Commission de Régulation
de l'Électricité et du Gaz

CREG

Study

(F)2590
14 September 2023

Study on the occurrence and impact of negative prices in the day-ahead market

Non confidential

CREG - rue de l'Industrie 26-38, 1040 Bruxelles, Belgique
T +32 2 289 76 11 - www.creg.be

TABLE OF CONTENTS

EXECUTIVE SUMMARY

In the spring of 2023, many hours with deeply negative prices were observed in the day-ahead market, on different occasions in multiple bidding zones of the Core region, up to a minimum of -500€/MWh in the Netherlands. The Netherlands also had the most hours with negative prices and often exported up to near its maximum export position, suggesting that the market coupling algorithm effectively worked to optimise the network constraints.

Negative prices, resulting from an intersection of demand and supply curves at a negative price, seem counterintuitive considering that supply curves should reflect the marginal costs of the different units. Two main reasons can explain this phenomenon: start-up and ramping costs of thermal units and a lack of exposure to prices of some market players on the production side but also on the consumers' side (effectively blocking the development of demand response). This can be for example due to (retail) contracts or subsidy schemes.

A statistical assessment of the occurrence of negative prices shows that the Netherlands have seen a particularly high number of negative prices in 2023 compared to previous years. Those prices mostly occurred during the middle of the day, when solar panels are producing the most.

The European day-ahead market possesses a mechanism to trigger second auctions in case of extreme negative or positive prices. Due to extreme negative prices in Netherlands, this mechanism was triggered 5 times in 2023. This mechanism, supposed to allow market participants to adapt their bids (for example in case of bidding error) and to reduce the extremeness of the price, lead to unsatisfactory results. Indeed, in an equal number of hours, prices after the second auctions were higher than before the auction, equal to those prices and lower than those prices. Analysis of supply and demand curves in the Netherlands shows that there are very little bids modifications in the second auctions. Second auctions have major impacts on the operations of the day-ahead market and vastly increase risks of decoupling. They reduce the contingency to solve operational problems by 69%.

Consumers, through dynamic contracts for offtake and injection, can have the possibility to be remunerated from their behaviour in hours of negative price. This incentivizes them to play an active role in the electricity system. However, those contracts are currently, for Belgian consumers, primarily accessible in Flanders. Those dynamic contracts also present risks in case of high (positive) prices, especially for consumers with little possibilities to adapt their consumption or production to price signals.

INTRODUCTION

Through this study, the COMMISSION FOR ELECTRICITY AND GAS REGULATION (hereafter (« the CREG ») presents the findings from its analyses regarding the occurrence of negative prices in the coupled day-ahead markets in Europe, observed in the spring and summer of 2023. These analyses follow from the operational data which are made available by transmission system operators (hereafter: « TSOs ») and nominated electricity market operators (hereafter: « NEMOs ») for Belgium and neighbouring zones.

The CREG presents, in the first chapter, the capacity calculation and market coupling results in week 22, when many hours with (deep) negative prices were observed. A theoretical explanation on the price formation mechanism of the European day-ahead market is presented, together with a description of how this mechanism can lead to negative prices, in chapter 2. The third chapter presents statistics on the occurrence of negative prices. In the fourth chapter, the functioning of the so-called « second auctions », which played a role in determining the market coupling results during hours with very deep negative prices, is explained. The fifth chapter, finally, presents the impact on consumers' bills, in particular through dynamic price contracts. Chapter 6 presents the conclusion of this study.

This study has been approved by the Board of Directors of the CREG on 14 September 2023.

1. INTRODUCTION: MARKET RESULTS IN WEEK 22

1. In the long Pentecost weekend (from Thursday 25 to Sunday 28 May 2023), many hours with deeply negative prices were observed, on different occasions in multiple Core bidding zones.[1] Figure 1-1 shows the evolution of the hourly clearing prices for the entire week, for CWE and non-CWE Core bidding zones.[2] During the noon-time hours of Tuesday, Thursday, Friday, Saturday and Sunday, the supply and demand curves cleared at negative prices, most often in the Netherlands.

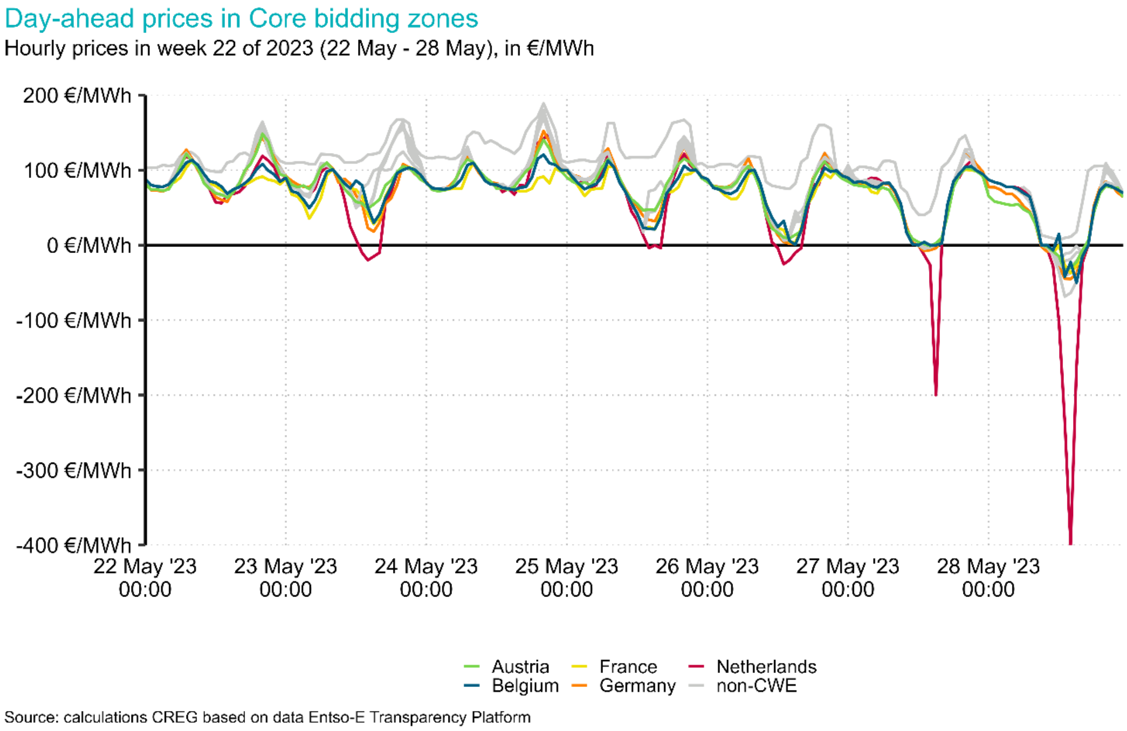

Figure 1-1 Day-ahead prices in Core bidding zones

2. The lowest observed price during that week – or anytime, in the history of the Single Day-Ahead Coupling (SDAC), for that matter[3] – was -400€/MWh, in the Netherlands. This price was reached on Sunday, 28 May 2023 at 14:00. In that specific hour, all Core zones except for Poland (11,2 €/MWh) saw negative prices, even though none of them anywhere near the level of the Netherlands (the second lowest was Czech Republic at -63,7 €/MWh).

3. In week 22, negative prices occurred in all Core bidding zones (except Poland), leading to a total of 109 such hours spread over the different zones. Zones with the most negative hours were the Netherlands (23 hours), Germany (12 hours) and France (11 hours).

[1] The Core bidding zones are Austria, Belgium, Croatia, Czech Republic, France, Germany/Luxembourg, Hungary, Netherlands, Poland, Romania, Slovakia and Slovenia.

[2] The CWE bidding zones are Austria, Belgium, France, Germany/Luxembourg and Netherlands. Focusing on the CWE bidding zones is done to highlight the relevance for Belgium and to avoid a cluttered figure, even though it is acknowledged that the distinction between CWE and non-CWE is no longer used since the entry into operation of the Core DA FB MC Project.

[3] With the exception of the -500€/MWh reached in Belgium in June 2019, but this price was the result of an incident in the market coupling procedures, and hence cannot be compared with the price formation under "normal" market circumstances. For a description of this event, please see: https://www.nemo-committee.eu/assets/files/sdac-report-on-decoupling.pdf (pdf document).

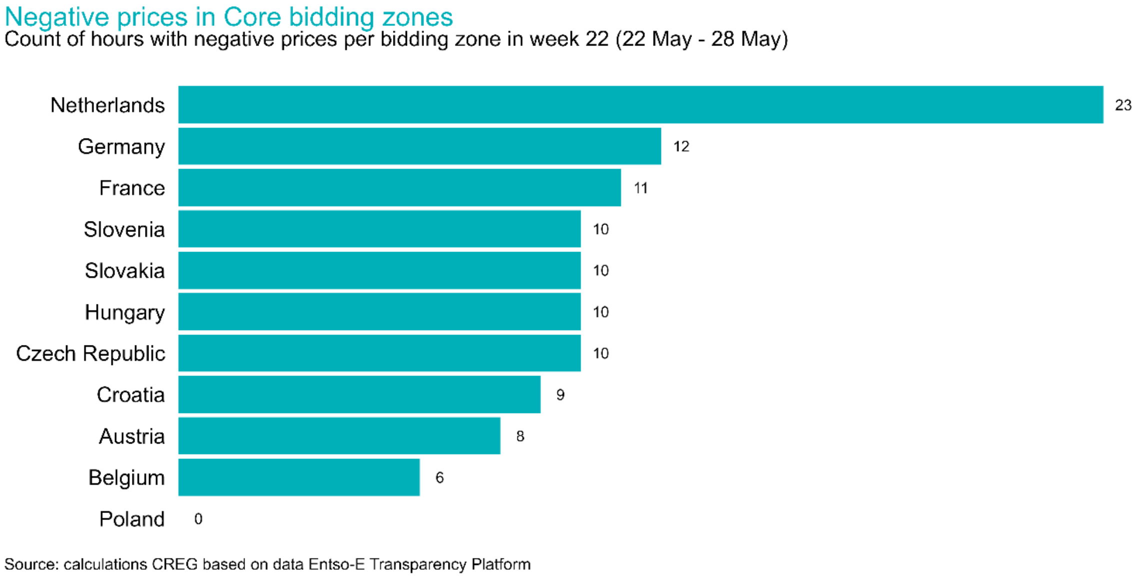

Figure 1-2 Negative prices in Core bidding zones

4. Given these very extreme market outcomes, it is not surprising that the net positions of the Netherlands have approached the boundaries of what is possible in the Core flow-based market coupling mechanism. Figure 1-3 shows these net positions, for both Belgium (top) and the Netherlands (bottom) as a blue line, while the range between the minimum and maximum net positions (the red lines) is shown in the grey area. While Belgium has at times been importing, at other times exporting, the position of the Netherlands has been almost consistently in the export direction and approaching the max export position. The hours where the net position approaches or reaches the max export for the Netherlands, correspond to the ones where very deep negative prices were observed.

5. This suggests that the market coupling algorithm works properly: given the transmission network constraints, the net position of the bidding zone with excess supply has been exporting almost to its maximum. However, the max net position, which reflects the size of the flow-based domain, was on average 4.556 MW for the Netherlands in week 22. This is generally lower than the Belgian max export position, yet the Netherlands have only two borders (with Belgium and Germany) in the Core region, while Belgium has three (Netherlands, Germany and France).

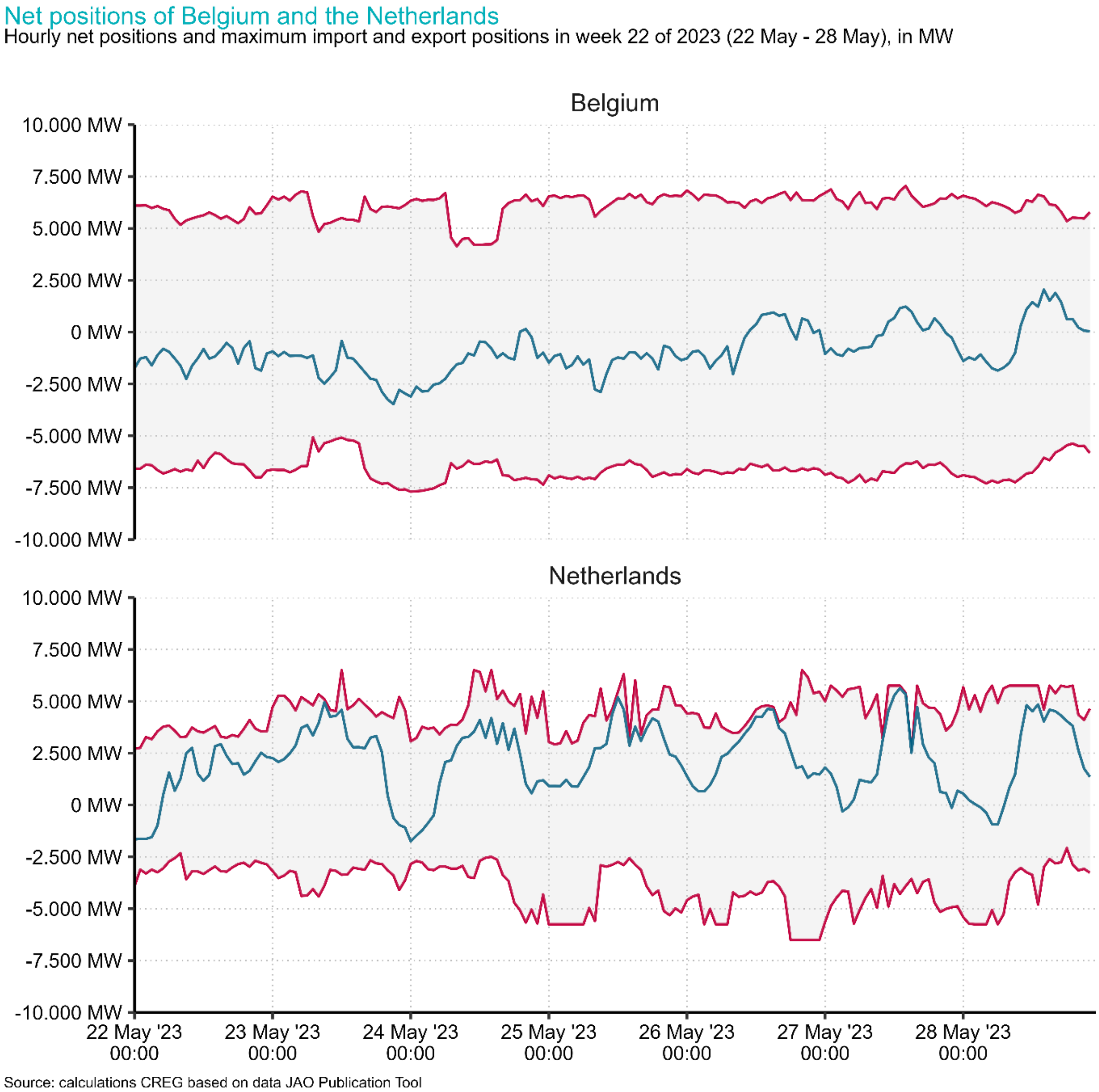

Figure 1-3 Net positions of Belgium and the Netherlands

2. PRICE FORMATION AND RATIONALE FOR NEGATIVE BIDS

2.1. MARGINAL PRICING IN DAY-AHEAD MARKETS[4]

6. The sequence in which electricity producing units are asked to contribute to the supply of electricity, is called the merit order. It is constructed by sorting the units by increasing variable cost of producing one additional MWh of electricity, also known as the marginal cost of that unit. These variable costs relate to the operation of electricity units and are mostly linked to the cost of the fuel. Fossil-fuel combustion power plants typically have high marginal costs, linked to the cost of underlying commodities such as coal, gas or oil, and the thermal conversion factors. By contrast, renewable and nuclear units have low operational costs per generated MWh of electricity, sometimes even close to zero. This means that they are found at the start of the merit order: to meet demand, they need to generate electricity before the more expensive units do. When ranked according to the merit order, the variable costs of the cumulatively generated output constitute the supply curve for electricity in any given hour of the day-ahead timeframe.

7. The price of electricity is then established according to the common economic theory of supply and demand. In the Belgian day-ahead market, which is part of a larger, coupled European market, the marginal pricing principle, also often named “pay-as-clear", dictates that the most expensive generation unit needed to cover the demand for electricity sets the price to be paid by all consumers as well as the revenue earned by all generators within one zone. The concepts of marginal price and merit order are illustrated with a theoretical figure in Figure 2-1 and real-life supply demand curves in Figure 2-2.

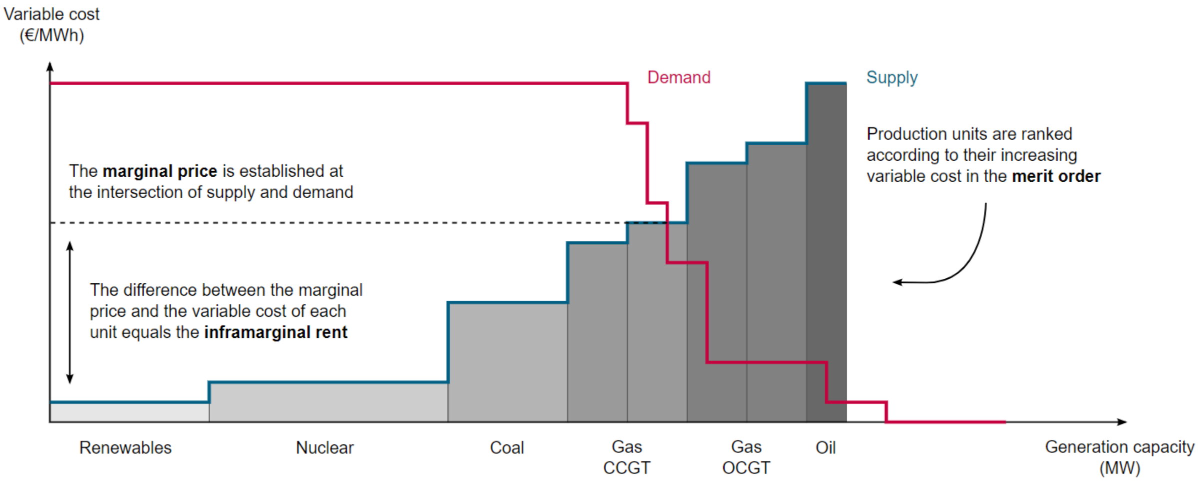

Figure 2-1 Functioning of the merit order and marginal price in theory

[4] This section is directly inspired from CREG’s article published on LinkedIn on 28 January 2022.

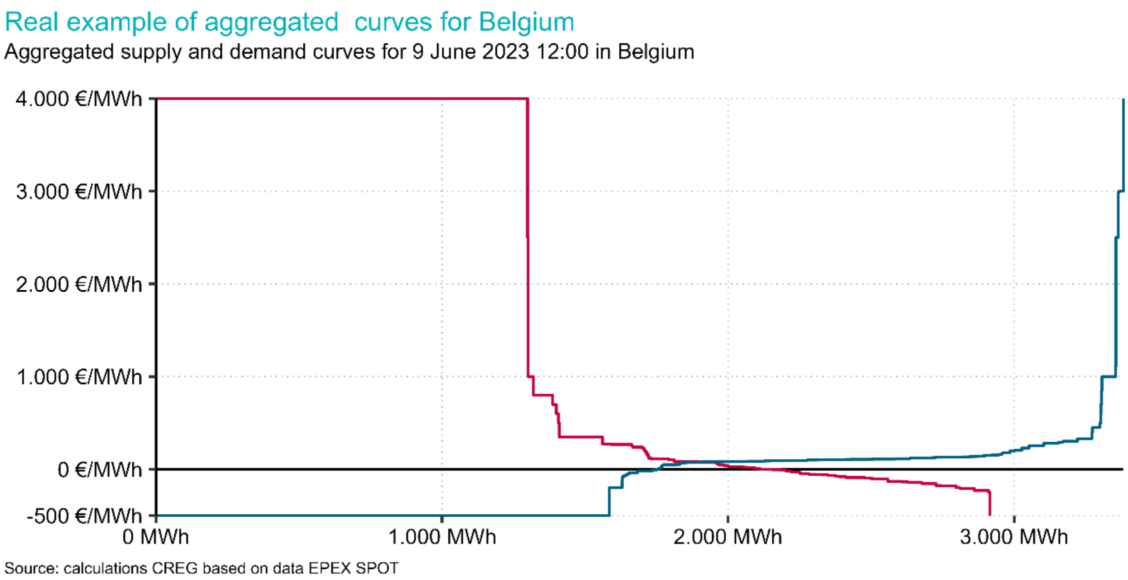

Figure 2-2 Functioning of the merit order and marginal price in practice

2.2. FORMATION OF NEGATIVE PRICES IN THE DAY-AHEAD MARKET

8. Considering the that supply curves should represent the marginal costs of the different generation units, negative prices in the supply curve seem counter intuitive. However, as shown on Figure 2-2 more than 1.500 MWh of the supply in Belgium on 9 June 2023 at 12h is offered at negative prices. Two main reasons can be identified for this bidding behaviour.

9. First, **the start-up and ramping** costs of thermal units contribute to a large part of a baseline of negative prices. Those units, whether they are fuelled by nuclear, coal, gas or else will face high costs to start, ramp up or down their generation. Therefore, in some situations where the plant is already producing, it can be preferable to bid at negative prices, showing a very high willingness to be selected to run even at the risk of a loss, rather than to lower the production of the unit.

10. Second, a **lack of exposure to prices** can incentivize market players to produce independently of the clearing price. This can be caused by subsidy schemes design, power purchase agreement design or producers that are not exposed to market prices. Indeed, across Europe, member states have designed various support schemes for specific type of generation plants. In parallel to those state-designed support schemes, Europe sees a rise in the signature of so-called power purchase agreements, typically between industrial consumers and generation companies. Both those schemes can incentivize to maximize the generation of the assets at all costs, independently from the market price. This is therefore why it is crucial to ensure that the amount of support/contract revenues of generation assets are decorrelated from their real production and rather incentivize an optimisation according to market prices. Lastly, (small) producers, such as residential photovoltaic panel owners, are not exposed to market prices. Those producers are therefore not incentivized to reduce their production in case of negative prices. This element will be further explained and assessed in chapter 5

11. When looking at Figure 2-2, another striking element is the amount of demand, around 1.300MWh, at a maximum price of 4.000€/MWh. This part of the demand represents the largest part of the demand that will be selected by the clearing algorithm. While we can expect that some consumers are really willing to pay this price (or a much higher one) for their consumption, it can also reasonably be expected that some consumers are just not exposed to the market price. Indeed, (household) consumers are typically relying on fixed-price or variable-price (relying on forward year or month-ahead prices) contracts that do not depend directly on the day-ahead price. While many consumers have contracts based on day-ahead prices, they are only exposed indirectly (and with a delay), as typically averages are taken over longer (quarterly) periods. Therefore, those consumers are not incentivized to consume less during period of high prices or consume more during periods of low prices through what we can call *demand-response*. By having an exposure to the day-ahead prices, consumers would therefore help minimizing the occurrence of those negative prices. This element will be further explained and assessed in chapter 5.

3. STATISTICS ON NEGATIVE PRICES

12. Hours with negative prices have been observed, with varying occurrence since 2015, in different European bidding zones. The analyses in this chapter focus on the (former) CWE bidding zones, being Belgium and Austria, Germany/Luxembourg,[5] France and the Netherlands. Data until 31 August 2023 are included. Figure 3-1 shows, for each of these bidding zones, the cumulative number of hours per year (from 1 January until 31 December) where negative prices were observed.[6]

13. This highest number of hours observed in a single year in one bidding zone is 319 hours, in 2020 in Germany. Most of the observed countries have observed the most hours with negative prices in either 2020 or 2021, except for the Netherlands: at the time of writing, end of August, already 212 hours with negative prices were registered, surpassing the previous record of 97 hours in 2020. These observations result from the very high number of hours between end of March and end of May where prices became negative.

14. Most of the negative hours can be found in the first half of the year, when days are longer and solar generation is higher. In recent years, however (since 2020), modest increases in the number of hours have been observed in the Christmas break as well, where the combination of low demand and high wind (which is typical, in the winter months) leads to prices below zero. This is particularly the case in Belgium, but also in Germany and the Netherlands.

15. Prices tend to become negative most frequently around noon, and – to a lesser extent – at night and in the morning. Figure 3-2 demonstrates this, showing also that negative prices rarely occur during the evening peak hours, between 17:00 and 20:00. This important observation will be discussed in section 5where the impact of negative prices on consumers' bills will be addressed. Essentially though, it follows from the logic that high renewables' generation (mainly solar PV, as far as the noon-time hours are concerned, but also wind during the night-time hours) and low demand tend to drive prices below zero (see also Table 3-1).

[5] Before October 2018, Germany/Luxembourg and Austria constituted one bidding zone. These statistics are added to Germany only, as this represents the biggest part of the joint bidding zones. Hence, data for Austria are only available since end 2018.

[6] Note that the y-axes for the different plots are not identical, given the difference in number of hours between bidding zones.

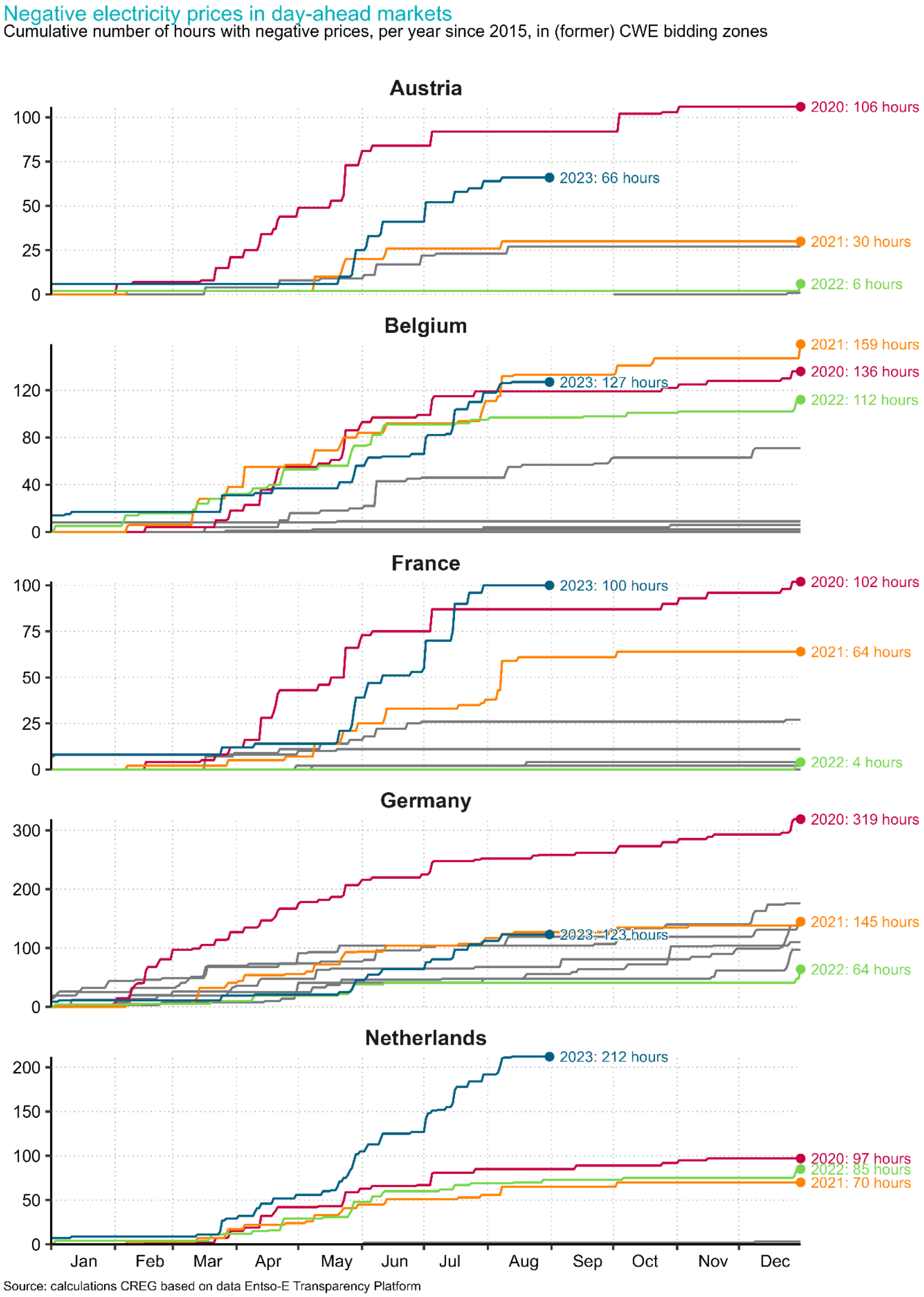

Figure 3-1 Negative electricity prices in day-ahead markets

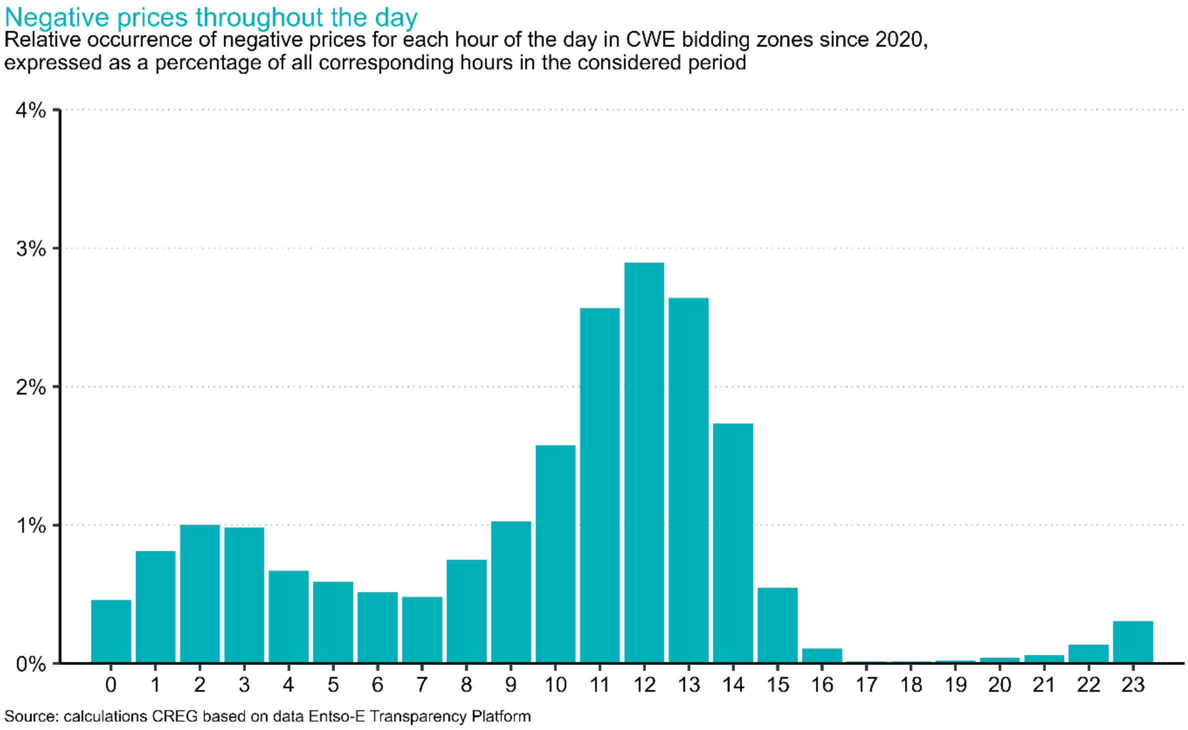

Figure 3-2 Negative prices throughout the day

Hour with:	Price	Nuclear	Solar	Wind	Load	Max export
Positive price	114,4 €/MWh	4.701 MW	372 MW	1.437 MW	9.217 MW	5.951 MW
Negative price	-19,0 €/MWh	4.753 MW	1.549 MW	2.620 MW	8.207 MW	6.585 MW

Source: calculations CREG based on data Entso-E Transparency Platform

Table 3-1 Average Belgian generation, load and export capacity during hours with negative and positive prices since 2020

[7] Max export relates to the maximum positive net position, calculated in the flow-based market coupling, on the basis of the flow-based domains. Higher values indicate that more capacity is available to export electricity to neighbouring bidding zones.

4. SECOND AUCTIONS

4.1. FUNCTIONING

16. In case of extreme prices, either high or low, nominated electricity market operators (NEMOs) have implemented in some member states so-called second auctions. Those second auctions allow for market participants to modify their bids in case of realised extreme prices in a first auction run. The rationale behind those auctions is to provide market participants with a possibility to adapt to situations with high risks of extreme prices and to correct any potential bidding mistake. When a second auction is triggered in a bidding zone, NEMOs have the choice, according to the second auction procedure,[8] to allow market participants from other bidding zones to adapt their bids.

17. Across the continent, those second auctions are not harmonized, as shown on Figure 4-1 where we can observe that the different bidding zones observe different rules with regards to the application of those rules but also with regards to the thresholds as of which those second auctions are triggered. Furthermore, some NEMOs place restrictions on the modifications of bids that market participants are allowed to perform. For example, EPEX SPOT[9] only allows market participants to modify their bids in a direction that would reduce the price peak (in case of extreme negative prices, to decrease the quantity or increase the price of their supply bids, increase the quantity or the price of their demand bids).

Figure 4-1 Implementation of second auctions across the single day-ahead coupling
Source: 50Hz

[8] Special procedure on second auctions: https://www.nemo-committee.eu/assets/files/SDAC_SPE_01%20-%20Impact%20of%20Second%20Auctions%20-%20redacted-4accda159b701e07e899fe0a7a9e6555.pdf

[9] As indicated in EPEX SPOT's operational rules, page 9, https://www.epexspot.com/sites/default/files/download_center_files/EPEX%20SPOT%20Market%20Rules_0_0.zip

4.2. ORGANISATION OF SECOND AUCTIONS IN CASE OF NEGATIVE PRICES IN 2023

18. So far in 2023, 5 second auctions were triggered by extreme negative prices in the Netherlands.[10] The results of those auctions are summarized in Table 4-1 Prices for first and second auction in the Netherlands. It is surprising to note that for some hours (market in bold), the prices of the second run are more extreme than the prices of the first run. Those results will be assessed in the section 4.2.1. Furthermore, those second auctions also lead to delays in the operations of the SDAC. Those delays and their impact will be assessed in the section 4.2.2.

4.2.1. Impact of second auctions on price formation

19. In general, during 5 of the 15 considered hours, the prices resulting from second auctions were less extreme, during 5 hours they did not change and during 5 hours they became more extreme. This means that in only one third of the considered hours, the second auctions have delivered on their intended purpose, namely the reduction of extreme price peaks. Even when successfully reducing the extreme prices, the impact was very limited most of the time (up to 5€/MWh), except for hour 13 on 2 July, when the price increased with 45,53 €/MWh (becoming less negative).

Delivery date	Hour	NL – 1st auction price (€/MWh)	NL – 2nd auction price (€/MWh)	2nd auction compared to 1st auction
19 April	14	-200,00	-194,20	Less extreme
	15	-200,00	-195,41	Less extreme
	16	-150,00	-150,00	Same price
27 May	16	-200,00	-200,00	Same price
28 May	**14**	**-200,00**	**-235,96**	**More extreme**
	15	-400,00	-400,00	Same price
	16	**-160,00**	**-162,55**	**More extreme**
29 May	**14**	**-161,52**	**-161,70**	**More extreme**
	15	-186,09	-185,86	Less extreme
2 July	12	-255,00	-252,92	Less extreme
	13	-495,1	-449,57	Less extreme
	14	-500,00	-500,00	Same price
	15	-500,00	-500,00	Same price
	16	**-499,00**	**-500,00**	**More extreme**
	17	**-167,08**	**-172,39**	**More extreme**

Source: EPEX SPOT and Nord Pool

Table 4-1 Prices for first and second auction in the Netherlands

20. In the following paragraphs, we present on the bidding curves before and after the organization of second auctions, in order to assess how and to which extent the changed bids have altered the market outcome. We will focus on two cases, the ones where the second auctions have had the highest impact on the clearing price in either direction (less and more extreme, respectively 2 July 13:00 and 28 May 14:00).

[10] Second auctions have been triggered by threshold violations in other bidding zones as well (e.g. Germany/Luxembourg, Austria and Denmark1), yet these are not considered in these analyses (even though some are on overlapping hours with the ones under consideration).

21. The difference in the supply and demand curves for 2 July 2023 hour 13 between the first auction (dotted lines in Figure 4-2) and the second auction (solid lines) are hardly noticeable. Note that these curves only include bids from Dutch market participants. In order to approximate the intersection between supply and demand, the net export position of the Netherlands (4.573,4 MW in first auction and 4.663,8 MW in second auction) should be added.[11] Given that the reaching of the threshold in the first auction also triggers the organization of second auctions in other (neighbouring) bidding zones, the price obtained from the second auction also includes the effect of non-Dutch supply and demand bids' modifications in the second auctions. Considering the negligible difference between the Dutch demand curve in the first and second auctions, it is likely that the change in the clearing price (45,53 €/MWh increase) is due to altered bids in other markets.

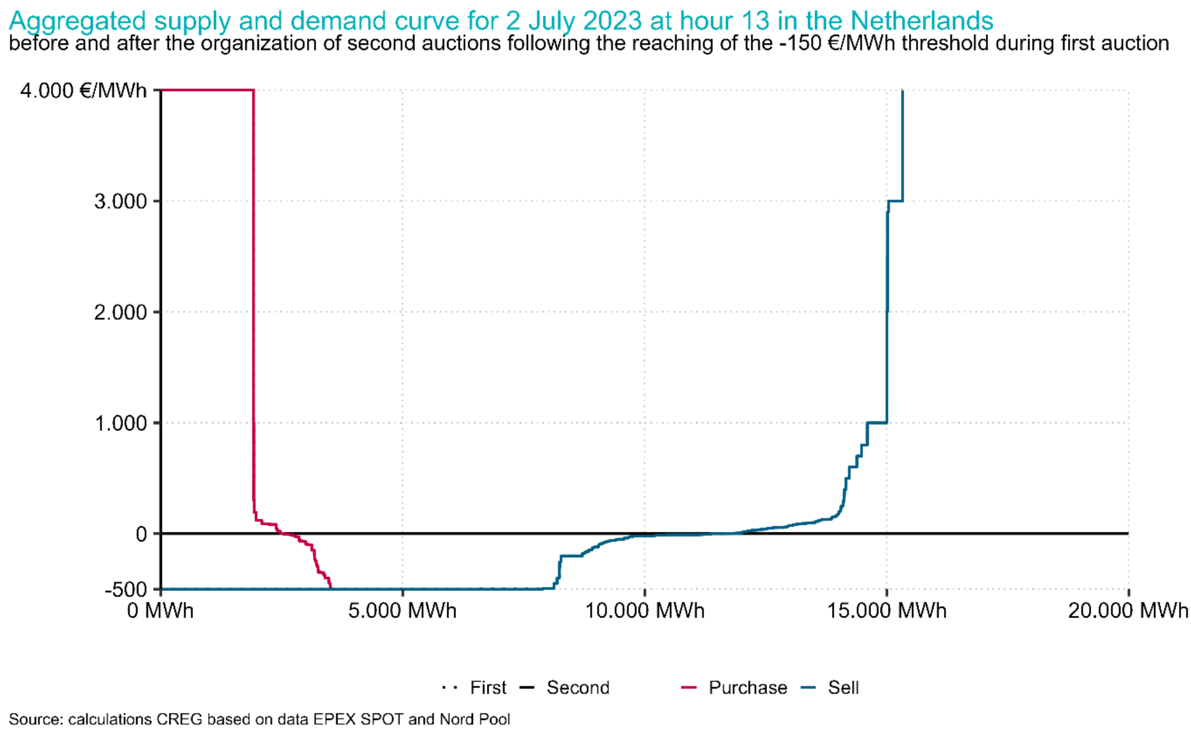

Figure 4-2 Aggregated supply and demand curve for 2 July 2023 at hour 13 in the Netherlands

[11] Even then, still, the intersection between both curves will not exactly match the market clearing price, given that no block orders are included in the curves and these impact the market clearing.

22. On 28 May 2023, hour 14, a clear difference between the supply curves in the first (dotted line in Figure 4-3) and second (solid line) auctions can be observed. This resulted from a modified supply bid (or combination of bids) totalling 566,6 MWh, where the bid price was lowered from -250 €/MWh to -300 €/MWh. Such bids, while allowed, lower the clearing price even further, contrary to the foreseen objective of the second auction.

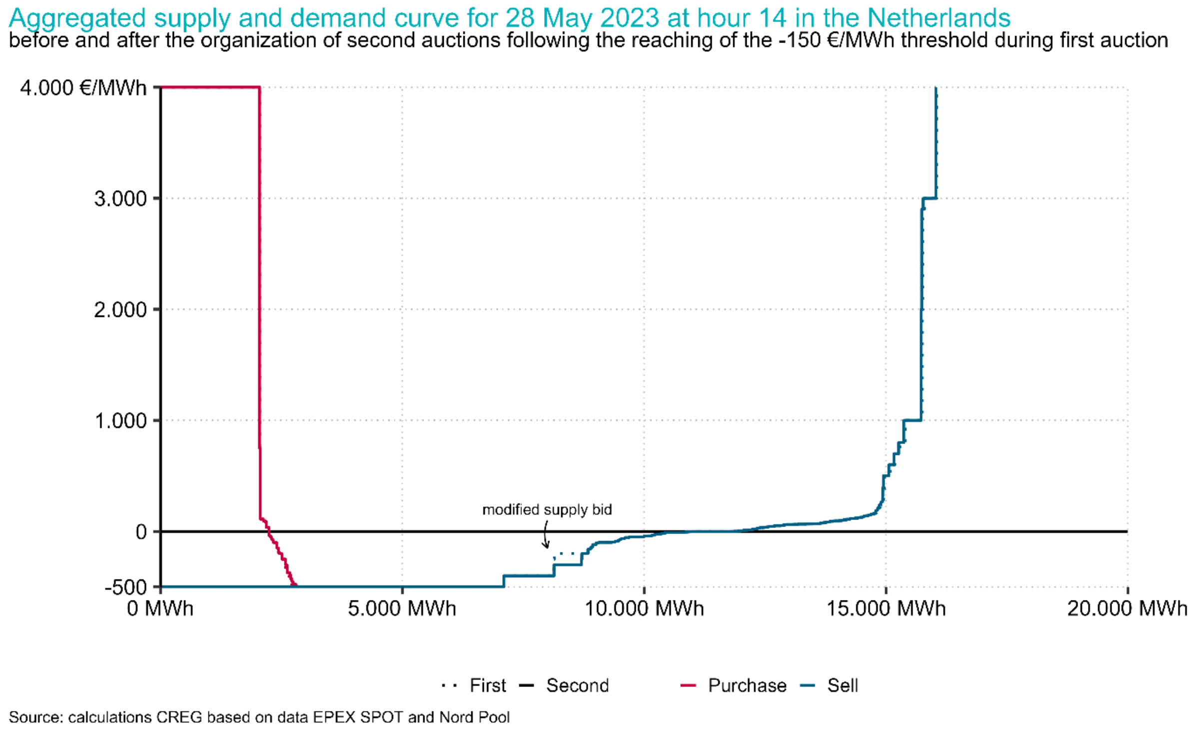

Figure 4-3 Aggregated supply and demand curve for 28 May 2023 at hour 14 in the Netherlands

23. The impact of the modification of supply and demand bids in zones where thresholds trigger second auctions and neighbouring zones where these auctions are organized as well (despite no thresholds being reached) on clearing prices is not straightforward to estimate. This is apparent from the observations in Figure 4-2 and Figure 4-3. The clearing price after the second auction is the result of the combined effect of supply and demand bid modifications, change in import and export positions, (modified) block orders, etc. As a new session of the market clearing algorithm is ran, over different affected bidding zones, the change in the results may vary in magnitude.

4.2.2. Impact of second auctions on single day-ahead coupling operations

24. The SDAC follows, on a daily basis, a clear operational sequence of events bound by tight timings. The main deadlines of the SDAC, related to the coupling phase (from order book closure to publication of results) are described in Table 4-2. When a second auction is triggered, normally shortly after the 12h45 deadline to publish the preliminary results, a second round of orderbook opening and consequent calculations is re-opened, delaying the publication of the final results to close to the 14h20 deadline to publish results before declaring a full decoupling event. In a full decoupling event, the allocation of cross-border capacity and energy is no longer done in an implicit and single calculation. This means that the flows are allocated in a non-optimal way and have a major impact on the SDAC social welfare benefits, ranging in average 10 billion € per trading session.

Event	Deadline
Normal day - Closure of order books	12h00
Normal day - Publication of the preliminary results	12h45
Normal day - Publication of final results	12h57
Latest deadline to publish results in case of issues before declaring a full decoupling event	14h20

Table 4-2 Main SDAC operational timings

25. Table 4-3 shows the timings at which the operational messages were sent for the 5 second auction events that occurred in 2023. It can be observed from the table that, at best, publication of results can be achieved at 13h54, which represents a 57 minute delay compared to a normal day scenario and which leaves 26 minutes of buffer in case of operational issue before declaring a full decoupling, compared to 83 minutes when no second auctions are triggered. On 27 May, the second auctions lead to a publication **after** the full decoupling deadline (indicated in bold and red) but did not trigger any full decoupling event. NEMOs indicated that the decision not to trigger a full decoupling was taken according to the operational procedures. The late publication of 27 May was caused by an operational issue that occurred in the confirmation phase of the coupling process.

Operational message	18 April	26 May	27 May	28 May	1 July
Reopening of order books	12h55	12h45	12h46	12h40	12h49
Further delay of the market coupling session	13h52	13h50	13h50	13h50	13h50
Nomination process delayed (sent to TSOs)	/	/	14h21	/	/
Publication of results	14h16	14h02	**14h26**	13h54	14h06

Table 4-3 Operational timings of sent messages of 2023 second auctions

26. NEMOs share the conclusion that frequent second auctions lead to operational risks. They consequently took the decision to modify the trigger as of which second auctions are triggered in case

of negative prices from -150€/MWh to -500€/MWh in several member states (including Belgium and the Netherlands). This decision was published on 12 June for an entry into force on the trading session of 15 June.

4.3. CONCLUSION ON SECOND AUCTIONS

27. From the 5 second auctions organized in 2023 as well as the analysis performed in sections 4.2.1 and 4.2.2, we can form a preliminary view on their impacts on the price formation and their operational impacts. It can first be concluded that the second auctions only seldom achieve their initial objective of reducing price spikes. Indeed, only 5 out of 15 hours for which a second auction was organized reached this objective and the same proportion of hours achieved the opposite of objective. Furthermore, the modification of order books by market participants in case of second auctions seems to be very minimal. On the other hand, the operational impact of the organisation of those auctions is severe, reducing in the best case, the contingency to solve critical operational events which would lead to a full decoupling of the SDAC, with social welfare impacts that could be in the billion € range, by 69%.

28. In a context of potential increase of the algorithm computation time, squeezing even more the operational timings and with the above-described conclusion, CREG does not believe that second auctions are a suitable market design feature to achieve an objective of limiting price spikes. CREG considers that alternative design features should be studied to ensure that the benefits that second auction provide, for example in case of bidding mistake by market participants, can be kept.

5. IMPACT FOR CONSUMERS

29. Most consumers in Belgium have fixed-price or variable-price contracts, whereby the variable prices are calculated on some monthly or quarterly (day-ahead or forward) price indexes. The impact of negative prices is similar, for consumers with variable contracts at least, to the impact of low (but positive) prices: they tend to lower the price index on the basis of which bills are calculated. Nevertheless, they do not involve inverse financial flows by remunerating consumers for their offtake at the negative price (unless prices become more often negative than positive).

30. In order to truly benefit from negative prices, i.e. by increasing your consumption in order to increase the remuneration received on the basis of the negative price, it is necessary to have a dynamic electricity price contract. These dynamic prices are based on the price observed in power exchanges, but rather than averaging them out as an index over longer periods, they are applied on an hour-to-hour[12] basis to the real, measured consumption of a consumer. This requires that the consumer has a smart meter installed, which allows measuring and sharing metering data with the system operator on a continuous basis.

31. The Electricity Directive[13] establishes, in its Article 11, the right for consumers to sign – when they have smart meters installed – such dynamic contracts with their supplier. For this reason, suppliers with a customer base of at least 200.000 final consumers have to offer these contracts. The right to request dynamic prices has been transposed into national[14] and regional legislations.[15]

Article 11

Entitlement to a dynamic electricity price contract

1. Member States shall ensure that the national regulatory framework enables suppliers to offer dynamic electricity price contracts. Member States shall ensure that final customers who have a smart meter installed can request to conclude a dynamic electricity price contract with at least one supplier and with every supplier that has more than 200 000 final customers.

2. Member States shall ensure that final customers are fully informed by the suppliers of the opportunities, costs and risks of such dynamic electricity price contracts, and shall ensure that suppliers are required to provide information to the final customers accordingly, including with regard to the need to have an adequate electricity meter installed. Regulatory authorities shall monitor the market developments and assess the risks that the new products and services may entail and deal with abusive practices.

3. Suppliers shall obtain each final customer's consent before that customer is switched to a dynamic electricity price contract.

4. For at least a ten-year period after dynamic electricity price contracts become available, Member States or their regulatory authorities shall monitor, and shall publish an annual report on the main developments of such contracts, including market offers and the impact on consumers' bills, and specifically the level of price volatility.

[12] As of 2025, it can be expected that this granularity will be even up to a quarter-hour basis.

[13] Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity

[14] Belgian Electricity Law, article 22quinquies

[15] Flemish Energy Decree, article 4.4.1, paragaph 1, 4° in Flanders, Walloon Energy Decree, article 34bis, paragraph 1, h) in Wallonia and Brussels Electricity Market Ordinance, art. 25 in Brussels Capital Region.

32. In Belgium, 5 suppliers meet the criterium of having a portfolio of at least 200.000 final customers: ENGIE, Luminus, Total Energies, Eneco en MEGA.[16] The legal obligation to offer these dynamic price contracts notwithstanding, only few suppliers truly offer these products to final consumers (either residential or small businesses). In total, according to the numbers available to the CREG, approximately 800 consumers have signed such contracts.[17]

33. By consulting the regional price comparison tools (with data for August 2023), an overview of the available dynamic products (offtake and injection) is established in Table 5-1.

	Flanders	Wallonia	Brussels
Offtake	**6** *(Ebem, Eneco, Engie, Frank Energie, Mega, OCTA+)*	**1** *(Eneco)*	**0**
Injection	**6** *(Ebem, Eneco, Engie, Frank Energie, Mega, OCTA+)*	**0**	**0**

Source : CREG based on data V-Test (VREG), CompaCWaPE (CWaPE) and BruSim (Brugel)

Table 5-1 Available dynamic offtake and injection products for residential consumers in Belgian regions, August 2023

34. Dynamic offtake contracts are mostly suited for residential consumers having the possibility to adapt their demand to the variation of the spot prices, for example through flexible consuming assets such as heat pumps or electricity vehicles. Other consumers, with little possibility to respond to a price signals, can be exposed to very high prices (up to the current maximum price of the day-ahead market of 4.000€/MWh) with limited possible reactions. In case of long-term periods of high prices, both types of consumers can be exposed to those short-term high prices. CREG therefore advises residential consumers to be cautious when signing such contracts and encourages suppliers to offer additional measures to protect consumers from extremely high prices, such as an affordability option which could effectively limit the exposure of residential consumers.

5.1. DYNAMIC OFFTAKE CONTRACTS

35. Where dynamic price contracts are based on day-ahead prices, consumers who have signed these know the price on which their consumption will be charged at least 11 hours in advance. Day-ahead prices are calculated and published, under normal circumstances, by 13:00 CET on the day preceding the delivery. Based on this information, consumers can anticipate their offtake to ensure that it is highest during hours with low or negative prices. This requires that consumers are active in the sense that they follow up closely and anticipate their consumption, as following a typical consumption profile is likely to be more expensive, given that prices tend to increase when global demand increases.

36. Referring back to Figure 3-2, it is clear that it is more profitable for consumers to increase their offtake in the hours where prices are (more often) negative, i.e. the night-time hours and the hours around lunchtime. We see, from Figure 5-1 and Figure 5-2, that this is not the case on a global level:

[16] Studie (F) 2605 over de samenstelling van de productportefeuilles per leverancier en het besparingspotentieel voor huishoudens op de Belgische elektriciteits- en aardgasmarkt (NL);
Étude (F) 2605 sur la composition des portefeuilles de produits par fournisseur et potentiel d'économies pour les particuliers sur le marché belge de l'électricité et du gaz naturel
[17] idem

the total electricity consumption (measured on the Elia network) is lowest at night, the lunchtime peak is – albeit higher than during most of the remainder of the day – still much below the evening peak. To avoid increasing the price paid for electricity consumption with a dynamic tariff, it is important that consumption is therefore different from the average profile, by increasing consumption at night and around lunch, and decreasing during the evening peak.

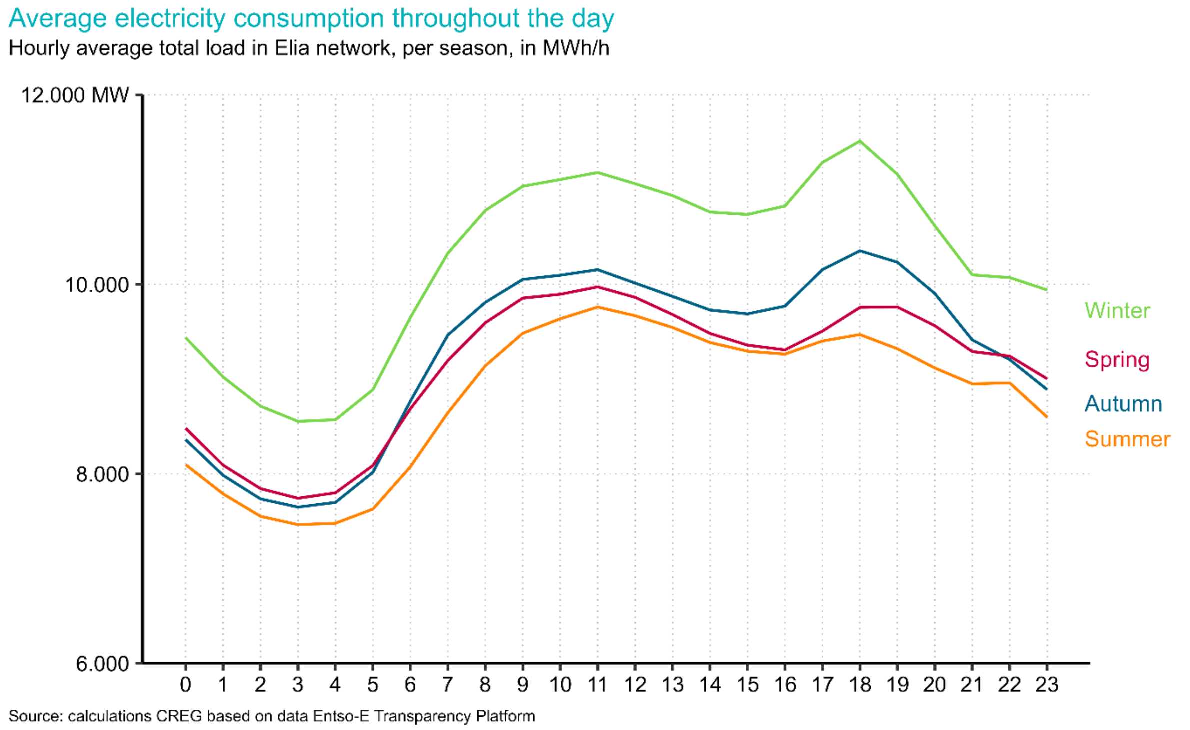

Figure 5-1 Average electricity consumption throughout the day

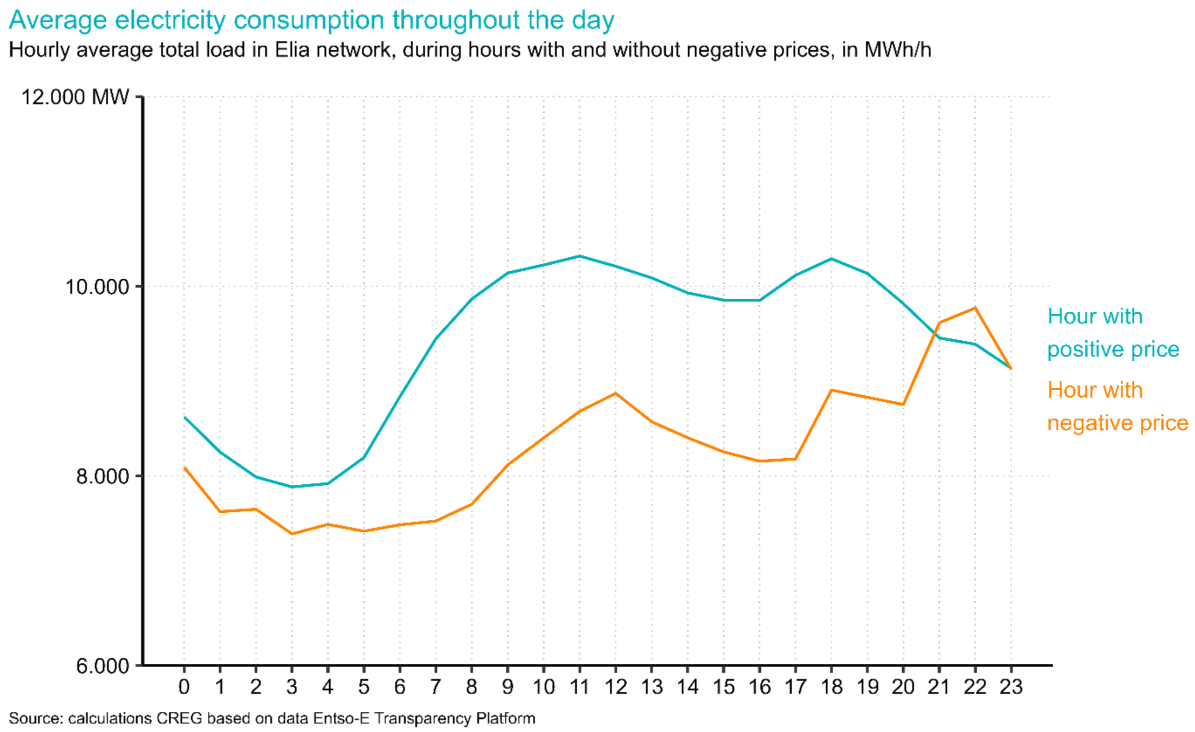

Figure 5-2 Average electricity consumption throughout the day

5.2. DYNAMIC INJECTION CONTRACTS

37. In the same way as offtake contracts, some suppliers offer dynamic injection contracts. These injection contracts remunerate the consumer who has solar PV panels installed, for the energy supplied to the grid which is not consumed behind the meter. The remuneration is based on the hourly injection, measured via a smart meter, in combination with the hourly spot prices. At the moment, only few of these contracts are actively offered to the market, yet it can be expected that the importance of these types of products will increase in the future.

38. While dynamic offtake contracts offer the consumer a clear (financial) incentive to optimize its consumption based on the known day-ahead prices, this is less straightforward (but still possible) for dynamic injection contracts. The injection of electricity into the grid largely depends on the meteorological conditions: on sunny days the production from solar PV panels will always be much higher than on cloudy, dark days. In combination with negative prices, this might create a dangerous situation: as shown in Figure 3-2, negative prices most frequently occur around noon, when there is high solar irradiation and high production from solar PV panels. When, during such hours, a consumer cannot consume all of its locally produced electricity behind the meter, the excess generation will be injected in the grid and remunerated at a negative price, meaning that the consumer essentially needs to pay to inject its solar PV production. As more and more solar PV will be installed, it can be expected that this situation will occur more frequently (by increasing the number of hours where prices become negative). A hypothetical example of this situation is presented in Figure 5-3.

39. From a consumer perspective, this situation can be avoided by several actions, which require that a consumer, in the first place, is aware that prices are negative (by following up on the evolution of day-ahead electricity prices):

- during hours with negative prices, self-consumption should be maximized in order to avoid that excess electricity is injected in the grid;
- solar PV panels could be shut down (manually or automatically) in order to avoid generating electricity when prices are negative;
- fixed-price or variable-price injection contracts could be considered, where the remuneration (in c€/kWh) is calculated over (multi-)yearly, quarterly or monthly periods.

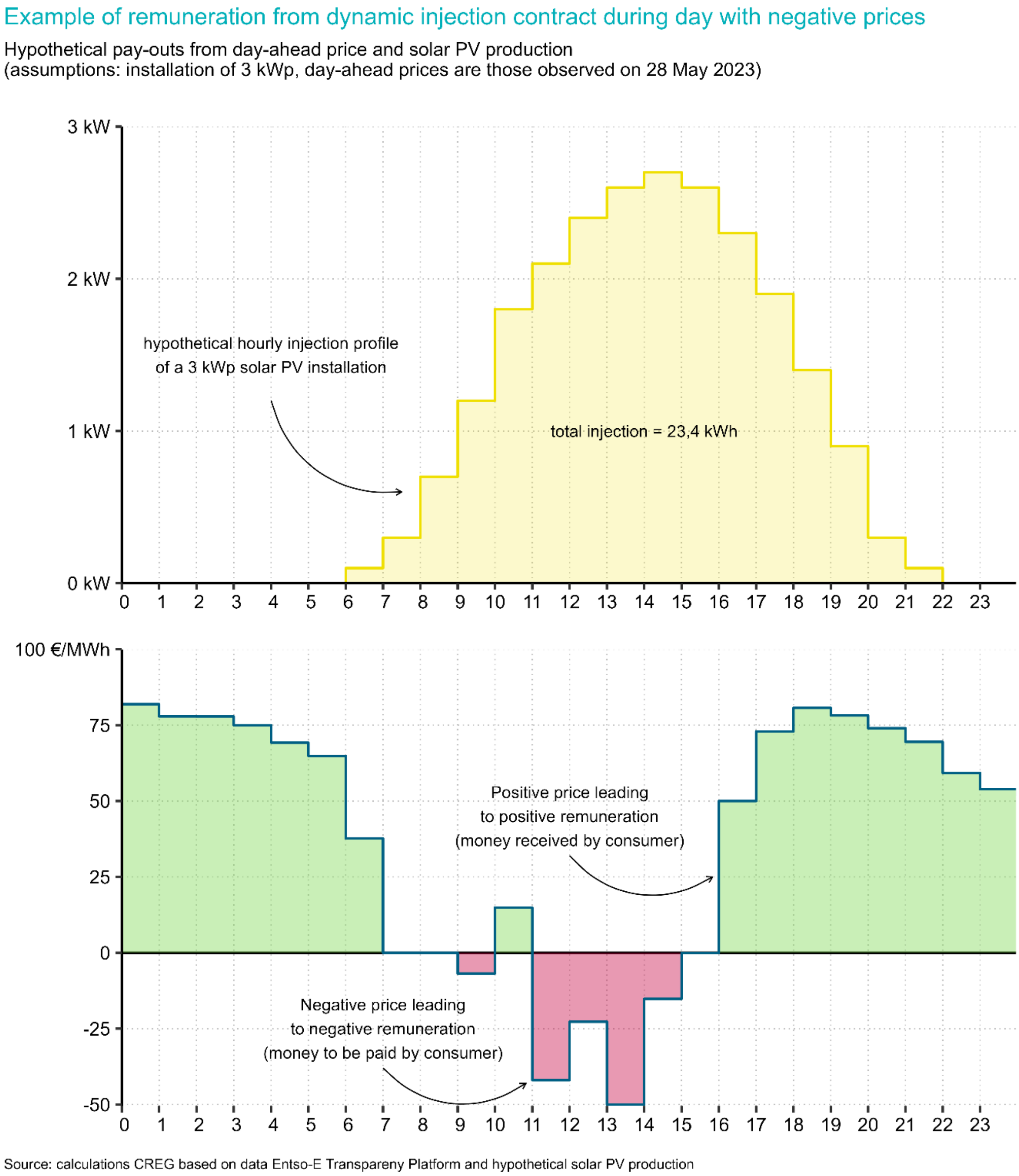

Figure 5-3 Example of remuneration from dynamic injection contract during day with negative prices

40. In the example above, the prosumer receives a remuneration for its injection during hours 6, 10 and 16-22 (when day-ahead prices are positive, and electricity is injected). During the hours 9 and 11-15) where the price becomes negative, the remuneration will be negative as well, and it will entail a financial transfer from the prosumer to its supplier. Given this rather common PV profile, with high injection around the noon-time hours, the negative remuneration will be rather large. Based on this example, the positive prices multiplied by the injection during that hour lead to a remuneration of 49,65 €, while the negative prices lead to a negative remuneration of -32,21 €, leading to a net remuneration (during all hours combined) of 17,4 €.[18]

[18] This is only the energy component: no taxes or network fees are considered in this example. The prices refer to those observed on 28 May 2023 in Belgium. Furthermore, no self-consumption is assumed, for simplification. This is jus

6. CONCLUSION

In this study, the CREG presented the findings from its analyses regarding the occurrence of negative prices in the coupled day-ahead markets in Europe, observed in the spring and summer of 2023.

This study shows, in particular, the remarkable results from the market coupling mechanism during week 22, where prices close to, or equal to, the minimum threshold of -500 €/MWh were reached.

This study presents, in addition to the market coupling results of week 22, a theoretical description of the price formation mechanism and how negative prices materialize. In particular, the CREG highlights the impact of start-up and ramping costs of thermal units, and the lack of exposure to day-ahead prices of certain (segments of) market participants, both on the supply and demand side.

The impact of the organization of « second auctions » is described in this study. This mechanism has been triggered, at multiple occasions (in particular in week 22), with the aim to avoid the deepest negative prices, once a threshold (-150 €/MWh) has been met. The CREG shows that, despite the intentions of this mechanism (reducing the extremeness of the price), the results of its application are unsatisfactory. Comparing the supply and demand curves before and after the organization of the second auctions, shows very few and light modifications of the bids, and clearing prices moving, depending on the case observed, equally often in the desirable and non-desirable direction. Given the major impact of these second auctions on the operations of the day-ahead market, the CREG concludes that these second auctions do not constitute a suitable market design element and urges the involved NEMOs to study and consider possible alternatives.

Negative prices have an impact on consumers' bills, to a varying extent depending on the consumers' contract type. Especially when dynamic contracts are in place, there can be – in theory – a clear financial incentive to consumers to adapt its offtake to benefit from (deeply) negative prices. However, the CREG recommends a cautious approach, to avoid or mitigate their exposure to (extremely) high prices.

For the Commission for Electricity and Gas Regulation :

Andreas TIREZ	Laurent JACQUET	Koen LOCQUET
Director	Director	Acting Chairman of the Board of Directors