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ELFI/TIF proposed market design: analysis of impact on wholesale power prices

FINAL REPORT

2ND DECEMBER 2022

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Content

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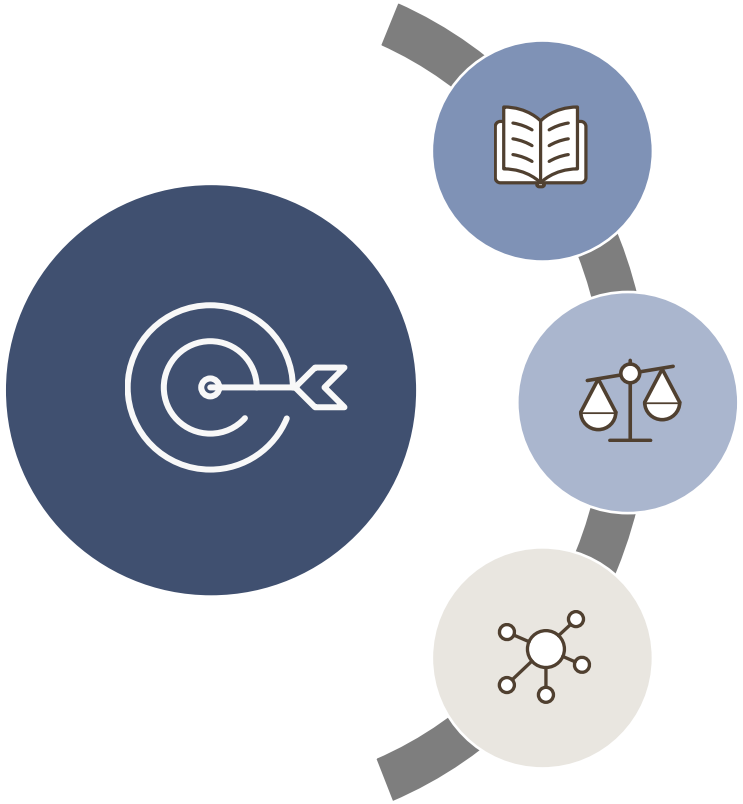
Content

EXECUTIVE SUMMARY – BACKGROUND AND APPROACH



Association of Energy Users in Finland (ELFI) and Technology Industries Finland have proposed a market design, which generally is a combination of two clearing models. In the proposed design, the market is first optimised as today by matching demand and supply, together with cross border flows. Thereon, to clear the market, the design proposes a combination of pay-as-clear and pay-as-bid clearing methods

The ELFI/TIF proposed market design splits the wholesale electricity pricing into three categories. Generators (supply) are effectively split into two separate categories whereas the consumers (demand) are given one uniform category

AFRY's modelling tool and data is used to model the electricity prices generated by the ELFI/TIF proposed market design. The modelling in this analysis is focusing to Germany, considering Germany as an island market with fixed in- and outflows of electricity, based on 2021 data. Three scenarios with different clearing splits are conducted

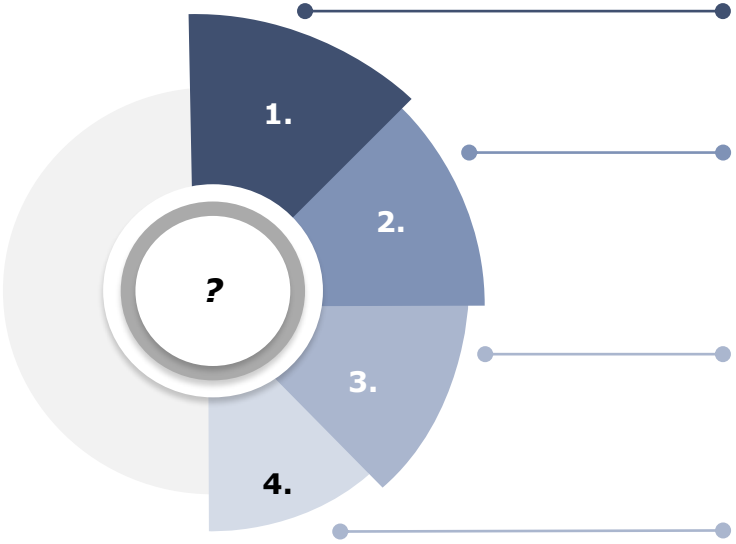
EXECUTIVE SUMMARY – KEY FINDINGS

ELFI/TIF Proposed Market Design

AFFECTED GROUP	EFFECT[1]	DETAILS
Generators	Lower received wholesale electricity prices (for most generators)	– Price received by the generators is split into two categories – Most of the generators receive a lower price than with the current market design for most of the time
Consumers	Lower paid wholesale electricity prices	– All consumers pay a uniform price – The price is significantly lower when the supply curve is steeper[2]
Overall market	Decreased producer surplus	– Generator surplus is reduced as the price received by the generators is lower than the overall system price

(1) The three different scenarios have slightly varying implications and results but the overall findings from them are common.
(2) Steeper curve may occur when e.g. delta between the cost of generation with gas and coal is higher (increased gas prices), or when delta between the cost of generation with renewable energy sources and coal is higher (periods of high wind)

EXECUTIVE SUMMARY – FURTHER RESEARCH NEED



How will the lower electricity prices for demand affect incentives for the current and future demand side response?

How will the lower electricity prices affect investments and development in new flexible production capacity as the results show cutting of peak electricity prices?

How may the ELFI/TIF proposed market design change bidding behaviour of the market participants, and how are the bidding behaviour functioning close to the border of the clearing cut-off?

How will the transparency and replicability of the ELFI/TIF proposed price calculations ensured as it requires visibility to the order data?

Content

This study aims to quantify the effect of the ELFI/TIF proposed market design in the wholesale electricity prices

BACKGROUND AND AIM OF THE STUDY

- Technology Industries of Finland is the lobbying organisation for technology industry companies and promotes competitiveness and the operational preconditions for technology industry, the largest and most important export sector in Finland. Technology Industries of Finland has about 1,800 member companies
- Technology Industries of Finland is in close cooperation with Association of Energy Users in Finland (ELFI), an energy industry interest group focusing on the electricity market. ELFI has promoted an updated market design where the clearing and pricing in the wholesale electricity market would deviate from the current design
- Technology Industries of Finland tasked AFRY to make quantitative analysis of the ELFI/TIF proposed market design, to analyse and understand the effects it may have to the electricity wholesale prices.

KEY QUESTIONS ANSWERED IN THIS STUDY

1. What the effects of the ELFI/TIF proposed market design would have been to the 2021 wholesale electricity prices in Germany with fixed flows?
2. How would adjustment and variation in the clearing cut-off within the ELFI/TIF proposed market design affect the 2021 wholesale electricity prices in Germany with fixed flows?

Association of Energy Users in Finland (ELFI) has proposed a market design, which is a combination of two clearing models

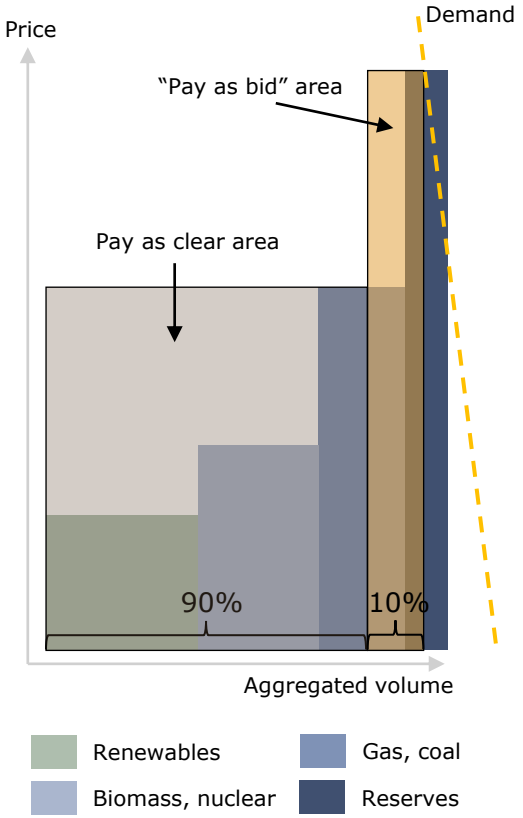
GENERAL BACKGROUND TO THE CLEARING METHODS

- Pay-as-clear: All participants receive the price of the most expensive item procured – *currently used in the European day ahead wholesale electricity market*
- Pay-as-bid: Each market participant receive the price they have bid into the market with

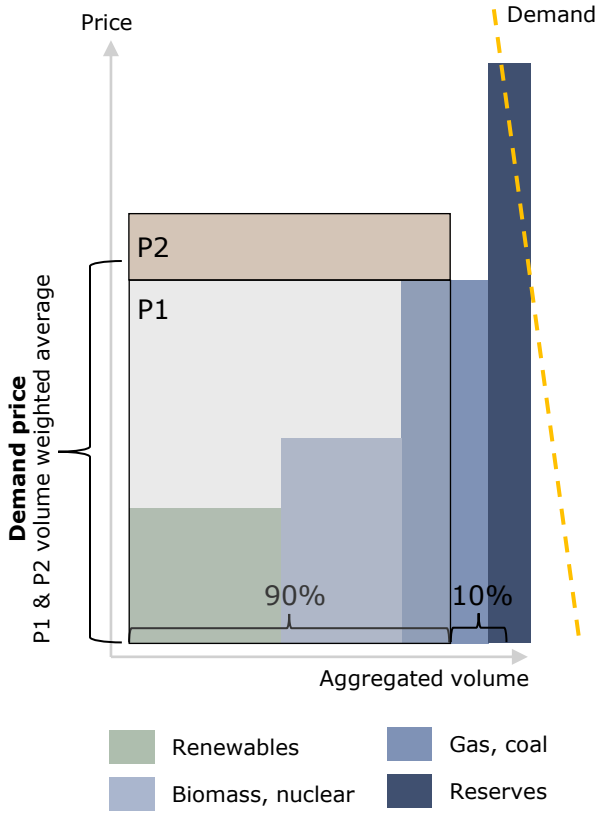
MARKET DESIGN PROPOSED BY ELFI[1]

- The market is first optimised as today by matching demand and supply, together with cross border flows
- Thereon, to clear the market, the ELFI/TIF proposed market design applies a combination of pay-as-clear and pay-as-bid clearing methods that would be applied as:
  - Least cost 90% of volume cleared with pay-as-clear
  - Highest cost 10% of volume cleared with pay-as-bid[2]
- P1 received price would be set by the most expensive accepted sales order within the least cost 90% accepted sales orders
- P2 average received price would be set by volume weighted average of the accepted sales orders within the most expensive 10% of the accepted sales orders
- Demand would pay a volume weighted average price of the P1 (pay-as-clear) and P2 (pay-as-bid) prices, demand price

ELFI/TIF PROPOSED MARKET DESIGN CLEARING SPLITS[1]

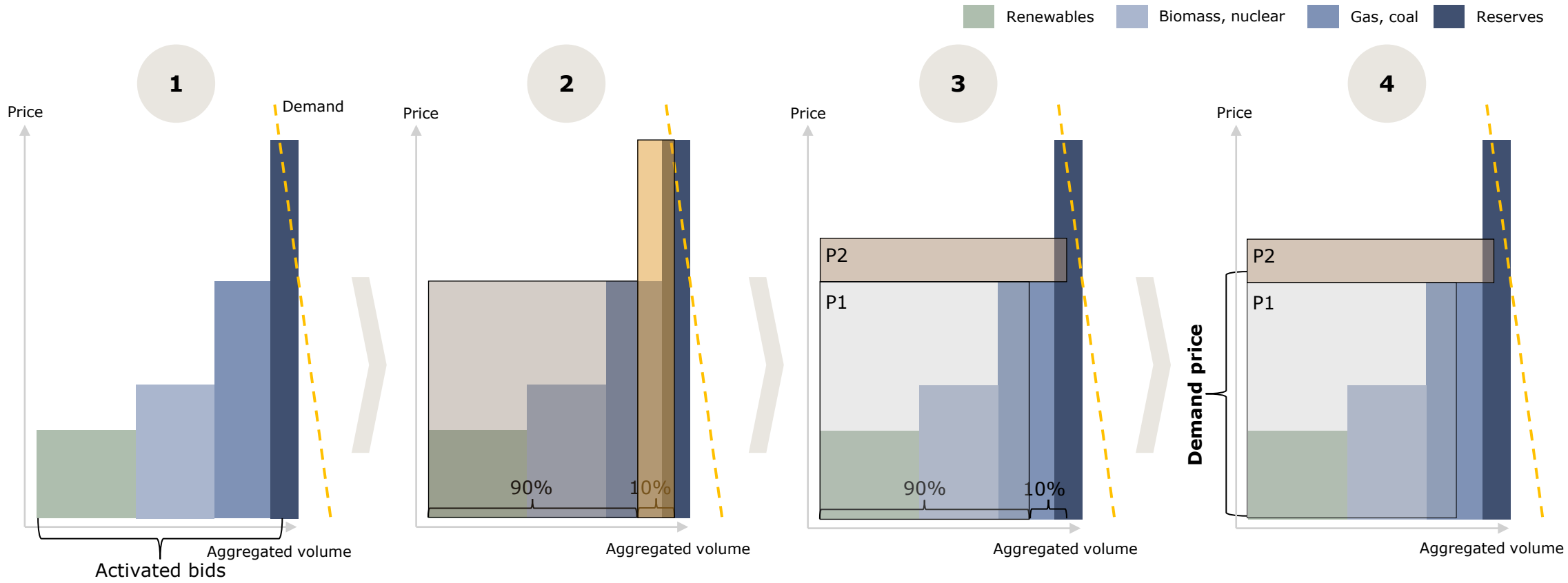


ELFI/TIF PROPOSED MARKET DESIGN PRICE AREAS[1]



(1) As received from Teknologiateollisuus Ry
(2) Pay-as-bid for day ahead hourly curves (with multiple price/volume pairs) is not self-evident. This study uses a volume weighted average price of the 10% most expensive accepted sales orders to form an average received price for the pay-as-bid portion of the market.

ELFI/TIF proposed market design formulates hourly prices in four steps



Hourly supply bids activated to meet the hourly demand

Activated bids divided into two groups: least cost 90% and most expensive 10%

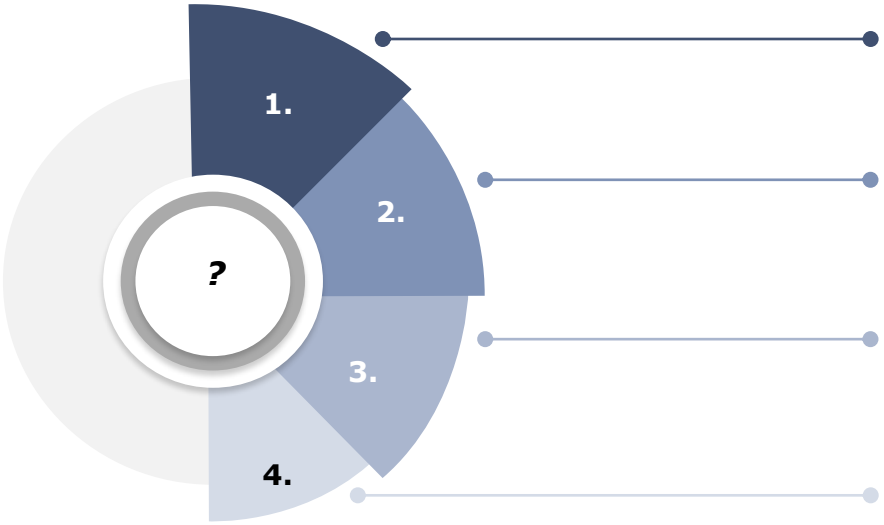
P1 received price and P2 average received price are calculated

Demand price is calculated as volume weighted average of P1 and P2

The ELFI/TIF proposed market design has some open questions and further research needs that should be considered, but were not part of this assignment

While the modelling results of this project show that generally the wholesale electricity prices would have been lower in 2021 Germany, the European wide wholesale market dynamics and further effects of the ELFI/TIF proposed market design remain unanswered

FOUR KEY OPEN QUESTIONS



1. How will the lower electricity prices for demand affect incentives for the current and future demand side response?
2. How will the lower electricity prices affect investments and development in new flexible production capacity as the results show cutting of peak electricity prices?
3. How may the ELFI/TIF proposed market design change bidding behaviour of the market participants, and how are the bidding behaviour functioning close to the border of the clearing cut-off?
4. How will the transparency and replicability of the ELFI/TIF proposed price calculations ensured as it requires visibility to the order data?

Content

Currently the wholesale electricity prices for Germany are calculated in European wide optimisation through daily auctions

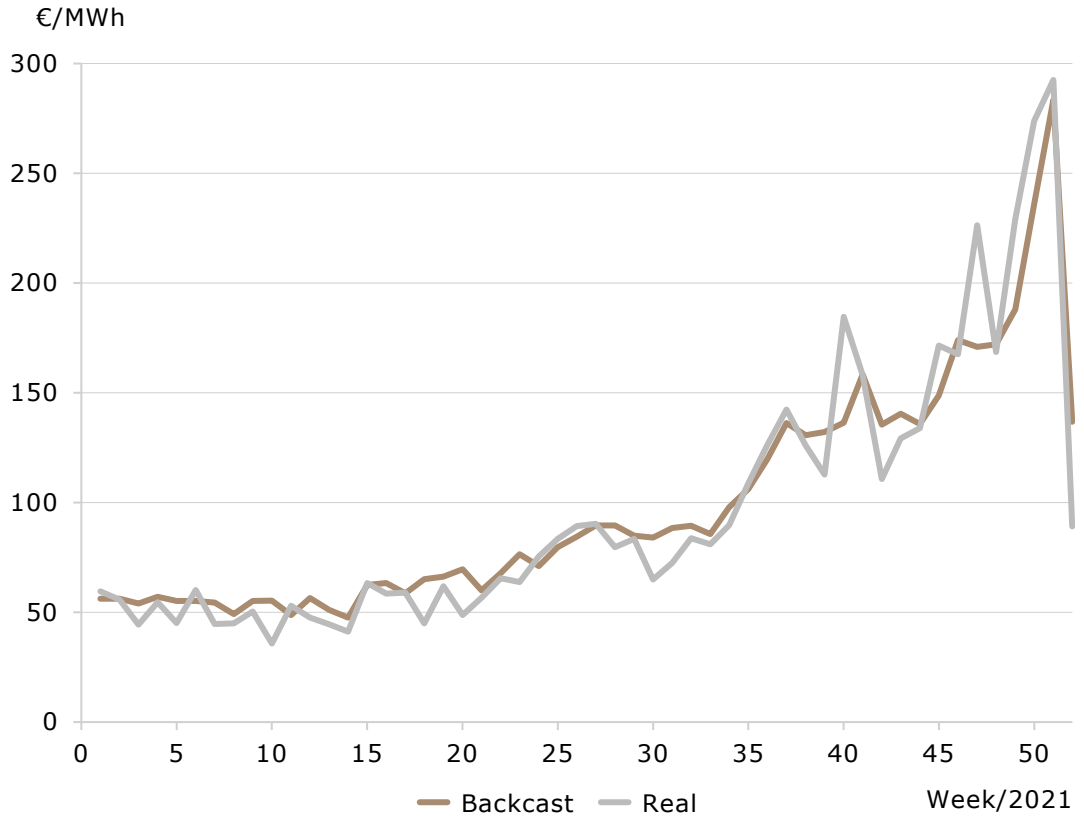
WHOLESALE ELECTRICITY MARKET PRICES ARE SET IN AN INTEGRATED CROSS-BORDER OPTIMISATION

- The currently applied price formation in the electricity wholesale markets is a multi step process involving various parties and countries
- In the heart of the European internal electricity market is ”Single Day Ahead Coupling (SDAC)” that is the main sphere for daily wholesale trading of electricity, and the place where the wholesale prices are set in one optimisation for the whole Europe. Germany is part of this European wide optimisation
- The SDAC optimisation takes into account cross-border flows and other relevant grid constrains, as well as offers to buy and sell electricity in various countries. The optimisation is carried in a cooperative manner by the various European Power Exchanges
- The SDAC optimisation allocates cross-border flows as well as calculates the wholesale prices by optimising the total social welfare for the whole participating region. The price formation follows the pay-as-cleared methodology where the last activated production unit to meet the demand sets the price for a given country (or price zone)

COUNTRIES PART OF SDAC OPTIMISATION

AFRY modelling with internal data provides a very close representation of the real wholesale prices in Germany 2021

AFRY BACKCAST DATA COMPARED TO REAL HISTORICAL DATA



- AFRY's modelling tool, BID3[1], is used to model future electricity prices, along with all parameters of the power system. BID3 projects physical operation and economic behaviour of all plant types:
  - Cost optimising electricity market dispatch model
  - Optimal regional power flows subject to transmission constraints
  - Cost based dispatch with complex thermal plant dynamics & additional scarcity pricing
  - Detailed storage & hydro modelling optimises reservoirs and storage dispatch
- The graph shows AFRY's backcast calculation of Germany in BID3 (based on AFRY data) against the real wholesale power prices in 2021 Germany.
- The observed deviations are small, and the trend follows the real-life well. Thus, the representation and replication of the real-life market is considered accurate in order to compare the results of the ELFI/TIF proposed market design in this analysis

(1) BID3 description in the Annex 1

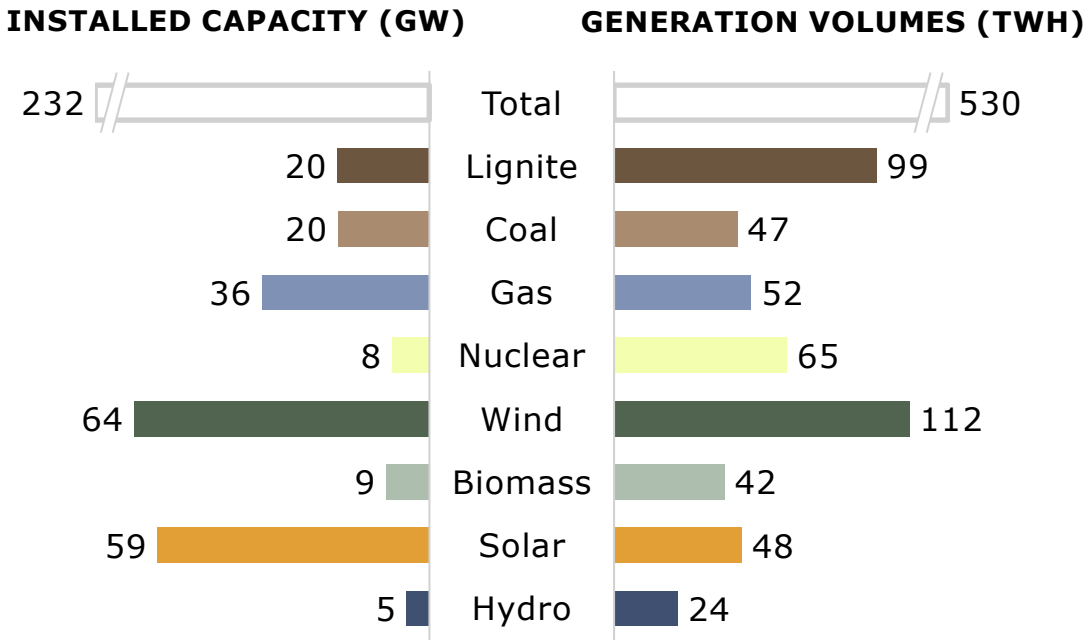
ELFI/TIF proposed market design analysis is limited to Germany 2021 with fixed in and out flows to analyse possible differences in one country

ASSUMPTIONS ON WHICH THE MODELLING IS BASED ON

- Modelling performed in this assignment is based on AFRY market data, as the real historical bid data is confidential information owned by the Power Exchanges. However, as the backcast results illustrate, AFRY data is a close estimation of the real data and has been proven[1] to reflect real market well
- In order to analyse a single country, Germany is re-calculated as an islanded market with fixed in and out electricity flows, based on AFRY 2021 market data
- The modelling uses one-hour day-ahead resolution for the purchase and sales orders, matching the real-life market functionality and granularity
- Smart products (e.g. block orders), which were available and used in Power Exchange markets in 2021, are not included as such in the modelling due to the inaccessibility of the real order data. However, AFRY data includes representation of the smart product bid behaviour
- The analysis assumes that the presence of the clearing split methodology does not affect bidding behavior, and all sellers continue to bid assuming pay-as-cleared

RENEWABLES PROVIDE THE MAIN PORTION OF THE MERIT ORDER STACK IN GERMANY IN 2021[2]

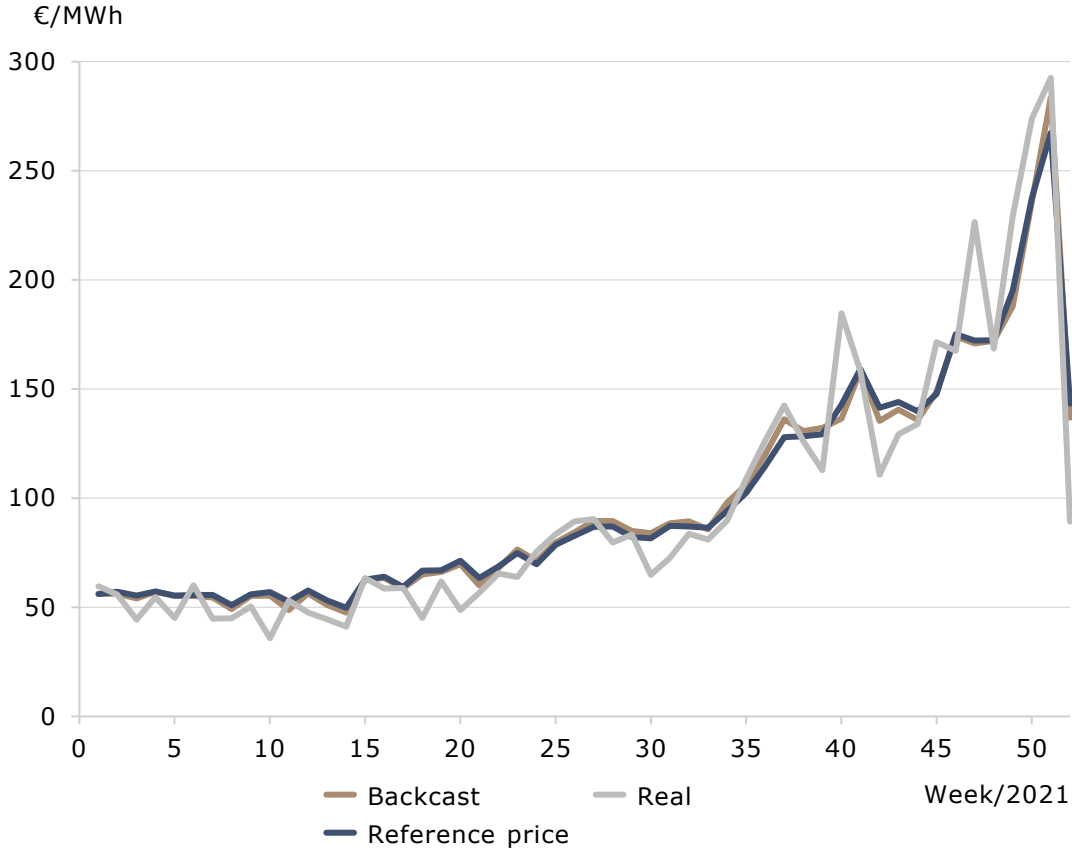
Installed capacity: 232GW	**Generation: 530TWh**	**Demand: 505TWh**
Fossil fuel share: 33 %	Fossil fuel share: 41 %	Peak demand: 1,7 TWh/day
Nuclear share: 3 %	Nuclear share: 13 %	Grid losses: 30 TWh
Renewables share: 63 %	Renewables share: 46 %	



1) More information and references for BID3 in Annex 1 2) Federal Statistical Office of Germany

Although the modelling in this analysis optimises Germany with fixed flows, the calculated reference price is close to the backcast and real price

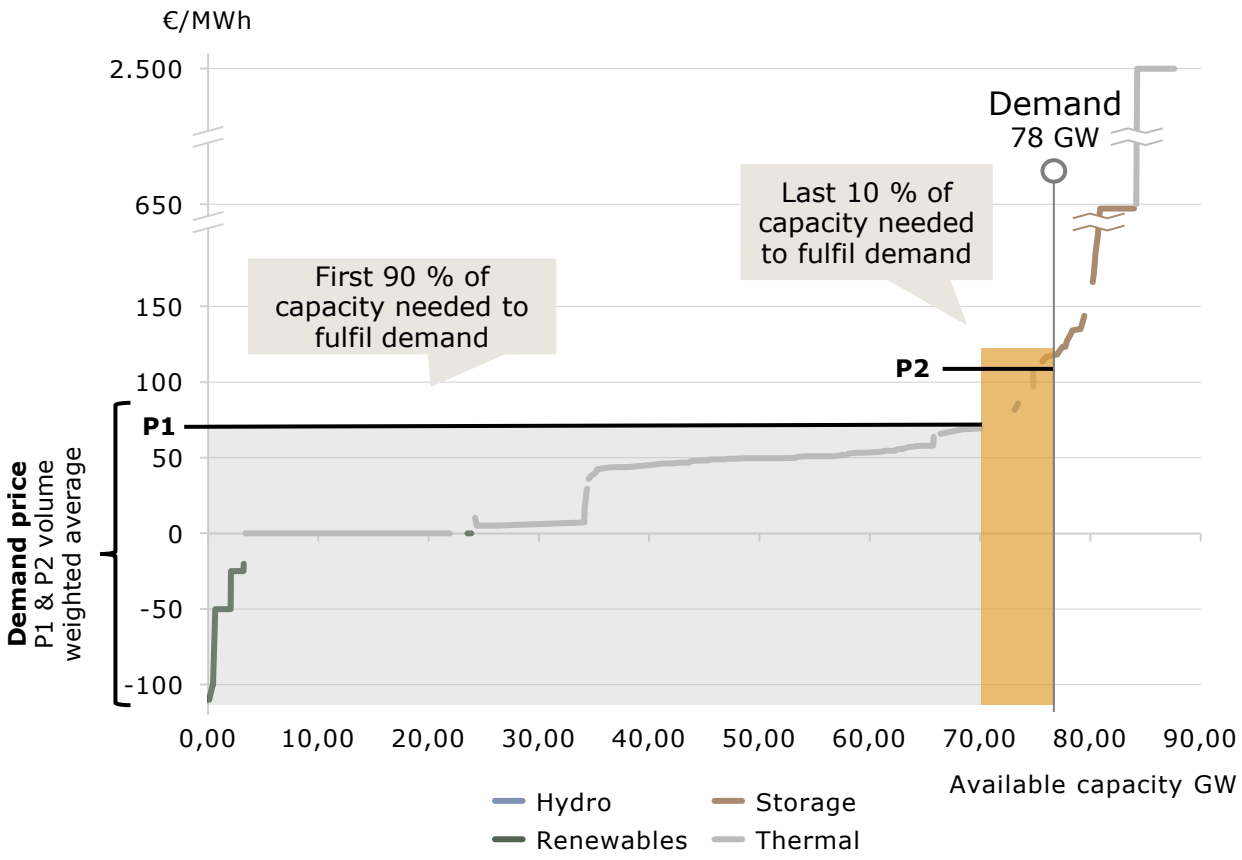
DEVIATIONS BETWEEN AFRY BACKCAST AND CALCULATED MARGINAL PRICE



- As explained earlier, the modelling in this analysis is performed considering Germany as an island market with fixed in- and out-flows of electricity based on 2021 data. This is done to be able to analyse one country without having to optimise the whole Europe
- Consequently, the marginal price for the whole Germany system may deviate slightly from the backcast and real-life European wholesale electricity prices since dynamic flows are not allowed
- However, the deviations between the backcast and fixed flow modelling are illustrated in the graph, showing that the deviations in this modelling are neglectable and thus the analysis with fixed flows will provide a close approximation of the real-life

AFRY modelling of the ELFI/TIF proposed market design follows the outlined principles to derive the new set of prices

GERMANY HOURLY SUPPLY CURVE FOR ONE HOUR IN 2021



MODELLING METHODOLOGY

- Germany is modelled as an island market using the fixed in- and out-flows of electricity from AFRY backcast. Only German prices are optimised, and any price changes do not have an impact on imports and exports
- Demand is set to be net demand determined by the fixed in and out flows as:
  - Demand = Germany demand + export – import

1. Activated bids from the hourly supply curve (merit order) determined based on the demand needed to be fulfilled
2. Bids divided into the first 90% of capacity and last 10 % of capacity
3. Price received by the first 90% of the production is set based on the price of the highest order activated within the first 90% of capacity, and set as the **P1 received price**
4. Average received price for the last 10% of production is calculated based on the volume weighted average price of the bids within the last 10% of capacity, and set as the **P2 average received price** to represent "pay-as-bid"
5. The **demand price** is based on the volume weighted average of the P1 and P2 prices

Content

The modelling results show three different prices as in the ELFI/TIF proposed market design, as well as reference price to the current market design

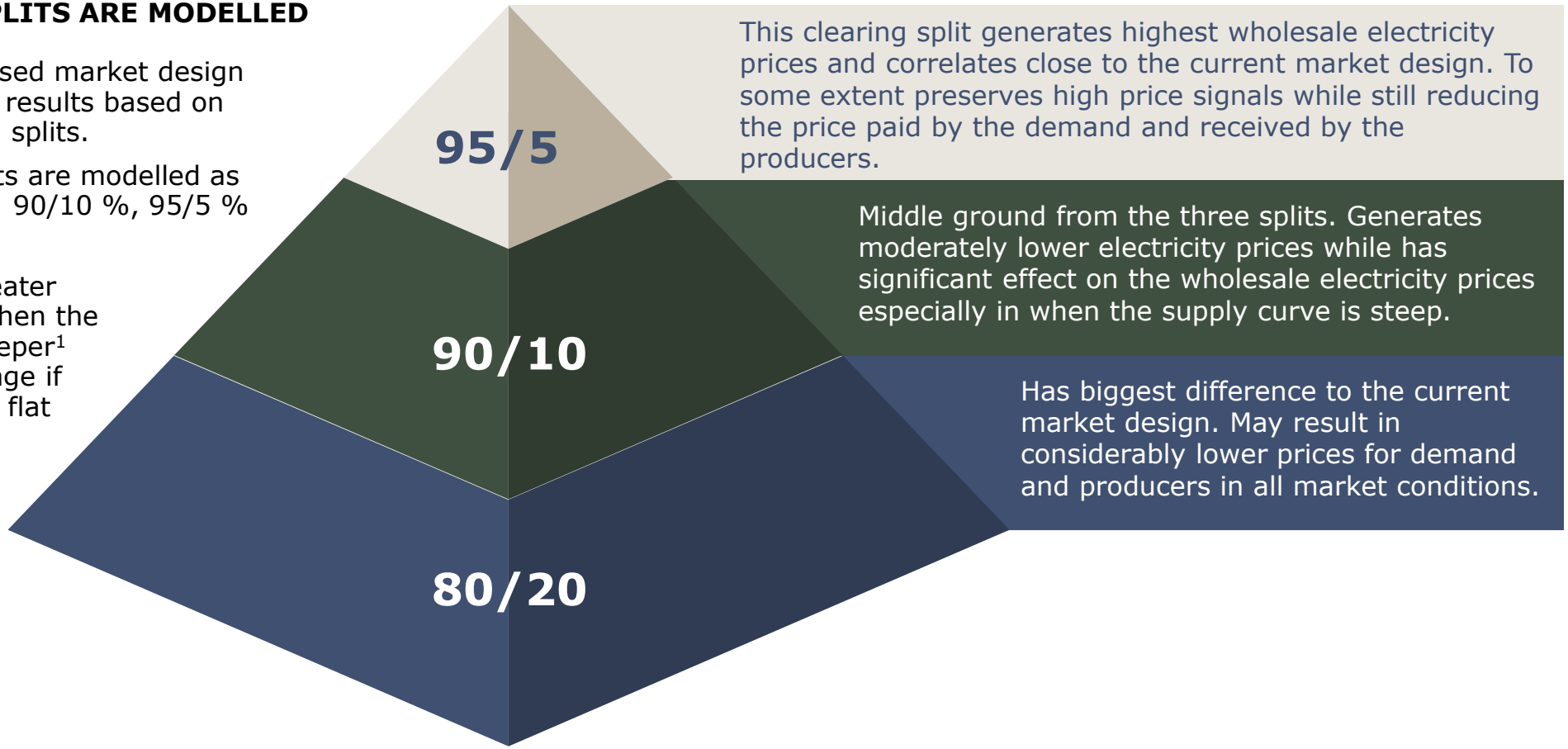
- ELFI/TIF proposed market design will split the wholesale electricity pricing into three categories. Each price category is applicable for all market participants within the respective sub-set of market participants:
  1. Uniform price (P1) for all production in the least cost 90% of the successful orders in the market optimisation
  2. Average received price (P2) for the production in the most expensive 10% of the successful orders in the market optimisation
  3. Uniform price for all demand (volume weighted average of P1 and P2)
- These prices are illustrated in the following pages as part of the result analysis. The nomenclature for these prices is shown in the Table below. In addition, a reference price is calculated, representing the price that would have been calculated with the market design as we have now, by matching the supply and demand at the system marginal cost of production

Coverage		Price name	Definition
Price applicable to the current market design		Reference Price	Representing the price that would have been with the current market design with system wide pay-as-cleared price formation in the islanded (fixed flows) Germany.
Prices applicable for the ELFI/TIF proposed market design		P1 received price	Price that is applicable for the least cost 90% of the supply
		P2 average received price	Price that is on average applicable for the most expensive 10% of the supply
		Demand price	Price that is applicable for the demand (volume weighted average of P1 and P2)

ELFI/TIF proposed market design lowers wholesale electricity prices in all chosen clearing splits – with differences in the magnitude of change

THREE DIFFERENT SPLITS ARE MODELLED

- The ELFI/TIF proposed market design generates different results based on the chosen clearing splits.
- Three different splits are modelled as part of this project: 90/10 %, 95/5 % and 80/20 %
- All splits create greater price differences when the supply curve is steeper[1] and very little change if the supply curve is flat



This clearing split generates highest wholesale electricity prices and correlates close to the current market design. To some extent preserves high price signals while still reducing the price paid by the demand and received by the producers.

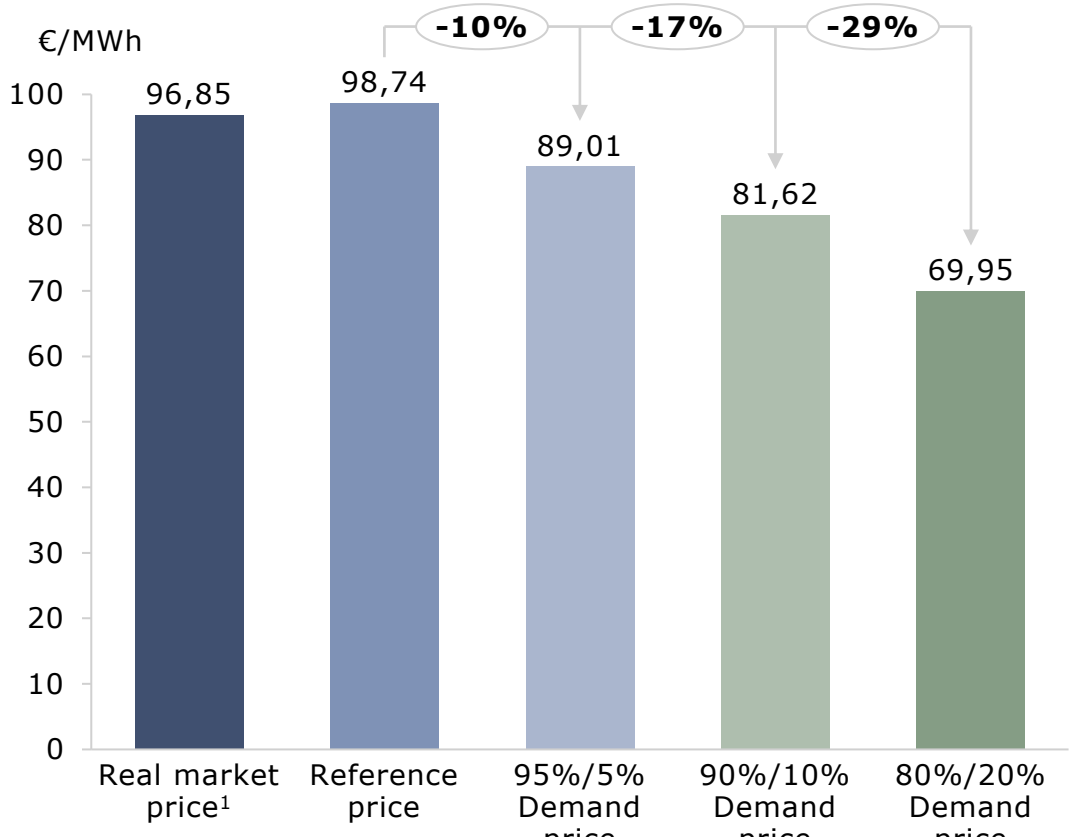
Middle ground from the three splits. Generates moderately lower electricity prices while has significant effect on the wholesale electricity prices especially in when the supply curve is steep.

Has biggest difference to the current market design. May result in considerably lower prices for demand and producers in all market conditions.

(1) Due to e.g. periods of high wind (low marginal cost of production compared to rest of the required generation) or periods of high gas prices (high marginal cost of production compared to rest of the required production)

On annual average, the ELFI/TIF proposed market design lowers wholesale electricity prices for demand from moderate to significant amount

ANNUAL AVERAGE WHOLESALE ELECTRICITY PRICES GERMANY 2021 (€/MWH)

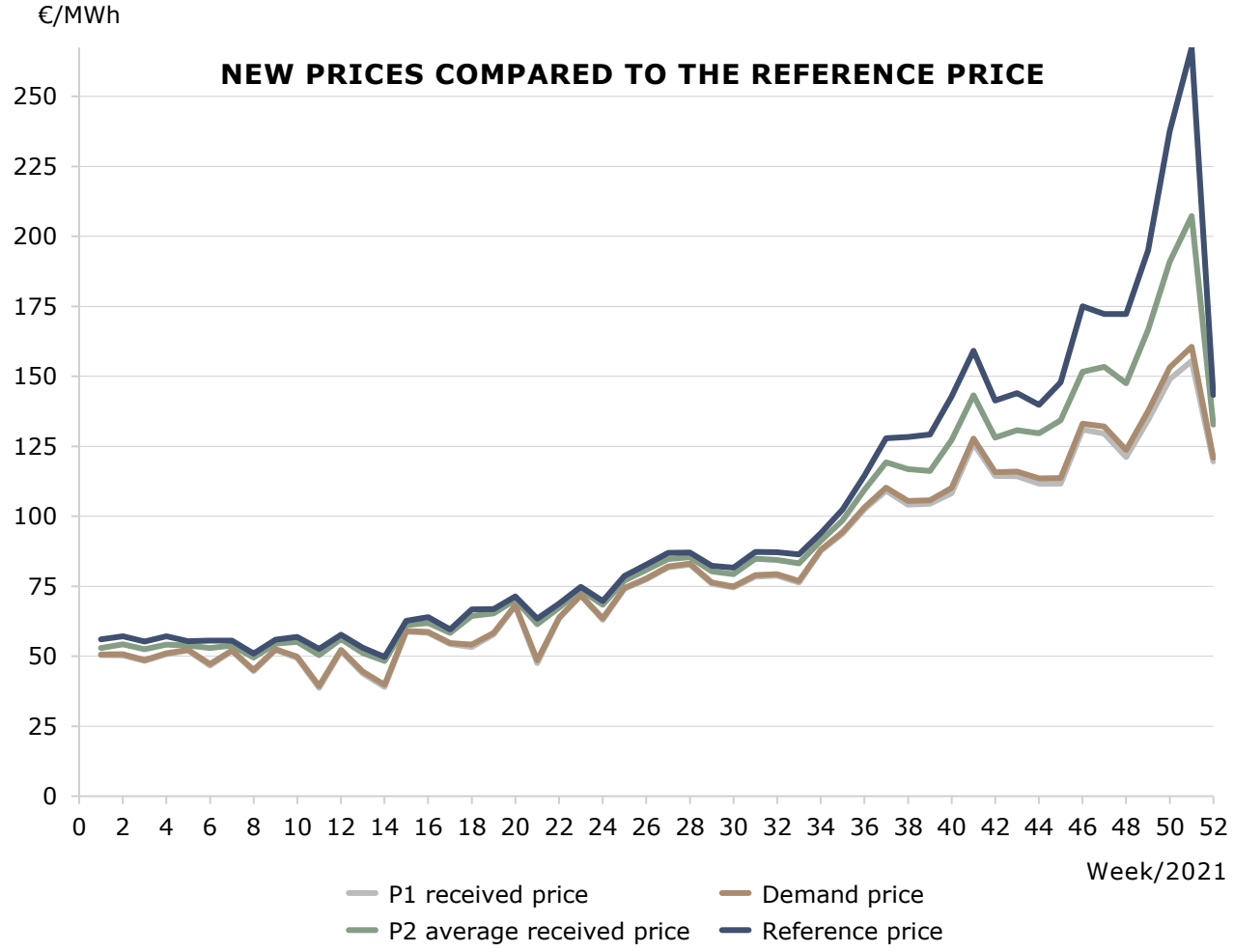


Sources: 1) Nordpool

- Reference price in this chart represents the price that would be formed in Germany 2021 with the current market design for all market participants. It is calculated based on AFRY data and modelling tool with fixed flows
- The annual average of the modelled reference price is close to the real annual average wholesale electricity price in Germany 2021
- The modelled annual average wholesale electricity price paid by the consumers is lower than the reference price with all clearing splits using the ELFI/TIF proposed market design
- The trend shows that the higher the clearing split is, the lower the wholesale electricity price will be for the consumers:
  - With 95/5 % split the demand price is moderately (-10%) lower than the reference price on annual average
  - With 90/10 % split the demand price is notably (-17%) lower than the reference price on annual average
  - With 80/20 % split the demand price is significantly (-29%) lower than the reference price on annual average

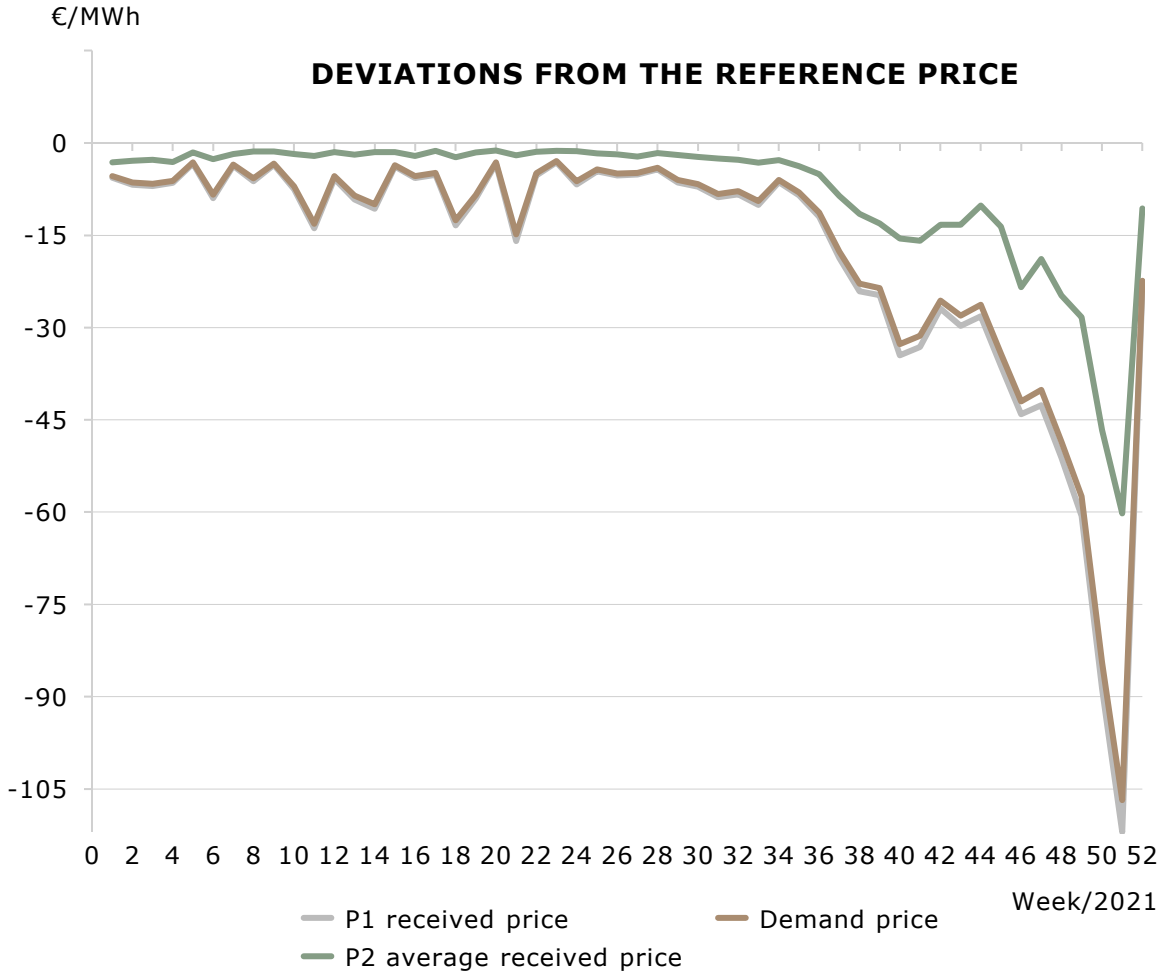
Content

ELFI/TIF proposed market design generates lower wholesale electricity prices for demand and supply



- Reference price in this graph represents the price that is formed with the current market design for all market participants. In 2021 the price was increasing significantly towards the end of the year.
- All three new prices as per the ELFI/TIF proposed market design remain below the reference price throughout the year while P1 and demand price are reduced significantly in high price periods
- Generally, the P1 is correlating heavily with the demand price. This is an expected outcome given that the demand price is calculated as volume weighted average price, and here the P1 includes majority of the volumes
- The P2 falls between the P1 and reference price, given the volume weighted average application for the “pay-as-bid” portion

The ELFI/TIF proposed market design has a significant effect on the wholesale electricity prices especially when the supply curve is steep



- The graph on the left illustrates the difference in €/MWh between the reference price (i.e. the price with current market design) and the three new prices formed based on the ELFI/TIF proposed market design
- The modelling results reveal moderate differences between the current market design and the ELFI/TIF proposed market design with 90/10 % clearing split for the first few quarters of 2021
- Thereon, the P1 and demand price start to significantly detach from the reference price due to e.g. increasing gas prices having major impact in the merit order in Germany. Similarly, the P2 starts pull away from the reference price
- Overall, the results imply that with normal and flat supply curves the 90/10 split does not provide vastly different results to the current market design.
- However, with steeper supply curve[1] (as from end of 2021 throughout 2022) the ELFI/TIF proposed market design may have significant impact on the market prices, especially for P2 and demand price

(1) Steeper curve may occur when e.g. delta between the cost of generation with gas and coal is higher (increased gas prices), or when delta between the cost of generation with renewable energy sources and coal is higher (periods of high wind)

On average the modelled new prices are close to the historical wholesale electricity prices while being significantly lower when the supply curve is steep

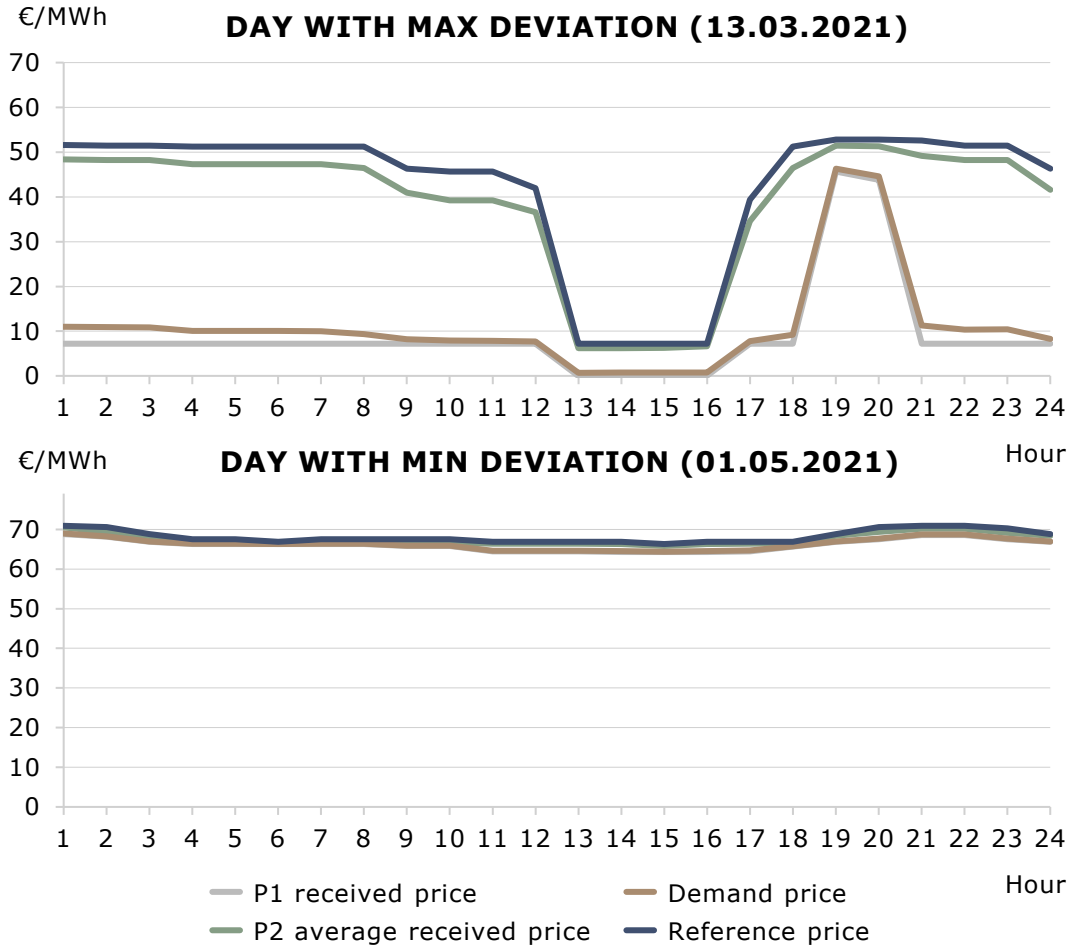
- The table below provides real 2021 average monthly wholesale electricity prices that were reported by a power exchange. The prices are not directly comparable (see page 15) but aims to illustrate potential differences to the modelled prices
- The ELFI/TIF proposed market design would provide three separate wholesale electricity prices. When compared to the real-life price data, it can be observed that until August there is very little to no deviation in the monthly averages. However, from September onwards the prices start to diverge from the historical price
- Practically, the results show that the ELFI/TIF proposed market design would shave off peak prices for all price categories

AVERAGE REAL MONTHLY AND ANNUAL WHOLESALE ELECTRICITY PRICES AGAINST NEW MODELLED PRICES AS PER ELFI/TIF PROPOSED MARKET DESIGN

Price / Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
2021 real market price[1]	53	49	47	54	53	74	81	83	128	139	176	221	97
Reference price	56	54	55	59	67	75	84	91	124	144	166	205	99
Demand price	50	49	47	54	58	71	78	84	106	116	126	139	82
P1 received price	50	49	47	53	57	70	78	83	105	114	124	135	81
P2 average received price	53	52	54	58	65	74	82	88	115	130	146	170	91

Sources: 1) Nordpool

The ELFI/TIF proposed market design may create zero prices for demand that could distort incentives for both storage and demand side response



- These two graphs are singled out days from the result data representing on average maximum and minimum possible deviations between the reference price and the three new prices as per the ELFI/TIF proposed market design
- The maximum deviation day illustrates that the P2 and demand price may be significantly lower than the reference price. In this case the reference price is almost 40€/MWh higher than the P2 and demand price with the ELFI/TIF proposed market design
- This suggests that there can be large differences compared to the current market design when the supply curve is steep due to excess low-cost renewable energy production (wind). This has a potential to distort the price signals for the demand side response and storage.
- On the other hand, the day with minimum deviation illustrates that there may be days where all three prices are very close or identical to the reference price. In such days the ELFI/TIF proposed market design makes no difference to the current market design

Additional metrics from the results show on average moderate discrepancy between the ELFI/TFI proposed market design and the current market design

- Demand price average difference is 14%, illustrating that the demand price is moderately close to the reference price most of the time. Maximum deviation is considerably higher.
- Demand price is not at a close range to reference price (within 2%) for any of the days

- P1 is very close to the demand price across the year
- As for demand price, P1 is not in a close range to the reference price for any of the days

- P2 follows closest the reference price being within close rage for 63 days in 2021 and on average within 6% from the reference price

Additional metrics for demand price compared to reference price	Value
Average difference %	-14 %
Average difference €/MWh	-17 €/MWh
Maximum difference %	-74 %
Maximum difference €/MWh	-150 €/MWh
Number of days that have max 2% difference	0 days

Additional metrics for P1 compared to reference price	Value
Average difference %	-15 %
Average difference €/MWh	-18 €/MWh
Maximum difference %	-79 %
Maximum difference €/MWh	-157 €/MWh
Number of days that have max 2% difference	0 days

Additional metrics for P2 compared to reference price	Value
Average difference %	-6 %
Average difference €/MWh	-8 €/MWh
Maximum difference %	-27 %
Maximum difference €/MWh	-92 €/MWh
Number of days that have max 2% difference	63

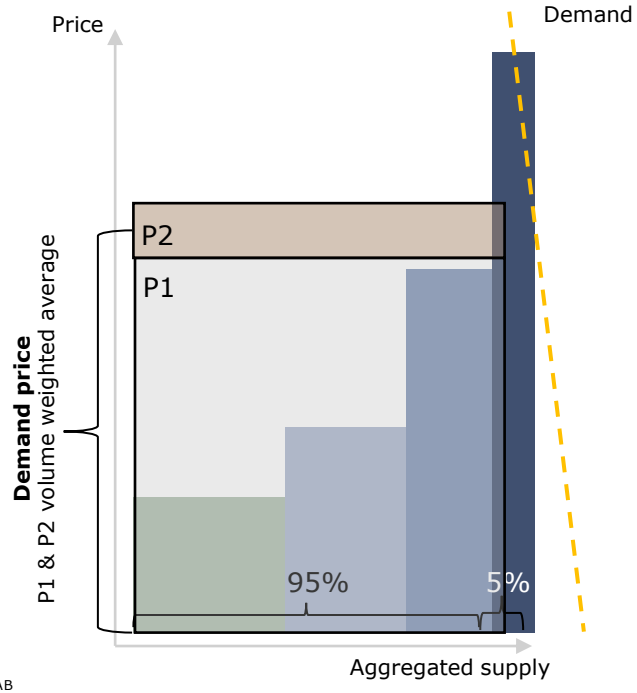
Metrics are based on daily average price data

Content

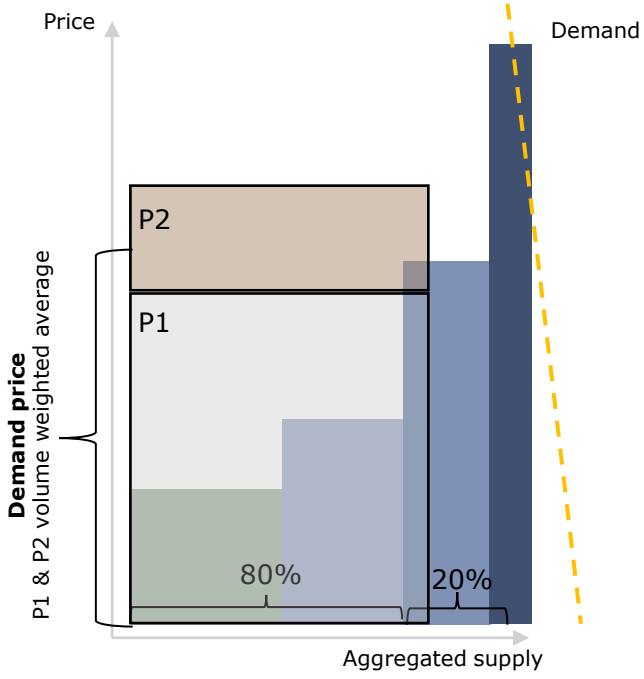
Two sensitivity analyses of the ELFI/TIF proposed market design have been modelled

- Two sensitivity analyses were modelled to investigate the effect of the clearing cut-off split to the new prices.
  - Firstly, analysis is done for clearing with 95% least cost and 5% most expensive split. Secondly, an analysis is done for clearing with 80% least cost and 20% most expensive split
- Such static clearing split is very sensitive to the daily and seasonal variations as the cut-off point may be located in different levels in the merit order hour by hour

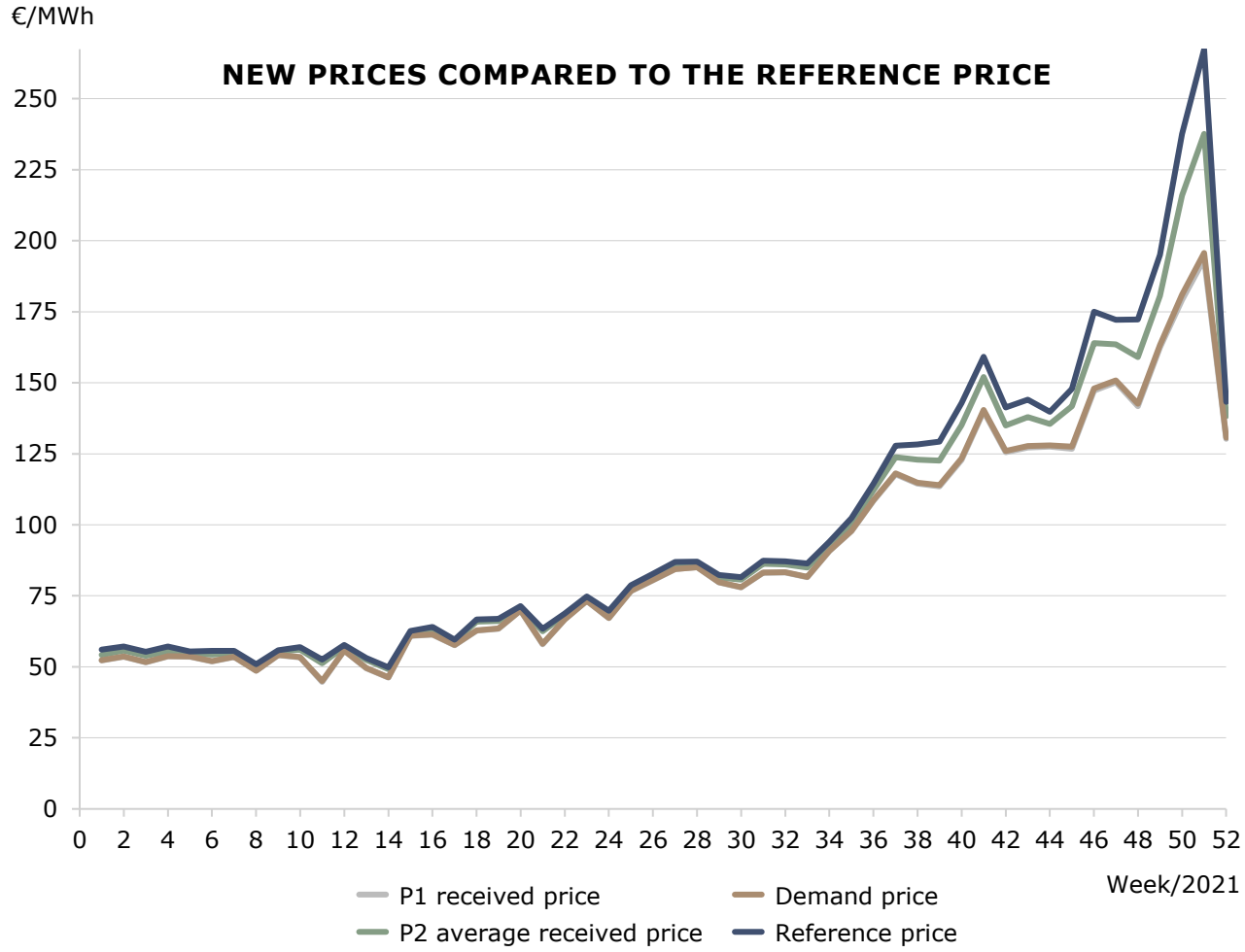
SENSITIVITY ANALYSIS 95/5



SENSITIVITY ANALYSIS 80/20

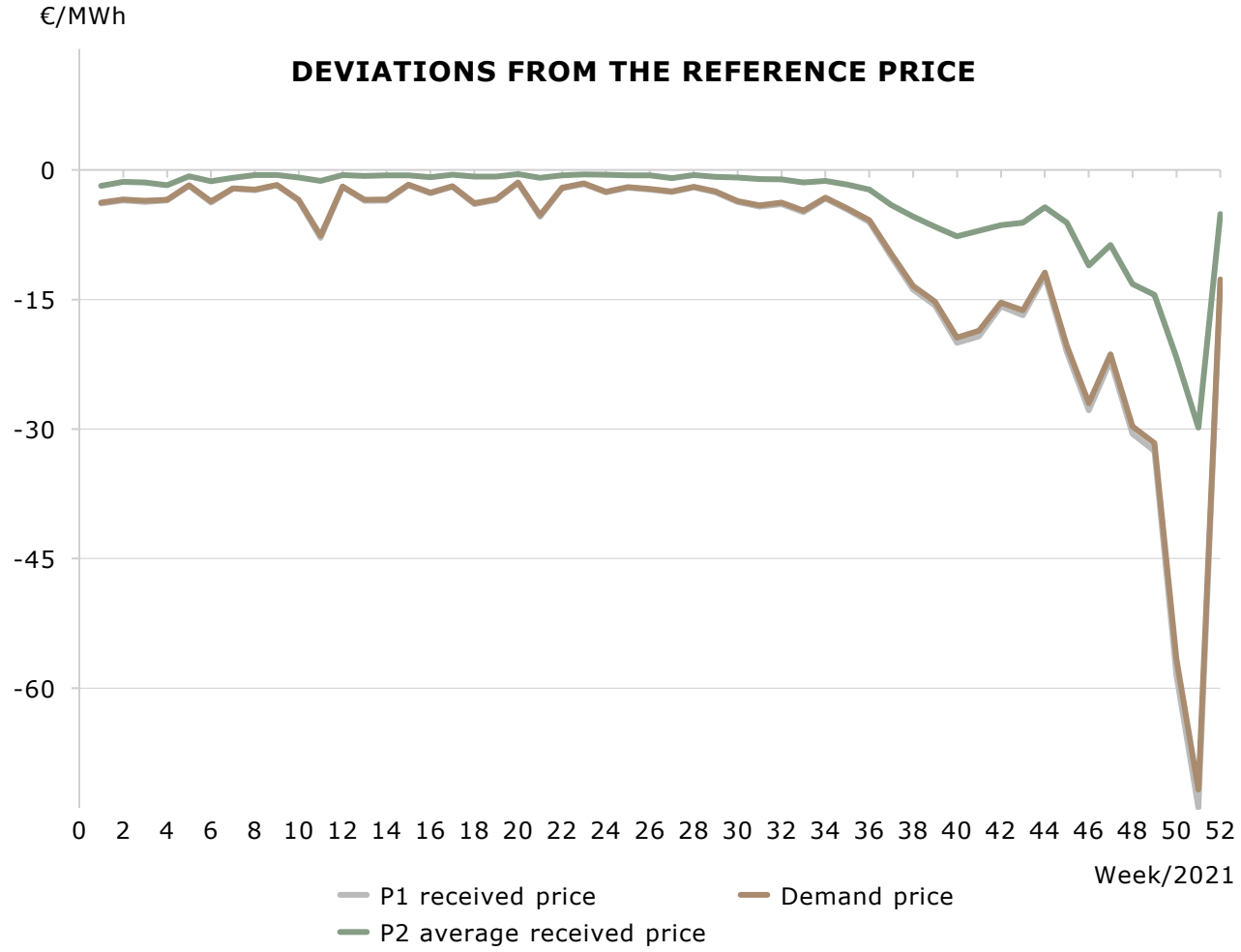


ELFI/TIF proposed market design with 95% / 5% clearing split to some extent preserves high price signals while still shaving off the most extreme prices



- ELFI/TIF proposed market design with clearing cut-off at 95% shows much closer correlation with the reference price than the base case (90/10 split)
- This is most apparent during the last quarter of 2021 where the base case saw high discrepancy between the reference price and P1 / Demand Price whereas the 95% / 5% clearing split show smaller deviation also within this period compared to the base case
- The sensitivity analysis also shows even higher correlation between P1 and demand price since the demand price is calculated as volume weighted average price, and the P1 range has even higher share of the total volumes
- The 95% / 5% split seems to preserve the price spike signals better than the 90% / 10% split, while still shaving off the most extreme prices

ELFI/TIF proposed market design with 95% / 5% clearing split generates closer match with the current market design with flat supply curve



- In the sensitivity analysis with 95% / 5% split the deviations between the new prices and reference price, representing the differences between current and ELFI/TIF proposed market design, are close to zero most of the year
- This implies that in normal market conditions the ELFI/TIF proposed market design with 95/5 split would have little difference to the current market design
- Towards the end of the year 2021 with more steep supply curves the 95/5 split shows more conservative deviations from the reference price than the base case (90/10 split).
- However, even with 95/5 split very high deviations from current market design may occur when highest price spikes are smoothed out with the ELFI/TIF proposed market design

ELFI/TIF proposed market design with 95 / 5 % clearing split follows the current design more closely

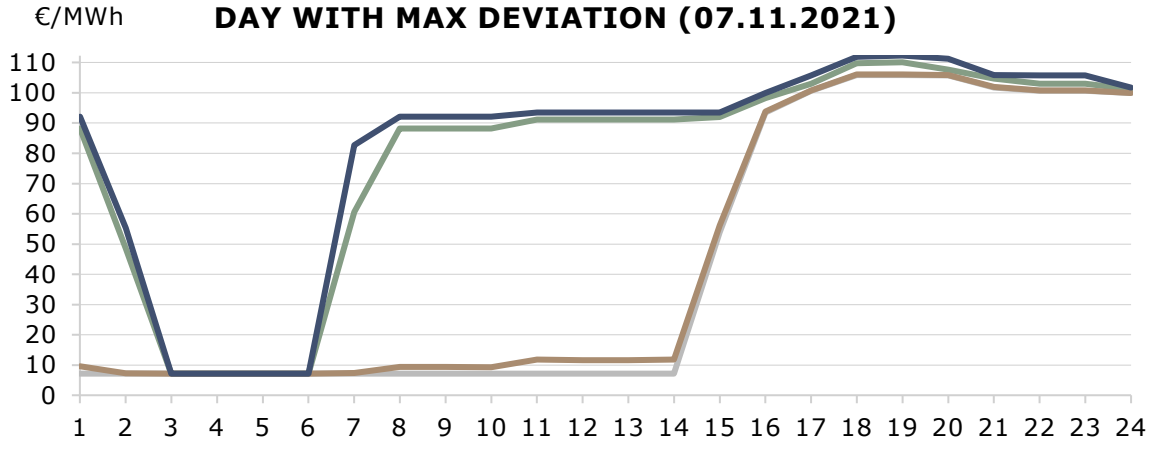
- The table below provides real 2021 average monthly wholesale electricity prices that were reported by a power exchange. The prices are not directly comparable (see page 15) but aims to illustrate potential differences
- The prices with the 95/5 split are slightly higher the first three quarters of 2021 due to the differences between AFRY backcast and real data, as well as the limitation of this modelling with fixed flows.
- However, the prices remain relatively close to the real-life historical prices all the way until November / December, showing that the 95/5 is more resilient to smaller price increases and only when bigger deviations start to occur, the clearing methodology starts to significantly lower the prices

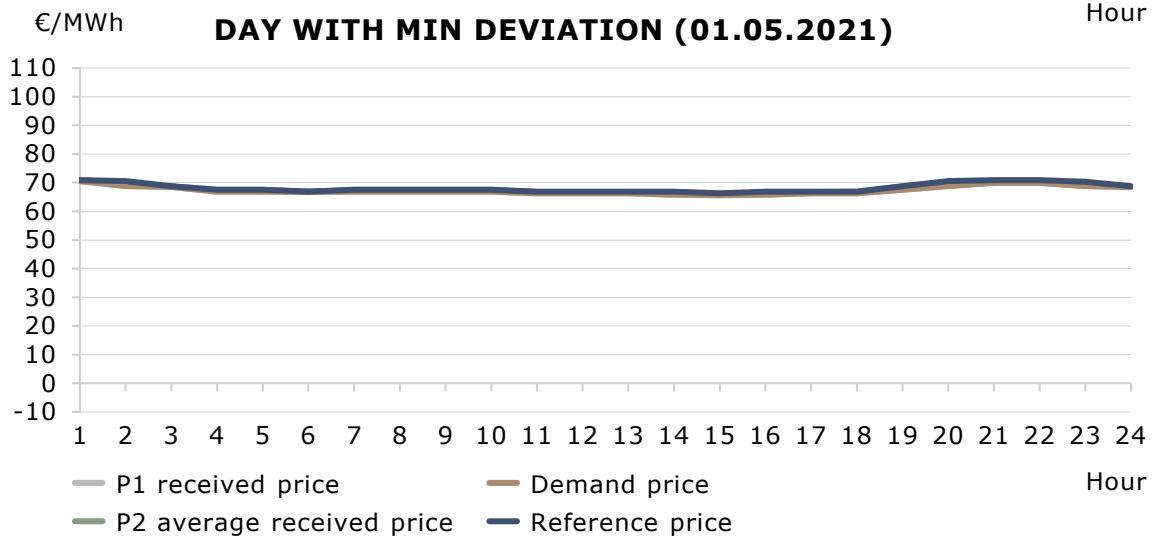
AVERAGE REAL MONTHLY AND ANNUAL WHOLESALE ELECTRICITY PRICES AGAINST NEW MODELLED PRICES AS PER ELFI/TIF PROPOSED MARKET DESIGN

Price / Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
2021 real market price[1]	53	49	47	54	53	74	81	83	128	139	176	221	97
Reference price	56	54	55	59	67	75	84	91	124	144	166	205	99
Demand price	53	52	52	57	64	73	81	87	114	127	142	164	89
P1 received price	53	52	51	57	64	73	81	87	113	127	142	162	89
P2 average received price	55	53	55	59	66	75	83	90	120	137	157	188	95

Sources: 1) Nordpool

ELFI/TIF proposed market design with 95/5 clearing split may have identical days with the current market design while having large impact on other days





- These two graphs are singled out days from the result data representing on average maximum and minimum possible deviations between the reference price and the three new prices as per the ELFI/TIF proposed market design
- In the maximum deviation day with 95/5 split, all prices are correlating well half of the day. However, for some hours a radical deviation of almost 100€/MWh occurs. This shows that while on average the 95/5 is stable and well correlating split, it may still have sudden and radical deviations hour by hour
- The minimum deviation day with 95/5 shows very close to identical values for all prices. This illustrates that with normal and flat supply curves, the 95/5 split may not have major impact to prices compared to the current market design
- The 95/5 also has a rare case that may occur with the ELFI/TIF proposed market design where the split cut-off happens in a middle of a large accepted sales order. Since there are no detailed rules for the ELFI/TIF proposed market design, it has not been defined how such case should be resolved. In AFRY modelling, the full bid is included in the P1 group and consequently all three prices will be equal (hours 3-6 in the max deviation day)

Additional metrics from the sensitivity analysis results show higher prices than the other modelled clearing splits

- Demand price has on average less difference to the reference price than in the base case.
- Maximum difference remains high

- The additional metrics show that demand price is heavily correlated with P1 with this clearing split as all the additional metrics are close to identical

- P2 is at very close range to the reference price for nearly 60% of time in 2021
- Maximum difference is only moderate compared to the base case

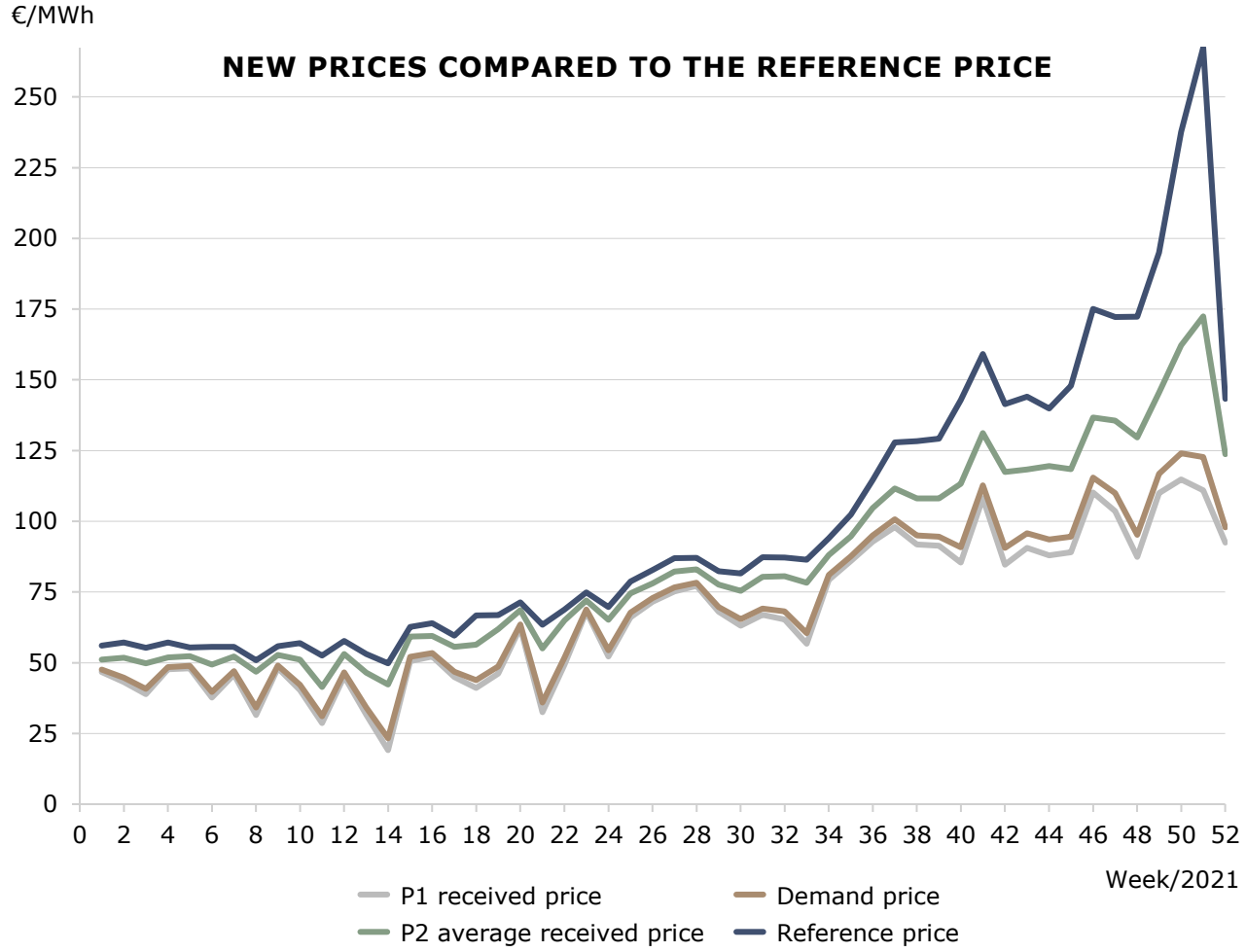
Additional metrics for demand price compared to reference price	Value
Average difference %	-8 %
Average difference €/MWh	-10 €/MWh
Maximum difference %	-44 %
Maximum difference €/MWh	-117 €/MWh
Number of days that have max 2% difference	23 days

Additional metrics for P1 compared to reference price	Value
Average difference %	-8 %
Average difference €/MWh	-10 €/MWh
Maximum difference %	-46 %
Maximum difference €/MWh	- 121 €/MWh
Number of days that have max 2% difference	20 days

Additional metrics for P2 compared to reference price	Value
Average difference %	-3 %
Average difference €/MWh	-4 €/MWh
Maximum difference %	-18 %
Maximum difference €/MWh	-45 €/MWh
Number of days that have max 2% difference	218 days

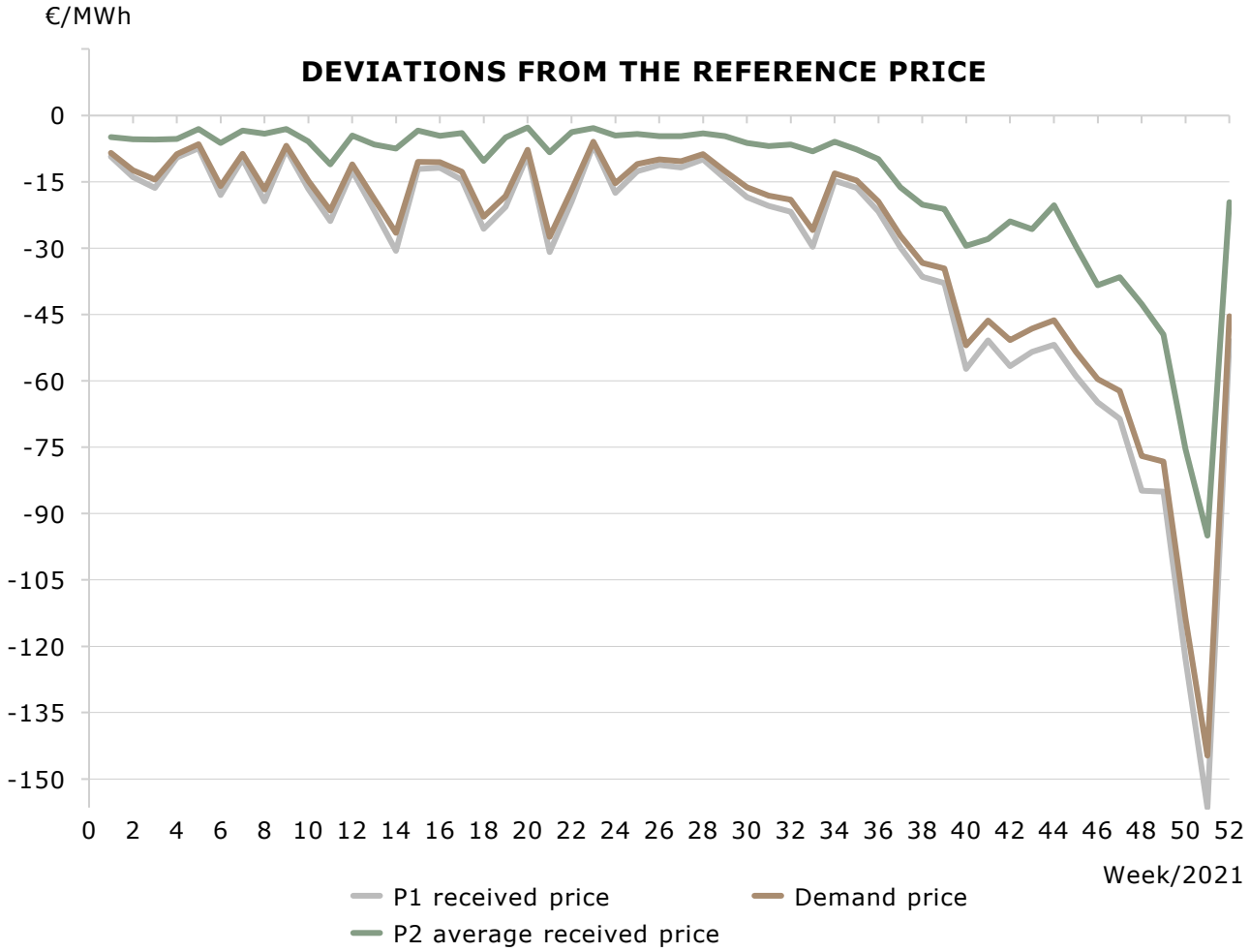
Metrics are based on daily average price data

ELFI/TIF proposed market design with 80/20 clearing split may result in considerably lower prices for demand and supply in all market conditions



- The 80/20 clearing split for the ELFI/TIF proposed market design clears 80% of the generation with even lower cost in the merit order, this also has stronger effect on the volume weighted average of P1 and P2, further impacting the demand price
- Peak prices are more radically shaved with this clearing split as well as demand price being considerably lower than the reference price throughout the year
- Compared to the base case (90/10 split), there is clearly higher separation of the prices throughout the year. This is specifically apparent in the last quarter of 2021 when there is visible detachment of the P1 and demand price, that were closely correlated in the case base
- The base case showed high correlation during normal market conditions, whereas the 80/20 creates separation of the prices also in these conditions, observed for the first quarter of 2021

ELFI/TIF proposed market design with 80/20 clearing split in steep supply curve generates radically lower prices for demand



- In the sensitivity analysis for 80% / 20% split the deviations between the new prices and reference price, representing the differences between current and ELFI/TIF proposed market design, are significant, especially for the P1 and demand price
- This implies that even in normal market conditions the ELFI/TIF proposed market design with 80/20 split would create major difference to the current market design and share of the overall social welfare
- Towards the end of the year 2021 with more steep supply curves, the 80/20 split brings the P1 and demand prices significantly lower than with the current market design. By doing this the peak (and high) prices are fundamentally capped

ELFI/TIF proposed market design with 80% / 20% clearing split generates considerably lower price for demand throughout the modelled year

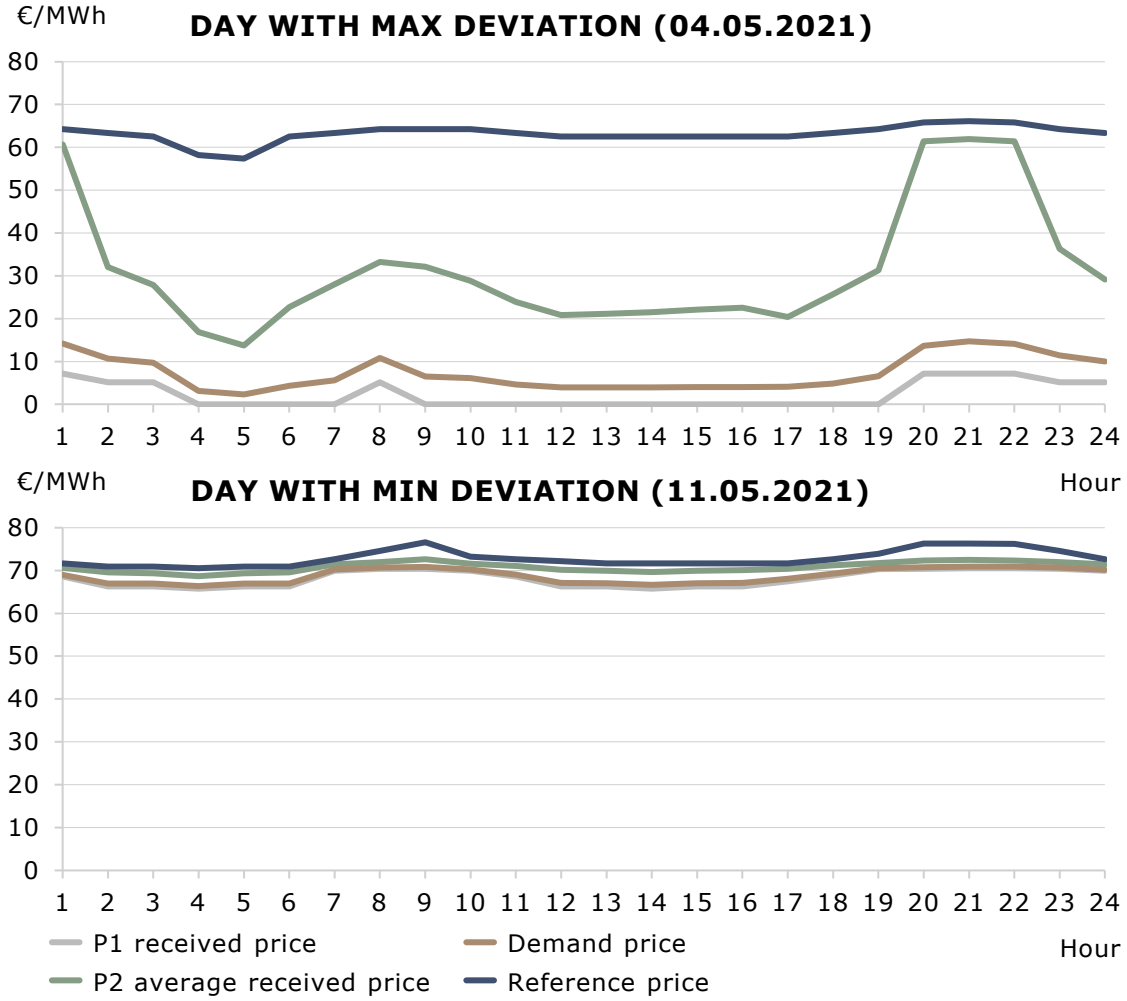
- The table below provides real 2021 average monthly wholesale electricity prices that were reported by a power exchange. The prices are not directly comparable (see page 15) but aims to illustrate potential differences
- The prices in 80/20 sensitivity analysis are moderately lower for the first three quarters of 2021. Effectively, this sets the P1 received price lower than in the base case. Further, it affects the demand price that is also brought considerably lower
- This effect is most evident in December 2021 when the modelled ELFI/TIF proposed market design prices are over 100€/MWh lower than the real 2021 prices

AVERAGE REAL MONTHLY AND ANNUAL WHOLESALE ELECTRICITY PRICES AGAINST NEW MODELLED PRICES AS PER ELFI/TIF PROPOSED MARKET DESIGN

Price / Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
2021 real market price[1]	53	49	47	54	53	74	81	83	128	139	176	221	97
Reference price	56	54	55	59	67	75	84	91	124	144	166	205	99
Demand price	46	42	40	45	48	64	71	74	96	96	106	111	70
P1 received price	44	40	38	42	46	62	69	71	94	91	100	102	67
P2 average received price	51	50	49	55	61	71	79	84	108	118	131	147	84

Sources: 1) Nordpool

ELFI/TIF proposed market design with 80/20 clearing split may create major wholesale electricity price deviations from the current market design



- These two graphs are singled out days from the result data representing on average maximum and minimum possible deviations between the reference price and the three new prices as per the ELFI/TIF proposed market design
- The 80/20 split may have significant hourly deviations, as well as significant deviation over full day in all market conditions.
- In the maximum deviation day with 80/20 split, the P1 has remained at zero almost for the full day whereas the reference price is above 60€/MWh for most of the day. P2 and demand price would have been low but not at zero
- The minimum deviation day with 80/20 split is similar as in the base case, showing that the ELFI/TIF proposed market design may return technically same prices as the current market design. However, with the 80/20 the P1 and demand price remain slightly below the reference price even in the minimum deviation day

Additional metrics from the 80/20 sensitivity analysis show potential for radical deviations from the current market design

- No days in 2021 are in close range to the reference price
- Both the maximum difference and average difference are significantly higher than in the base case

- Maximum difference between P1 and reference price is 283€/MWh, showing cases with very radical change in pricing compared to the current market design

- 80/20 clearing split produces higher deviations between the P2 and P1
- P2 has no days within a close range to the reference price

Additional metrics for demand price compared to reference price	Value
Average difference %	-27 %
Average difference €/MWh	-29 €/MWh
Maximum difference %	-88 %
Maximum difference €/MWh	-226 €/MWh
Number of days that have +- 2% difference	0 days

Additional metrics for P1 compared to reference price	Value
Average difference %	-30 %
Average difference €/MWh	-32 €/MWh
Maximum difference %	-96 %
Maximum difference €/MWh	-283 €/MWh
Number of days that have +- 2% difference	0 days

Additional metrics for P2 price compared to reference price	Value
Average difference %	-12 %
Average difference €/MWh	-15 €/MWh
Maximum difference %	-59 %
Maximum difference €/MWh	-149 €/MWh
Number of days that have +- 2% difference	0 days

Metrics are based on daily average price data

AFRY

ÅF PÖYRY

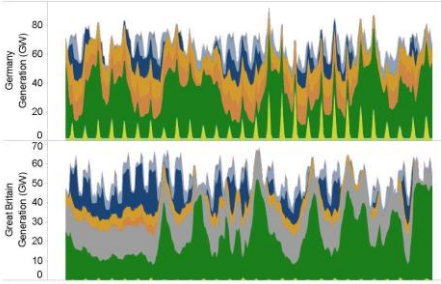
BID3 INFORMATION

Annex 1

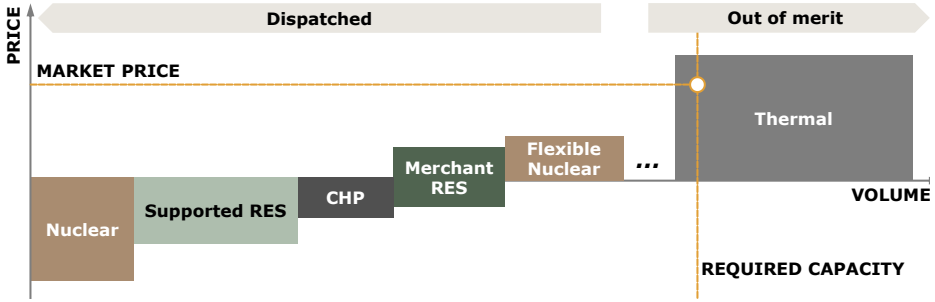
BID3 is used to model future electricity prices, along with all parameters of the power system

1. BID3 PROJECTS PHYSICAL OPERATION AND ECONOMIC BEHAVIOUR OF ALL PLANT TYPES

- Cost optimising electricity market dispatch model – optimisation on an **hourly basis out to 2060**.
- Optimal **regional power flows** subject to transmission constraints.
- Comprehensive modelling of **thermal plant dynamics**.



2. COST BASED DISPATCH WITH COMPLEX THERMAL PLANT DYNAMICS & ADDITIONAL SCARCITY PRICING



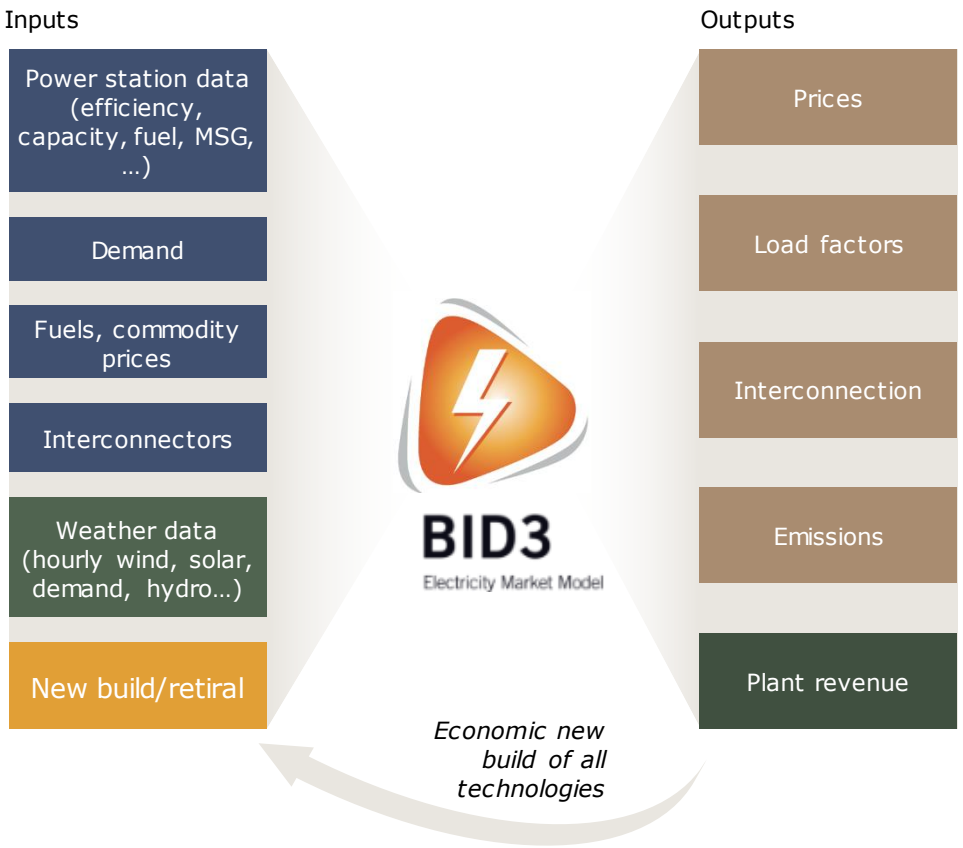
3. MULTIPLE HISTORIC WEATHER PATTERNS DETERMINE HOURLY RES GENERATION & DEMAND

4. DETAILED STORAGE & HYDRO MODELLING OPTIMISES RESERVOIRS AND STORAGE DISPATCH

- Multi-stage optimisation captures **physical limits/ decisions on storage & reservoir hydro**
- Detailed weekly simulation to **optimise storage charging, pumping & generation**

BID3 projects physical operation (generator output, electricity flows, emissions) and economic behaviour (electricity prices, revenues)

BID3 OVERVIEW

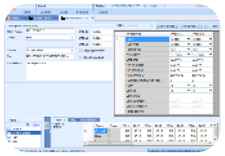


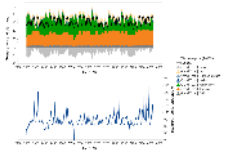
COVERAGE OF BID3

- BID3 is AFRY's state-of-the-art power market model
- BID3 is an optimisation which minimises the system cost in a year subject to constraints
- It models all hours of the year and accounts for varying renewables, demand-side management, hydro and storage
- It produces hourly price projections for 8760 hours per year up to 2060 for 20 weather simulations
- The model determines optimal exports and imports between regions, based on regional market economics and interconnection constraints

AFRY electricity market model, BID3, enables the quantitative evaluation of decarbonisation developments on power markets

KEY FEATURES

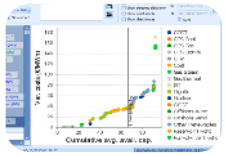

Detailed power station database

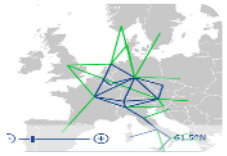

Flexible charting and pivoting of any data


Zonal, FBMC and nodal pricing

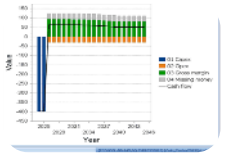

Energy-only and energy + capacity markets

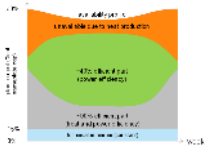

Sophisticated hydro modelling

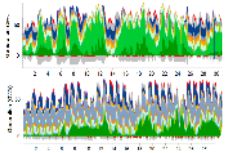

Supply curves, marginal plant

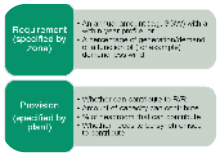

Flexible pricing areas + fixed flows

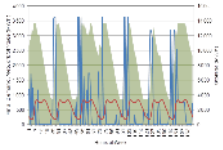

Auto Build module

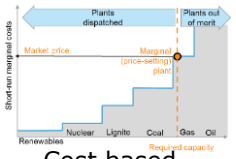

Profitability, IRR calculations


Detailed CHP modelling

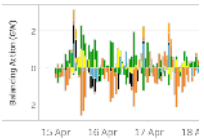

Intermittent generation

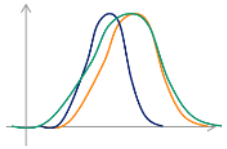

Reserve and response


Demand-side management

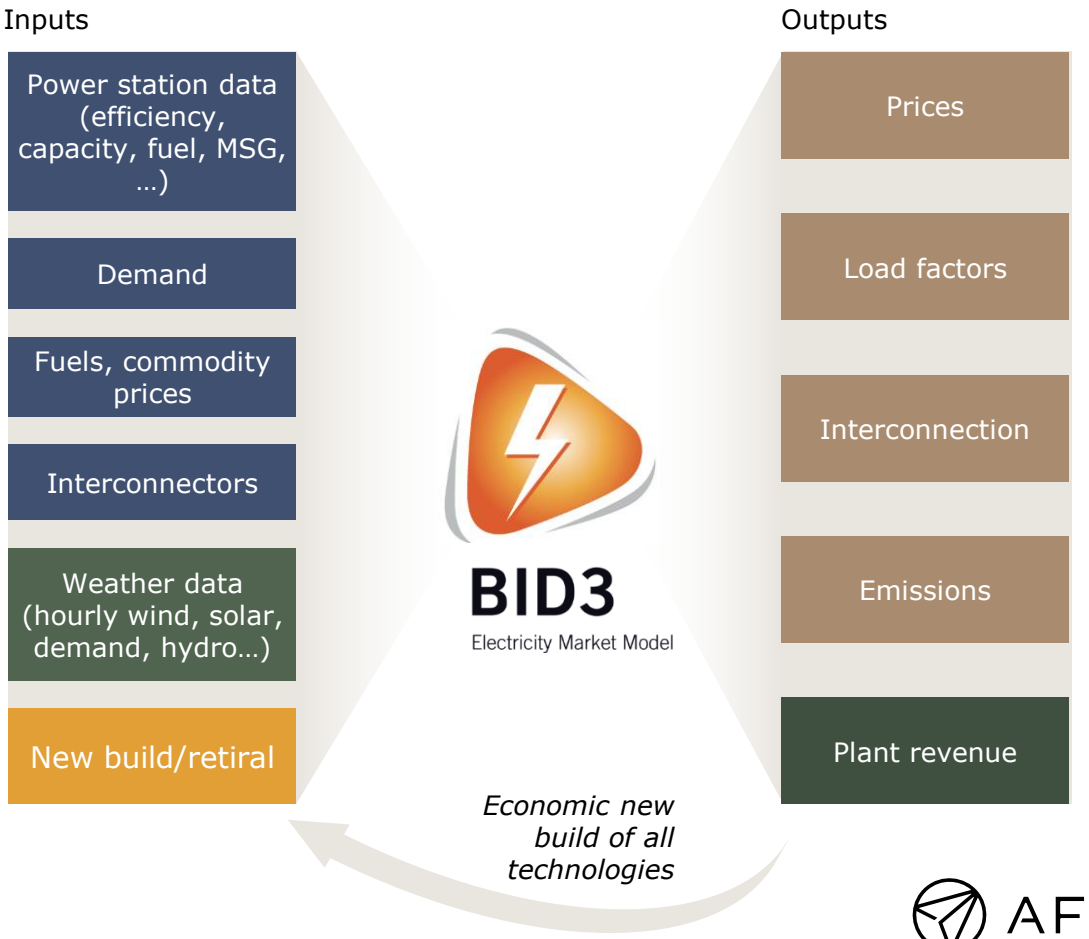


Cost based dispatch

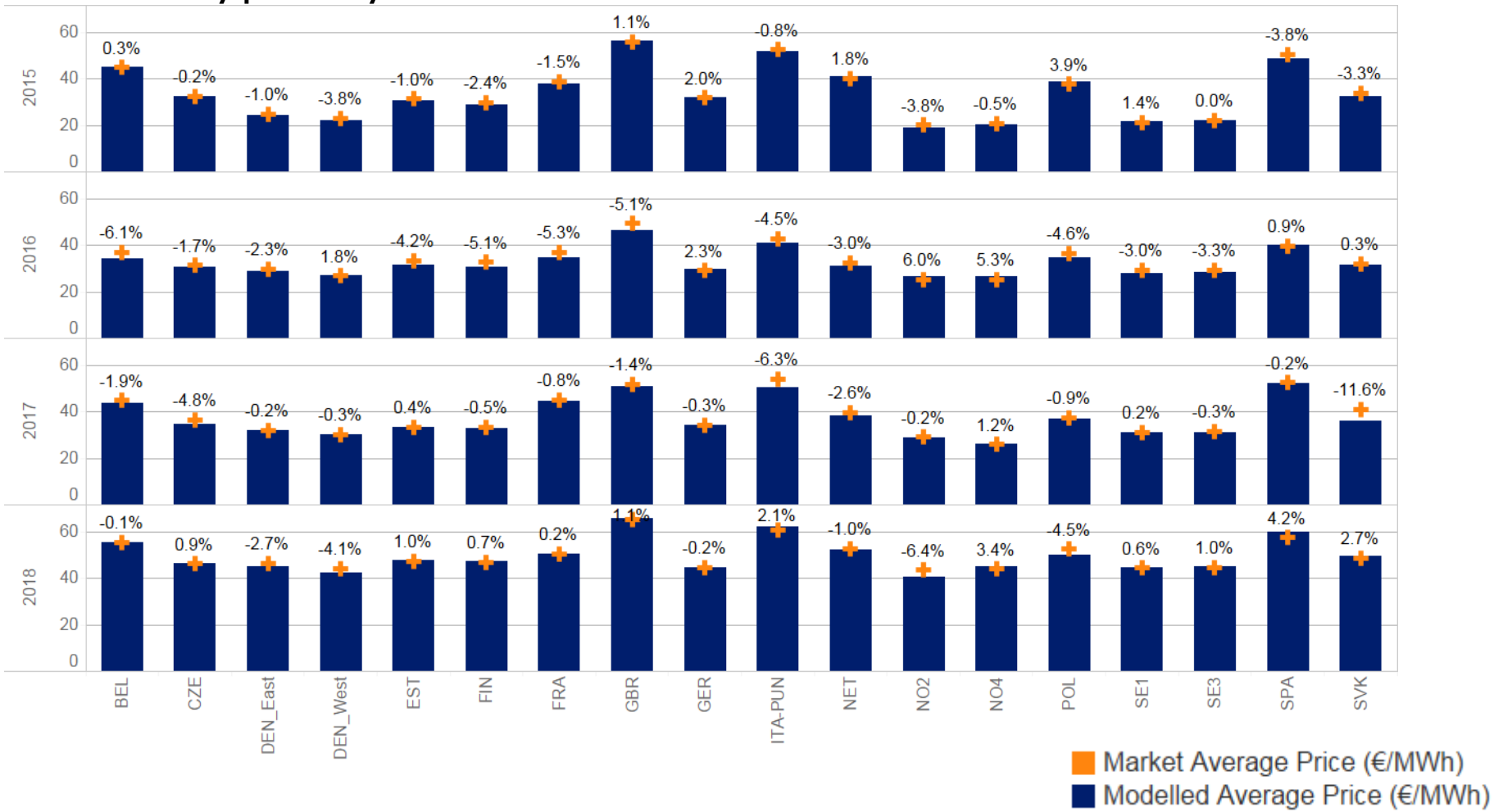

Within-day calculations


Monte Carlo analysis

INPUTS AND OUTPUTS OF BID3



BID3 provides a highly accurate representation of all European markets, with annual errors typically 2-3%



BID3 is used on a daily basis by utilities, regulators and TSOs across Europe

CLIENT	OFFERED SERVICE
uniper	Forward curve modelling and strategic analysis
Statnett	Uses BID3 extensively for interconnector valuation studies, and also to model continental power markets
TRANSNET BW	Use BID3 for market simulations to feed their network modelling system, Integral
ENERGINET/DK	Use BID3 for interconnector studies, grid studies and capacity adequacy studies
drax	Net zero carbon simulations, forward curve modelling and strategic decision making
nationalgrid	AFRY provided BID3 platform for revenue assessment
EnBW	AFRY provided BID3 platform for market pricing
Terna	AFRY provided BID3 platform to evaluate policy impacts
AES	AFRY provided BID3 platform to assess client's market entry
e·on	EON contracted-out market modelling to assess Market entry and portfolio appraisal

AFRY

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