

Market Review

2015

Electricity market
insights

Introduction



For those with a professional interest in the electricity sector, TenneT publishes this yearly TenneT Market Review. In this publication we describe the developments in the Western European electricity market, particularly in the Netherlands and Germany, where, as the transmission system operator (TSO), TenneT has a central role in facilitating the market.

In this publication we give you the highlights of what was a dynamic year for the electricity market and put the most important developments into perspective, allowing you to deepen your knowledge of the events driving the market in 2015.

While average wholesale prices rose in the majority of European countries, including Belgium and France, they decreased in Germany and the Netherlands. For Germany this was the fourth time in a row and in the Netherlands the third successive time.

This price development was driven by the developments in the production capacity. Renewable energy production capacity grew strongly again in Germany, following the long-term subsidy policy. The new offshore wind farms that were connected to the TenneT grid contributed significantly. Also, the Netherlands showed some growth in the installed capacity of renewables, but here the main development came from the full commercial production of the three new coal-fired power plants. Belgium was hit by a number of planned and unplanned outages, which led to a sharp increase in imports from the Netherlands and France, resulting in record exports for the Netherlands.

The increased need for imports into Belgium was facilitated by the go-live of Flow Based market coupling for Germany, the Netherlands, France and Belgium. This enlarged the possibilities to make capacity available for international trade, on the border where it is most valuable.

In this fourth edition of the TenneT Market Review, we also want to draw your attention to the substantial impact that the German energy transition has on the daily operation of the electricity system. Replacing conventional generation by renewable generation on a different location and with different production patterns in 2015 led to a situation where redispatch measures were needed on 90% of the days. The ongoing grid reinforcements will alleviate this problem.

This TenneT Market Review was created in close cooperation with IAEW from RWTH Aachen University, and we hope that you will enjoy reading it as much as we enjoyed creating it.

Day-ahead price developments

In 2015, average wholesale prices in Germany and the Netherlands dropped further. Prices also decreased in Poland and the Nordic countries. Other European countries witnessed rising wholesale prices in 2015.

Figure 1 shows the development of wholesale prices for the Central Western Europe (CWE) region of Germany, the Netherlands, Belgium and France.

The yearly average price (base price) in Germany went down by 3.6% in 2015 to 31.63 €/MWh and also in the Netherlands by 2.7% to 40.05 €/MWh. For Germany it was the fourth year in a row of decreasing wholesale prices.

Wholesale prices in France and Belgium were on average higher than in 2014, with price peaks in February and October. On average, the French and the Dutch wholesale prices were almost equal in 2015, where the French price used to be much lower. Belgian prices were highest in the CWE region, notably in April, September and October.

Base prices across Europe are depicted in Figure 2. The price levels for different European market areas for 2014 and 2015 are visualised by the colours: the greener the colour of the market area, the lower the price. In addition, Figure 2 shows the percentage of hours in which a country had the exact same wholesale price as the Dutch, respectively the German, market area (i.e. full price convergence). Germany and Austria constitute one market area, meaning there is full price convergence of 100%.

In 2015, prices dropped in Nordic countries, Poland, Germany and the Netherlands. Conversely, the prices of all other market areas went up on average.

Monthly Average Day-ahead Wholesale Prices in CWE countries

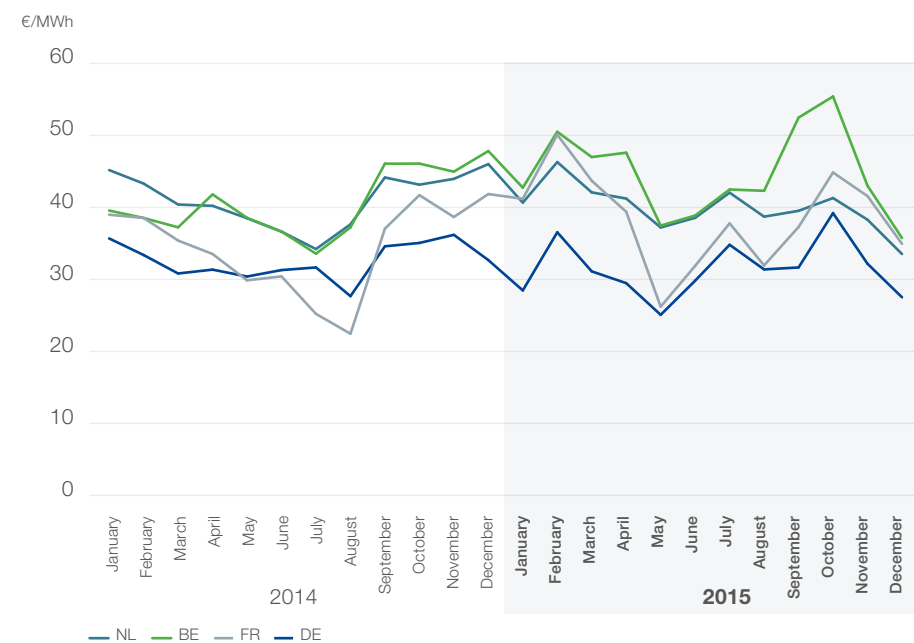


Figure 1: Monthly average of hourly Day-ahead wholesale prices in CWE countries.
Source: EPEX Spot, energeat

Day-ahead price developments

Price convergence generally remains at similar levels. The price convergence of Belgium with the neighbouring countries decreased in 2015. Also the number

of hours with full price convergence between France and Germany and between Denmark and Germany decreased.

European Wholesale Prices and Price Convergence

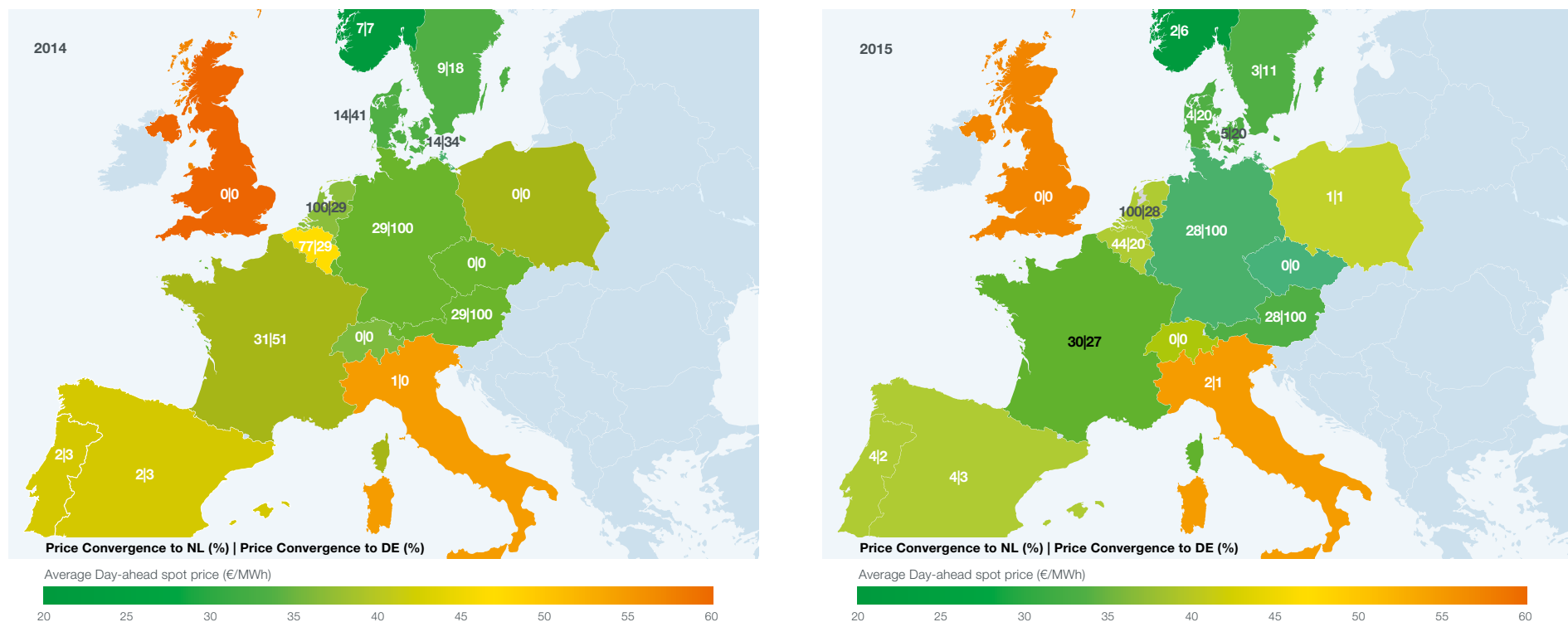


Figure 2: Yearly average of hourly Day-ahead prices and % hours full price convergence (in relation to the Dutch and German market area) of different market areas¹ in Europe.

Source: energeat, APX, EEX, Nordpool Spot, POLPX, OTE, GME, OMIP

¹ For countries with multiple market areas, one market area interconnected to one in another country was chosen: Italy: North, Norway: NO2, Great Britain: GB2

Day-ahead price developments

Figure 3 shows the development of full price convergence in the CWE region in more detail. The monthly pattern of the convergence between German and Dutch prices in 2015 is similar to that of the previous year, but with lower values in spring and higher values in autumn.

Among other CWE countries, greater differences could be observed with lower full convergence in 2015 compared to 2014 for most months. Between the Netherlands and Belgium, significantly lower price convergences were witnessed from April onward. Price convergence was very low between France

Price Convergence between CWE countries

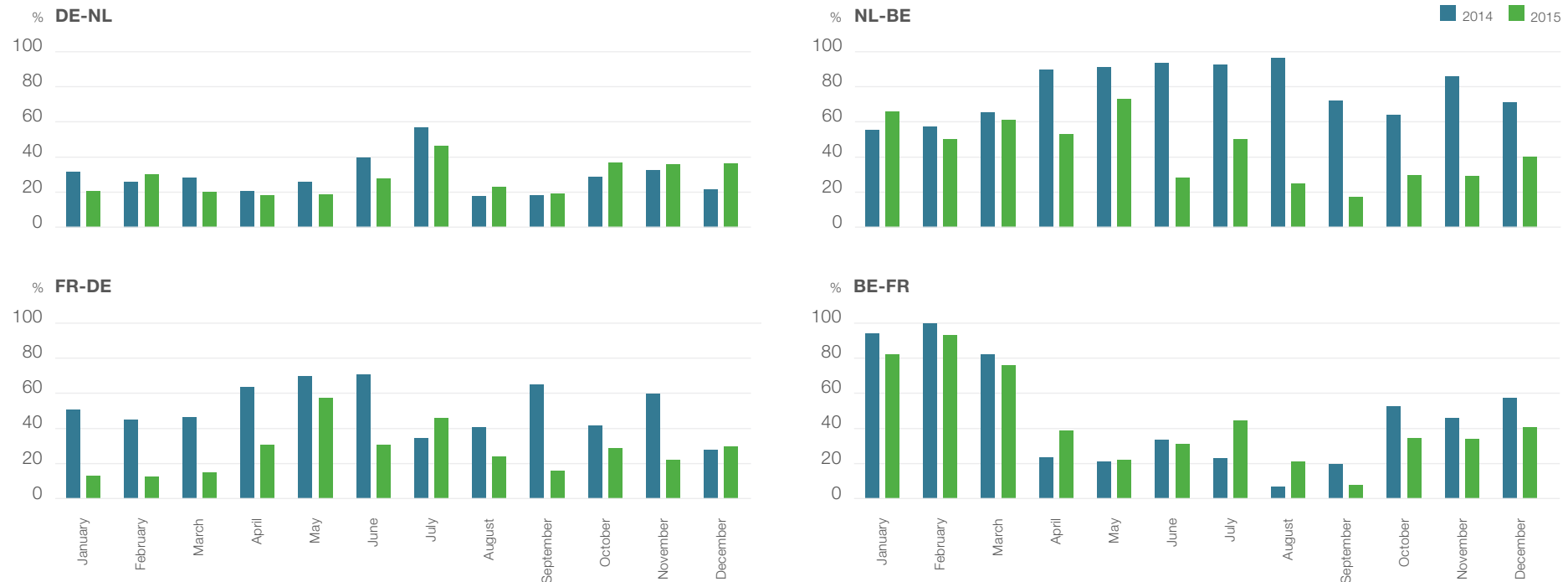


Figure 3: Shares of hours with full price convergence between CWE countries (2014-2015). Source: EPEX Spot, energate

Day-ahead price developments

and Germany with the exception of May and July. Although there were high levels of price convergence between Belgium and France returned in the first three months, it was low for the rest of the year, with Belgian prices structurally above French prices.

The standard deviations of hourly Day-ahead prices in Europe are shown in Figure 4. In general, price movements were less volatile and more evenly distributed, with the exception of Belgium. The standard deviation in Belgium is heavily impacted by two days with extreme prices (cf. chapter 9).

Especially prices in Poland and Spain were less volatile, while prices in the Nordic countries were more volatile, moving slightly in the direction of other countries on the levels of the European electricity market.

Prices in the Nordics and the Netherlands were the ones with the lowest price volatility in 2015. All bidding zones adjacent to the Netherlands (Germany, Belgium and Great Britain) showed a higher volatility compared to the Netherlands in 2015.

Volatility of European wholesale prices

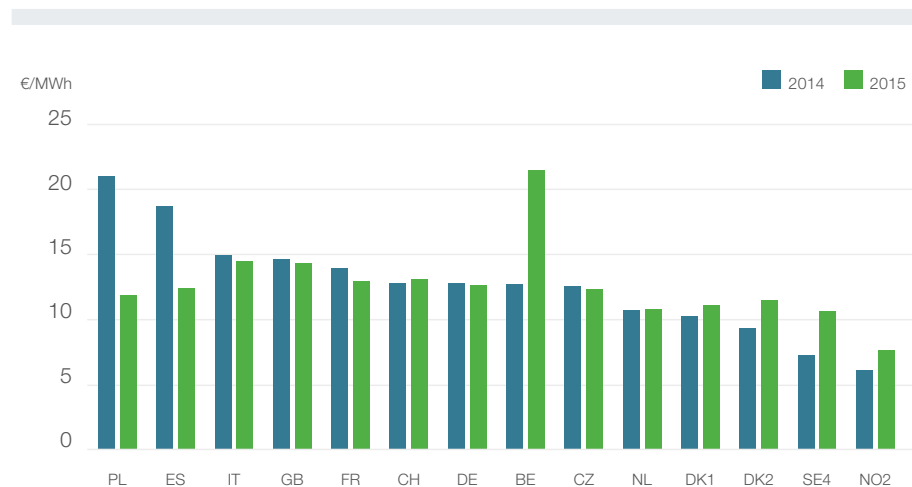


Figure 4: Standard deviation of European Day-ahead wholesale prices in 2014 and 2015.
Sources: EPEX Spot, Energate, APX, EEX, Nordpool Spot, POLPX

Flow Based Market Coupling

On May 20th 2015, Flow Based² Market Coupling (FB) had its go-live in the CWE region. Due to the sophisticated capacity calculation used in FB, import and export capacities increased. This had a dampening effect on wholesale prices in the Netherlands and Belgium.

Under FB, a sophisticated capacity calculation procedure enables the use of the transmission capacity of the grid to be optimized. The previous Available Transfer Capacity (ATC) based market coupling used fixed values for the interconnection capacity between the countries of the CWE. Now, under FB, a domain of possible combinations of flows is used in the market coupling algorithm. This allows for more degrees of freedom for the algorithm to optimize. This optimization can lead to flows between countries that are larger than under ATC. This is clearly shown in Figure 5, where an increase of net positions³ can be observed after the introduction of FB on May 20th.

There are two possible ways to look at the price developments since the introduction of the FB. The first one is to compare historical prices and their convergences before the introduction of FB with the prices after the introduction. Obviously, that does not take into account changes in other factors that determine price levels and price convergence discussed in the following chapters. The second way is to compare the actual outcome with the outcome of the parallel run⁴. This has the drawback that changes in bidding behaviour are not taken into account.

Changes of Price Deltas since FB went live

In Figure 1 we saw a decreasing price delta between the Netherlands and Germany after the introduction of FB. Figure 6 below shows the distribution of price deltas between selected combinations of CWE market areas in 2014 and 2015. The results show only minor changes in the distribution of price differences between the Netherlands and Germany as well as Belgium and France in these two years. In contrast, the price differences between both the Netherlands and Belgium, and France and Germany show significant changes. Less price convergence and a greater number of high price differences between these bidding zones can be observed. This reflects the insight of Figure 6 that less price convergence between the Netherlands and Belgium occurred. Additionally, a broader range of price differences, in some cases exceeding 20 €/MWh, can be noticed.

² In this report we only discuss Flow Based Intuitive Market Coupling (as implemented) which only allows positive commercial schedules from market areas with lower prices into market areas with higher prices.

³ The net position of a market area is the volume it will export or import in a given hour resulting from the nominations on long-term capacities and the outcome of the market coupling calculations.

⁴ Before go-live there was a FB parallel run, after go-live there was an ATC parallel run until September.

Flow Based Market Coupling

CWE Flow based net positions

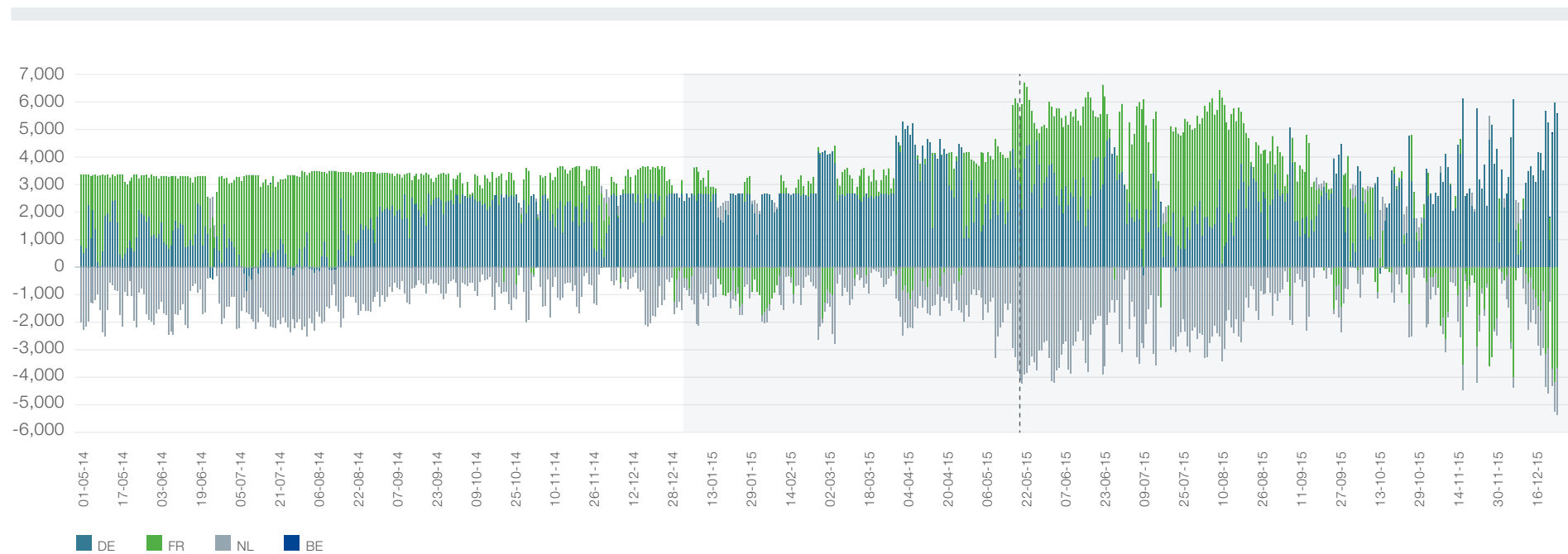


Figure 5: Daily net positions of CWE countries from May 2014 – December 2015. Source: ENTSO-E

Flow Based Market Coupling

Impact of Flow Based on Hourly Price Difference between CWE countries



Figure 6: Hourly price difference between the CWE countries divided over clusters of price difference for 2014 and 2015. Source: EPEX Spot, energeat

Comparing FB with ATC parallel run

To exclude the impact of other influencing factors, we have to evaluate the functioning of FB based on the results from the parallel run. Figure 7 shows the resulting number of price areas for the FB and the parallel ATC run in

the CWE region for May to September 2015. Structural differences between the market results from FB and the ATC model can be observed, showing that FB leads to more differentiated results.

Flow Based Market Coupling

On the one hand, the FB approach presents more hours of full price convergence in all CWE countries. On the other hand, there is a higher share of hours in which the CWE region is split into four price areas. In contrast, the ATC methodology mostly results in two or three price areas. So, the full price convergence increases between two countries, whereas the partial price convergence in CWE decreases with FB.

This leads to two main findings: firstly, a more efficient and flexible allocation of available capacities is accomplished; secondly, the existing available capacities are still restrictive for achieving full price convergence for the whole CWE region, but monthly levels around 40% were reached in May and July.

Figure 8 plots the Day-ahead prices⁵ against the net positions⁶ of the market area for the FB and the parallel run with an ATC calculation. Looking at the net positions of Belgium, it is obvious that FB allows for significantly larger imports (negative net positions) into Belgium. FB is much less restrictive than ATC.

The same is apparent for Germany and France, which have both higher positive and negative net positions, indicating that FB provides additional room for the market. Even though FB enables the Netherlands to increase imports, the bottom right graph in Figure 8 indicates a restriction at around 4 GW. This limit reflects an external constraint which is added by the TSOs to the FB algorithm to ensure system reliability. Overall, imports in the CWE region under FB were 43% higher than they would have been under ATC, whereas exports were 30% higher.

⁵ Please note that on this scale the graph does not show the extreme price levels that occurred in Belgium; please refer to Chapter 9 where these situations are discussed

⁶ The net position of a country is the amount of electricity this country imports or exports in a given hour following the outcome of the market coupling calculations

Flow Based Market Coupling

Comparing the resulting prices of the two methodologies in the period May until September, it can be noted that the average wholesale prices of the Netherlands and Belgium decreased considerably as a result of FB, whilst average prices increased slightly in Germany and France, as shown in the table below.

	FB	ATC	Difference
BE	44.1	55.1	-20.0%
NL	39.9	46.7	-14.7%
DE	32.2	30.9	4.0%
FR	34.9	32.7	6.9%

Impact FB on the shares of the number of price areas within CWE countries

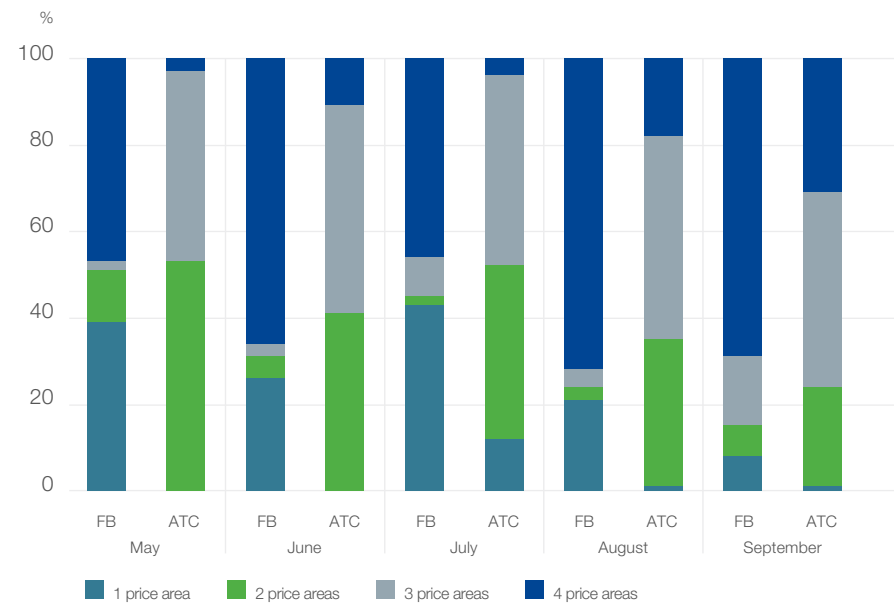


Figure 7: Shares of the number of price areas within CWE for Flow Based and the parallel run ATC for May-September. Source: TenneT

Flow Based Market Coupling

Flow Based effects on wholesale prices and net positions

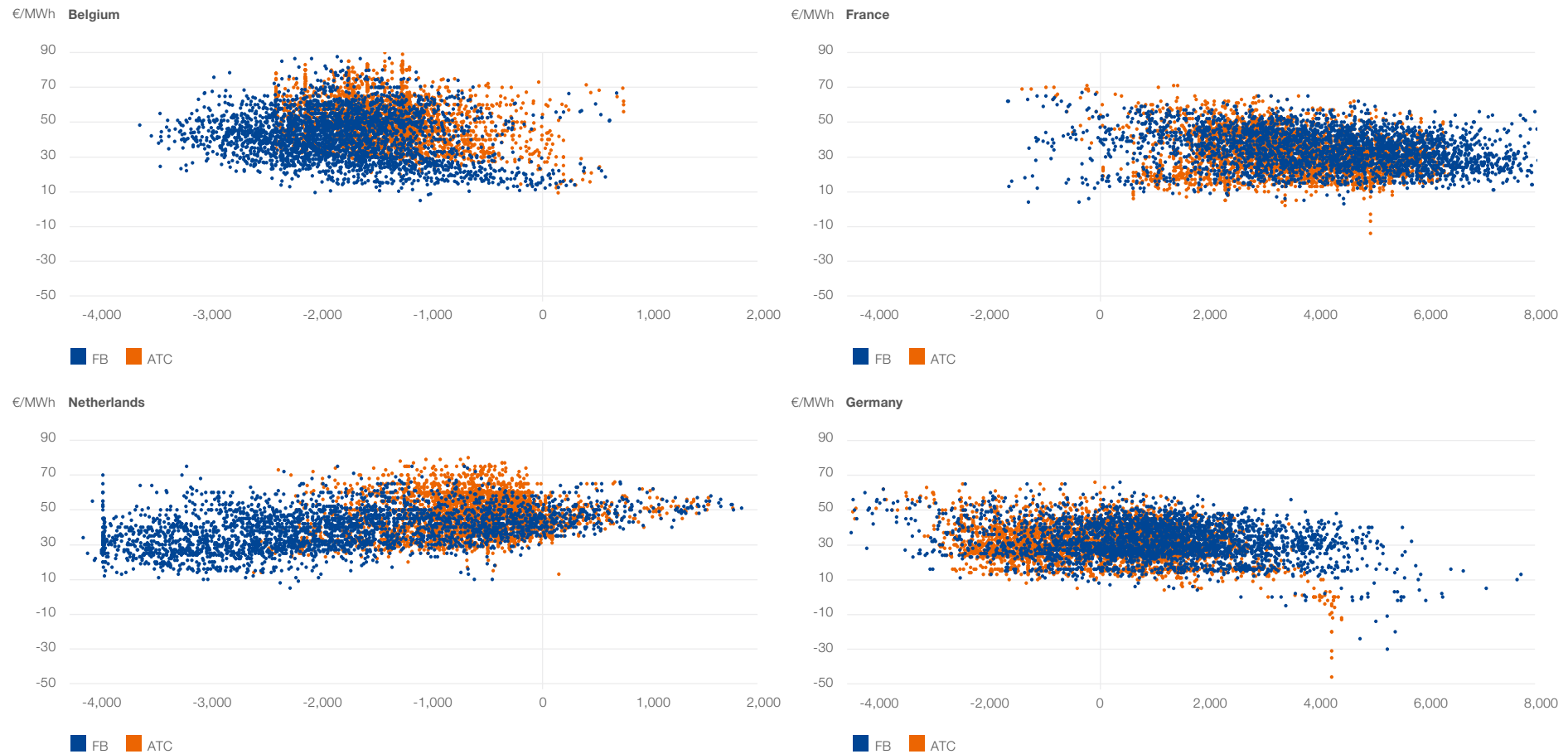


Figure 8: Average Day-ahead wholesale prices and net positions for the CWE countries as in FB and in the parallel run ATC from May-September 2015. Source TenneT

Flow Based Market Coupling

Figure 9 underlines the fact that capacity calculation used in FB provides additional room for the market on the border of the Netherlands and Germany. The dashed black line represents the exchanges from Germany to the Netherlands in 2015 in descending order. In about 1,500 hours the import exceeds the limit that was used in the ATC Market Coupling methodology.

In summary, the investigation of the parallel run of FB and ATC methodology leads to the conclusion that FB has been implemented and is now working successfully. In general, the advanced capacity calculation methods applied in FB provide more cross-border capacity where the value is highest.

Duration Curves Commercial Exchanges between Germany and the Netherlands

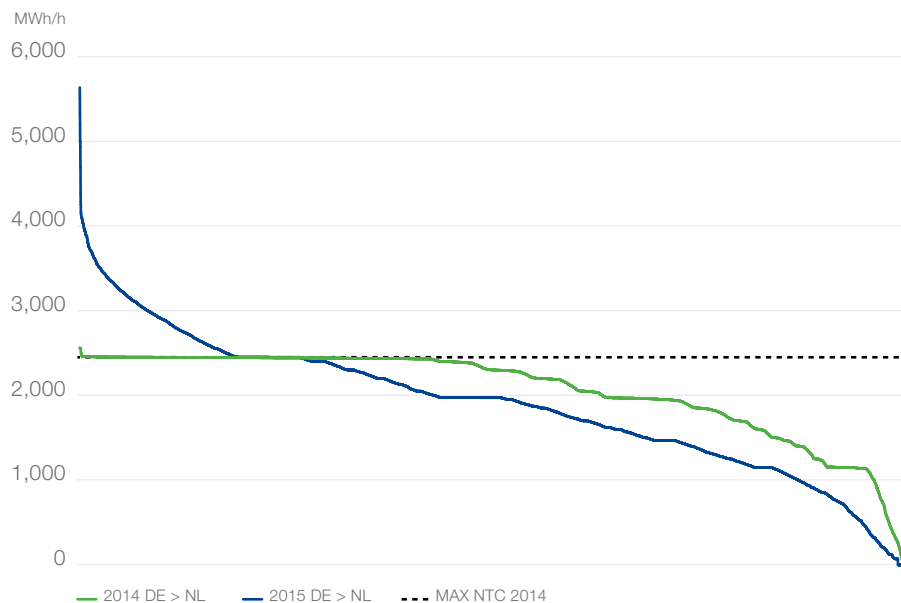


Figure 9: Duration Curves of the Commercial Exchanges between Germany and the Netherlands in 2014 and 2015 compared with the NTC cap in 2014. Source: ENTSO-E

Consumption and production

In Germany, conventional power plants are being replaced by wind and solar, leading to a record renewable production of 32.5% of domestic demand. In the Netherlands, renewables are growing, but at a much lower pace; coal-fired power plants replaced gas-fired power plants. The development of gas and coal prices brings electricity prices in the two countries closer together.

Consumption

As depicted in Figure 10 a downward trend of electricity consumption in CWE can be reported for recent years. But this trend was not maintained in 2015. A slight increase of consumption in Belgium, the Netherlands and France could be witnessed, whereas the consumption in Germany remains on a downward trend for the fifth year in a row.

Annual electricity consumption compared to the base year 2010

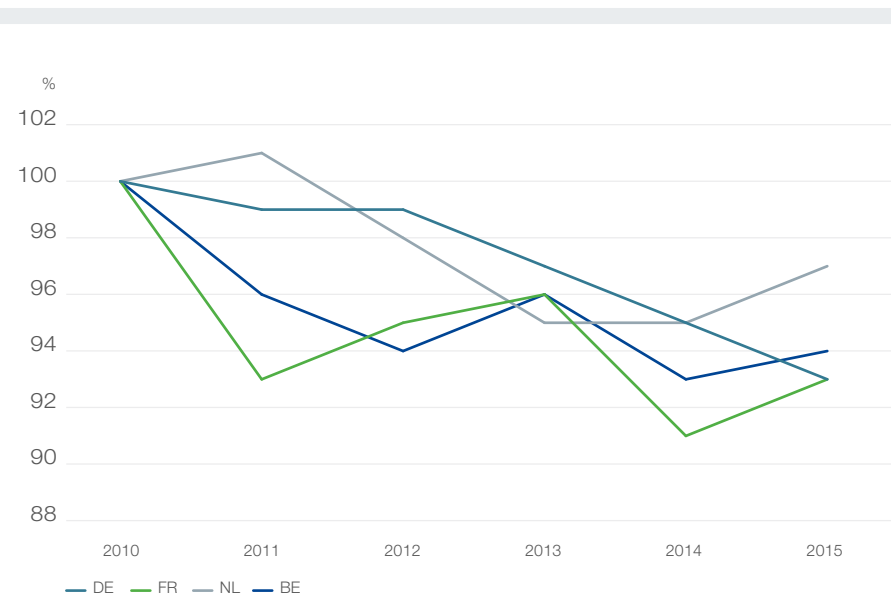


Figure 10: Annual electricity consumption compared to the base year 2010 in CWE countries.
Source: ENTSO-E

Consumption and production

Figure 11 shows the monthly demand of CWE countries in 2015 and 2010. There are no monthly structural changes observable. The demand has slightly decreased in 2015 throughout CWE since 2010. Besides economic growth, innovations and efficiency measures, the temperature profile is also a driver for the amount of electricity consumption. This can be further illustrated with the example of the consumption in December for France in 2010 and 2015. The average temperature in Paris in December 2010 was 0° Celsius in contrast to 9° Celsius in 2015, which led to much higher consumption in December 2010 than in 2015.⁷

Development of Monthly Electricity Consumption in CWE countries

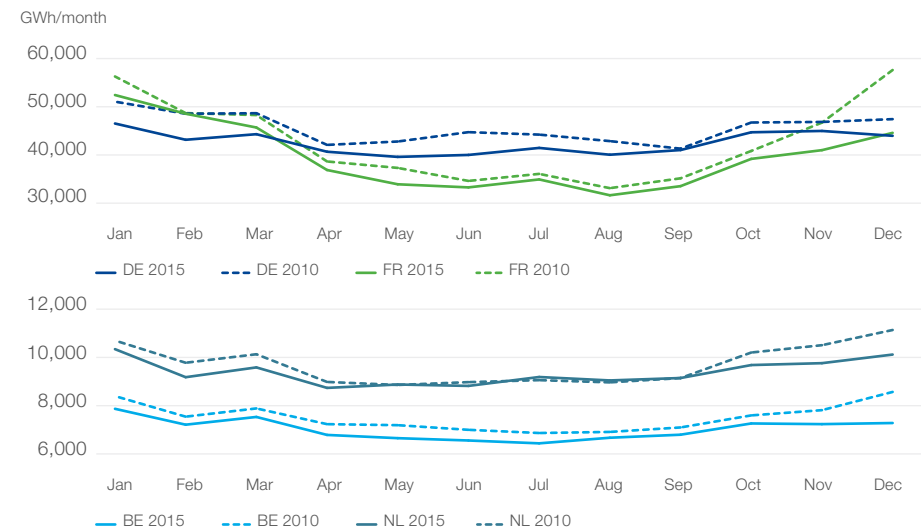


Figure 11: Monthly electricity consumption in CWE countries. Source: ENTSO-E

In order to compare the demand between 2014 and 2015, Figure 12 shows the differences in demand between 2014 and 2015. Interestingly, French electricity consumption in February was on average 4 TWh/month higher in 2015 due to lower temperatures in 2014. A high heating demand leads to an increased electrical demand due to the widespread electric heating systems in France. This was one fundamental driver for the observed high prices in February 2015 in France. In contrast, the consumption in December 2015 was almost 5 TWh/month lower compared to 2014, which can be explained by the previously

⁷ Temperatures from Weather Underground

Consumption and production

mentioned high average temperature in 2015. Therefore, the low consumption in this month can be identified as one driver for the low prices in France in December 2015.

Monthly Load differences in CWE countries

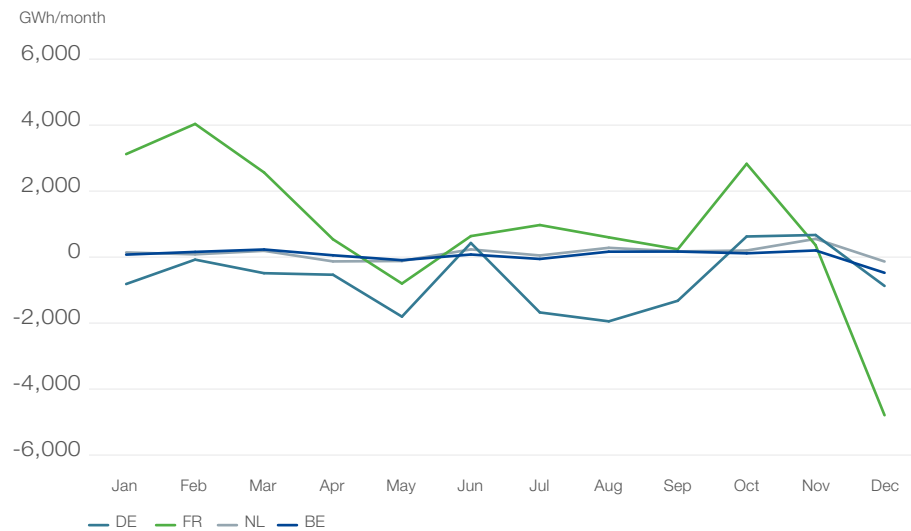


Figure 12: Monthly electricity consumption delta between 2015 and 2014 in CWE countries.
Source: ENTSO-E

Consumption and production

Production

The supply side of the German and Dutch power systems are analyzed below. The following paragraphs provide an overview of the Dutch and German electricity production by looking at the three main drivers: generation stack, generation including renewable generation, and fuel prices.

Dutch and German generation capacity

The trend of increasing generation capacities based on renewable energy sources in Germany, which could be witnessed over the last years, continued in 2015. Figure 13 compares the operating capacities between 2014 and 2015, showing the transition from conventional to renewable.

Power plants fired by oil, natural gas or hard coal and one nuclear power plant were shut down. Following the German political decision to gradually phase out nuclear until 2022, the power plant Grafenrheinfeld (1275 MW), located in the north of Bavaria was, shut down at the end of June 2015.

In contrast, a high increase of renewable generation was observed. The offshore capacity in 2015 increased fourfold from 2014, with an absolute increase of more than 2 GW.

Including generation capacities based on solar power, hydro and biomass, the addition of renewable generation came to more than 6.8 GW in compared with the 2.8 GW of nuclear and fossil-fuel power plants that were decommissioned.

German Operating Generation Capacities

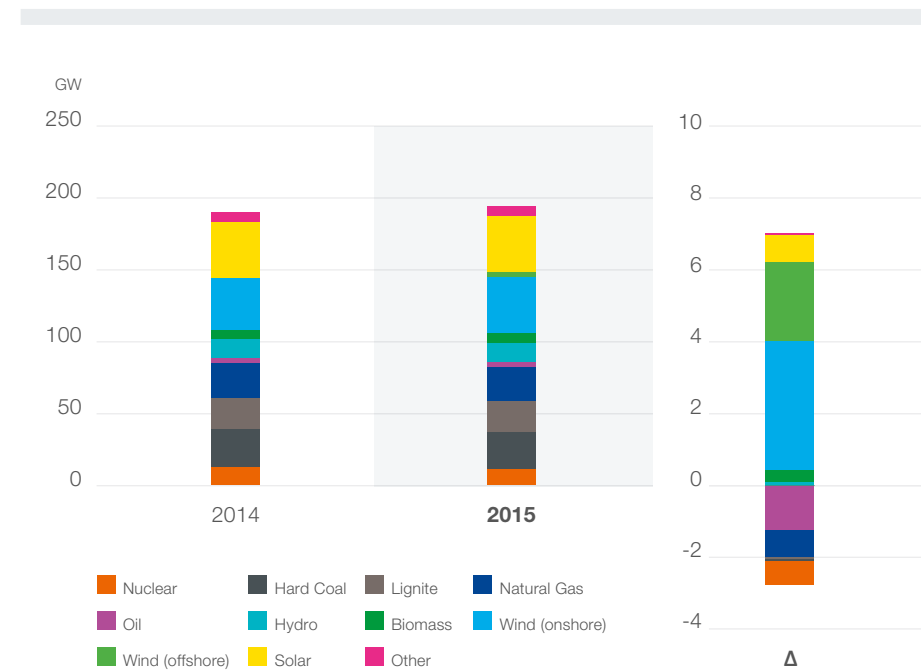


Figure 13: German Operating Generation Capacities in 2014 (at 29 October 2014) and 2015 (at 10 November 2015) per fuel type and the changes in Generation Capacities in 2015.
Source: Kraftwerkslisten der Bundesnetzagentur

Consumption and production

Figure 14 shows the development of operational generation capacity in the Netherlands. Overall in 2015 the coal-fired capacity decreased in the Netherlands as a result of the closing of three older coal-fired power plants with a combined power of 1.6 GW at the end of 2015 (officially at January 1st 2016). Since the hard coal-fired generation capacity increased in 2014 with 1.5 GW and the abovementioned closures to place at the end of 2015, the Dutch generation capacity throughout 2015 was characterized by a temporary higher share of coal-fired capacity. Operational capacity of gas-fired power plants showed an continuing decreasing trend with a reduction of 1.9 GW in 2014 followed by a reduction of 0.9 GW in 2015, of which 0.4 GW was mothballed.

Also in the Netherlands, the installed capacity based on wind and solar sources increased in 2015. The installed capacity of solar panels showed an estimated growth in 2015 of 0.35 GW resulting in a projected installed capacity of 1.4 GW at January 1st 2016. The generation capacities based on wind increased by 0.6 GW last year, reaching a total of more than 3.6 GW at the end of 2015.

Dutch Operating Generation Capacities

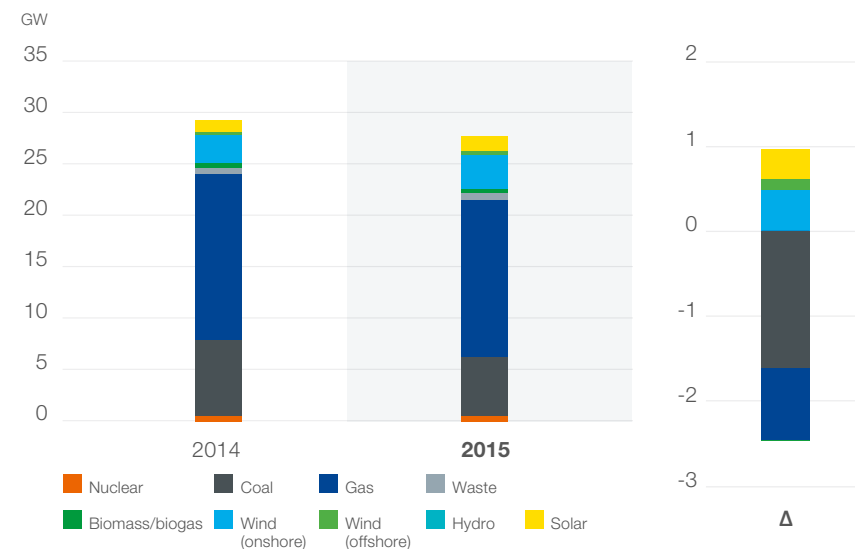


Figure 14: Dutch Operating Generation Capacities in 2014 (at 1 January 2015) and 2015 (1 January 2016) per fuel type and the changes in Generation Capacities in 2015.

Source: TenneT

Consumption and production

The observation in the generation stack of the Netherlands, with a temporary high share of installed capacities of hard coal-fired power plants in 2015, is reflected in the production. A shift towards more coal- and less gas-fired generation output in the Netherlands can be conservatively concluded by taking a look at Figure 15, as gas-fired units facing strong competition.

Since the last month of 2014, the generation by hard coal power plants increased significantly due to the new installed capacities. The overall generation of natural gas and hard coal power plants was rather stable comparing the same months of 2014 and 2015, which supports the perception of generation based on gas being replaced by a generation based on hard coal. However, it should be noted that three older coal-fired plants, with a combined capacity of 1611 MW closed officially on 1 January 2016. In 2015, these three plants together accounted for 21.7% of coal-fired generation.

On the other hand, the growth of installed wind and solar capacities is also observed in Figure 16. Production from solar, especially in the summer months, becomes more and more relevant. In November we saw an absolute record for wind energy, with a production of over 1500 GWh. The total share of renewables in electricity consumption in the Netherlands in 2015 was 11.1%⁸.

Comparing Figure 16 with Figure 20 further below, the high correlation between renewable production in the Netherlands and Germany becomes obvious. Despite the growth of renewable production in the Netherlands, the price impact is still largely due to high imports from Germany in times of high renewable production.

Dutch Coal and Gas Electricity Generation

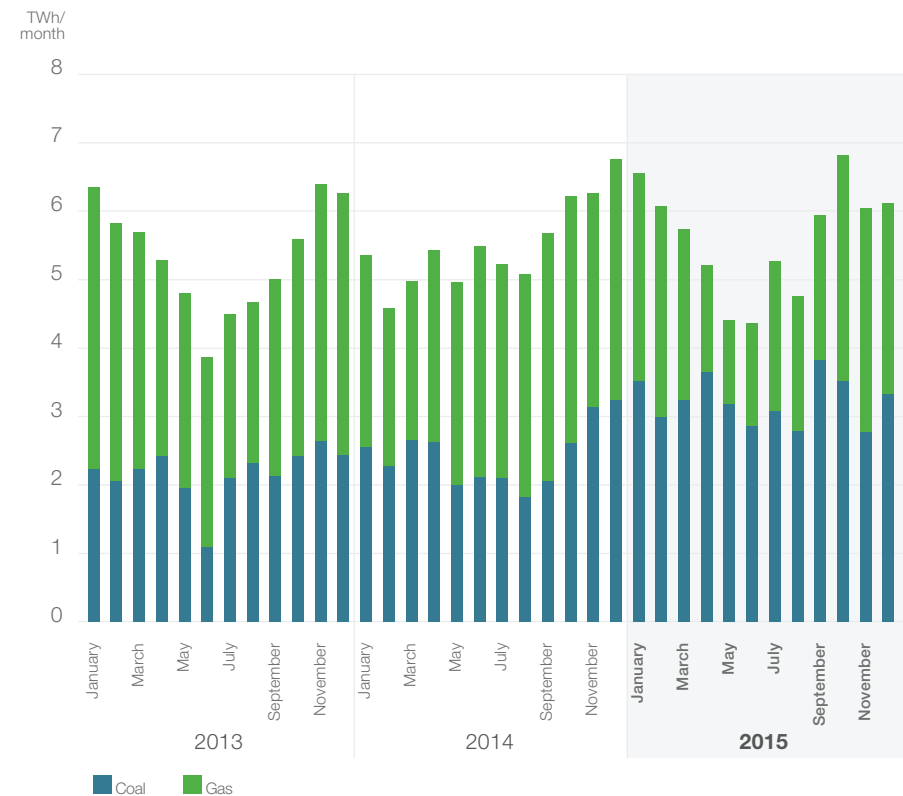


Figure 15: Dutch gross electricity generation from coal and gas plants (>10MW). Source: TenneT

Consumption and production

Dutch Monthly Average Solar and Wind Feed-in

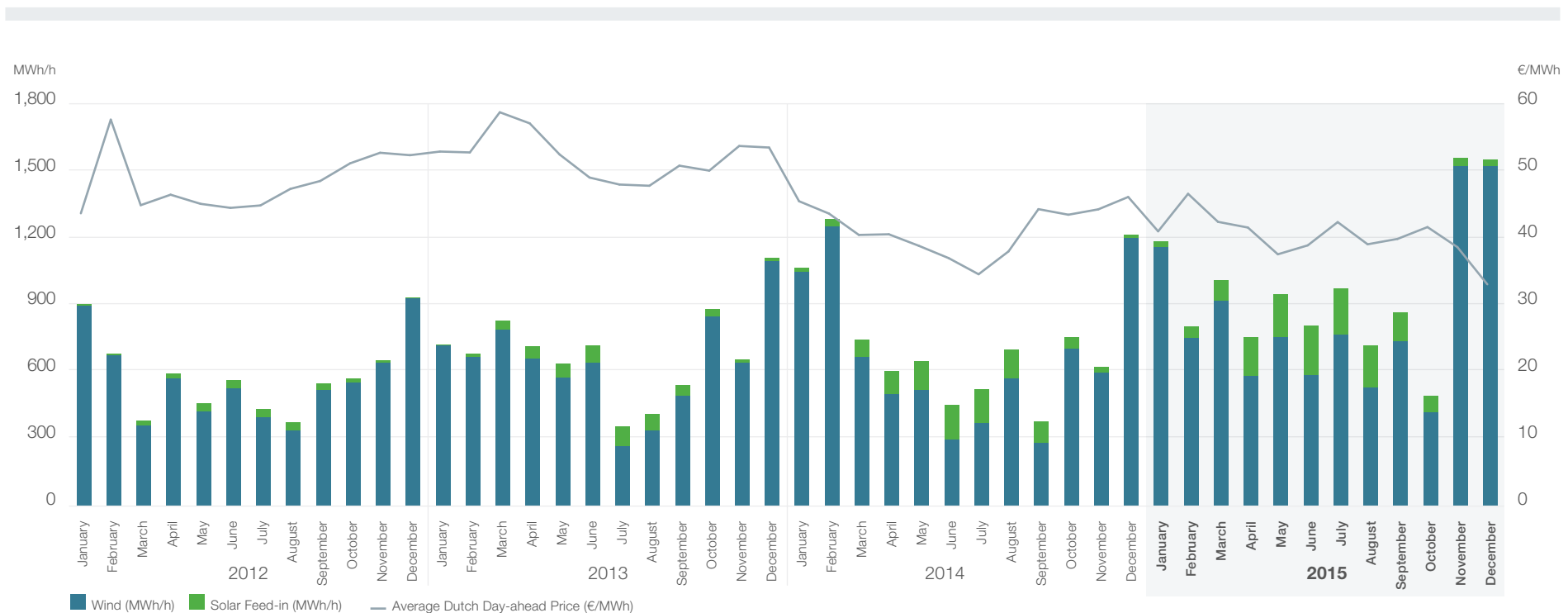


Figure 16: Dutch monthly average wind and solar feed-in and Day-ahead price. Source: CBS, EnTranCe

Also for Germany too, the change of the generation stack is reflected in the electricity production as shown in Figure 17. The share of renewable generation – especially wind and solar – continuously increased over recent years and reached a record of 30% of gross electricity generation. Due to the net

exporting position of Germany, this leads to a share of 32.5% of Germany's electricity consumption. The German political target of 35% renewable energy generation of consumption in 2020 seems within reach.

Consumption and production

German Power Generation

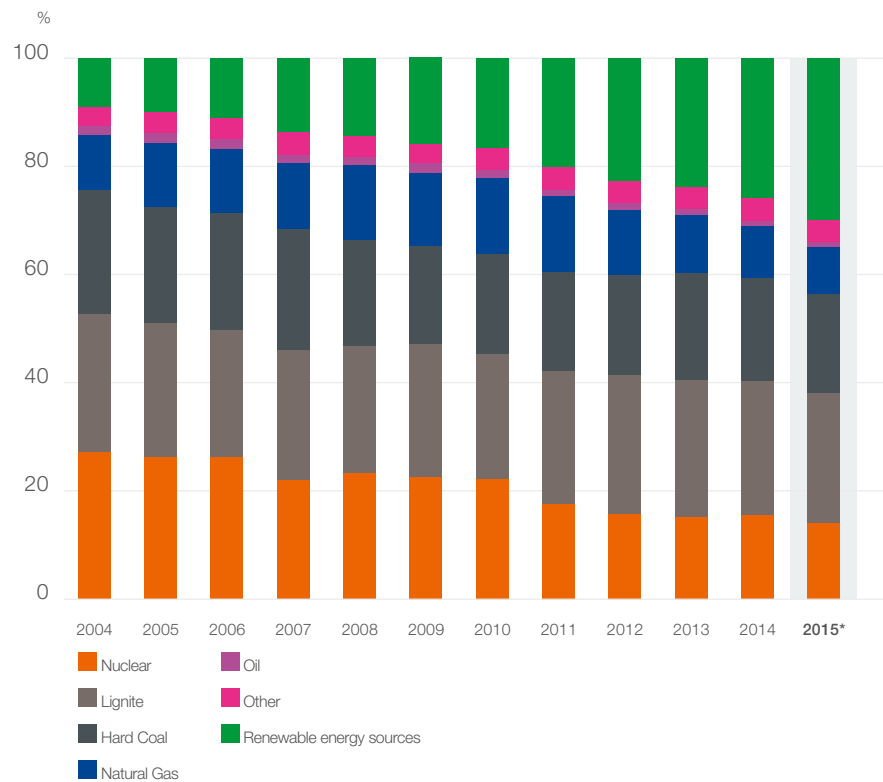


Figure 17: Shares of gross electricity generation per generation type in Germany (2004-2015). Source: AG-Energiebilanzen (*Preliminary values for 2015)

Figure 18 compares the distribution of the feed-in from renewables between different sources in Germany. In 2014, more than one-third of the renewable feed-in was produced from onshore wind turbines and only 1% from offshore wind capacities (but the latter increased in 2015 to 4%). The share in production from offshore wind is larger than its share in capacity. A rough calculation indicates that 1 MW installed capacity offshore produces 50% more electrical energy compared to 1 MW installed capacity onshore. Wind energy contributed a total of 44% of renewable production.

Due to the strong growth of wind energy, the share feed-in by solar decreased to 22% of the total renewable production despite its growth in absolute figures.

Distribution of Renewables in Germany

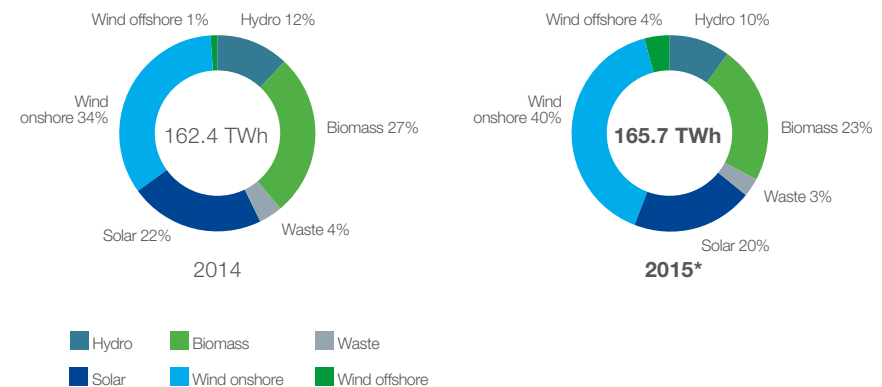


Figure 18: German distribution of renewables shares feed-in. Source: AG-Energiebilanzen (*Preliminary values for 2015)

Consumption and production

Figure 19 depicts the German average monthly feed-in from solar and wind over the last four years. A high monthly variation of feed-in – and thereby full load hours of solar and wind – can be observed. The feed-in of solar and wind are complementary on a monthly basis. In the winter months from autumn to spring, the average feed-in of wind turbines is relatively high and the solar feed-in low, whilst in the summer months it is usually vice versa, but still there

is a strong variation. In March and October of 2015, the feed-in by wind turbines was remarkably low, which was one important driver for higher average Day-ahead prices in the German market area. In contrast, the average feed-in increased in November and reached a record in December of 2015. The high renewable feed-in in these two months reduced the average Day-ahead prices due to the merit order effect.

German Monthly Average Solar and Wind Feed-in

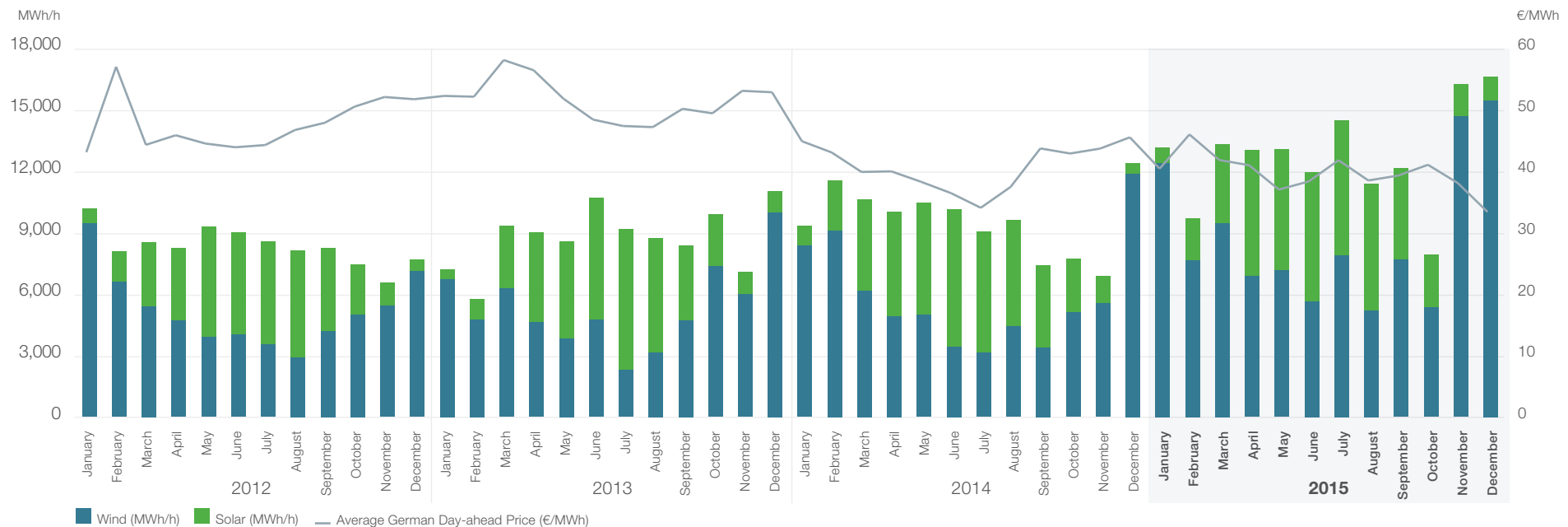


Figure 19: German monthly average wind and solar feed-in and Day-ahead price. Source: EEX, ENTSO-E

Consumption and production

A more general effect of solar energy on the wholesale price is shown in Figure 20. First, the average feed-in by solar power increases year over year due to the additional installed capacities. Second, the base price decreased over the last three years. Especially around noon, feed-in by solar power is the main driver for decreasing prices.

German Solar Feed-in and Day-ahead prices

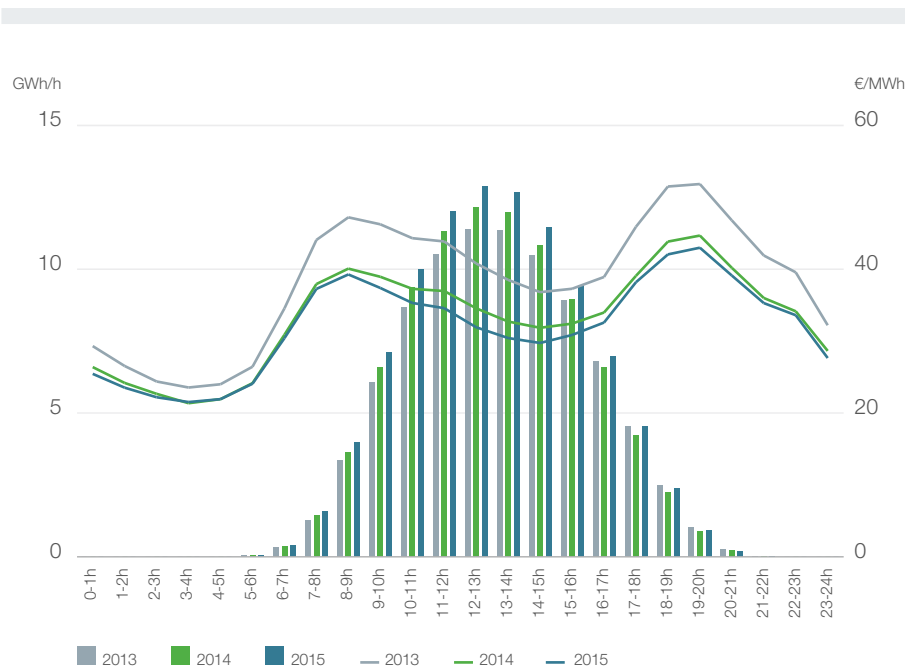


Figure 20: German average hourly solar feed-in 2013-2015 and average hourly Day-ahead prices.
Source: EEX, Anlagenregister der Bundesnetzagentur

Figure 21 depicts the distribution of renewable feed-in in the different German control areas. The major share of solar and wind feed-in is in the TenneT control area. Due to the long coast line of the German TenneT control area, especially with the North Sea, most of the offshore wind farms are connected with the TenneT grid. Apart from high feed-in by onshore and offshore wind turbines, TenneT is challenged by the integration of the feed-in from photovoltaic panels in underlying distribution networks, predominantly in Bavaria.

Furthermore, taking a look at the renewable average feed-in per month in 2015, the development of offshore capacities is visible. Although a very small amount of feed-in by offshore capacities at the beginning of the year can be observed, a significant increase of the average feed-in through the year can be reported. As an example, the HelWin2 Project has been in operation since June 2015 and provides a DC-grid connection of 690 MW for wind farms in the eastern North Sea. This connection is used to integrate the feed-in such as the Amrumbank West wind farm with a generation capacity of 288 MW.

Consumption and production

German Wind and Solar Feed-in by TSO and per Month

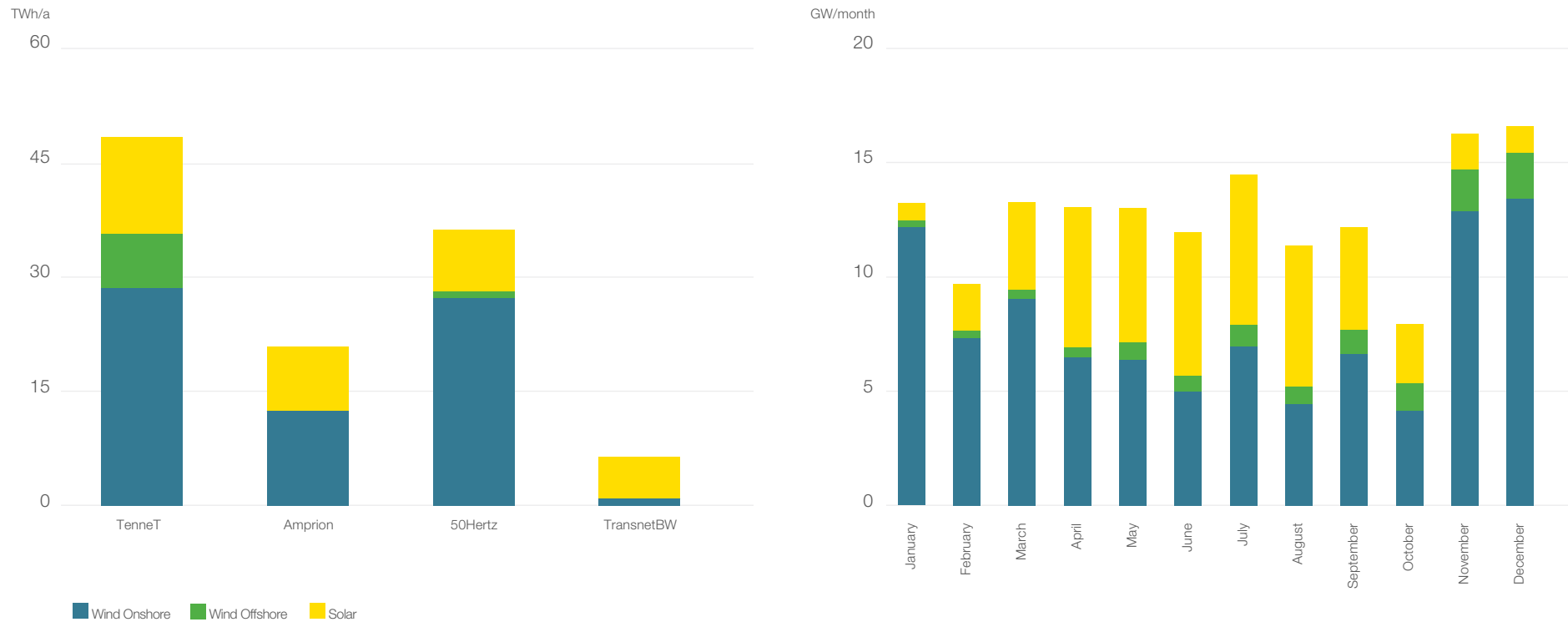


Figure 21: Distribution of German wind onshore, offshore and solar feed-in among TSOs and monthly among 2015. Source: ENTSO-E

Consumption and production

Marginal costs

In order to explain the developments described, primary fuel prices as well as prices for CO₂ certificates are investigated in more detail. Figure 22 shows the corresponding graphs for the prices of natural gas at the Title Transfer Facility (TTF), hard coal (API#2) and CO₂ emission allowances.

Primary fuel prices continued to fall, whilst CO₂ prices increased in 2015. Due to this contrary development of primary energy prices and CO₂ emission allowances, a distinction between different technologies is necessary.

Prices for Natural Gas, Hard Coal and CO₂ Certificates

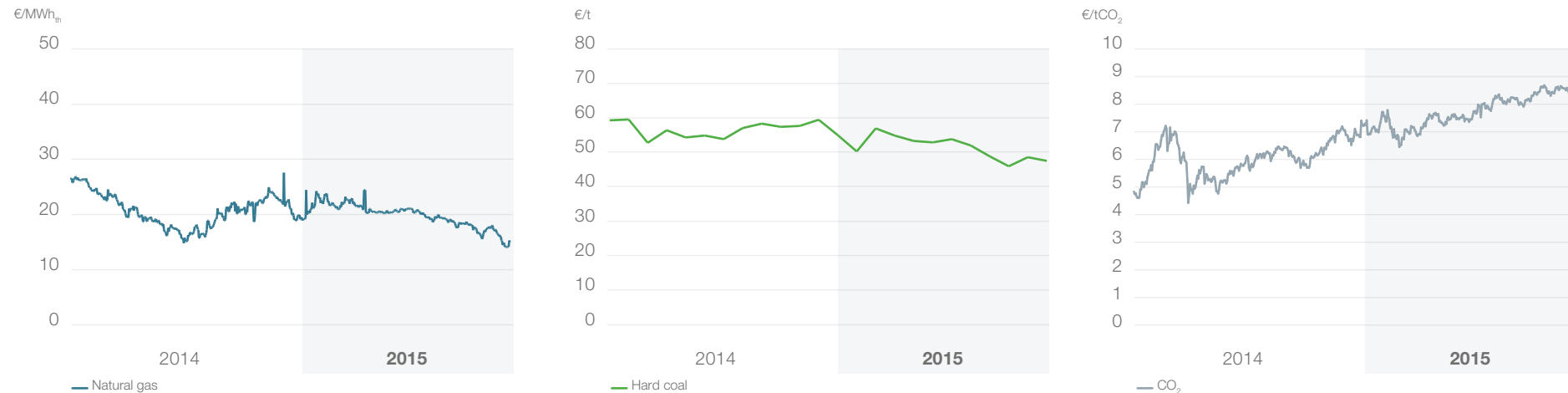


Figure 22: Daily Day-ahead gas prices from EEX TTF Index, monthly hard coal prices from API#2 ASK (CIF ARA) and daily CO₂ future price for years 2014/2015 traded through 2013/2014/2015. Source: Energate⁹

The outcome of a marginal generation cost calculation for hard coal- and natural gas-fired power plants is shown in Figure 23. The price movements of hard coal and CO₂ emission allowances compensated each other in 2015. However the decrease of natural gas prices predominated the increase of the CO₂ emission allowances prices, which resulted in a small reduction of the marginal generation costs.

⁹ Assumptions: Gas EEX TTF daily Day-ahead Index (Energate), API#2 hard coal monthly (CIF ARA) (Energate), CO₂ future price daily for years 2013/2014/2015 traded through 2013/2014/2015 (EEX, Energate). API#2 index published in \$ and converted here to €, in order to be comparable to the other primary energy prices.

Consumption and production

The spread between gas and coal generation costs was stable between 2014 and 2015 on average but a decreasing spread over the course of 2015 could be observed. This contributes strongly to price convergence between the Netherlands and Germany in the second half of 2015. This is because in 2015 gas remained the price-setting technology in the Netherlands, in contrast to

hard coal in Germany for most of the hour, despite the growth of hard coal-fired generation in the Netherlands and the growth of renewables in Germany. Therefore the difference in marginal generation costs shown in Figure 23 is the most important driver for the difference in the wholesale prices in the two countries.

Marginal Generation Costs Gas and Coal

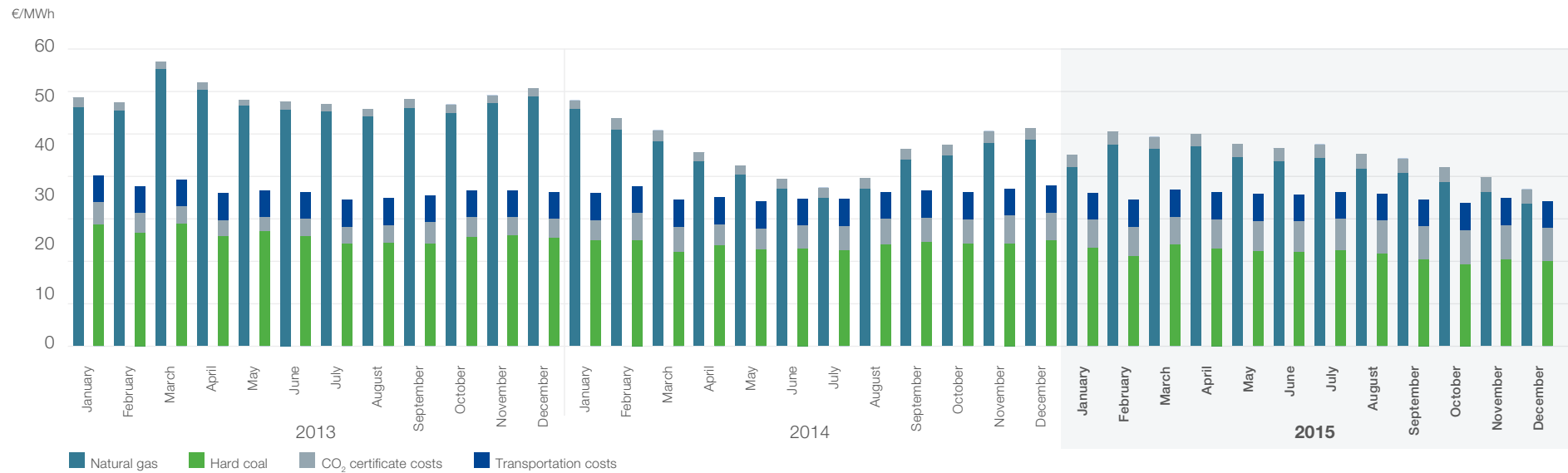


Figure 23: Marginal generation costs of hard coal and natural gas power plants. Source: EPEX, energate¹⁰, IAEW

¹⁰ Assumptions: Gas EEX TTF daily Day-ahead Index (Energate), API#2 hard coal monthly (CIF ARA) (Energate), CO₂ future price daily for years 2013/2014/2015 traded through 2013/2014/2015 (EEX, Energate). API#2 index published in \$ and converted here to €, in order to be comparable to the other primary energy prices.

Intraday markets

In 2015, Germany saw a growing importance of Intraday trading. This was supported especially by the development of the intraday auction and driven by the demand from market parties for quarter-hourly products for shaping, and to be able to act on improving forecasts during the day to balance their portfolio.

Intraday trading is becoming increasingly important due to two factors. First, the forecasts of renewable feed-in are updated during the day and through the ongoing expansion of renewable generation, Intraday trading is more and more relevant. Second, whilst in the Day-ahead market the tradable products are based on hourly granularity, the possibility to trade quarter-hourly products in the Intraday market provides the participants with a better trading product for ramp rates. This is very helpful for trading the feed-in of solar power, which is always associated with high – and predictable to a high degree – gradients. Furthermore, average hourly products cannot be sufficient for managing balancing groups in quarterly-hour granularity, especially in respect to ramp rates.

In Germany there were two ways to participate in the Intraday market. On the one hand, there is the continuous trading which allows the participants to trade hourly and quarter-hourly products from 4 pm the previous day up to the gate closure time of 30 minutes before delivery. This continuous trading option is based on an open order book. On the other hand, since December 2014 there is the Intraday auction clearing at 3 pm, shortly after the Day-ahead auction. This auction allows trading quarter-hourly products one day before delivery with a market clearing price system.

Figure 24 depicts the traded volumes of the products on the respective Intraday market. An overall growth rate from 2013 to 2015 underlines the increasing relevance of the Intraday market. The traded hourly product in the continuous trading increased by about 7 TWh/a, reaching a new record of 26 TWh/a in 2015, whereas a small decrease of continuous traded quarterly-hour products can be reported. This small decrease is due to

the introduction of the Intraday auction, which accounts for 4 TWh/a. Summing up the quarter-hourly products of the auction and the continuous trading and comparing it to 2014, an increase of 60% is achieved.

German Intraday trading volumes

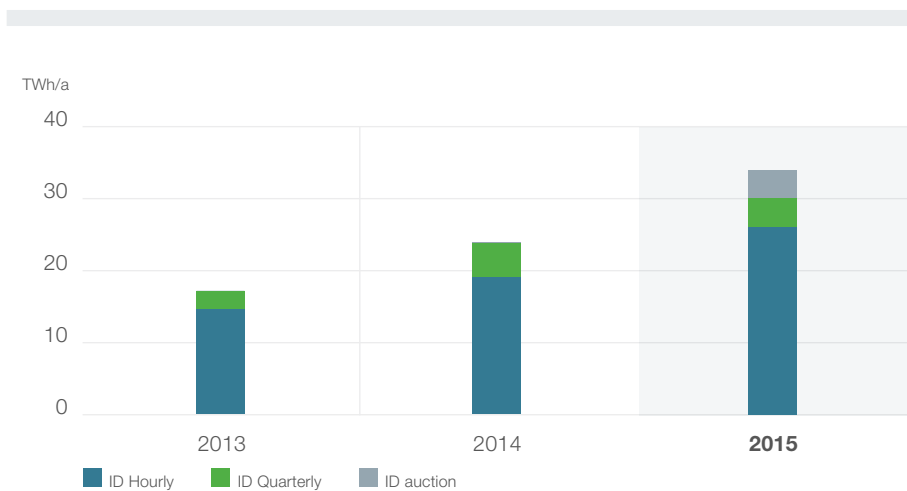


Figure 24: Intraday Auction, Quarterly and Hourly trading volumes in Germany. Source: EPEX

As already mentioned, one reason to provide tradable products to the market are ramp rates. Such ramp rates can increase with additional installed generation capacity based on solar due to the natural predefined gradient over the day. Due to the quarterly settlement, balance-responsible parties will want to match the predicted production in the market on a quarterly basis.

Intraday markets

Figure 25 differentiates the traded volume between the quarter-hours. It shows that significantly higher volumes in the first quarter-hour and in the fourth quarter-hour were traded than in the second or third quarter-hour. This shows how quarter-hour products are used to fulfill ramp rates because hourly

products can only trade the hourly average, which results in a 'block profile' that does not match the continuous developments in load and renewable production and does not match the balancing responsibility of market parties on a quarter-hourly basis.

German Quarterly traded Intraday volumes

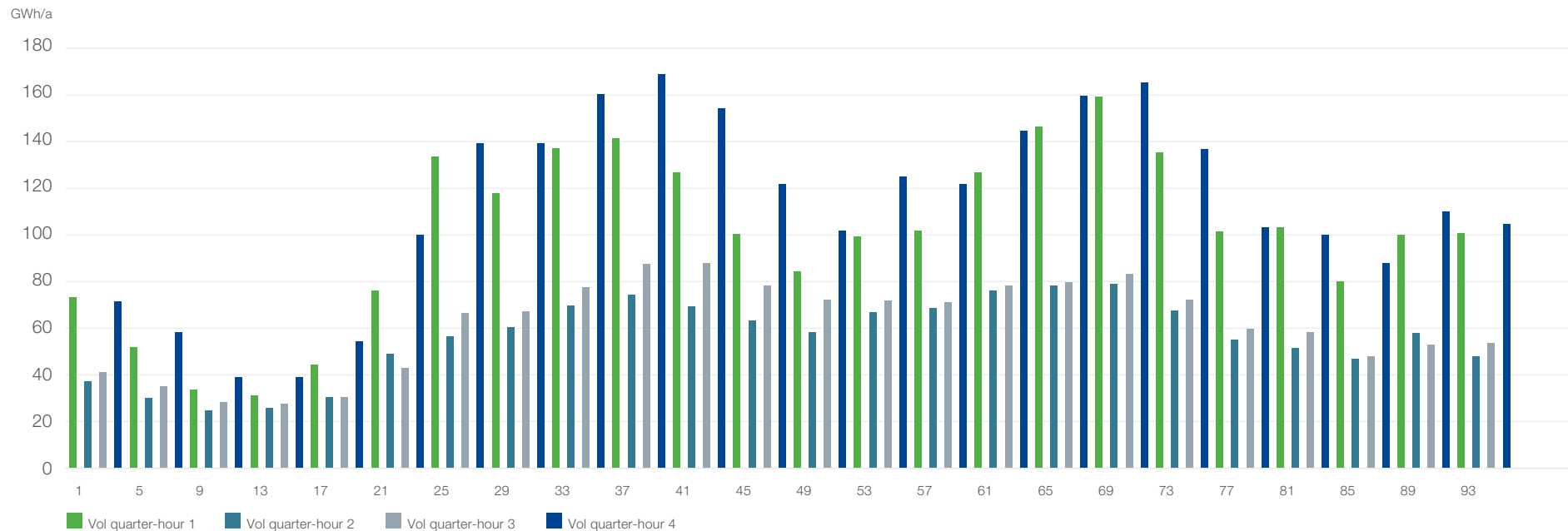


Figure 25: Quarterly traded Continuous and Auction intraday volumes in 2015 in Germany. Source: EPEX

To combine this insight with the knowledge of the natural solar gradient over the day, Figure 26 depicts the weighted average price (WAP) of the continuous traded quarter-hour over the day and the average feed-in by generation capacities based on solar in 2015. It is observed that the WAP of the first

quarter-hour is higher than the WAP of the fourth quarter-hour in the morning, and vice versa in the afternoon. One explanation is the ramp rate of solar feed-in. If market participants trade the expected hourly average on the Day-ahead market – even without any forecast errors – trading on the Intraday market

Intraday markets

or a new dispatch of the own portfolio is necessary to be balanced within a quarter-hour. In the morning with a positive slope of the solar feed-in, one would be short in the first quarter of the hour and long in the fourth quarter. This is reflected in the prices. Although one should not neglect other drivers

for Intraday prices like residual load, forecast errors and bidding strategies, it points out the relationship between renewable generation, especially solar, and the Intraday market due to ramp rates of solar is one driver for systematic quarterly ramp demand.

German average Quarterly Intraday prices and average Solar Feed-in

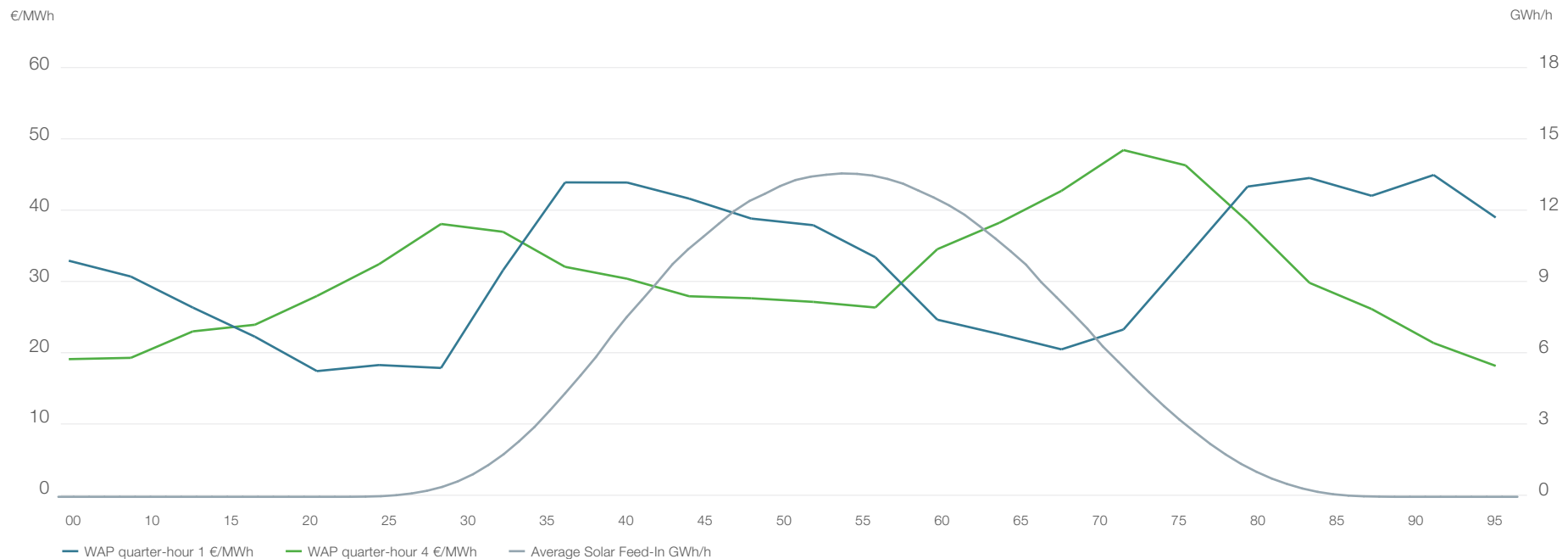


Figure 26: Yearly Weighted Average Prices of Quarterly traded products during the day in 2015 in Germany and Yearly Average solar feed-in. Source: EPEX

Market integration and interconnection flows

Figure 27 shows the yearly aggregated commercial scheduled flows (Day-ahead) for the CWE region and at the German borders in 2014 and 2015.

In 2015, the exports from Germany to southern countries (France, Switzerland, Austria and the Czech Republic) significantly increased in comparison to 2014. At the same time, exports from Germany to Scandinavian countries decreased. In total, the German net commercial exports were 17 TWh/a higher in 2015.

In 2015, the exports from the Netherlands increased, most significantly the exports towards Belgium increased by 69% to 6.1 TWh. On the other hand, imports into the Netherlands decreased, most significantly from Belgium, decreasing 58% to 1.4 TWh, but also from Germany, with a decrease of 7.8% to 16.6 TWh. Patterns on the DC interconnectors remained stable with structural imports from Norway and structural exports to Great Britain. Despite the overall decrease of imports and the increase of exports, the Netherlands remained a net importer in 2015.

Such imports and exports reflect the net positions that result from the market coupling calculations. In 2014, the market coupling algorithm was based on ATCs. In 2015, this was changed to the Flow Based method, which has a more sophisticated way of taking available transportation capacity into account (cf. chapter 3).

In contrast to Figure 27, Figure 28 shows the yearly aggregated physical flows for the CWE region and at the German borders in 2014 and 2015. In 2015, more exports from Germany to Switzerland and Austria could be observed. Exports to the Netherlands decreased slightly. Imports from France, Switzerland and the Czech Republic to Germany also decreased.

The commercial schedules reflect the transactions that are needed for settlement between market areas with a positive net position and those with a negative net position in any given hour. The physical cross border flows – shown in Figure 28 – that result from these net positions and the subsequent intraday trade will depend on where in a market area consumption and production take place and the capacities in the transmission grid, irrespective of country borders and also include transit flows and loop flows.

Market integration and interconnection flows

European Commercial Cross-Border schedules

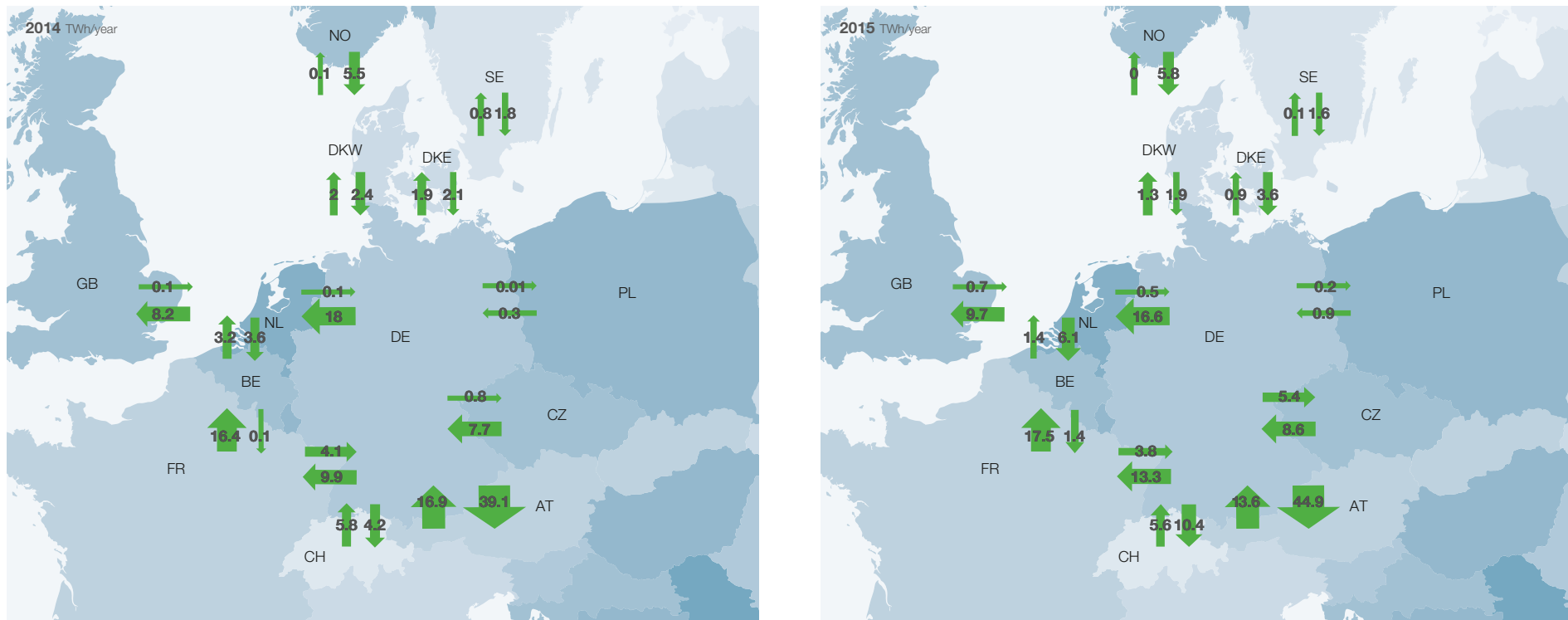


Figure 27: Annual total of commercial Day-ahead cross-border schedules in CWE region and at the German borders in TWh. Source: TenneT, ENTSO-E, BritNed, Swissgrid

Market integration and interconnection flows

European Physical Cross-Border Flows

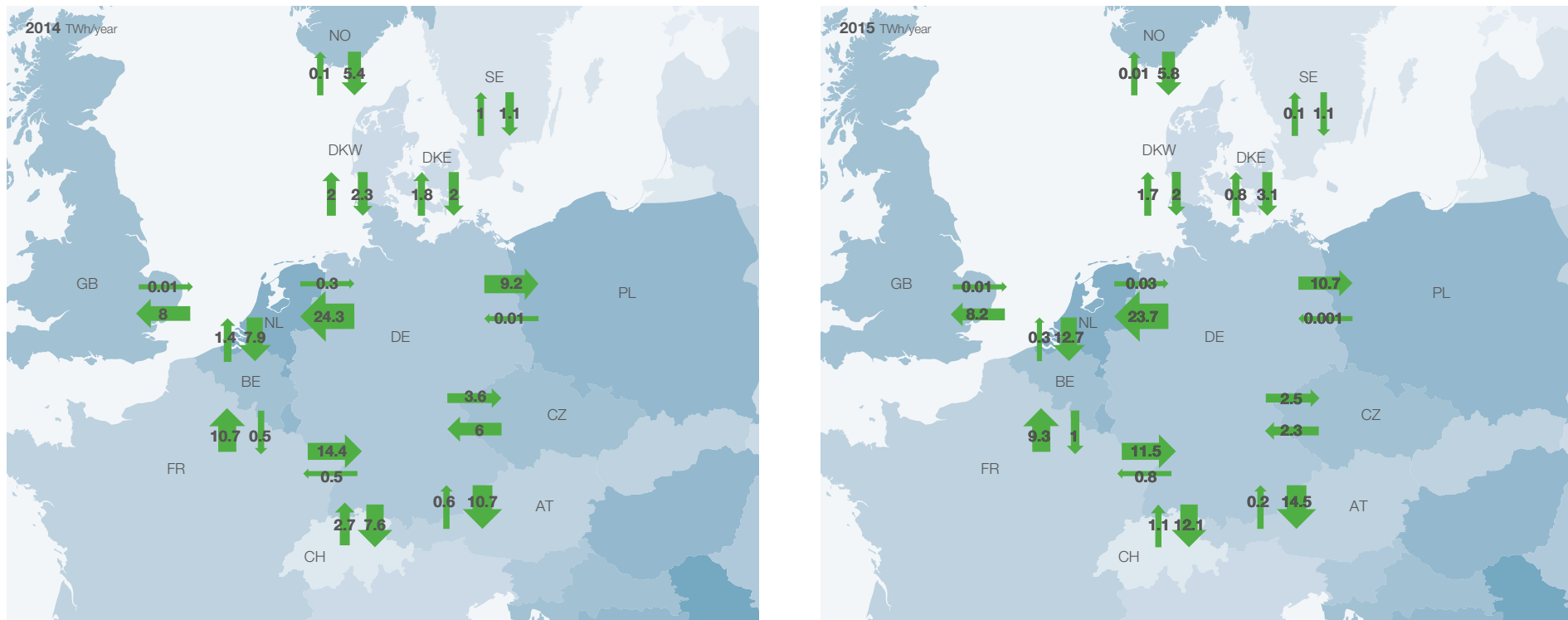
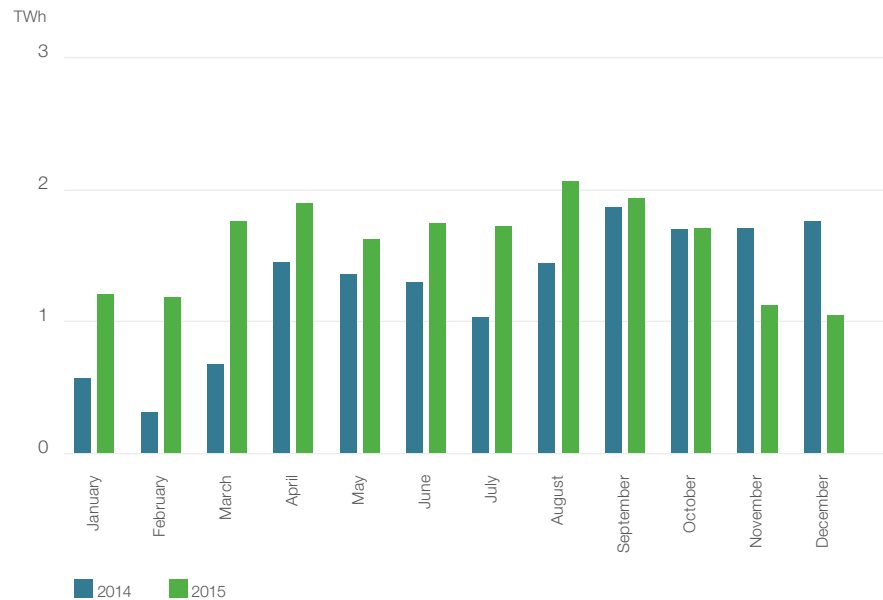


Figure 28: Annual total of physical cross-border flows in CWE region and at the German borders in TWh. Source: TenneT, ENTSO-E, Swissgrid

Market integration and interconnection flows

Belgium net Imports



Particularly Belgium showed an increasing commercial import dependency. Figure 29 shows the monthly net imports into Belgium. During the first eight months, a significant import increase can also be seen to be supported by high production unavailability. Chapter 9 discusses the price peaks that occurred in Belgium in 2015 in more detail).

Figure 29: Monthly commercial net imports (import – export) from Belgium in 2014 and 2015.
Source: TenneT, ENTSO-E

Balancing

Germany saw a further improvement of the balancing performance of balance-responsible parties in 2015, as is testified by the reduced volumes of net imbalances; smaller volumes of reserves were activated significantly more often than in the two years previous, as the number of periods with a small net imbalance increased and the volumes of undersupply decreased. However, both the Netherlands and Germany saw an increase in the occurrence of more extreme imbalance prices in 2015.

The difference between the imbalance price and the market price can be seen as the incentive for market parties to be balanced. Typically, one wants this incentive to increase when the system shows a larger imbalance. Figures 30 and 31 therefore show this price difference¹¹ in relation to the net imbalance in 2015, for the Netherlands and Germany respectively. The graphs also show a count of the number of imbalance settlement periods¹² (ISPs) in which the net imbalance volume fell within a certain range.

In both countries we see that the differences between the spot prices and the imbalance prices increase when the net imbalance is larger, reflecting the scarcity or abundance of energy in the system. However, in Germany there are also significant differences between the spot and imbalance prices in situations without significant net volumes of activated reserves (between -100 MW and +100 MW), this was discussed in more detail in the TenneT Market Review 2014.

In Figure 30, the 90th percentile of the price delta in the Netherlands reaches similar values for a range of different volumes of imbalances. This reflects bidding behaviour on the merit order list and could be an indication of limited liquidity.

Furthermore, in both countries we see that the net imbalance is more often positive than negative. Apparently there is a tendency for market parties to oversupply the system. Figures 32 and 33 show that this tendency has developed in recent years.

Another effect we can see in Figures 32 and 33 is that the number of ISPs in which the system was well balanced has increased significantly again in Germany in 2015, whereas for the Netherlands this has somewhat decreased.

The significant improvement (decrease) of the volumes of reserve activation can most likely be attributed to further improvement of the actions of balance-responsible parties, both in forecasting and in real time. The incentive for balance-responsible parties to improve their actions can likely be attributed to the improvements in the calculation of the German imbalance price that have been applied since 1 December 2012 to improve the consistency between the imbalance price and the market value of energy in the (intraday) spot price.

¹¹ For Germany the Intraday auction price was taken as the relevant market price, whereas for the Netherlands the Day-ahead Market price was used, in the absence of a liquid intraday market.

¹² The imbalance settlement period (ISP) is the period in which imbalances are settled with balance-responsible parties. This period is equal to 15 minutes for both Germany and the Netherlands.

Balancing

Net Imbalance and Balance Incentives for the Netherlands

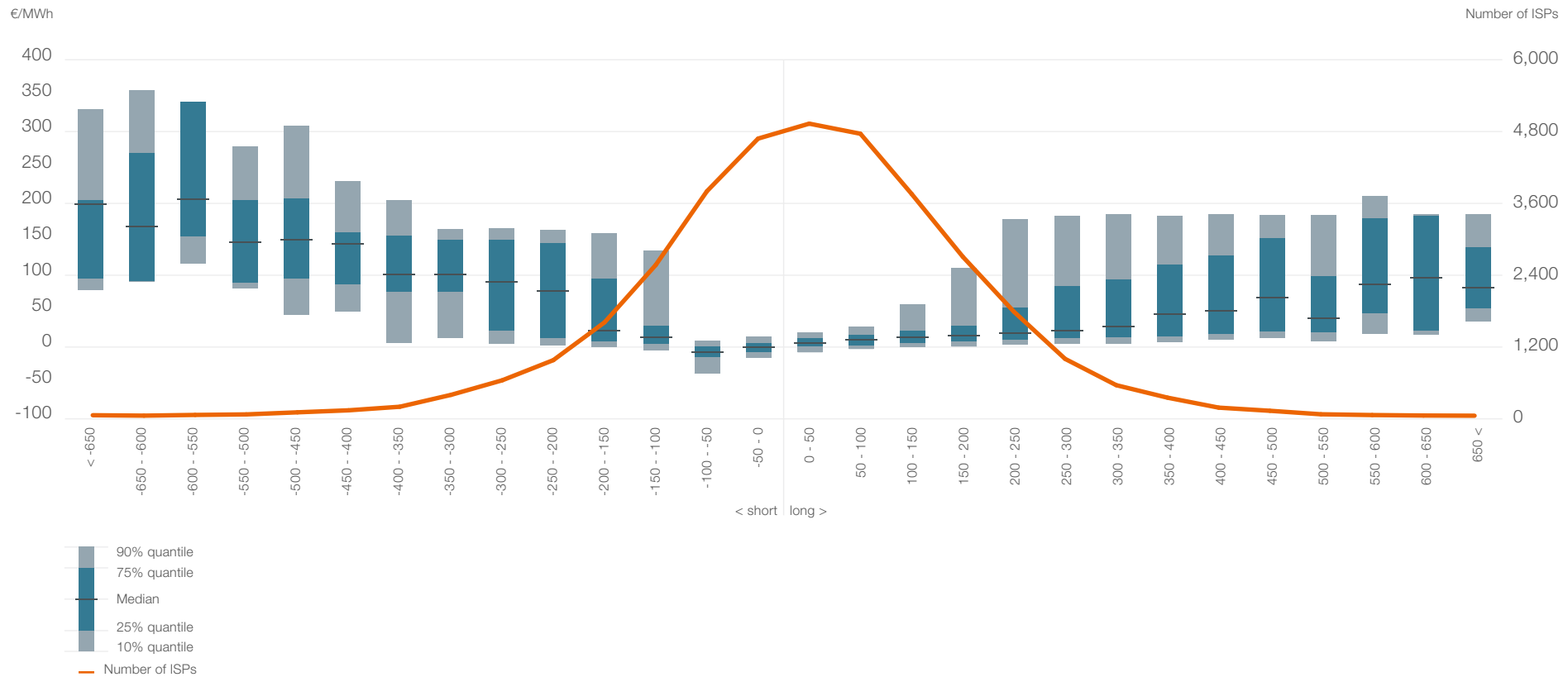


Figure 30: Net imbalance clusters (in MW) and differences between the imbalance price and the Day-ahead price in the Netherlands. Source: TenneT, EPEX Spot

Balancing

Net Imbalance and Balance Incentives for Germany

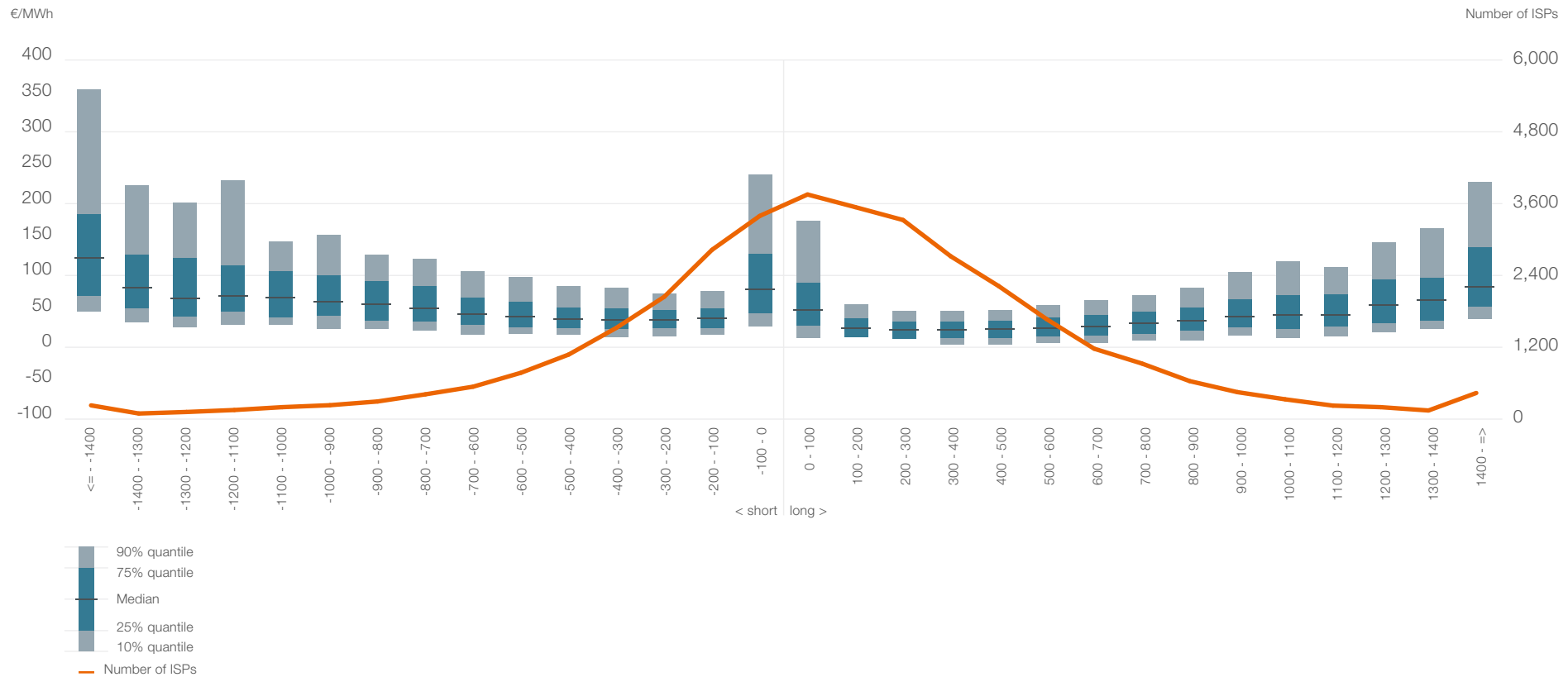


Figure 31: Net imbalance clusters (in MW) and differences between the imbalance price and the Intraday price in Germany. Source: Regelleistung.net, Energate, TenneT

Balancing

Dutch Imbalance volume distribution development

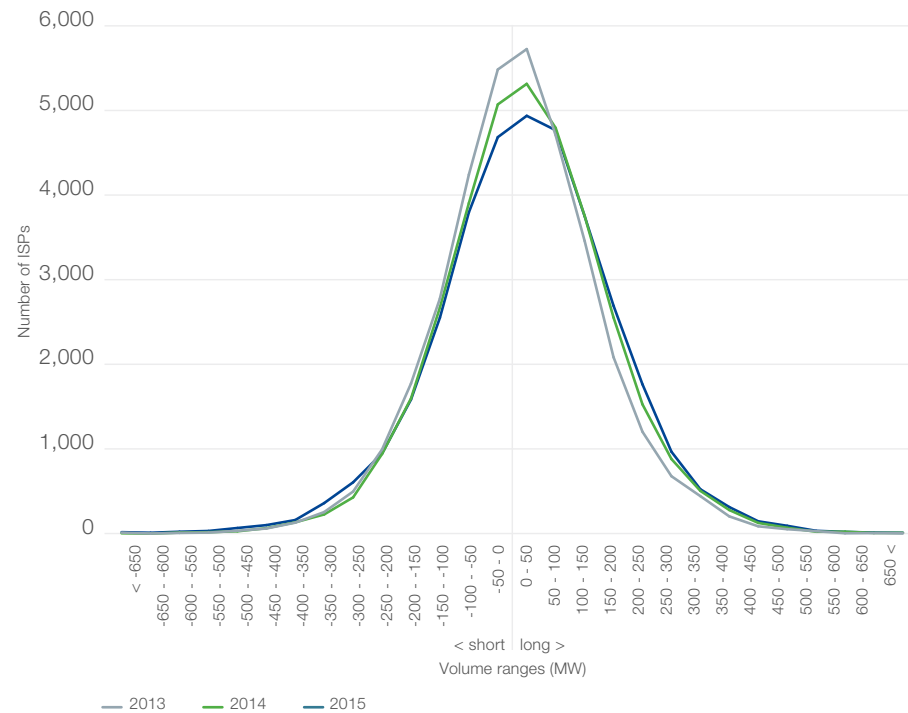


Figure 32: Net imbalance volume distribution in the Netherlands by Net imbalance clusters (in MW).
Source: TenneT

German Imbalance volume distribution development

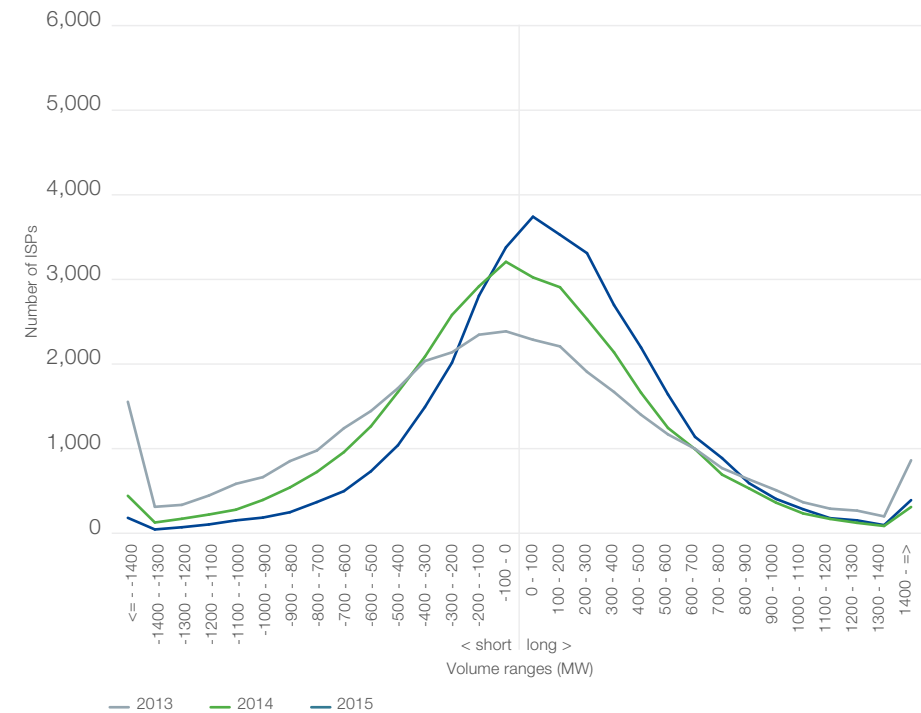


Figure 33: Net imbalance volume distribution in the Netherlands by Net imbalance clusters (in MW).
Source: regelleistung.net

Balancing

Figures 34 and 35 give insight in the distribution and the development of difference between the imbalance prices and the market prices in the Netherlands and Germany respectively. In both countries we see that the number of ISPs with a large price difference increases. The price differences below -50 €/MWh and above 50 €/MWh are highlighted as the striped surface in Figures 34 and 35. In the Netherlands the frequency of price differences of below -50 €/MWh increased for injection and withdrawal with 41.3% and 49.0% respectively, as for above 50 €/MWh increased with 59.9% and 51.6% respectively. In Germany the price differences below -50 €/MWh decreased with 13%, whereas the price differences above 50€/MWh increased with 34%. This means that, for both Germany and the Netherlands, high differences become more frequent.

This is true for both sides: the imbalance prices are more often much lower, but also more often much higher than the market prices. This trend is shown in the top 20 highest price differences on both the negative and positive side. For the Netherlands, the top 20 maximum prices on the negative side clearly increased by a maximum price of -697 €/MWh and on the positive side remained the same. For Germany, the top 20 maximum prices clearly increased on both sides to 6328 €/MWh and -6027 €/MWh.

Finally, for the Netherlands it is relevant to note that the number of ISPs with two imbalance prices¹³ increased to 14%. In 2014, this number decreased, but in 2015 it was back at 2013 levels.

¹³ The Dutch balancing regime applies a different imbalance price for settlement of positive and negative imbalance for those ISPs where TenneT has dispatched upward regulating bids as well as downward regulating bids.

Balancing

Dutch price duration curves imbalance prices

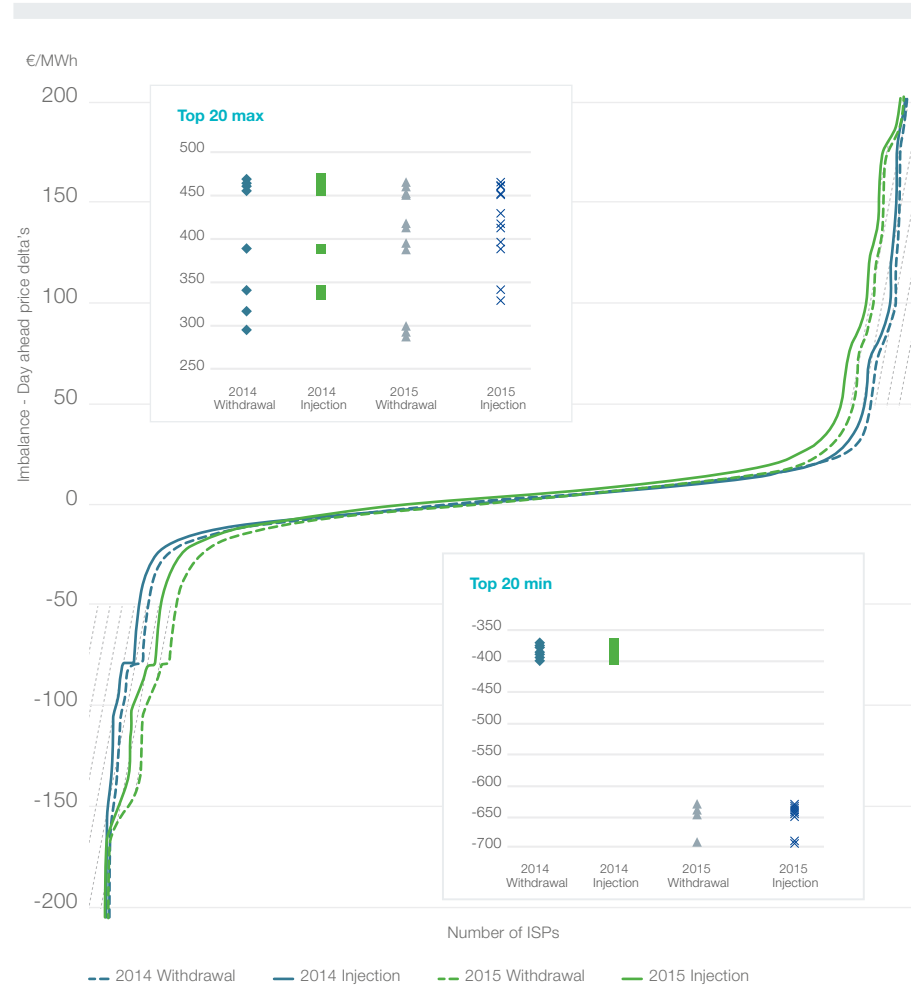


Figure 34: Price duration curve difference between imbalance prices and Day-ahead price for the Netherlands

German price duration curves imbalance prices

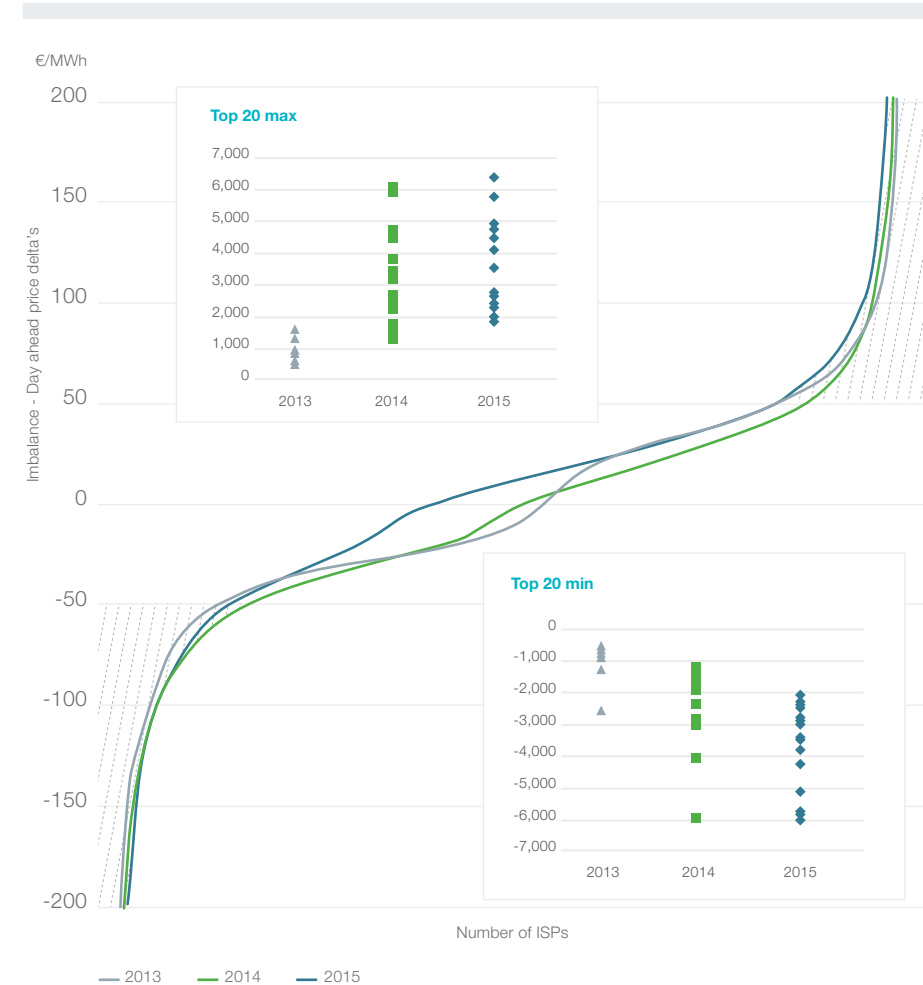


Figure 35: Price duration curves differences imbalance prices and Day-ahead prices for Germany

Redispatch

The energy transition has a major impact on the system operation of the TSOs. The new renewable generation has different production patterns and is produced at different locations than the conventional generation it replaces. Redispatch measures, whereby generators modify their production schedule on request of the TSO, were needed on 90% of the days in 2015, so have become standard practice in Germany.

Figure 36 shows the development of redispatch volumes per month since 2014 for the German TenneT control zone by type of redispatch measure. The bars point out how much redispatch has increased in 2015 compared to a year before, but also the variation in the need for redispatch measures from month to month.

Also, it shows significant increases in 2015 in the use of multilateral remedial action (MRA) and countertrade, especially in August and September, and of the power plants in the grid reserve, especially in November and December. Both aspects are explained below.

Monthly redispatch TenneT control zone in Germany

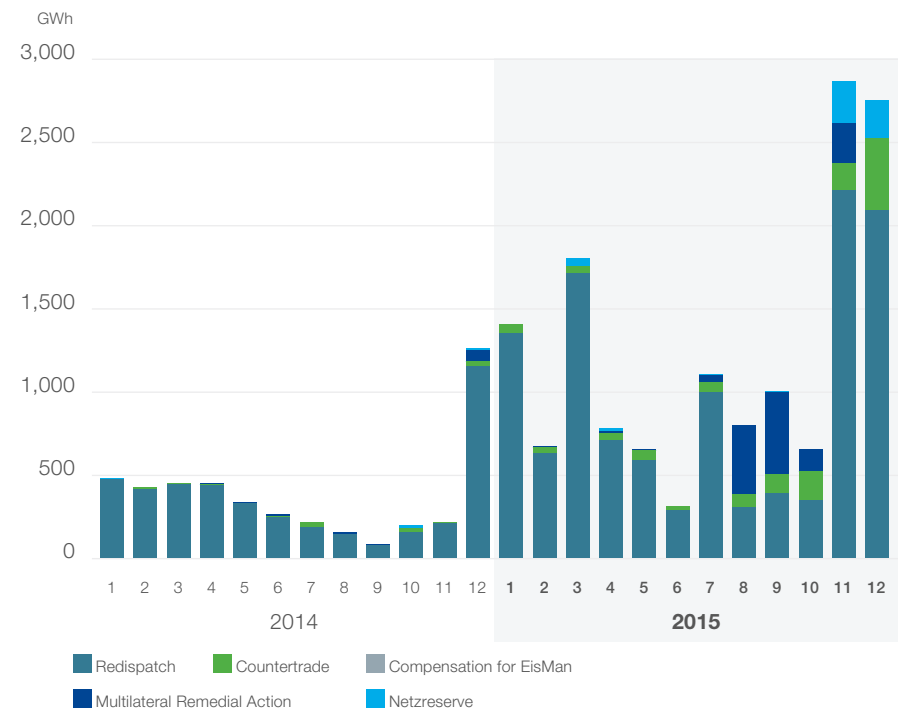


Figure 36: Monthly redispatch volume by German TenneT control zone in 2014 and 2015 by different types of redispatch measures. Source: TenneT

Redispatch

The increased need for MRA in August and September is due to the Polish grid situation in that period. During August, the prolonged heatwave caused a gradual increase of unscheduled outages of conventional power plants due to the reduced availability of cooling water. The unavailabilities of conventional power plants in the Polish control area led to MRA activations instead of redispatch.

Due to wind power representing the highest share of renewable power production in Germany, and its connection to high north-south transits, redispatch measures were taken in 90% of the days and therefore became a daily business for the German transmission system operators. The high level of measures that had to be taken in November and December can be explained by the high production of wind energy in these months. Figure 37 shows the correlation between the level of the wind energy production and the total capacity of the measures TenneT has to take to ensure security of supply. It clearly shows that higher wind feed-in leads to a higher need for measures for a given network.

Frequently, the need for measures is so high that virtually no additional measures would remain, and grid reserves have to be called upon. The network expansions that are needed to reduce the number of measures are progressing. Still, there is a mismatch between the pace at which production locations change as a result of the energy transition and that at which the necessary infrastructure can be realized.

Redispatch for Wind feed-in power adjustment

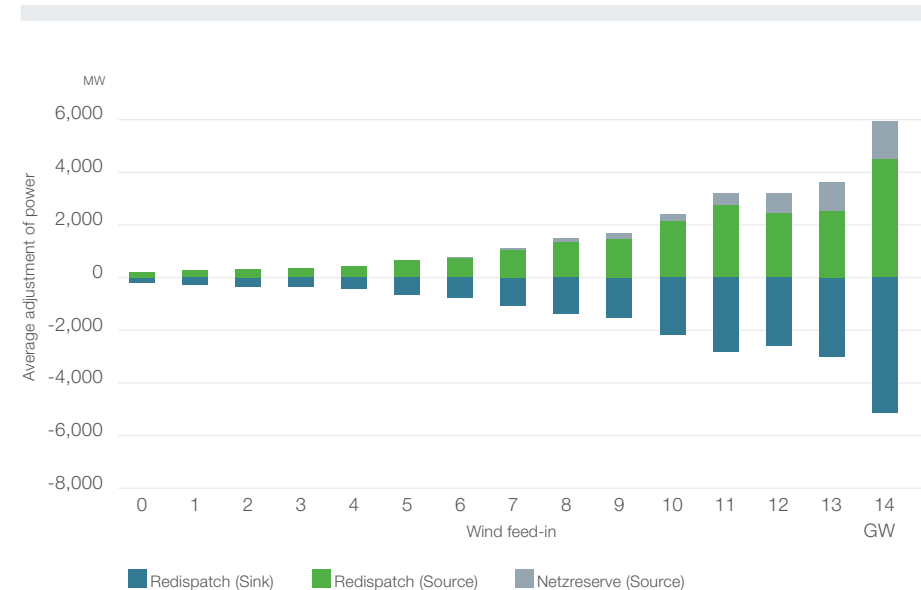


Figure 37: Average redispatch versus wind feed-in in the TenneT Germany control area.
Source: TenneT

Special events

in 2015

Besides the general trends in the Dutch and the German electricity market, we want to highlight three special events that took place in 2015. These are the solar eclipse, the price peaks witnessed in the Belgian market, and the day on which a record share of demand was covered by renewable energy.

Solar eclipse

This year was marked by a rare event that proved to be a special test case for the power markets and power system – a solar eclipse on the 20th of March 2015. Due to the high solar capacities already installed in the German generation stack, the eclipse led to predictably high gradients of the solar feed-in. Hence, other power plants had to provide the flexibility to cover these gradients, coordinated by the power markets. The solar feed-in on that day is depicted in Figure 38, also showing the maximal gradient, a positive slope of 4.26 GW/15min that appeared at 11 AM.

Solar eclipse solar Feed-in Germany March 20th

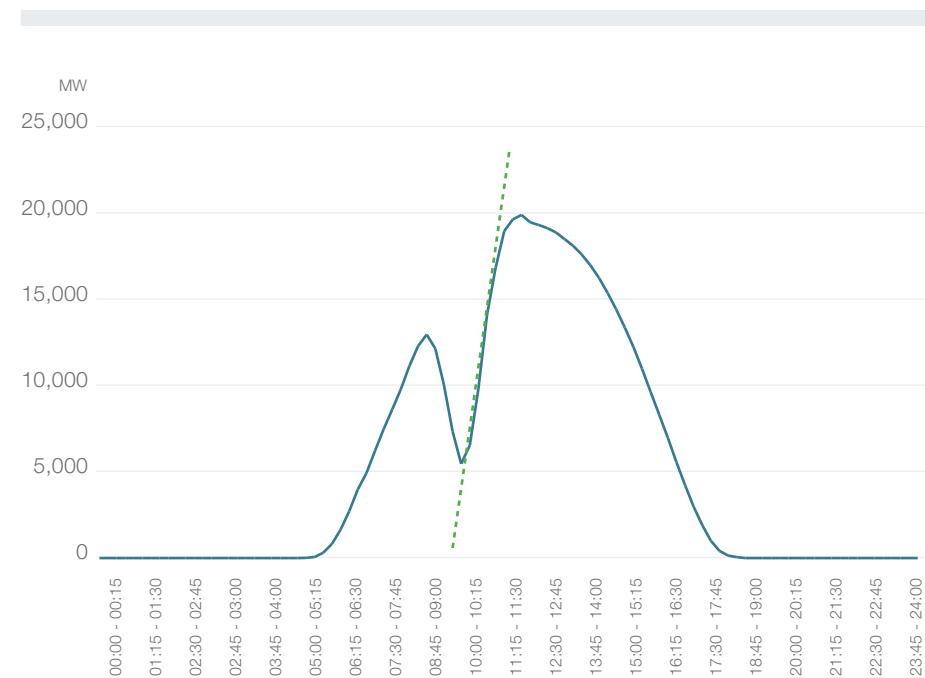


Figure 38: German solar feed-in on March 20th of 2015. Source: EPEX, German TSOs

Special events

in 2015

Without a solar eclipse, such gradients could only occur during normal operation if Germany had an installed solar capacity of 54 GW. In the German Grid development plan this is foreseen for the year 2025.

This follows from the analysis of historic positive gradients between 2011 and 2013, which were below the gradient observed during the solar eclipse, and scaling to 4.26 GW per 15 minutes. Using only the 99.9%-quantile of the historically observed gradients, solar capacities of 77 GW are possible until such a positive slope can be reached during normal system operations. This leads to the conclusion that this was an extraordinary event which will not become a feature of normal operation in the coming few years.

	Installed Solar Capacities	Foreseeable realization
Max	54 GW	2025 (NEP)
99.9%-quantile	77 GW	2050 (EU-Trends)

Nonetheless, the plannability and anticipation of the upcoming solar eclipse led to much preparation on the part of the system operators and market participants. Hence, as Figure 39, the expected high ramps led especially to high prices on the Intraday auction the day before. The lower weighted average prices during continuous trading on the Intraday market indicate conservative strategies or lower than expected ramp rates. The solar eclipse was handled with the available trading options on the intraday market.

Special events

in 2015

Day-ahead and Intraday markets during solar eclipse

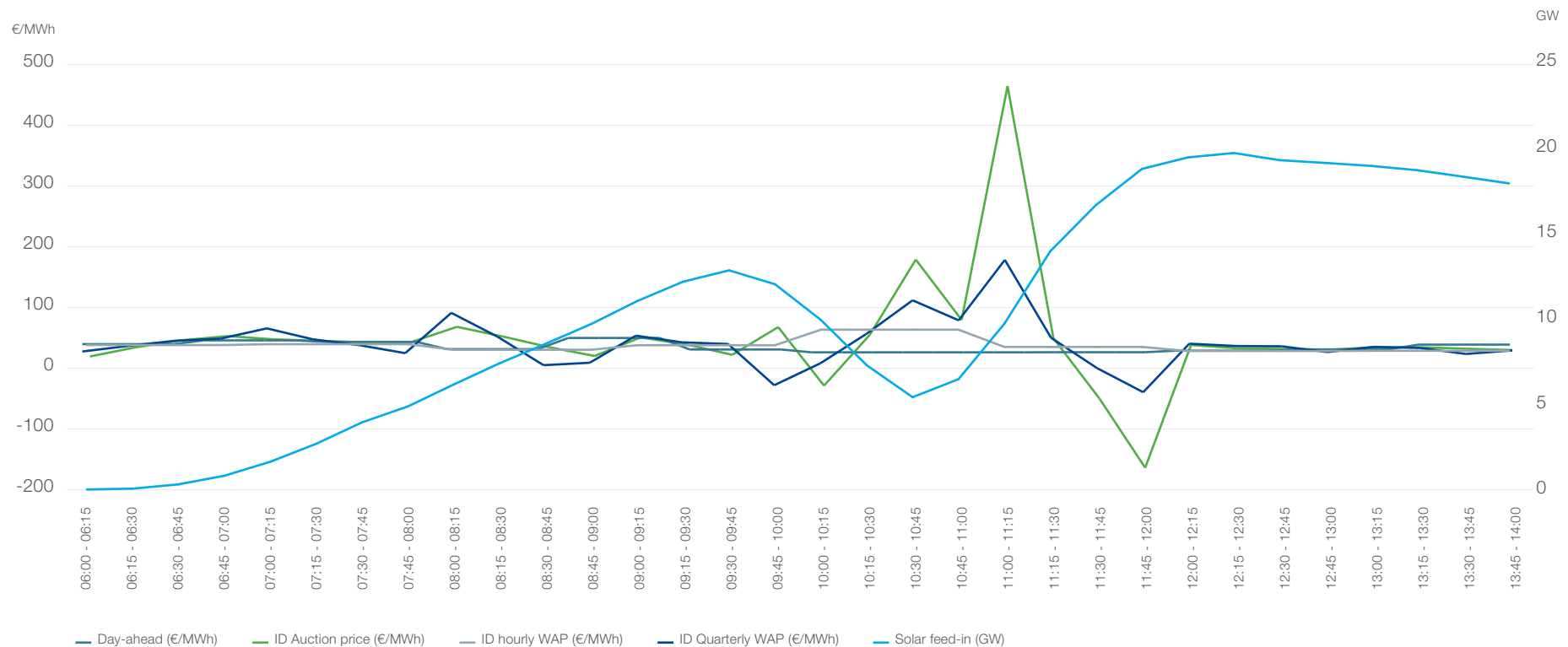


Figure 39: Solar Feed-in and Intraday market volumes during the solar eclipse on March 20th. Source: EPEX, German TSOs

Special events

in 2015

In preparation and to be able to ensure system stability, the German TSOs contracted additional reserve capacities ahead of the solar eclipse, as shown in Figure 40. These included higher secondary control reserve capacities for

the whole day due to the product length. Additional tertiary control reserve capacities were auctioned only for the critical product from 8 to 12 AM and a minor surplus for the product from 12 to 16 PM.

Contracted Control Reserves during solar eclipse

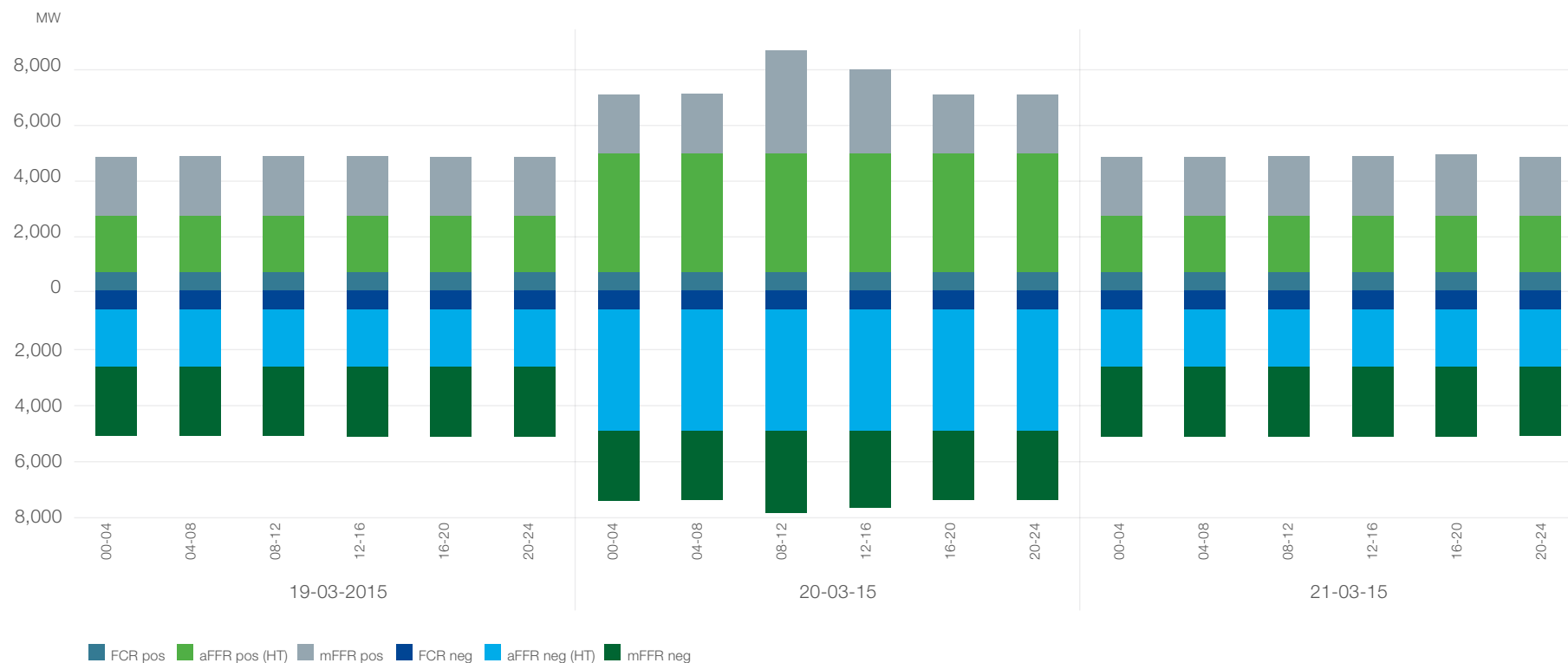


Figure 40: Contracted control reserve capacities during solar eclipse in Germany on March 20th. Source: regelleistung.net

Special events

in 2015

The higher than usual auction volumes also led to higher prices as depicted in Figure 41. The highest impact could be observed on the prices for negative secondary control and positive tertiary control reserve.

Prices for Contracted Control Reserves during solar eclipse

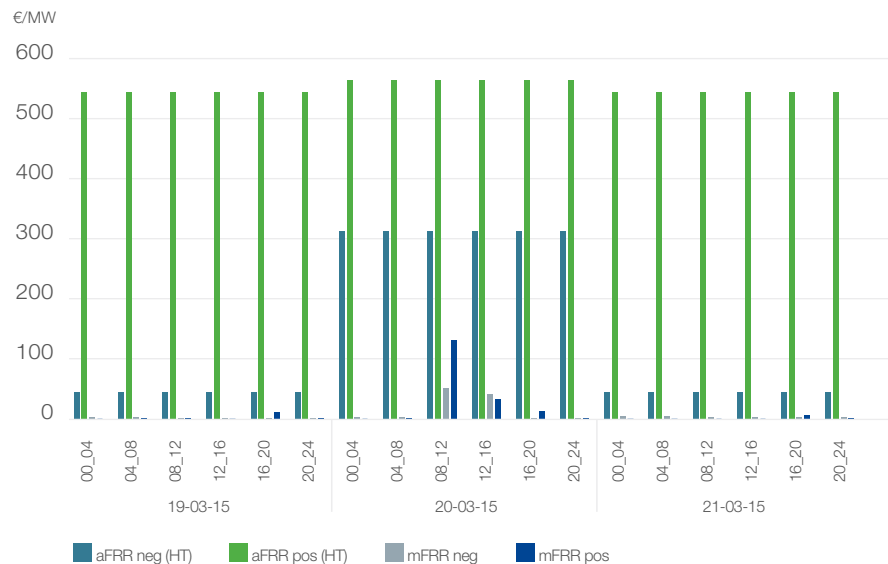


Figure 41: Prices for contracted control reserve prices during solar eclipse in Germany on March 20th. Source: regelleistung.net

Belgian price peaks

Throughout 2015, Belgium faced high rates of unavailability, both planned and unplanned, of its conventional generation stack, as can be observed in Figure 42.

Special events

in 2015

Unavailability Belgium Power Plants

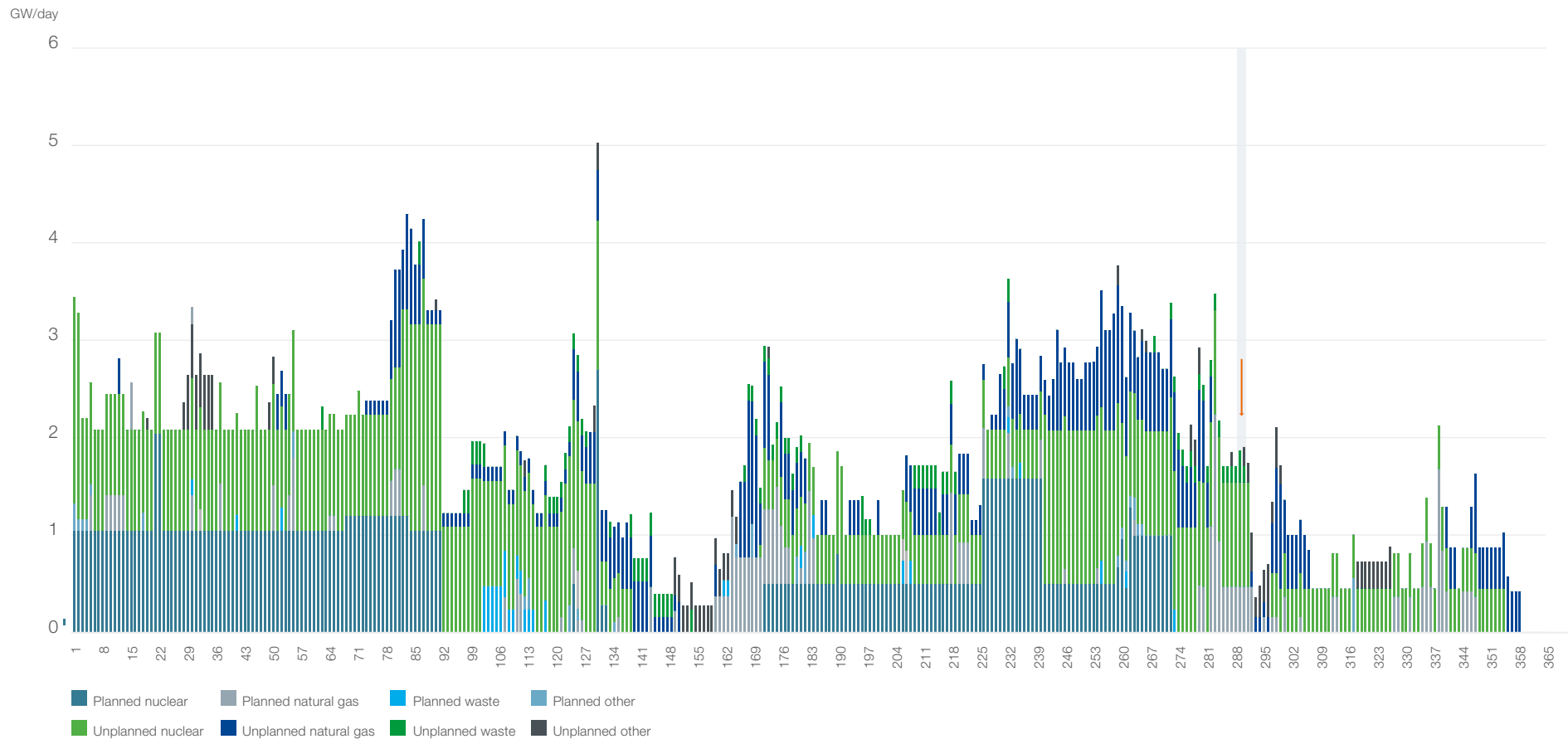


Figure 42: Planned and unplanned unavailabilities of Belgian power plants. Sources: ELIA, Federal agency for nuclear

Special events

in 2015

This led to some serious adequacy concerns for the Belgian system, which in turn also led to price peaks. Especially during the end of September and middle of October, several planned power plant outages plus planned infrastructure work on the Belgian high-voltage grid led to a high unavailability of generation and transmission capacities and a high volume of international flows through the Belgian system. International redispatch measures were needed on several days to relieve the transmission grid and to maintain system security.

An exemplary situation is illustrated in Figure 43 for two days in the middle of October in 2015. During those two days the spot price was consistently very high during the day, with the highest peaks reaching 450 €/MWh. This led to most of the thermal generation stack being utilized, even oil-fired power plants, whilst importing at maximum capacity throughout the period. The very high prices represented a generation adequacy challenge in Belgium for those days, but in cooperation with its neighbouring countries, Belgium managed to prevent any acute adequacy issues from materializing.

Analysis by the TSOs showed that these exceptional price spikes would not have occurred under Flow Based Plain Market Coupling. Unlike the implemented Flow Based Intuitive this method does not have the restriction that only allows an outcome in which commercial flows only go from a market area with lower prices to market areas with higher prices. The reason for the introduction of this restriction was that it was considered counter-intuitive by stakeholders to have commercial flows from higher to lower priced areas. In this particular event this restricted further imports into Belgium, leading to higher prices.

This exemplary situation, as well as the price levels and high degree of unavailability of generation capacities throughout the year, shows how much planned and unplanned outages are an impact factor on prices in Belgium in the current tight situation.

Special events in 2015

Price peaks in Belgium on October 15th and 16th

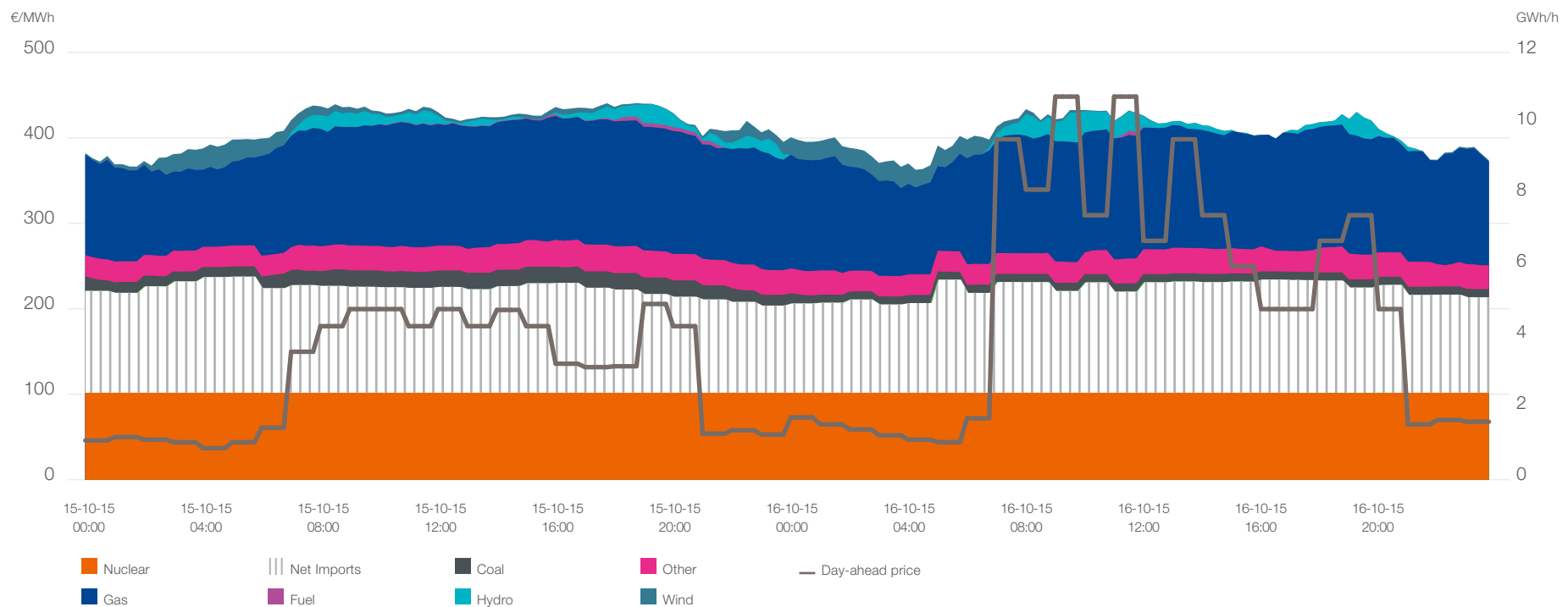


Figure 43: Day-ahead generation schedule and Day-ahead prices during 15th and 16th of October 2015 in Belgium. Sources: Elia, TenneT

Main findings

Average wholesale prices in Germany and the Netherlands decreased in 2015 following downward commodity prices for coal and gas and increased generation from solar and wind.

In the course of 2015, the marginal generation costs of gas- and coal-fired generation converged. Typically this contributes to the convergence of the wholesale prices for electricity in Germany and the Netherlands.

Additionally, the increasing share of coal-fired generation at the expense of gas-fired generation in the Netherlands contributes to price convergence in hours where coal-fired generation becomes price-setting in both countries.

The introduction of Flow Based market coupling on May 20th, further increased the interconnection capacity that can be made available if the CWE price differences are large.

However, strong growth of generation from wind energy in Germany and sharply increased exports from the Netherlands to Belgium caused the percentage of hours of full price convergence to remain similar to that in 2014.

In Germany the generation stack and the generation itself is under a long-term transition. So in 2015, the ongoing trends led again to the shutdown of one nuclear and some conventional units, whereas additional capacities of renewable generation, especially offshore wind turbines, entered the market. Additionally, the increase of solar capacities amplified the merit order effect around noon. Thus, the pressure on income for conventional power plants remains unabated.

In the Netherlands, the generation from renewables also grew. The production from solar panels, although still small, now becomes significant at the system level. Despite its growth, the gap between the Netherlands and Germany grew wider. Where the German targets for 2020 seem within reach, the Netherlands will need a very steep increase to reach its goals.

Intraday markets are becoming increasingly important for balancing ramp rates and forecasts in Germany. Supported by the introduction of Intraday auctions, intraday volumes grew significantly with the growing need to balance renewables.

The balancing performance in Germany improved, especially the negative net imbalances (where the system is 'short') decreased. Imbalance prices in the Netherlands and Germany in 2015 were more extreme than in 2014.

The number and volume of necessary redispatch measures in Germany increased sharply during 2015. The need for redispatch is strongly correlated with the amount of wind energy production for which there are not yet sufficient north-south transmission capacities. Redispatch to ensure system stability has become a daily necessity in Germany.

Colophon

This Market Review is a publication of TenneT

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