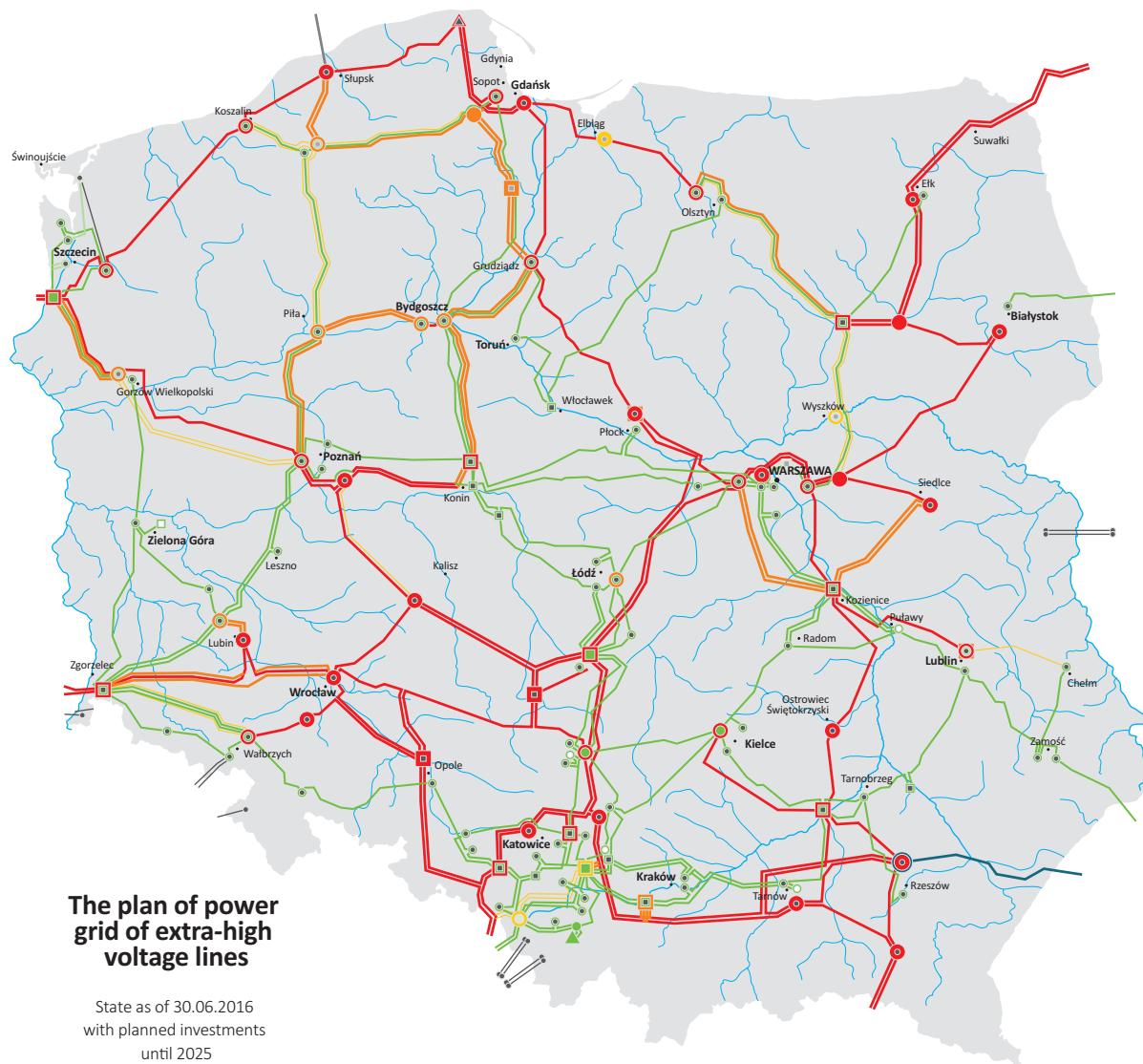
On the other hand, the penetration of fed-in RES into distribution grids has substantially changed during the last 15 years. For 110 kV distribution grids the RES share of fed-in power has increased from 0.4% in 2002 to 51.9% in 2015, in medium voltage grids the RES share of fed-in power increased from 1.5% in 2002 to 34.4% in 2015, and in low voltage grids the RES share of fed-in power amounted to 1.3-2.6% in 2015. So, RES fed-in and modernisation of distribution grids resulted in decreasing transmission losses. Further potential of decreasing transmission losses without further investments can be e.g. achieved mainly by the management of reactive power flows.

However, transmission grids still have to be extended and modernized, and until 2025 a reshape of the picture of the Polish transmission grid is planned. Historically, the transmission grid was

prepared to send large amounts of electricity from southern Poland to central and (to a lesser extent) northern Poland due to Poland's energy mix based on coal power plants mainly located close to coal mines in Silesia and in the Lublin region. PSE investment plans are going to change this picture substantially. The extension of the transmission grid is planned in northern Poland in order to provide energy to central Poland, and furthermore at the western border to increase import capacity. This extension is only partly related to the development of onshore wind farms, which are generally located in the northern half of Poland. The grid extension prepares transmission capacity for major strategic investment projects planned at the Baltic coast, i.e. offshore wind farms and, less likely, nuclear power plants.

Figure 34

TRANSMISSION GRID STRUCTURE AND ITS EXTENSION IN POLAND UNTIL 2025
SOURCE: PSE S.A. - INCLUDING REGIONAL BRANCH OFFICES



LINES:

750 kV +/- 450 kV 400 kV 220 kV 110 kV

Existing



Under construction



Planned



CONVERSIONS

400/110 kV



400/220/110 kV



220/110 kV



STATIONS:



Distribution



Distribution under construction



Distribution planned



POWER PLANTS:

Thermal



220 SN



Thermal under construction



Thermal planned



Water turbine



According to the Polish transmission system operator grids are prepared for up to 9 GW of wind power in 2020, so further increase of wind power would not cause any technical problems. What is more challenging is the fact that wind power reduces more and more load hours of operating coal power plants, which has been noticed by the Polish plants a few years ago. At the beginning, the Polish state-controlled utilities tried to keep pace with private investors and foreign utilities and took over their share in wind farm projects. The current market share of the Polish utilities in wind energy amounts to 20% which is relatively low compared to their overall market share. Since 2016 this strategy has changed and generally the Polish government does not intend to further increase the installed capacity of onshore wind farms, whose development has been blocked by introducing a required minimum distance of 10 times tip height from the next residential or valuable forests – for modern wind turbines with a 200m tip height the 10 times tip height rule practically stops further development of competitive onshore wind farms. Even in the event in which this exaggerated requirement would be reduced to a more moderate number, e.g. 5 times tip height, establishment of new master plans and

issuance of new environmental decisions will further delay the development, therefore no new farms will be on the grid before 2023/2024. Generally, this policy approach explicitly does not include offshore wind farms which, however, due to a long term of authorization and construction process will also not get connected to grid before 2023/2024.

This time frame is required for restructuring the Polish coal mining sector, but also for further modernisation of the grid infrastructure and, subsequently, for rolling-out smart meters for demand-response management on consumer markets. Recently, in February 2017, the Polish parliament enacted a special law regarding the extension of transmission infrastructure covering 28 investments. According to this law, administrative procedures are streamlined to achieve valid building permits for such investments, e.g. for further extension of the transmission grid infrastructure for the Kozienice coal power plant.

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The Polish balancing market is operated by PSE and open to all service providers. Generators from 50 MW (not including large wind farms) are managed by PSE in a centralised way for balancing services.

Balancing market and capacity market

The Polish balancing market is operated by PSE and open to all service providers. Generators from 50 MW (not including large wind farms) are managed by PSE in a centralised way for balancing services. At the balancing market a minimum price of PLN 70 per MWh is guaranteed (and a maximum price cap is also introduced), and for this reason the Polish energy market so far has not observed negative wholesale prices like Germany in case of high penetration of wind power.

Furthermore, PSE auctions a so-called cold reserve mechanism (so-called IRZ) and an operating (spinning) reserve mechanism (so-called ORM) with a one-hour reaction time (see also figure 22 “Monthly development of the installed capacity used in 2015” above) for scarcity purchase of electricity at peak-load between 7 a.m. and 10 p.m., both types of capacity reserve mechanisms, but not for market segments where a reaction time of less than one hour is required (primary reserve, secondary reserve, tertiary reserve) – especially this market segment should be strengthened by capacity markets according to the EU winter package. For primary reserve (a 30 second-reaction time) and secondary reserve (a 5 minute-reaction time) market no capacity mechanism has been implemented, and a tertiary reserve (a 15 minute-reaction time) market is not organized by PSE. In order to take part in the operating reserve mechanism, a generator has to qualify as a centrally-managed power generator (so-called JWCD), whereas (intermittent) RES generators do not qualify as such generators. In 2017, the budget for the existing operating reserve mechanism has been increased by 11% in the distribution tariffs (although power consumption increases in line with the GDP growth rate), however, the budget for the cold reserve mechanism is not subject to further increase.

Under the draft Revised Market Regulation as of the “winter package” regional cooperation will be strengthened. TSOs decide within the ‘Regional Operational Centres’ on those issues where fragmented and uncoordinated national actions could negatively affect the market and the consumers (e.g. in the fields of system operation, capacity calculation for interconnectors, security of supply and risk preparedness). Functions to be carried out at a regional level include “the dimensioning of a reserve capacity” and “the procurement of balancing capacity”. Therefore, the capacity markets will have to be regionalized for reserve capacity and balancing capacity services, which will have a major impact on the implementation of the planned Polish capacity market for large combustion plants. According to the EU Commission, regional tenders for those services are required, under the reservation that physical flows comply with the contracted services. Due to current energy mix, Polish utilities might not be competitive in such tenders.

The capacity markets shall also cover non-frequency services at the distribution grid level. However, this market segment does not face the market risk of international tenders. So, an alternative to strengthening frequency services at the national level might be strengthening ancillary services at the non-frequency level, i.e. at the distribution grid level. According to the Revised Market Regulation, the minimum bid size for those services is as little as 1 MW, and imbalance settlement periods are set to 15 minutes by 1 January 2025.

Smart meters and future role of consumers

According to the enacted version of the so-called Morawiecki Plan, a strategy planning document drawn under the leadership of the Minister for De-

velopment and Finance Mateusz Morawiecki, a roll-out of one million modern smart meters according to the EU definition covering 10 basic functions is planned by 2030. This planning has been mainly influenced by the URE Energy Regulatory Authority, which promoted a later roll-out of smart meters for full development of their potential after the grid in-

According to the enacted version of the so-called Morawiecki Plan, a strategy planning document drawn under the leadership of the Minister for Development and Finance Mateusz Morawiecki, a roll-out of one million modern smart meters according to the EU definition covering 10 basic functions is planned by 2030.

frastructure will have been enforced. However, due to an already high penetration of distribution grids by RES, this explanation does not seem to be fully understandable, as the distribution grids are already prepared for a high RES penetration, and the still lacking extension of the transmission grids has no influence on smart metering and smart grids as the distribution level. Currently, modern 10-function-smart meters as required by the EU Commission are not accepted as eligible costs for distribution tariffs by the URE. However, partly less-functional smart meters have been implemented by all DSOs, mainly by Energa amounting to approx. 800,000, but also by Tauron amounting to approx. 400,000 and by Innogy (former RWE Stoen) amounting to 50,000 – 100,000. A more conservative investment policy is favored by the largest DSOs PGE and Enea with a joint amount of the installed smart meters amounting to less than 100,000. According to the 2009 Third Energy Package, Poland, similarly to all member states, is subject to cost efficiency evaluation – and is motivated to roll-out smart meters in 80% of all households until 2020, i.e. currently 14 million households. This target will not be fulfilled as the development of grid infrastructure at distribution level is delayed. Therefore, with the Forth Energy Package currently processed, the EU Commission resigned from binding smart meter targets for the EU member states and counts on voluntary roll-out schemes by changing the tariff structure.

According to the draft of the revised EU Directive on the Internal Market for Electricity (the Revised IMED) to be implemented by the member states in 2021 the rights of consumers and prosumers are enhanced in various ways, e.g. (i) all consumers are entitled to request a dynamic price contract, where prices depend on fluctuating wholesale prices – this will put an end to the obliging tariff structure set by the Polish Energy Regulatory Office for consumers and will stimulate the voluntary roll-out of smart meters by the consumers -, (ii) the consumers will have the right to switch energy providers in case of price increase within three weeks, whereas termi-

nation penalties generally cannot be charged if the contract was not concluded for a fixed period of time, e.g. the contract included the purchase of a device like a smart meter, (iii) all the consumers are to be entitled to conclude contracts with aggregators, e.g. prosumers (the winter package calls them “active consumers”) with providers of virtual power plants, without the consent of their supplier, and to terminate such contracts within three weeks, (iv) “Local energy communities” will be strengthened, i.e. organisations “effectively controlled by local shareholders or members, generally non-profit driven or generally rather value- than profit-driven (...) engaged in the local energy generation, distribution, aggregation, storage, supply or energy efficiency services, including those across borders”.

Additionally, according to the draft of the revised Renewable Energy Directive (RED II), prosumers, or “renewable self-consumers”, shall be entitled to sell their surplus electricity “without being subject to disproportionate procedures and charges that are not cost reflective”, to receive a market price for electricity feed into the grid, and not to be regulated as electricity suppliers if they do not feed in more than 10MWh (as a household) or 500MWh (as a business) annually. In 2016 Poland has introduced a net-metering for individual prosumers operating RES generators with up to 10 kW installed capacity- slightly below above 10MWh threshold-, and there are plans in 2017/2018 to further extend net-metering for business prosumers operating micro-installations up to 50 kW or even small RES generators with up to 200 kW.

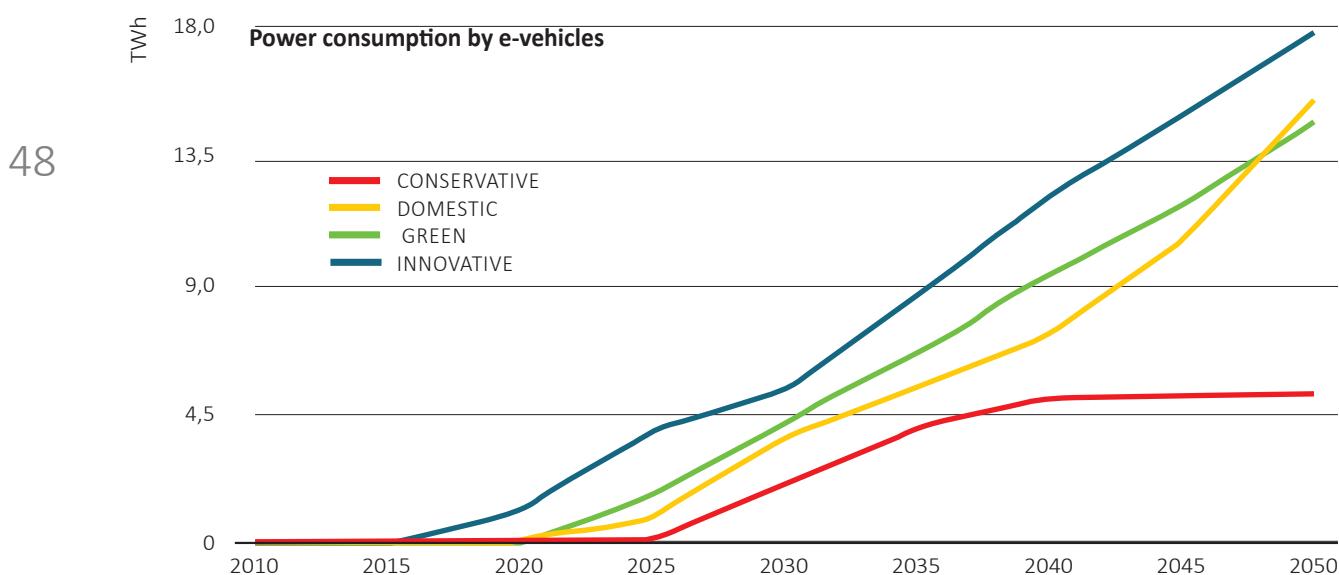
E-Mobility and storage facilities

One of the major strategic investments according to the Morawiecki Plan is e-mobility. The ambitious plan is that Poland will witness one million electricity-driven passenger cars by 2030 – the currently charging infrastructure is generally hardly installed and pure e-vehicles amount to a few hundred cars. For the time being, no special promotion programmes are yet clear, however, the Ministry of Energy and the Ministry of Development are working on this topic. Besides special promotion programmes, in order to motivate consumers to purchase e-vehicles and cities to purchase e-buses, this plan should also lead to an increase of power consumption. However, even most ambitious scenarios will not lead to a power consumption exceeding 5 TWh in 2030, and most likely a substantial part will be self-consumption of electricity produced by prosumers.

Figure 35

POWER CONSUMPTION SCENARIOS BY E-MOBILITY IN POLAND UNTIL 2050

SOURCE: INNOGY S.A.



Therefore, e-mobility will not be a game changer for electricity consumption in Poland, which might have a remarkable influence on the future energy mix.

However, the role of the Distribution System Operators (DSOs) in this attractive growing market is limited. According to the Revised IMED, DSOs may only “own, develop, manage or operate” charging points if the regulator allows them to after an open tender process in which nobody else expresses an interest in doing it. And even then, the service assumed by the DSO must be re-tendered every five years. Furthermore, similar open tender rules would apply to the development, operation and management of storage facilities by either DSOs or TSOs. For TSOs, there would be an additional requirement that the storage services or the facilities concerned are “necessary” to ensure efficient and secure operation of the transmission system, and are not used to sell electricity to the market.”



Part III: References

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Agricola, A.-C., Richard, P., Kobel, H., Einhellig, L., Behrens, K., von Preysing, L., . . . Meyer, R. (2014). Einführung von Smart Meter in Deutschland. Berlin: Deutsche Energie-Agentur GmbH (dena).

AHK. (28. 11 2016). Stromzonentrennung: E-Control verweist auf Preiszonen-Studie. Von <https://oesterreich.ahk.de/>: <https://oesterreich.ahk.de/newsroom/news/news-detailansicht/stromzonentrennung-e-control-verweist-auf-preiszonen-studie/> abgerufen

BDEW. (2014). Einführung des ERRP-Planungsprozesses zur Meldung von Kraftwerksdaten an die ÜNB. Implementation Guide für Deutschland. Berlin: Version 2.0.

Bloomberg. (2 2016). Here's How Electric Cars Will Cause the Next Oil Crisis. Von Bloomberg: <http://www.bloomberg.com/features/2016-ev-oil-crisis/> abgerufen

BMWi. (2014). Ein Strommarkt für die Energiewende – Diskussionspapier des Bundesministeriums für Wirtschaft und Energie. Berlin: Grünbuch.

BNetzA. (30. 10 2012). Beschluss in dem Verwaltungsverfahren der Festlegung von Kriterien für die Bestimmung einer angemessenen Vergütung bei strombedingten Redispatch-Maßnahmen und bei spannungsbedingten Anpassungen der Wirkleistungseinspeisung. S. K8-12-019-A.

BNetzA. (01. 02 2013). Regelenergie. BNetzA. Bonn. Von http://www.bundesnetzagentur.de/cln_1432/DE/Sachgebiete/ElektrizitaetundGas/Unternehmen_Institutionen/Versorgungssicherheit/Stromnetze/Engpassmanagement/Regelenergie/regelenergie-node.html abgerufen

50

BNetzA. (2014). Monitoringbericht 2014. Bonn: Bundesnetzagentur.

BNetzA. (2015). Monitoringbericht 2015. Bonn: Bundesnetzagentur.

BNetzA. (2016). 3. Quartely Report 2015 regarding network and security measures. Bonn.

BNetzA. (2016). Monitoringbericht 2016. Bonn: Bundesnetzagentur.

Büchner, J., Katzfey, J., Flörcken, O., Moser, A., Schuster, H., Dierkes, S., . . . van Amelsvoort, M. (2014). „Moderne Verteilernetze für Deutschland“ (Verteilnetzstudie). Berlin: BMWi.

Bundesnetzagentur. (2016). Monitoringbericht. Bonn.

Burger, B. (2017). Stromerzeugung in Deutschland im Jahr 2016. Freiburg: Fraunhofer-Institut für Solare Energiesysteme ISE.

Burges, K., Döring, M., Nabe, C., Härtel, P., Jentsch, M., & Pape, C. (2014). Untersuchung Energiespeicher in Schleswig-Holstein. Kurzfassung. Berlin: Ecofys, Fraunhofer IWES.

burof. (2017). 10 Batterie-Großspeicher im Megawattbereich sind installiert, rund 10 sind im Bau. Von <http://www.burof.de/> abgerufen

Castillo, A., & Gayme, D. F. (11 2014). Grid-scale energy storage applications in renewable energy integration: A survey. Von Energy Conversion and Management, Volume 87: <http://dx.doi.org/10.1016/j.enconman.2014.07.063> abgerufen

Coibion, A., Pickett, J., Gracia, N., Pritzsche, K. U., Lignières, P., Gimenez, J., . . . Van Driessche, L. (December 2016). European Commission presents Energy Winter Package. Linklaters.

DoE. (2016). U.S. Department of Energy (DoE) Global Energy Storage Database. Von <http://www.energystorageexchange.org/> abgerufen

DOE Global Energy Storage Database. (2017). Von <http://www.energystorageexchange.org/> abgerufen

EC. (30. 11 2016). Final Report of the Sector Inquiry on Capacity Mechanisms . Von <http://ec.europa.eu/>: http://ec.europa.eu/competition/sectors/energy/capacity_mechanisms_final_report_en.pdf abgerufen

EC. (13. 04 2016). Interim Report of the Sector Inquiry on Capacity Mechanisms. Von <http://ec.europa.eu/>: http://ec.europa.eu/competition/sectors/energy/capacity_mechanisms_swd_en.pdf abgerufen

EC. (n.d.). Smart grids and Meters. Von <https://ec.europa.eu/>: <https://ec.europa.eu/energy/en/topics/markets-and-consumers/smart-grids-and-meters> abgerufen

Ecofys. (2012). Abschätzung der Bedeutung des Einspeisemanagements nach § 11 EEG und § 13 Abs. 2 EnWG. Auswirkungen auf die Wind-energieerzeugung in den Jahren 2010 und 2011. Berlin.

Ecofys. (2013). Abschätzung der Bedeutung des Einspeisemanagements nach § 11 EEG und § 13 Abs. 2 EnWG. Auswirkungen auf die Wind-energieerzeugung in den Jahren 2011 und 2012. Berlin.

Ecofys. (2015). Weiterentwicklung des Einspeisemanagements. Bewertung von Ansätzen. Berlin: Hg. v. BWE.

Egerer, J., von Hirschhausen, C., Weibezahl, J., & Kemfert, C. (2015). Energiewende und Strommarktdesign: Zwei Preiszonen für Deutschland sind keine Lösung. DIW, 183-190.

EIA. (2012). Annual Energy Outlook. Von U.S. Energy Information Administration: <https://www.eia.gov/todayinenergy/detail.cfm?id=6930> abgerufen

ene't. (2017). www.enet.eu. Von www.enet.eu/portfolio/analysen/karten abgerufen

Entso-e. (2016). Annual Report 2015 Electricity without boarders. Von <http://online.fliphtml5.com/ovdo/apbz/index.html#p=54> abgerufen

FrontierEconomics. (2013). Bidding zone configuration. London: frontier, consentec.

Götz, P., Henkel, J., Lenck, T., & Lenz, K. (2014). Negative Strompreise: Ursachen und Wirkungen. Eine Analyse der aktuellen Entwicklungen und ein Vorschlag für ein Flexibilitätsgesetz. Berlin: Agora Energiewende.

GTAI. (11 2015). Market Status & Outlook on Batteries for Stationary Energy Storage in Germany.

Hirth, L., & Ziegenhagen, I. (2015). Balancing Power and Variable Renewables: Three Links. Von [Neon-energie.de: http://www.neon-energie.de/Hirth-Ziegenhagen-2015-Balancing-Power-Variable-Renewables-Links.pdf](http://www.neon-energie.de/Hirth-Ziegenhagen-2015-Balancing-Power-Variable-Renewables-Links.pdf) abgerufen

ICIS. (01. 09 2016). ACER to back Germany-Austria electricity zone split, €25bn of open positions at stake. Von [www.ICIS.com: https://www.icis.com/resources/news/2016/09/01/10030712/acer-to-back-germany-austria-electricity-zone-split-25bn-of-open-positions-at-stake/](http://www.icis.com/resources/news/2016/09/01/10030712/acer-to-back-germany-austria-electricity-zone-split-25bn-of-open-positions-at-stake/) abgerufen

Industriemagazin. (21. 12 2016). Industriestrom wird 2018 erheblich teurer. Von [www.industriemagazin.at:](http://www.industriemagazin.at/) [https://www.industriemagazin.at/a/industriestrom-wird-2018-erheblich-teurer](http://www.industriemagazin.at/a/industriestrom-wird-2018-erheblich-teurer) abgerufen

IRENA. (2015). Battery storage for renewables: market status and technology outlook. Von International Renewable Energy Agency: http://www.irena.org/DocumentDownloads/Publications/insight_Battery_Storage_report_2015.pdf abgerufen

ISEA. (2016). Wissenschaftliches Mess- und Evaluierungsprogramm Solarstromspeicher. Von ISEA RWTH Aachen: http://www.speichermonitoring.de/fileadmin/user_upload/Speichermonitoring_Jahresbericht_2016_Kairies_web.pdf abgerufen

JRC. (2014). Energy Technology Reference Indicator projections for 2010-2050. Von <http://publications.jrc.ec.europa.eu/repository/handle/JRC92496> abgerufen

Lazard. (11 2015). Lazard's leveled cost of storage analysis. Von <https://www.lazard.com/perspective/leveled-cost-of-storage-analysis-10/> abgerufen

MELUR. (2015). Abregelung von Strom aus Erneuerbaren Energien und daraus resultierende Entschädigungsansprüche in den Jahren 2010 bis 2014.

Nabe, C., & Neuhoff, K. (2015). Intraday- and real time activity of TSOs: Germany. Von <https://ideas.repec.org/p/zbw/esrepo/111265.html> abgerufen

Netzentwicklungsplan Strom. (2015). Netzentwicklungsplan Strom 2025, Offshore-Netzentwicklungsplan 2025. Version 2015, 1. Entwurf. Zahlen-Daten-Fakten.

Prof. Rehtanz, C., Greve, M., Dr. Häger, U., Hilbrich, D., Kippelt, S., Kubis, A., . . . Teuwsen, J. (2014). Requirements for a secure and reliable power supply with a high percentage of renewable energy. Berlin: dena.

52

Prof. Sterner, M., Thema, M., Eckert, F., Prof. Moser, A., Dr. Schäfer, A., Drees, T., . . . Stöcker, P. (2014). Stromspeicher in der Energiewende. Berlin: Agora Energiewende.

RMI. (2014). The economics of grid defection. Von Rocky Mountain Institute: http://www.rmi.org/PDF_economics_of_grid_defection_full_report abgerufen

Roland Berger. (15. 11 2012). Technology / Market Drivers for Stationary and Automotive Battery Systems. Von Roland Berger: http://www.google.be/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=0ahUKEwjgwtiUoKnMAhWjOsAKHdzeAEoQFggoMAE&url=http%3A%2F%2Fonlinelibrary.wiley.com%2Fdoi%2F10.1002%2Fese.3.47%2Ffull&usg=AFQjCNHD3n6z4jToxWqg-6RUg26G8Y3xfQ&sig2=EEc2-Zmg_hfA83F abgerufen

Sauer, D. U. (12. 9 2016). Problemstellungen von Speichern und Flexibilitätsproblematik. Von RWTH Aachen: Potsdam abgerufen

Schleswig-Holstein Netz AG. (2017). EEG-Kataster. Planung in den Netzgebieten. Last time checked on 02.01.2017.

Thalmayr, C. (4. 12 2015). E-Control: Breite Front gegen Trennung des gemeinsamen Strommarktes mit Deutschland . Von E-Control: https://www.e-control.at/documents/20903/388512/2015_12_04_PA_Zwischenbilanz_Klage_Beschwerde_Strompreiszone.pdf/e843a2fe-9b6a-40da-8d47-d27b27f956cf abgerufen

Zakeri, B., & Syri, S. (2 2015). Electrical energy storage systems: A comparative life cycle cost analysis. Von Renewable and Sustainable Energy Reviews, Volume 42: <http://dx.doi.org/10.1016/j.rser.2014.10.011> abgerufen

Zha, W. (28. 09 2016). Austria Bides Time as Ejection From Top EU Power Market Looms. Von www.bloomberg.com: <https://www.bloomberg.com/news/articles/2016-09-28/austria-bides-time-as-ejection-from-top-eu-power-market-looms> abgerufen

