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Factors Affecting Market Participant Decision Making in the Spanish Intraday Electricity Market: Auctions vs. Continuous Trading

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Abstract: Intraday markets can be organized as continuous trading or discrete auction sessions. While many studies have attempted to compare the liquidity of these two models, additional external factors specific to each system, such as the balancing market design and number of bidding zones, affect overall market liquidity. In this regard, the Spanish hybrid intraday markets seem like an excellent case study to compare the two market models. Since the two intraday models are implemented in the same system (the Spanish one), the same conditions apply to their implementation. However, a direct comparison of liquidity is still challenging due to two factors: (1) differences exist in market architecture (timing, pricing scheme, bidding formats, etc.) between the two models, which create preferences among market players for one or the other; (2) the opportunistic behavior of market players in the system responding to the market price signals may affect the liquidity dynamics. We demonstrate the relevance of these two factors coming into play in the Spanish intraday markets, first carrying out a qualitative analysis of the market architecture of both models and then empirically analyzing a market manipulation attempt, which we refer to as the 15:10 rush. Our analysis points towards the need for more efficient regulation governing the interaction of the continuous intraday market with intraday auction markets and the potential risks from increased algorithmic trading.

Keywords: intraday markets; intraday auctions; continuous intraday trading; Spanish electricity markets; strategic bidding

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1. Introduction

Intraday (ID) electricity markets allow market participants to adjust their market positions, taking as a starting point the day-ahead (DA) ones to better match their real-time generation or consumption levels. The need for flexibility in the intraday timeframe emerges from the increasing forecast accuracy of weather-dependent generation and load profiles closer to real time, operational schedule modifications, or additional plant outage information available in this time frame with respect to DA [1–3]. ID markets can also be used to manage the technoeconomic constraints of the plants, particularly when certain formats of complex bids are not permitted in the DA markets [3]. By using the ID markets to adjust the DA market positions, market participants can reduce the imbalance costs associated with the difference between their real-time output and market commitments.

Intraday markets play a key role in integrating high shares of renewable energy, especially wind and solar. Weber [4] claims that liquidity in intraday markets is a major factor that reduces the societal costs of wind integration. However, as observed by Weber and Chaves-Ávila, liquidity is not uniformly defined throughout the literature [4,5]. The metrics used for measuring ID liquidity include traded volume and number of trades [2,6,7], transaction costs [4], bid–ask spreads and market depth [8], and liquidity costs [9]. Despite the differences in the approach, several studies indicate that the ID market liquidity in many European countries falls short of theoretical benchmarks [3,4]. The examination of

'successful ID market designs' [2–4] reveals internal factors that drive the use of ID markets. An alternative to ID market participation is for agents to self-balance within their portfolios or to manage large imbalances bilaterally. In Spain, market participants are obliged to make adjustments through ID markets, increasing the trade volumes [2,10]. In Italy, the lack of complex DA bids requires the participants to use the ID market to manage their technical constraints [10]. Additionally, the existence of multiple bidding zones in Italy advises the involvement of agents in ID markets for cross-zonal capacity allocation for portfolios with assets spread throughout the country. Furthermore, external factors such as the type of imbalance pricing applied (single or dual), the market share of agents, and the share of intermittent resources, among others, influence ID liquidity [2,11].

Assuming all the external factors remain equal, ID liquidity is closely tied to the market model. In Europe, the DA market is organized as a unified pan-European auction market, called the Single Day-Ahead Coupling (SDAC) market [12]. However, despite the fact that there is also a Single Intraday Coupling (SIDC) market at the European level, in some countries, there are additional regional and national intraday markets coexisting alongside SIDC. The SIDC market is organized as a continuous trading market where the market participants can submit bids as soon as they have new information that can affect their operational schedule [13]. In contrast, in those countries with additional regional and national intraday markets, these markets are structured as auction markets [14]. The participants can submit their bids till an established gate closure time (GCT) [15]. After the GCT, the market operator (MO) clears the market by minimizing the total procurement cost.

The selection of a continuous trading model for SIDC is primarily driven by historic reasons [16]. At the time of SIDC implementation, Nordic countries had already obtained significant experience operating a continuous ID market. On the other hand, Spain, Italy, and Portugal had discrete auction-based ID markets in place. These countries opted for a hybrid design, maintaining the status-quo ID auction markets but complementing them with SIDC [14].

The organization of the market, whether through an auction or continuous trading-based, can determine the overall efficiency of the intraday markets and condition the behavior of the market players. Hence, many academic works have studied the differences between auction-based and continuous-trading-based market structures. The main advantage of the auctions is related to their ability to accumulate offers and efficiently allocate the scarce transmission capacity [10,16,17]. In contrast, continuous trading models allocate the cross-border transmission capacity on a first come first serve basis. As a result, the generators with the lowest bids or demand with the highest bids may not be allocated the capacity, reducing the allocational efficiency of the market [16,17]. Auction systems employ a merit-order-based clearing mechanism that prioritizes the most efficient trades and ensures the creation of transparent congestion rents. In a study comparing different ID markets in Europe, Weber [4] states that market players may also develop a preference for auction designs due to their planning processes. Inflexible power plants may have technical restrictions that prevent instantaneous rescheduling in response to trades occurring in continuous intraday (c-ID) markets.

On the other side of the argument, in a renewable-dominated power grid, there is a value in increasing the speed at which new information is integrated into the market schedule [6,16]. The speed advantage serves as an incentive for the participants to invest in more accurate forecasting methods and improve their planning procedures. In this aspect, continuous trading systems are advantageous, as they incentivize the participants to use the new information as fast as possible [16,18]. Henriot [19] argues that restricting trading to certain hours, as occurs in an auction design, can lead to market inefficiencies and opportunity losses. The evolution of the accuracy of forecasts varies across market players, making it extremely challenging for market designers to select optimal timings for ID auctions (ID-a). A similar argument is made by Scharff and Amelin in [6], where the authors state that inflexible generators, such as thermal power plants, need to offer their flexibility much earlier than flexible generators like hydro plants.

However, if the Spanish auction market is taken as an example, one can argue that such inflexibilities can be accommodated by ID auction markets with a sufficient number of discrete auctions [2]. The thermal generators typically participate in the first few auction sessions, giving them sufficient time for planning and operation. Also, it is worth highlighting that many studies comparing the two ID market models, discrete auction and continuous trading, often compare one model implemented in one country to the second model implemented in another country. While doing so, some factors external to the ID market, such as national regulation and the balancing market design, play a major role in determining the performance of the corresponding ID market. In this regard, the hybrid ID market structures in Spain, Portugal, and Italy may appear as excellent case studies to compare the performance of the two ID market designs, as the external factors remain the same within a country. However, closer examination reveals that even within a country, certain factors prevent the direct comparison of two different market designs.

The first is related to the differences in market architecture between the two models. Despite trading the same product within the same timeframe, there can be subtle nuances that distinguish one market type from another, such as the differences in the bidding formats and geographic scope. The second factor is related to the behavior of market participants. Profit-maximizing firms will strategize their bidding decisions to leverage any market arbitrage opportunities that may arise in the market. These arbitrage attempts may not necessarily indicate flaws in the market model but rather highlight potential challenges stemming from ill-designed market regulation.

Considering these factors, this paper aims to provide insights into the market-architecture-related and market-behavior-related factors that pose challenges when directly comparing ID auctions and continuous ID market models. We use a qualitative assessment centered on a review of the operational rules for both models to examine the main differences in their market architecture. Later, for the market behavior analysis, we conduct an empirical analysis of the Spanish market data to try to identify clear cases of strategic bidding. We further discuss the implications of implementing each of the two market designs, and both in parallel, as well as those of implementing efficient alternative market models.

To our knowledge, this is the first time a detailed comparative study of the Spanish intraday market architecture and the gaming opportunities corresponding to the two main ID market models has been performed in the literature. This is particularly relevant considering the future plans outlined by ACER (Agency for the Cooperation of Energy Regulators) to combine the continuous intraday trading model with complementary intraday auctions [20]. By examining the Spanish market in detail, this study can offer valuable insights into the potential challenges associated with such a hybrid model, which will soon be applied in many European countries. Also, the comparison of intraday market models is extremely relevant for countries where intraday markets are still not in place or under development. It is especially important for countries that aim to integrate a high share of intermittent renewables into their energy systems. Hence, understanding the differences between the performances of the two markets is important in designing efficient, fair, and nondiscriminatory markets.

This paper also addresses the coordination between national markets (Spanish markets in this case) and higher-level regional markets (European coupled markets). The issues discussed in this paper provide valuable examples and insights for market coordination projects in other regions, such as the Central America Power Market, South African Power Pool, Nile basin initiative, and others [21]. The lessons from the interaction of Spanish intraday auction markets with the European continuous intraday trading markets will provide insights into potential challenges and pitfalls in the coordination mechanisms.

Furthermore, the ongoing discussions focusing on the introduction of new products into the intraday markets, such as 15 min and 30 min products, will add another layer of complexity to these studies [22,23]. Exploring the implications of these developments will contribute to a better understanding of the intraday market dynamics and the participant behavior in each of them.

This paper is structured as follows. Section 2 provides a brief background of the evolution of the Spanish intraday markets, particularly focusing on the developments that led to the adoption of a hybrid market model. In Section 3, the methodology used for our study is described. Section 4 presents a detailed discussion of the differences in the market architecture between the two ID models. Section 5 provides the main results of the empirical analysis, along with a discussion of its significance. Section 6 concludes the work and provides some policy recommendations.

2. The Evolution of Spanish Intraday Markets

The intraday auction market has been a part of the Spanish electricity market ever since the beginning of an open wholesale market in 1998 [24]. The main motivation behind the implementation of the six-session ID auction market was to allow the market players to make adjustments to their schedules and to deal with unexpected events, such as the unavailability and outage of plants. In 2004, the Santiago International Agreement was signed by Spain and Portugal to create the Iberian Electricity Market (MIBEL) as a regional integration project [25,26]. The spot markets of MIBEL (day-ahead and intraday) became functional in July 2007. Meanwhile, at the European level, the development of pan-European day-ahead and intraday projects was under discussion. In 2014, SDAC was successfully implemented, shifting the focus to the SIDC project [12].

However, unlike DA markets, ID markets were not developed according to a single market design (such as double-blind auctions in the case of DA). As mentioned in Section 1, the use of ID continuous trading in continental Europe and the Nordics greatly drove the adoption of a continuous trading model for SIDC. Although the continuous trading model allows the fast integration of the latest available formation within the procurement schedule, it inherently suffers from inefficient cross-zonal capacity allocation. Identifying this potential inadequacy, the Capacity Allocation and Congestion Management Guidelines (CACM) directed the regulators to develop a single pricing methodology for efficiently pricing the cross-zonal capacities [27].

Consequently, ACER decided to complement continuous ID trading with an auction-based cross-zonal capacity pricing methodology. This was based on the principle that each capacity recalculation in the intraday timeframe must be priced first in an intraday auction [28]. As the adoption of such ID complementary auctions is a long-term process, a medium-term option was to have complementary regional ID auctions (CRIDA) [14,16]. According to this approach, relevant Nominated Electricity Market Operators (NEMOs) and Transmission System Operators (TSOs) jointly develop these markets. Once the complementary intraday auctions are adopted at the European level, the existing CRIDAs, such as those between Spain and Portugal and Italy and Greece, will gradually transition towards a pan-European auction market. Considering these factors, when ID continuous trading was introduced in June 2018, it did not replace the existing ID auction markets but rather created a hybrid market combining both ID auction and continuous trading.

In the case of Germany, the introduction of intraday auctions for 15 min products complementing the continuous trading markets was associated with a significant increase in traded volumes, as demonstrated in [10]. Within just four months of implementation, the German ID auction volumes nearly matched the status quo continuous trading market volume. However, in the Iberian markets, the traded volume in continuous ID trading remained between 30% and 60% of the ID auction volumes, even one year after its implementation, as shown in Figure 1 [29]. This could be attributed to path dependencies, driving the participants to the more familiar ID auction market. Also, compared with the German case where a new product was introduced, the Iberian continuous intraday markets offered an already existing ID product (1-h blocks) [13,30]. However, it is tough to conclude on the factors contributing to the existing differences in the traded volume between the two market types without assessing the differences in market architecture between them. Hence, in Section 4, we discuss the main differences between the market architecture of the two models.

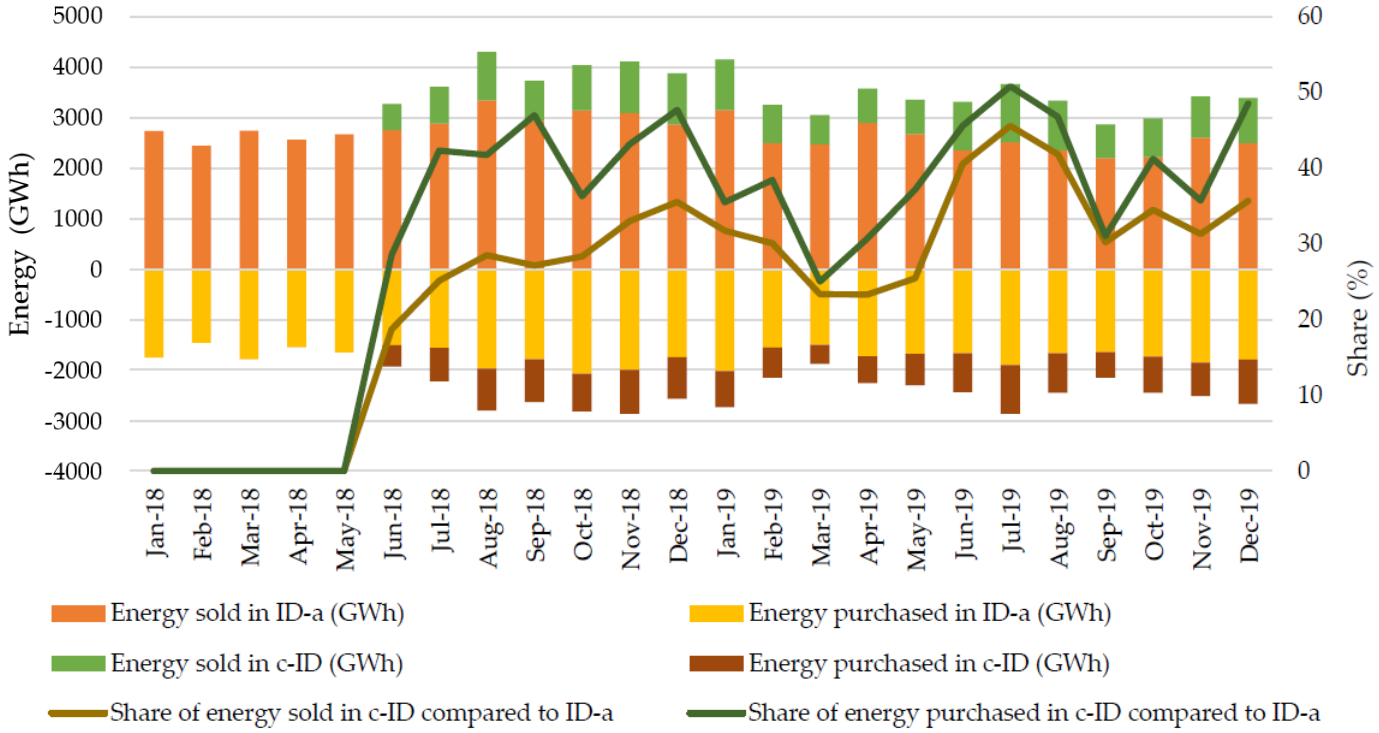

Figure 1. Energy traded in the intraday auction (ID-a) and continuous intraday trading (c-ID) during 2018–2019 in the Iberian market. Source: OMIE [15].

3. Methodology

In this study, we aim to understand the factors contributing to the significant differences in the traded volumes between ID auctions and continuous trading, as depicted in Figure 1, while pointing out the challenges that prevent a clear comparison from being carried out. We take a two-step approach to analyze the market architecture and participant behavior for both types of markets.

In the first step, we conduct an analysis of the market architecture to identify the factors driving the differences in the traded volume between the two market models. We specifically investigate four key aspects of market architecture: market timing, pricing schemes, available bidding formats, and geographic scope. The main source of data for this part of the study is the market regulation published by the Iberian market NEMO, OMIE and the Spanish TSO, Red Eléctrica de España (REE) [29,31]. By examining the regulations governing the two markets, we can understand the structural and operational factors affecting the traded volume. Additionally, to validate the assumptions, we supplement our analysis with empirical evidence from the published market data available in the transparency portals of OMIE and REE.

In the second step, we focus on analyzing the behavior of the market participants. We base our analysis on the hypothesis that the behavior of market players is notably driven by the monetary incentives associated with participating in each market. Specifically, we investigate how participants adapt their bidding strategies to the observed price differences between the ID auction and continuous markets. To demonstrate this point, we select a particular period in 2022 where a substantial price difference between ID auctions and the ID continuous market was observed. By examining the bidding patterns of agents in this period, we aim to provide evidence of market participants' responses to price differences and their impact on traded volumes.

In June 2022, the Spanish government introduced a mechanism to adjust the method applied to compute the price in the wholesale markets, a measure widely known as the 'Iberian exception', to drive down the high electricity prices resulting from the increase in gas prices [32]. As a result, in the following months, the wholesale market prices in

Spain and Portugal remained much below the prices in continental Europe (see Figure A1 in the Appendix A). In addition to this, at the same time, there was a disruption in the supply of low-cost French nuclear energy due to the simultaneous occurrence of power plant maintenance and repair works affecting a large number of units [33]. As a result of these, in the period of minimum coupling (16:00 18 August 2022), the price differential between Spain (99 EUR/MWh) and France (535.4 EUR/MWh) DA markets was as high as 436.4 EUR/MWh [34]. This price differential was clearly reflected in the prices of intraday markets, as shown in Figure 2. The prices in the Spanish continuous intraday market, associated with those in continental Europe, rose high above the DA and ID auction market prices in MIBEL. The correlation between these prices is tabulated in Table 1.

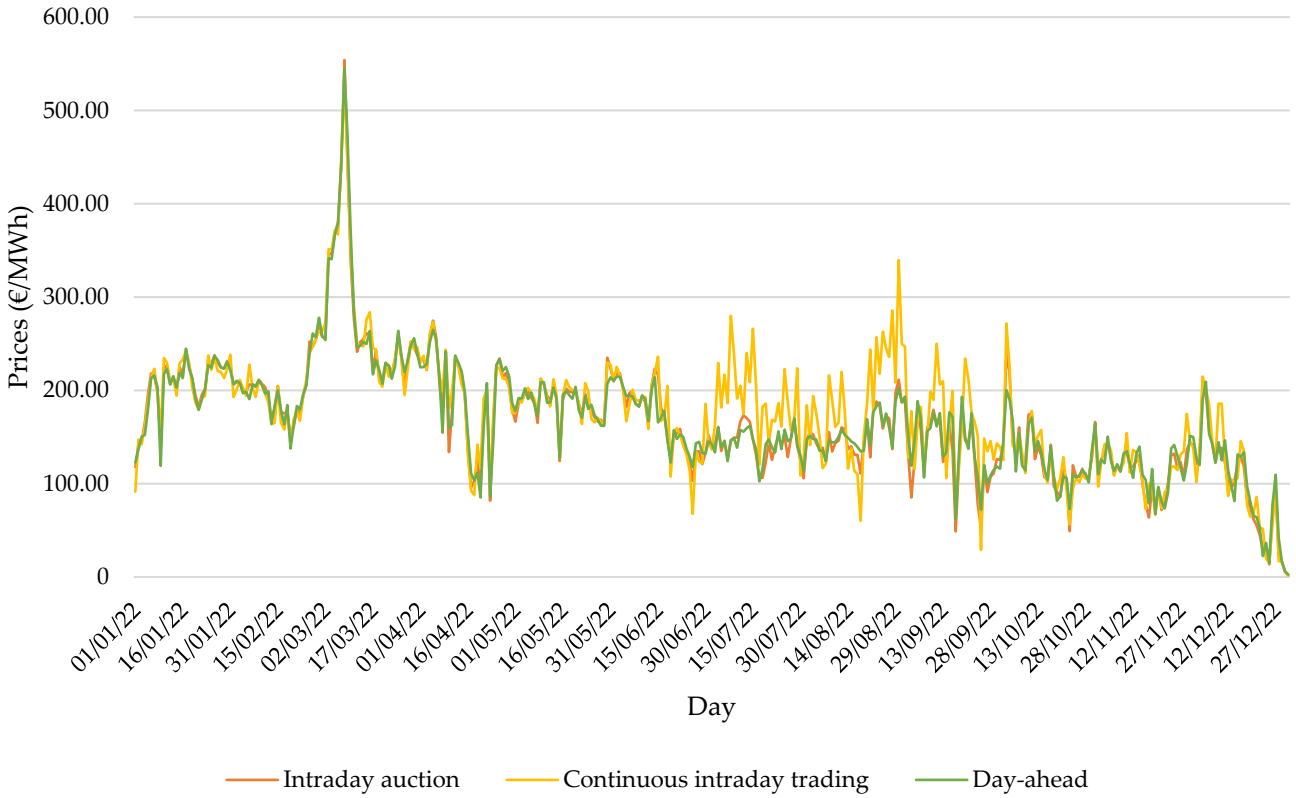

Figure 2. Wholesale market prices in the Spanish wholesale markets during 2022. Source: REE [31].

Table 1. Correlation between the average daily prices in the Spanish wholesale markets. The highlighted area represents the period when the price in the continuous intraday market (c-ID) diverges from those in the day-ahead (DA) and the intraday auctions (ID-a). Own elaboration based on data published by REE [31].

Month	ID-a and DA	c-ID and DA	ID-a and c-ID
January	0.9846	0.9364	0.9700
February	0.9733	0.9381	0.9637
March	0.9937	0.9868	0.9916
April	0.9780	0.9407	0.9721
May	0.9379	0.9240	0.9611
June	0.9458	0.8069	0.8996
July	0.8935	0.4855	0.4303
August	0.9493	0.6505	0.6929
September	0.9513	0.6606	0.6757
October	0.9536	0.8996	0.9516
November	0.9054	0.6874	0.8408
December	0.9814	0.9339	0.9656

From January to May and in December, the correlation between continuous intraday (c-ID) and day-ahead (DA) markets is consistently above 0.9. However, between June and November, these correlation values decrease and fall below 0.9, reaching their lowest point in July. A similar pattern can be observed in the correlation values between intraday auctions (ID-a) and continuous intraday (c-ID) markets. Based on these correlation values, we divide the selected period of study, January 2022–November 2022, into a convergence period (January 2022–May 2022) and a divergence period (June 2022–November 2022). We use the market data available in the transparency portals of OMIE [29] and Red Eléctrica de España (REE) [31] to analyze how the two markets interact with each other and how the behavior of market players changes during this period.

4. The Differences in the Market Architecture

In this section, the main differences in the market architecture between the ID auction and continuous ID trading markets are discussed. Along with the discussion, we provide a brief analysis of how each of these elements contributes to the observed difference in trading volume between the two markets.

4.1. Market Timing

The intraday auction market in Spain is organized into six discrete auction sessions, each with a different programming horizon (except auction session 1 and 3, sharing the same programming horizon). As the continuous trading session runs alongside ID auctions, issues like duplicate capacity allocation may occur. Hence, during the market clearing period of an ID auction, bidding in continuous markets is suspended for the scheduling periods covered in the corresponding auction session [15]. Once the results of the ID auction market are published, market participants have to reactivate their bids in the continuous markets, validating their limits on energy. Any bids that are not reactivated by the participants will remain inactive in the system, i.e., they cannot be matched with other orders. The schedule and the programming horizon of the ID auction sessions and ID continuous trading are given in Table 2.

Table 2. Spanish intraday market timings. ID-a*x* stands for the session *x* of intraday auction, and c-ID stands for continuous intraday trading. The delivery day is represented as D, and the day before delivery day is represented as D-1. Source: OMIE [15].

	ID-a1	**ID-a2**	**ID-a3**	**ID-a4**	**ID-a5**	**ID-a6**	**c-ID**
Market timing	14:00–15:00	17:00–17:50	21:00–21:50	01:00–01:50	04:00–04:50	09:00–09:50	15:10–(RT-1)
Publication of results	15:07	17:57	21:57	01:57	04:57	09:57	-
Programming horizon	(1–24) D	(21–24) D-1 and (1–24) D	(1–24) D	(5–24) D	(8–24) D	(13–24) D	(18–24) D-1 and (1–24) D

The nature of the market, either discrete or continuous, can have an impact on the market performance and the behavior of market players. In SIDC, market participants can see the prices and quantities of unmatched orders in the Order Book. The new bid submitted by a market-monitoring participant will be instantaneously matched if the purchase bid price is above the price of the existing sell bids or if the sale bid price is below the price of the existing purchase bids. Hence, instead of bidding for their marginal price, as they do in a double-blind auction, the participants can submit a bid based on the existing orders in order to maximize their profits. Here, the governing strategy for maximizing profits is to snatch the competitive bids as fast as possible. To do that, participants have to monitor the markets continuously, which requires the use of sophisticated market monitoring technologies. In this regard, an argument against the continuous trading market is that it gives an unfair advantage to large market players who can invest in such advanced technologies [16,18]. In July 2019, NordPool, a prominent European power exchange, declared that the share of intraday trades submitted through an application programming interface (API) had reached 52%, which directly points to the fact that more than half of the intraday trades

in NordPool are carried out by trading algorithms [35]. The technological advances in artificial intelligence, combined with the developments in advanced forecasting techniques, may bring down the investment costs of these technologies, making intraday trading more accessible for small market participants. Thus, until these technologies become more affordable for all participants, the availability of an intraday auction market represents an attractive alternative, where participants can trade even small quantities of flexibility, ensuring profitability.

4.2. Pricing Scheme

Auctions are based on a pay-as-clear mechanism, whereas continuous trading is based on a pay-as-bid mechanism. The ID auction starts by matching the simple bids and obtaining a clearing volume and price [30]. Later, complex conditions are added and iteratively tested to ensure that all the matched bids meet the corresponding declared complex conditions. The final clearing price is the price of the most expensive generator that is cleared in the market.

The bids in continuous intraday markets are sent through the market platform of the corresponding NEMO, which in the case of Spain is OMIE. The participants submit bids to the OMIE Trading Platform, which is connected to the Order Book of SIDC [36]. The participants' bids can match the orders that are submitted from their same bidding zone or from other zones, as long as the corresponding cross-zonal capacity is available. The matching is done when a sell bid offers a lower or equal price than a buy bid in the Order Book that the former can match or if a buy bid offers a higher or equal price than a sell bid in the Order Book that the former can match. If two bids offer the same price, priority is given to the bid that is entered first.

The bidding strategies used by each market player depend on the pricing scheme used for market clearing [37,38]. A pay-as-clear system incentivizes participants to bid their marginal production costs since their inframarginal revenues (revenues for units whose marginal production costs are below the bid setting the market price) will contribute towards the recovery of their capital investment costs. In a pay-as-bid system, this is not the case. In order to maximize their profits, the participants tend to set their bid price for it to be as high as possible while still having their bid accepted. However, they may fail to predict accurately the bids by others or may not be quick enough to snatch an attractive bid by a counterparty in the continuous market, which could result in their bid not being matched or accepted, even if they are cost-competitive against other market participants whose bids are accepted. Therefore, unlike in a pay-as-clear system, the prices negotiated in a pay-as-bid market typically do not represent the marginal cost of producing energy during a specific period [39–41]. The offer price may be influenced by the existing offers in the Order Book and the forecasted (or historical) prices in the intraday markets. Similarly to the what happens with the market monitoring algorithms, investments in price forecasting algorithms also fall unevenly on the small players, discouraging them from entering markets where benefits largely rely on their forecasting capabilities [37,41]. Additionally, as a direct consequence of the application of pay-as-bid pricing and the continuous matching of bids, an agent trading the energy of a particular plant at a specific time, or the energy to be used at a specific time in a specific location, may pay/earn different prices for different fractions of the same amount of energy traded. Analogously, different agents trading their energy in the same geographic location for the same period may earn/pay different prices for this energy in continuous markets. The resulting prices critically depend on the bidding price and the counteroffer matching the concerned one. Hence, achieving profit maximization in continuous intraday markets, or at least some market profits compatible with the recovery of the overall costs incurred, involves designing and implementing more complex bidding strategies than in an auction market, which negatively affects the traded volume in the former.

The differences between the bidding strategy used in ID auctions and the continuous ID market can also have consequences in terms of the market coordination level achieved.

Given that both markets basically trade the intraday flexibility, forwarding the unused bids in a market to the other (probably forwarding ID auction bids to the continuous trading market) should, in principle, increase the liquidity of these markets. However, this would also certainly affect the revenues of the market players and could, hence, affect their incentives to bid in each, since agents may consider that bids in the intraday auction market are not appropriate for the continuous one. The European Network of Transmission System Operators – electric (ENTSO-e) proposal for pricing intrazonal capacities clearly states that there will not be any automatic transfer of bids between the proposed cross-border ID auction and the continuous ID markets [42]. As the geographic scope and the type of products traded remain the same, it can be speculated that the advisability for agents to adapt the bids/offers submitted to the pricing rules may have prevented the market designers from implementing a bid-transferring system.

4.3. Available Bidding Formats

Within intraday markets, both auction and continuous trading, the agents offer intraday products, which essentially represent the flexibility of a firm to deviate from DA schedules during the intraday phase. Currently, the intraday products in Spain are limited to hourly products. Then, the difference between the market products in the two market types stems from the allowed bidding formats. The type of bidding formats allowed in a market determines the ease with which different technologies can be integrated into the market [43]. Complex bidding formats allow the participants to express those technoeconomic constraints and intertemporal links affecting the schedule of their resources that may be challenging to represent in a simple price–quantity pair.

The ID auction markets allow both simple and complex bids to be submitted [15]. Simple bids are price–quantity pairs that can be submitted for one or more hours of the scheduling period. Complex bids include, in addition to the simple bid requirements, at least one or more complex conditions within those shown in Table 3. Similar to the evolution of the markets to facilitate the integration of new technologies, the bidding formats evolve to represent the needs of the generation mix and other energy resources of the underlying power system. In the Iberian case, many of the existing complex conditions, such as the maximum energy and full acceptance ones, have been developed for pumped hydro units that are active participants in the Portuguese ID markets [34].

Table 3. Type of complex conditions allowed in the Iberian intraday auction markets. Source: OMIE [15].

Type of Complex Bid	Description
Load gradient	Expresses the maximum difference between the energy scheduled for an energy resource in two consecutive hours to avoid sudden changes in the output of production units
Minimum income	Expresses the condition that if the production unit concerned does not reach a specified minimum income, covering its fixed and variable costs as a result of its scheduling, this unit does not participate in the matching
Full acceptance in the matching of the first stretch of the sale bid	Represents intertemporal links that impose the scheduling of a whole block stretching over a number of scheduling periods if a block within one of these periods is matched in the market
Full acceptance in each hour in the matching of the first stretch of the sale bid	Represents the condition that other hourly blocks can only be matched if the first one is accepted in this same hour
Minimum number of consecutive hours of full acceptance in the first stretch of the sale bid	Establishes a period of consecutive hours for which a unit must either produce at a minimum level or stop
Maximum energy	Confines the availability of energy to an overall maximum such that the limitation of the resources associated with the production or consumption facility is taken into account

Certain complex conditions used in the ID market are also used in the Iberian day-ahead markets. Currently, the European day-ahead market, SDAC, is preparing to shift from a 60 min resolution to 15 min (the approach of a single-step change in market time unit from 60 min to 15 min is referred to as a 'Big Bang' of the market time unit [22]. Instead of a gradual shift from one MTU to another, in a Big Bang approach, all parties simultaneously switch from 60 min to 15 min MTU.) [22,44]. The simulations conducted for the new time resolution have shown a substantial reduction in the market performance level, leading the NEMO committee to reconsider the use of complex products, like PUN offers from Italy and minimum income condition (MIC) offers from Spain [45], in the DA markets. A public consultation is underway for replacing these bids with a new bid format called 'Scalable Complex Order (SCO)' that can improve the scalability of the market clearing problem [44]. SCOs are currently used in the DA markets of Ireland (along with other complex products). Taking the DA market development as a precursor, it can be speculated that the complex conditions available in the ID auctions market will be subject to change when they are coupled with the European markets.

The continuous intraday markets, on the other hand, do not consider the same complex conditions as the ID auction markets. Instead, the continuous market considers the trading of three different products and a set of execution conditions. The products offered are as follows:

1. **Regular order**: Also called limit order, it is a simple bid representing the willingness to buy or sell a certain quantity at a certain price.
2. **Iceberg orders**: A large order that is divided into smaller limit orders. Only a part of the total quantity associated with the Iceberg order is initially visible in the market. When a part of the Iceberg order is fully matched in trade, a new slice of the quantity associated with the Iceberg order is made available in the Order Book. If it is only partially matched, the remaining quantity of the same slice will remain in the Order Book. Iceberg orders feature the same behavior as a market participant submitting a new bid only when a previous bid is fully scheduled [46].
3. **Block orders**: Price–quantity pairs covering multiple consecutive hours.

The types of execution conditions allowed in a continuous ID market are described in Table 4.

Table 4. The list of execution conditions allowed in the Spanish intraday continuous markets. Source: OMIE [15].

Type of Execution Condition	Description
None (NON)	The order can be matched fully or partially. The unmatched volume will remain in the Order Book
Immediate or cancel (IOC)	The order is executed immediately, fully or partially, with the already existing orders in the Order Book. If it is not possible, the order is canceled immediately
Fill or Kill (FoK)	Similar to the IOC, but the order can only be matched fully. If the full quantity cannot be matched, the order is canceled immediately
Iceberg	A reduced quantity of the total volume is displayed in the Order Book. Only the agent submitting the bid can see the whole amount
Iceberg with a price increase	Each slice of the Iceberg order has a specific price. The price for each slice is higher than that for the previous one

Comparing the amounts of energy sold and purchased corresponding to the different technology types, given in Figure 3, shows a clear preference for auctions among market participants, independent of the technology type. Around 90% of the upward flexibility from coal and CCGT power plants are traded in auction markets. The preference of thermal generation for auctions may be attributed to the ability to set load gradient and minimum

income conditions within the bids submitted to these, which facilitates the internalization of the complex technoeconomic constraints of thermal resources.

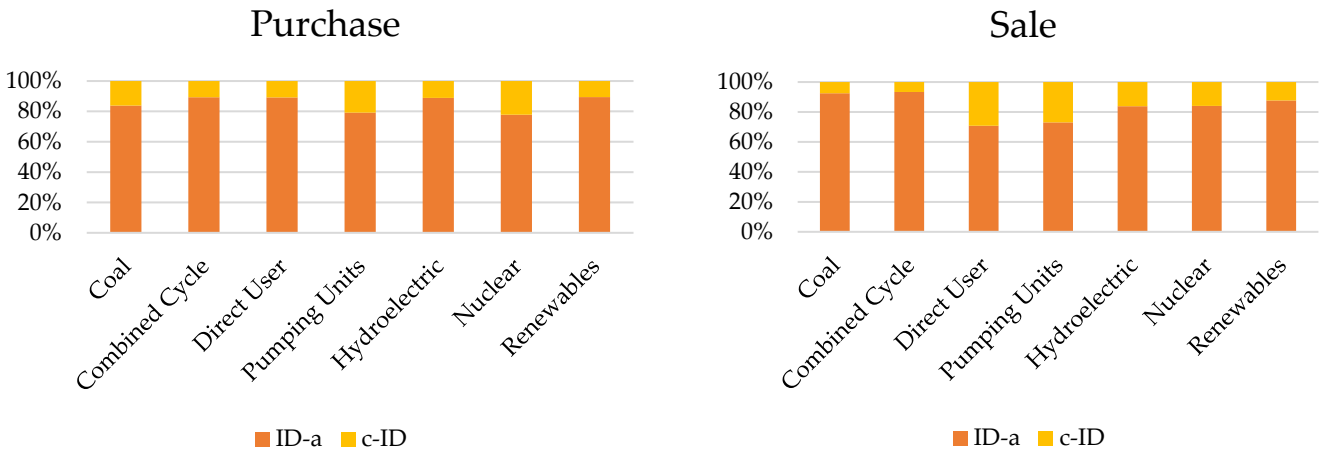

Figure 3. The energy traded in Spanish intraday auctions and continuous intraday markets by different technology types. Source: OMIE [29].

Additionally, the use of Iceberg orders in a continuous market affects the estimates of the liquidity available made by participants, which, in turn, determines their willingness to participate in this market instead of considering alternatives. Only a part (or a slice) of the Iceberg order is visible to the participants searching the Order Book, which means that the depth of the hidden liquidity is unknown to the participants (other than the agent who submitted the Iceberg offer). Iceberg offers are placed by participants who do not want to influence price formation by submitting a large order [47]. If financial markets are taken as an example, market participants can develop strategies to seek hidden liquidity, for instance, by placing orders with Fill or Kill (FoK) and Immediate or Cancel (IOC) execution conditions [48,49]. However, given the relative novelty of continuous ID markets in Spain, the participants may still need to get familiar with these concepts. In 2022, Iceberg bids made up 28% of the total number of purchase bids submitted to the continuous intraday markets (see Figure 4). Therefore, their effect on the perception by participants of the amount of liquidity available in the continuous ID markets cannot be ignored. As mentioned in the previous Section 4.2, the use of algorithmic trading platforms may play a crucial role in the utilization of the different execution conditions available in a continuous trading market. Therefore, the rise in the accessibility of these algorithmic trading platforms may increase the traded volumes in continuous ID markets.

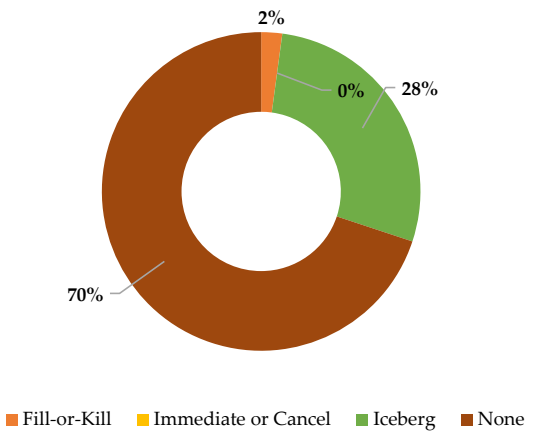

Figure 4. The share of purchase bids with different execution conditions in the continuous intraday markets in 2022. Own elaboration based on bidding data published by OMIE [29].

A potential concern of those considering their participation in future intraday markets is the absence of suitable bidding formats for storage and demand response. For storage systems, there are intertemporal links between the amounts of energy sold and purchased. Such conditions are tough to represent with the available formats of complex bids in the intraday auction markets. On the other hand, in continuous ID markets, buy bids and sell bids can be grouped inside a basket (called basket orders). Linked order conditions applied within baskets allow the participants to establish the condition that the matching of one bid (e.g., charging cycle represented as a demand) within the basket is contingent on the matching of another bid within the basket (e.g., discharging cycle represented as a generation) [15]. Although this represents an improvement compared with the ID auction market formats available, issuing linked orders requires the market participants to periods for buying and selling energy set in advance, which may not lead to an optimal use of their storage capacity [43]. The public consultation on the intraday products for SIDC shows that participants have identified the need for additional bidding formats that consider the increasing variety of technologies within their portfolios [50]. Nevertheless, one can assume that the sustained interest at the European level in creating more bidding formats will make the continuous trading market more open towards the participation in it of novel technologies.

At the moment, both models of intraday markets in Spain offer only hourly products. The lack of products considering a finer granularity (e.g., 15 min and 30 min products) limits the possibility of accurately representing fast variations of the amount of products available within the market schedules. Products with a fine enough granularity are also essential for unlocking the flexibility potential of small distributed resources like demand response and small-sized batteries [51].

4.4. Geographic Scope

The Spanish ID auction markets belong to a CRIDA project managing the price areas of Spain and Portugal. In addition to managing the Spain–Portugal interconnection, the free cross-border capacities on the Spain–Morocco and Spain–Andorra interconnections are also allocated within these auctions. On the other hand, continuous ID markets are part of the broader European coupling project. Hence, OMIE manages these continuous markets together with other market operators from continental Europe (EPEX Spot, BSP, and Nord Pool) [34]. The Iberian market players can exchange energy in the ID timeframe through SIDC, as long as the transmission capacity required for this (mainly on the Spain–France interconnection) is available.

The recalculation of the transmission capacity available in the intraday timeframe uses a flow-based approach [20]. According to the ACER intraday capacity calculation methodology, the TSOs should submit the updated cross-zonal capacities to the NEMO in three timeframes [20]:

(1) For all MTUs (between 00:00 and 24:00) of the following day for which flexibility is going to be traded (D) no later than 15 min before the ID cross-zonal gate opening time;
(2) For all MTUs (between 00:00 and 24:00) of the following day for which flexibility is going to be traded no later than 21:45 the day before that day (D-1);
(3) For MTUs between 12:00 and 24:00 of the following day for which flexibility is going to be traded (D) no later than 09:45 on D-1.

The cross-border capacities available in the continuous ID trading market depend on the level of coupling between the Spanish and French markets. Due to the limited interconnection capacity available, the French–Spanish border shows high occupancy rates resulting from the day-ahead market (here, the planning process after the day-ahead congestion management market is taken as the reference), as given in Figure 5. This leaves very limited cross-border capacity for intraday trading, which may limit the incentives for the market players to participate in pan-European continuous intraday markets instead of CRIDA auctions.

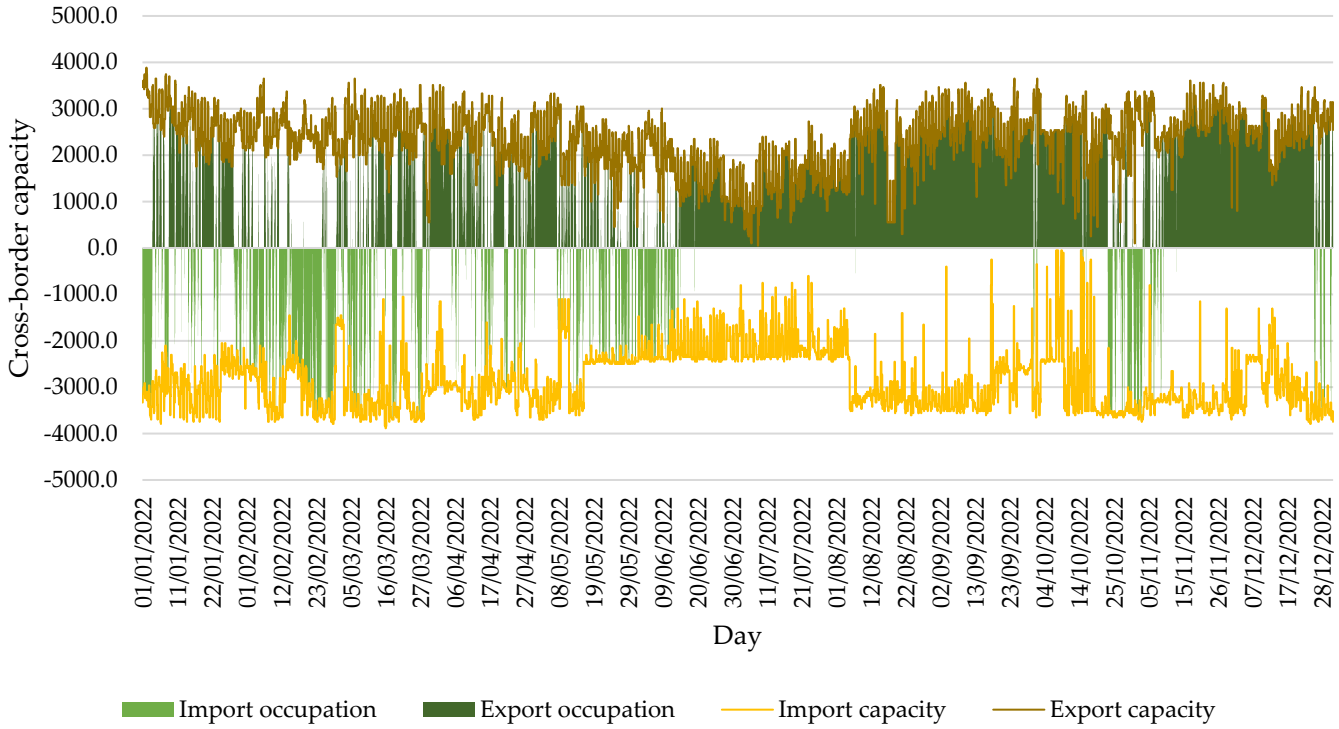

Figure 5. Availability and occupation of cross-border transmission lines between Spain and France after the day-ahead market.

It should be noted that an efficient allocation of interconnection capacity is ensured in the DA market, where a pay-as-clear system is used. This also results in congestion rents, which leads to the efficient allocation of a fraction of the cost of the interconnection capacity (that covered by the congestion rents) among the system agents and, by extension, their national systems. However, in a pay-as-bid continuous trading market, the interconnection capacity is allocated implicitly together with energy on a first-come-first-served basis. In this case, cross-border trades can take place as long as capacity is available. This scheme does not result in congestion rents that can be used to pay part of the cost of the interconnection capacity, which may reduce the efficiency of the allocation of the network cost. Apart from the auction-based pricing proposed by ACER, other alternatives to address the allocation of transmission capacities involve the explicit pricing of capacity. Detailed discussions on such proposals can be found in [5,18].

5. The Behavior of Market Participants

In this section, we analyze the behavior of market players in response to an observed divergence in market prices between the two intraday markets. We conduct this mainly by studying the distribution of the bidding activity throughout the trading period in the continuous intraday markets.

5.1. Period of Price Convergence between c-ID and ID-a

The average number of purchase bids submitted to continuous ID markets per hour, for each hour of the day, in two representative months (we select two or three months for clearly illustrating the data, and data for all months can be found in the Appendix A), March and May, throughout the period of convergence, is depicted in Figure 6. The daily bid distribution pattern is similar for other months during the period of convergence. This figure shows that there is a clear dependence of the number of bids submitted to the continuous ID markets on the timing of the publication of ID auction market results. At first sight, it may look like participants whose bids have not been selected in the ID auctions bid in the continuous intraday market as a second chance to be dispatched. However,

the number of bids submitted to ID auctions significantly increase immediately after the publication of ID auction markets results at least partly because, as discussed in Section 4.1, bidding in the continuous trading market is temporarily suspended during the ID auction clearing process. Then, all the bids submitted to the continuous market which cover the same programming horizon as the auction market are reactivated for matching purposes right after the auction clearing. When they are reactivated, they are deemed new bids at that time, even if they were submitted much earlier.

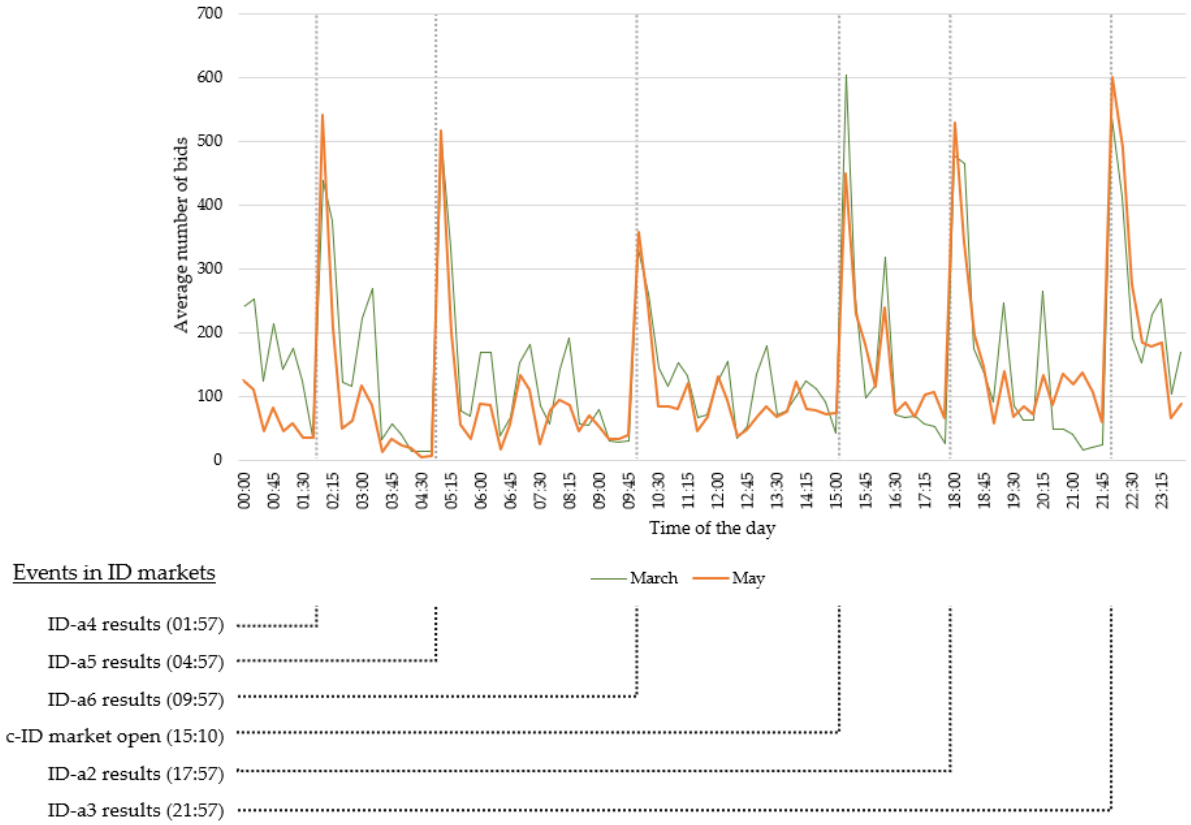

Figure 6. Average number of purchase bids submitted to continuous ID markets per hour, for each hour of the day, in March and May during the period of convergence. The timing of relevant events in the intraday auction session x (ID-a*x*) and continuous intraday market (c-ID) is given as reference. Own elaboration based on bidding data published by OMIE [29].

5.2. Period of Price Divergence between c-ID and ID-a

In the second half of 2022, ID-c and ID-a average prices showed significant divergence. Compared with the distribution of daily bidding activity observed in the previous months (see Figure 6), a gradual shift in the peak market activity from 22:00 to 15:00 can be seen during this period. The daily bidding activities with respect to the time of the day during May (reference for the convergence period), July, and September are shown in Figure 7. Data for other months during the period of study are given in Table A1 in the Appendix A.

A closer inspection of the trading activity reveals that in September, the average number of bids submitted each day at 15:10 (the gate opening time for the Spanish intraday continuous trading markets) was 17.8 times the corresponding number in May, as illustrated in Figure 8. Although the number of agents submitting bids at 15:10 increased threefold from May to September, this does not fully explain such a huge rise in the number of bids placed at that time from one month to another.

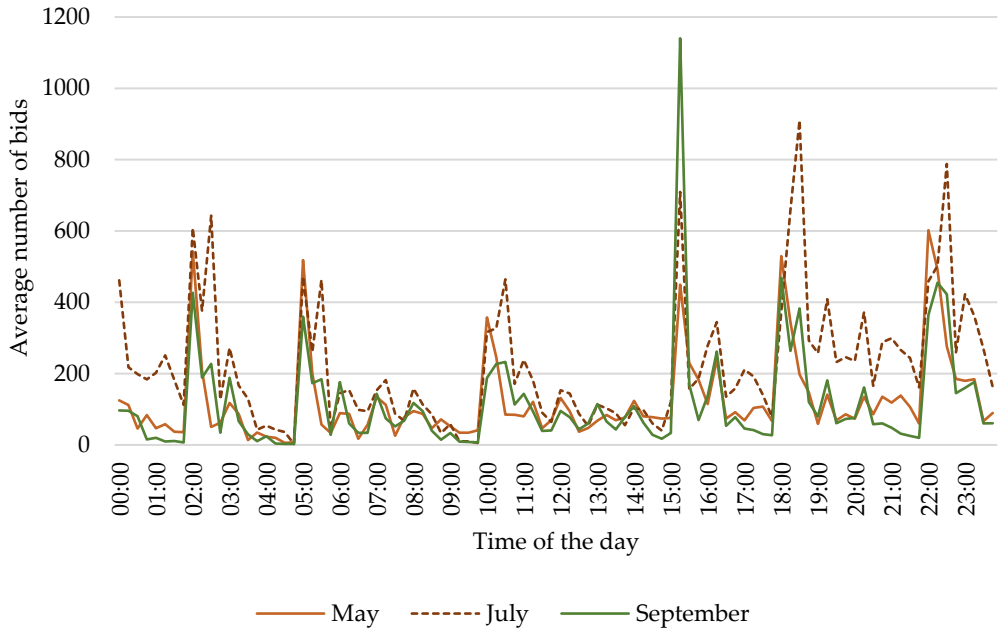

Figure 7. Average number of purchase bids per hour submitted to the continuous intraday markets in May, June, and September 2022. Own elaboration based on bidding data published by OMIE [29].

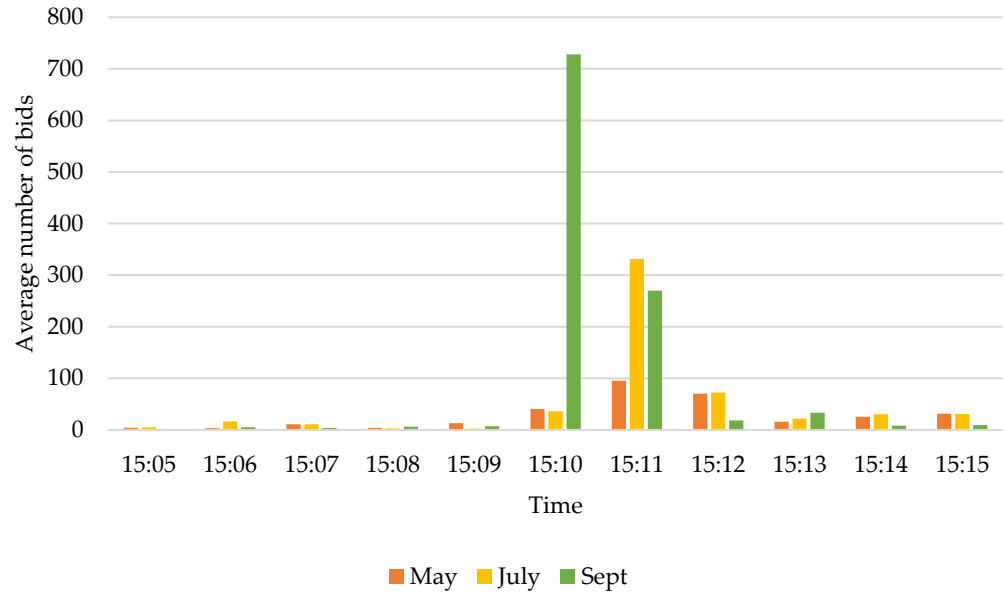

Figure 8. Increase in the number of daily purchase bids submitted exactly at 15:10 in the Spanish continuous intraday markets. Own elaboration based on bidding data published by OMIE [29].

The main factor behind this increase was the divergence between the prices in the ID-C and the ID-a markets that took place in this period combined with the first-come-first -serve allocation principle applied in the continuous markets and the reactivation mechanism applied to continuous intraday bids submitted during the intraday auction clearing process. The suspended bids in the continuous ID markets are reactivated in the order in which they are originally submitted. Hence, a bid submitted at the exact opening of the continuous trading market, at 15:10, will have priority over the other bids submitted later during the day, even if the difference in the timing of the bid submission is minimal. When the prices in the ID continuous trading and ID auction markets started to diverge, market players started leveraging the reactivation rule to have access to more attractive prices, rushing to

submit a large number of bids on the intraday continuous market as early as they could, i.e., at 15:10.

When trying to find and explanation for the bidding behavior of agents in this period of time, it is relevant to take into account these relevant findings:

(1) The surge in peaking activity is more prominent for purchase bids than sale bids (shown in Tables A1 and A2 in Appendix A).
(2) In September, 43 different agents submitted bids exactly at 15:10. Out of these, 24 agents submitted a large number of 0.1 MW bids (see Figures A2 and A3 in the Appendix A). On closer inspection, 22 of these agents were identified as retailers. The bids from these retailers shared some features: these were 0.1 MW bids and bid prices were large and negative (−30 EUR/MWh to −400 EUR/MWh). It was unlikely that these bids were going to be matched by some supply bids.

The relevant factors behind this increase in the bidding activity are the implementation of the Iberian exception, limiting the prices within the Spanish system in the DA and ID-a markets but not those in the c-ID market; the first-come-first-serve allocation principle applied in the continuous markets; and the reactivation mechanism applied to continuous intraday bids submitted during the intraday auction clearing process. The suspended bids in the continuous ID markets are reactivated in the order in which they are originally submitted. Hence, a bid submitted at the exact opening of the continuous trading market, at 15:10, has priority over the other bids submitted later during the day, even if the difference in the timing of the bid submission is minimal.

Due to Iberian exception, in the hours when gas-fired generation was dispatched, the final prices earned by sale bids not submitted by gas-fired generation in the Spanish ID-a market, which were limited by this piece of market regulation, were far less attractive than those prices that these sale bids could earn in the c-ID market, where prices were separately set for each transaction and were not limited. Hence, there was a strong incentive to submit sale bids on the c-ID market. However, if large amounts of sale bids had been placed on the c-ID market, the liquidity and trading conditions in the ID-a market would have deteriorated. Hence, the prices in the ID-a market would have increased. It looks like, in order to avoid this, some Spanish retailers rushed to place huge amounts of noncompetitive bids on the order book of the c-ID markets. Because these bids were the first ones to be placed, they were also the first ones to be considered, even if they were not attractive. Due to the huge number of them, the c-ID platform could not manage them and collapsed. Then, it was blocked for long periods of time, preventing competition from the c-ID market from affecting the clearing conditions in the ID-a market. Interestingly, the market share of all the strategic players involved in the '15:10 rush' was below 1%. This suggests that while their individual effect on the trading volume may be limited, collectively, the actions of these market players could have influenced the market performance. As expected, the surge in the number of bids during this short period overwhelmed the market platforms and raised potential operational risks [52].

Market activity has gradually gone back to the levels seen in the convergence period once the gas prices started decreasing and prices in the Spanish and French markets started converging again. The '15:10 rush' phenomenon point towards an inherent disadvantage of continuous trading systems: the incentivization of strategic behavior and speed over efficiency taking place in continuous markets, discussed in detail in [10,53]. The availability of algorithmic trading platforms allows the market players to continuously monitor the market easily and snatch attractive offers. Additionally, as observed in the Spanish market, a large influx of bids within a short period may cause computational backlogs and may risk the operational stability of the trading platforms.

Although continuous trading can elicit such behavior from market players, the main factors contributing to the surge in the number of bids here is the rule on reactivation and the inability of the market platform to handle high surges in bid volume. Freezing the bids on the continuous markets is a way to ensure the seamless operation of two parallel markets. Arguably, reactivation, which grants preference to the bids that are submitted

first, incentivizes the fast utilization of continuous trading markets. Moreover, there is no prohibition on submitting multiple small bids simultaneously instead of a large-volume bid. Yet, if such behavior is left unaddressed, other participants may also adopt similar strategies, further saturating the trading platforms and worsening the allocational efficiency.

In the future, the market platforms may be improved to manage large volumes of bids, thereby enhancing the resiliency to such events. However, at this moment, the platforms are not equipped to handle such volumes, necessitating the need for regulators to adopt appropriate rules to control these activities. Therefore, currently, the Spanish market regulator has amended the reactivation rule such that during reactivation, priority is given to the most competitive bids and the ones with shorter lead times [52]. However, this rule does not change the fact that some market players can still submit multiple bids of large quantities to saturate the system. This becomes even more relevant when different types of block bids and cross-matching between products of different MTUs are involved [10]. Therefore, improving the handling capacities of the market platform is of utmost importance. Alongside their development, the regulators must carefully consider the possible effects of increased strategic algorithmic trading on the current market platforms, especially on continuous intraday trading platforms.

6. Conclusions

The development of intraday markets in Europe points towards a possible hybridization of the market design involving the combined use of auction and continuous trading markets. Spanish intraday markets are a good example of this. However, even within a country, it remains challenging to conclude how market players develop preferences for one market type over the other. This seems to be primarily due to the nuances of the specific market architecture and the profit-maximizing behavior of the market participants.

The qualitative assessment of the architecture of each market type reveals notable differences between both market models in terms of available bidding formats, pricing mechanisms, market timing, and geographic scope, even if they trade energy products within the same timeframe. The complex conditions available to be set on bids in the ID auction markets allow market players to represent their technoeconomic constraints within the bids, such as the minimum income or the ramping rate. Hence, thermal units like CCGT and coal ones have a preference for bidding in auction markets, especially for the first few sessions. Continuous intraday markets, on the other hand, allow players to set execution conditions affecting the matching of bids rather than explicitly specifying the corresponding unit's technoeconomic constraints. Given that similarly complex conditions in day-ahead markets may be replaced with scalable complex orders, the available bid formats in ID auction markets can also be expected to undergo similar changes soon. This move may probably impact the participation of thermal units in the ID markets and may encourage additional market players (like those with thermal units) to consider the continuous ID markets as an alternative. Nevertheless, existing bidding formats in both intraday markets are not well-suited for nonconventional technologies like demand response and batteries. Introducing more sophisticated bidding formats, such as loop orders, will be instrumental in attracting liquidity across technological groups.

The choice between ID auction and continuous trading markets is also closely related to the pay-as-clear vs. pay-as-bid choice. The pay-as-bid pricing combined with the first come first serve principle of ID continuous trading markets can result in inefficient allocation of scarce transmission capacities. Additionally, in a pay-as-clear system, the participant has an incentive to bid their marginal cost, whereas, in a pay-as-bid system, the market profits it makes depend on its ability to snatch the most attractive orders in the Order Book as soon as they become available or predict the prices set for the orders yet to be made available. Hence, a participant in a pay-as-bid continuous trading system may require sophisticated market monitoring algorithms to snatch competitive bids in time. This may act as a barrier to the participation of small market players. The effect

of algorithm trading is also relevant from a market timing point of view, as continuous trading markets can incentivize speed over cost efficiency.

In the Spanish case, the differences in the geographic scope and regulations affecting the interaction between ID auction and ID continuous trading markets led the participants of continuous trading markets to arbitrage between the markets of both types. We have demonstrated this arbitrage behavior by market participants making use of data available on the continuous trading market results for the year 2022. The price difference between the ID auction and ID continuous markets during the period June 2022–November 2022 prompted certain participants to strategically submit to the continuous market multiple orders of a small size precisely at 15:10, the market opening time for continuous intraday trading. While market participants may opt to submit a large number of small-sized bids as an optimal way to offer their production/consumption capacities, in this case, this behavior was part of a potential platform destabilization attempt. Some preliminary ideas on the exact motivation behind the need for risk platforms are provided here, though this behavior needs to be further investigated. In any case, this is clearly not a desired behavior. This behavior in the continuous ID markets could be identified in the Spanish market and is associated with the fact that the differences in prices between the ID markets of both types in the aforementioned period deviated substantially from the usual ones. However, in a market solely reliant on ID continuous trading, such behavior by agents may be mistakenly interpreted as increased liquidity.

Additionally, the rise in the use of automated trading platforms in continuous trading markets requires careful consideration. In the end, intraday markets should be rewarding investments in low-cost technologies and the application of accurate forecasting techniques rather than solely favoring investments in advanced trading platforms. As the Spanish case study revealed, the participants engaged in this strategic behavior did not individually possess large enough market shares to influence the price formation. However, when multiple small firms engage in the same strategy, the overall market performance may be affected. Auction market design also has its own challenges. The performance of an auction market is largely dependent on the number of intraday auction sessions and their timing. Many studies have discussed the complexity of determining the optimal number of sessions or their timing.

A popular alternative to both continuous trading and auction models is frequent batch auctions [10,51,53]. This approach involves conducting discrete high-frequency auctions, allowing them to mimic the availability of a continuous trading market while increasing the tolerance for minor differences in the timing of bid submissions [51]. Such a design also eliminates the need for multiple rules governing the interaction between the two types of markets. This becomes particularly important as countries like Spain, where only hourly products are currently offered in markets, plan to expand their product offerings in the future, making the management of the interactions among markets even more challenging. The cross-matching of products, which is currently considered in SIDC, can also be considered as an option in frequent batch auctions. Future studies should look further into alternate options, exploring their feasibility and comparing them with the existing ID market models.

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Data Availability Statement: Publicly available datasets were analyzed in this study. This data can be found in the REE transparency portal (https://www.esios.ree.es/en, accessed on 7 March 2023) and OMIE market data portal (https://www.omie.es/en/file-access-list, accessed on 7 March 2023).

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Appendix A.1. Additional Figures

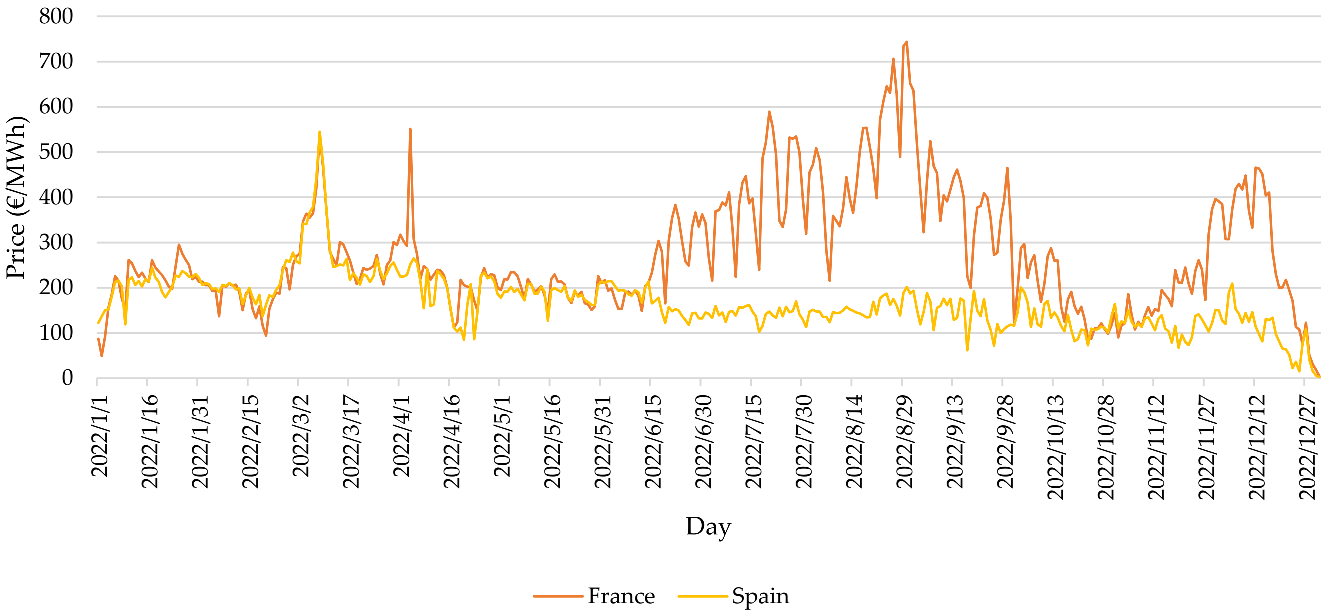

Figure A1. Daily average prices in Spain and France in 2022.

Date	Contract	Zone	Agent	Unit	Price	Quantity	Offer type	Execution condition	Validity condition	Reduced quantity	PPD	Submission time
26-09-22	20220926	10YES-REE------0	AGNT1	UNT1	−200,00	0.1	C		GTD			26-09-22 15:09
26-09-22	20220926	10YES-REE------0	AGNT1	UNT1	−200,00	0.1	C		GTD			26-09-22 15:09
26-09-22	20220926	10YES-REE------0	AGNT1	UNT1	−200,00	0.1	C		GTD			26-09-22 15:09
26-09-22	20220926	10YES-REE------0	AGNT1	UNT1	−200,00	0.1	C		GTD			26-09-22 15:09
26-09-22	20220926	10YES-REE------0	AGNT1	UNT1	−200,00	0.1	C		GTD			26-09-22 15:09
26-09-22	20220926	10YES-REE------0	AGNT1	UNT1	−200,00	0.1	C		GTD			26-09-22 15:09
26-09-22	20220926	10YES-REE------0	AGNT2	UNT2	−30,00	0.1	C		GTD			26-09-22 15:09
26-09-22	20220926	10YES-REE------0	AGNT2	UNT2	−30,00	0.1	C		GTD			26-09-22 15:09
26-09-22	20220926	10YES-REE------0	AGNT2	UNT2	−30,00	0.1	C		GTD			26-09-22 15:09
26-09-22	20220926	10YES-REE------0	AGNT2	UNT2	−30,00	0.1	C		GTD			26-09-22 15:09
26-09-22	20220926	10YES-REE------0	AGNT2	UNT2	−30,00	0.1	C		GTD			26-09-22 15:09
26-09-22	20220926	10YES-REE------0	AGNT2	UNT2	−30,00	0.1	C		GTD			26-09-22 15:09
26-09-22	20220926	10YES-REE------0	AGNT2	UNT2	−30,00	0.1	C		GTD			26-09-22 15:09
26-09-22	20220926	10YES-REE------0	AGNT2	UNT2	−30,00	0.1	C		GTD			26-09-22 15:09
26-09-22	20220926	10YES-REE------0	AGNT2	UNT2	−30,00	0.1	C		GTD			26-09-22 15:09
26-09-22	20220926	10YES-REE------0	AGNT2	UNT2	−30,00	0.1	C		GTD			26-09-22 15:09

Figure A2. A section of market data showing the multiple noncompetitive 0.1 MW bids submitted by the same agent at 15:10. Offer type 'C' stands for compra/purchase. The names of agents and units have been changed.

Date	Contract	Zone	Agent	Unit	Price	Quantity	Offer type	Execution condition	Validity condition	Reduced quantity	PPD	Submission time
26-09-22	20220926 :	10YES-REE------0	AGNT3	UNTC1	−400,00	0.1	C		GTD			26-09-22 15:10
26-09-22	20220926 :	10YES-REE------0	AGNT3	UNTV1	750,00	0.1	V		GTD			26-09-22 15:10
26-09-22	20220926 :	10YES-REE------0	AGNT3	UNTC1	−400,00	0.1	C		GTD			26-09-22 15:10
26-09-22	20220926 :	10YES-REE------0	AGNT3	UNTV1	750,00	0.1	V		GTD			26-09-22 15:10
26-09-22	20220926 :	10YES-REE------0	AGNT3	UNTC1	−400,00	0.1	C		GTD			26-09-22 15:10
26-09-22	20220926 :	10YES-REE------0	AGNT3	UNTV1	750,00	0.1	V		GTD			26-09-22 15:10
26-09-22	20220926 :	10YES-REE------0	AGNT3	UNTC1	−400,00	0.1	C		GTD			26-09-22 15:10
26-09-22	20220926 :	10YES-REE------0	AGNT3	UNTV1	750,00	0.1	V		GTD			26-09-22 15:10
26-09-22	20220926 :	10YES-REE------0	AGNT3	UNTV1	750,00	0.1	V		GTD			26-09-22 15:10
26-09-22	20220926 :	10YES-REE------0	AGNT3	UNTC1	−400,00	0.1	C		GTD			26-09-22 15:10
26-09-22	20220926 :	10YES-REE------0	AGNT3	UNTV1	750,00	0.1	V		GTD			26-09-22 15:10
26-09-22	20220926 :	10YES-REE------0	AGNT3	UNTC1	−400,00	0.1	C		GTD			26-09-22 15:10
26-09-22	20220926 :	10YES-REE------0	AGNT3	UNTV1	750,00	0.1	V		GTD			26-09-22 15:10
26-09-22	20220926 :	10YES-REE------0	AGNT3	UNTC1	−400,00	0.1	C		GTD			26-09-22 15:10
26-09-22	20220926 :	10YES-REE------0	AGNT3	UNTC1	−400,00	0.1	C		GTD			26-09-22 15:10
26-09-22	20220926 :	10YES-REE------0	AGNT3	UNTV1	750,00	0.1	V		GTD			26-09-22 15:10
26-09-22	20220926 :	10YES-REE------0	AGNT3	UNTC1	−400,00	0.1	C		GTD			26-09-22 15:10

Figure A3. A section of market data showing multiple noncompetitive 0.1 MW sent as both purchase and sale bids. Offer type 'C' stands for compra/purchase and 'V' stands for venta/sale. The name of the agents and units have been changed. Here, the market agent participates with a generation unit (UNTV1) and a consumption unit (UNTC1).

Appendix A.2. Additional Tables

Table A1. Total number of purchase bids submitted during the period between May and November. The values peak in September.

	May	June	July	August	September	October	November
15:00	198	175	131	450	79	252	75
15:01	126	57	68	381	30	156	37
15:02	252	71	281	46	231	115	28
15:03	138	126	490	44	124	120	55
15:04	210	233	667	105	18	259	125
15:05	128	292	141	46	54	364	63
15:06	104	167	493	130	157	134	43
15:07	334	268	328	33	112	230	105
15:08	112	214	91	41	190	114	38
15:09	393	119	81	78	216	80	30
15:10	1223	1299	1084	2262	21,837	12,628	11,071
15:11	2860	6438	9943	9824	8106	5072	4431
15:12	2109	3186	2176	1806	552	804	1453
15:13	483	2596	660	1853	996	533	424
15:14	769	620	913	557	249	327	928
15:15	944	1250	925	175	287	190	181
15:16	467	767	1532	169	196	336	97
15:17	1167	773	736	143	131	274	153
15:18	924	1962	654	165	454	234	215
15:19	1624	1155	833	516	737	602	901
15:20	943	975	986	442	808	541	735

Table A2. Total number of sales bids submitted during the May–November period. Compared with the peaks observed in the purchase bid distribution, the rise in the number of bids is not prominent. Also, note that a higher number of bids are submitted at 15:11 compared with 15:10 in all months except September.

	May	June	July	August	September	October	November
15:00	85	56	41	155	91	225	76
15:01	78	33	16	105	12	159	118
15:02	108	41	130	42	52	60	17
15:03	93	26	53	48	33	172	66
15:04	99	37	95	51	51	564	400
15:05	48	54	35	34	95	256	107
15:06	204	95	203	105	131	131	74
15:07	431	55	45	28	89	160	188
15:08	111	25	3	46	67	62	31
15:09	177	62	17	28	45	51	34
15:10	316	736	705	921	3702	2124	1298
15:11	1802	917	2053	2487	3519	2667	2372
15:12	1612	433	561	704	496	529	784
15:13	310	576	130	583	496	169	169
15:14	311	563	276	242	111	168	426
15:15	566	292	222	141	146	89	122
15:16	209	211	276	226	107	214	80
15:17	488	91	110	167	111	160	176
15:18	446	493	195	248	194	94	400
15:19	1095	183	220	490	730	478	675
15:20	743	204	461	455	824	442	793

References

1. Herrero, I.; Rodilla, P.; Batlle, C. Enhancing Intraday Price Signals in U.S. ISO Markets for a Better Integration of Variable Energy Resources. *Energy J.* **2018**, *39*, 141–165. [CrossRef]
2. Chaves-Ávila, J.P.; Fernandes, C. The Spanish Intraday Market Design: A Successful Solution to Balance Renewable Generation? *Renew. Energy* **2015**, *74*, 422–432. [CrossRef]
3. Hagemann, S.; Weber, C. Trading Volumes in Intraday Markets: Theoretical Reference Model and Empirical Observations in Selected European Markets. EWL Working Paper. 2015. Available online: http://hdl.handle.net/10419/113273 (accessed on 12 May 2023).
4. Weber, C. Adequate Intraday Market Design to Enable the Integration of Wind Energy into the European Power Systems. *Energy Policy* **2010**, *38*, 3155–3163. [CrossRef]
5. Chaves-Ávila, J.P. European Short-Term Electricity Market Designs under High Penetration of Wind Power. Doctoral Thesis, TU Delft, Delft, The Netherlands, 2014.
6. Scharff, R.; Amelin, M. Trading Behaviour on the Continuous Intraday Market Elbas. *Energy Policy* **2016**, *88*, 544–557. [CrossRef]
7. Borggrefe, F.; Neuhoff, K. Balancing and Intraday Market Design: Options for Wind Integration. DIW Berlin Discussion Paper No. 1162. 2011. Available online: https://www.diw.de/documents/publikationen/73/diw_01.c.387225.de/dp1162.pdf (accessed on 7 March 2023).
8. Balardy, C. Auction and Continuous Market for Power: Organization and Microstructure. Ph.D. Thesis, Université Paris-Dauphine, Paris, France, 2021.
9. Kuppelwieser, T.; Wozabal, D. Liquidity Costs on Intraday Power Markets: Continuous Trading versus Auctions. *Energy Policy* **2021**, *154*, 112299. [CrossRef]
10. Neuhoff, K.; Ritter, N.; Salah-Abou-El-Enien, A.; Vassilopoulos, P. Intraday Markets for Power: Discretizing the Continuous Trading? DIW Berlin Discussion Paper No. 1544. 2016. Available online: https://www.econstor.eu/bitstream/10419/127445/1/847305872.pdf (accessed on 7 March 2023).
11. Chaves-Ávila, J.P.; van der Veen, R.A.C.; Hakvoort, R.A. The Interplay between Imbalance Pricing Mechanisms and Network Congestions—Analysis of the German Electricity Market. *Util. Policy* **2014**, *28*, 52–61. [CrossRef]
12. Single Day-Ahead Coupling (SDAC). Available online: https://www.entsoe.eu/network_codes/cacm/implementation/sdac/#market-information (accessed on 23 November 2021).
13. SIDC. Single Intraday Coupling (XBID) Information Package. 2019. Available online: https://www.nemo-committee.eu/assets/files/SIDC_Information%20Package_April%202021-99076f6ed5001c4d47442ae5cccebf30.pdf (accessed on 13 June 2023).

14. CNMC; ERSE. Request for Amendments of the Spanish and Portuguese Regulatory Authorities on Common Spanish and Portuguese TSOs and NEMO Proposal for Complementary Intraday Regional Auctions in Accordance with Article 63 of Commission Regulation (EU) 2015/1222 of 24 July 2015 Establishing a Guideline on Capacity Allocation and Congestion Management. 2017. Available online: https://www.cnmc.es/sites/default/files/Request%20For%20Amendments.pdf (accessed on 7 March 2023).
15. OMIE. Day-Ahead and Intraday Electricity Market Operations. 2019. Available online: https://www.omie.es/sites/default/files/2019-12/market_rules_2019_non-binding_translation_0.pdf (accessed on 1 March 2023).
16. Ocker, F.; Jaenisch, V. The Way towards European Electricity Intraday Auctions—Status Quo and Future Developments. *Energy Policy* **2020**, *145*, 111731. [CrossRef]
17. IRENA. Adapting Market Design to High Shares of Variable Renewable Energy. 2017. Available online: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/May/IRENA_Adapting_Market_Design_VRE_2017.pdf (accessed on 12 April 2023).
18. Bellenbaum, J.; Bucksteeg, M.; Kallabis, T.; Pape, C.; Weber, C. Intra-Day Cross-Zonal Capacity Pricing. 2014. Available online: https://www.ofgem.gov.uk/sites/default/files/docs/2014/12/ude_report_on_intraday_cross-zonal_capacity_pricing_0.pdf (accessed on 28 May 2023).
19. Henriot, A. *Nuevo Funcionamiento Del Mercado Intradiario MIBEL*; European University Institute: Florence, Italy, 2012. Available online: https://cadmus.eui.eu/bitstream/handle/1814/24556/RSCAS_2012_63.pdf?sequence=1 (accessed on 11 May 2023).
20. ACER. Intraday Capacity Calculation Methodology of the Core Capacity Calculation Region in Accordance with Article 20ff. of the Commission Regulation (EU) 2015/1222 of 24 July 2015 Establishing a Guideline on Capacity Allocation and Congestion Management. 2022. Available online: https://eepublicdownloads.entsoe.eu/clean-documents/nc-tasks/CORE%20-%20ACER%20Decision%2006-2022%20on%20Core%20ID%20CCM%20AM1%20-%20Annex%20II.pdf (accessed on 13 June 2023).
21. IRENA. *Regional Markets—Innovation Landscape Brief*; International Renewable Energy Agency: Abu Dhabi, United Arab Emirates, 2019; ISBN 978-92-9260-131-7.
22. MCSC. MESC—Market Europe Stakeholder Committee. 2022. Available online: https://eepublicdownloads.azureedge.net/clean-documents/Network%20codes%20documents/MESC/2022%20MESC%20documents/220914_MESC_3.4_Update%20on%20MCSC.pdf (accessed on 13 June 2023).
23. European Commission. Proposal for a Regulation of the European Parliament and of the Council Amending Regulations (EU) 2019/943 and (EU) 2019/942 as Well as Directives (EU) 2018/2001 and (EU) 2019/944 to Improve the Union's Electricity Market Design. 2023. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52023PC0148&qid=1679410882233 (accessed on 28 April 2023).
24. OECD. Spain—Regulatory Reform in the Electricity Industry. 1999. Available online: https://www.oecd.org/regreform/sectors/2497385.pdf (accessed on 29 May 2023).
25. Ministerio de Asuntos Exteriores y de Cooperación. Convenio Internacional Relativo a La Constitución de Un Mercado Ibérico de La Energía Eléctrica Entre El Reino de España y La República Portuguesa, Hecho En Santiago de Compostela El 1 de Octubre de 2004. 2006, Volume BOE-A-2006-8892, pp. 19208–19212. Available online: https://www.boe.es/diario_boe/txt.php?id=BOE-A-2006-8892 (accessed on 30 June 2023).
26. Becerril Martínez, C. 25 Years of the Electricity Market, the Pride of the Entire Energy Sector in Spain. 2023. Available online: https://www.omie.es/sites/default/files/2023-02/2302_25%20a%C3%B1os%20de%20mercado%20el%C3%A9ctrico_EN_3.pdf (accessed on 29 May 2023).
27. European Commission CACM: Comission Regulation (EU) 2015/1222 Establishing a Guideline on Capacity Allocation and Congestion Management. *Off. J. Eur. Union* **2015**. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32015R1222 (accessed on 23 June 2023).
28. ACER. Methodology for the Price Coupling Algorithm, the Continuous Trading Matching Algorithm and the Intraday Auction Algorithm. 2020. Available online: https://www.nemo-committee.eu/assets/files/ACER%20Decision%20on%20Algorithm%20-%20Annex%20I%20-%20Algorithm%20methodology_30-2491dabdff4295fbbd6bb0cc1471b019.pdf (accessed on 1 April 2023).
29. Day-Ahead Hourly Price | OMIE. Available online: https://www.omie.es/en/market-results/daily/daily-market/daily-hourly-price (accessed on 13 June 2023).
30. OMIE. Daily and Intraday Electricity Market Operating Rules. 23 July 2012. Available online: https://www.omie.es/sites/default/files/2019-12/reglas_agosto_2012_ingles.pdf (accessed on 19 May 2023).
31. REE ESIOS Electricidad Datos Transparencia. Available online: https://www.esios.ree.es/es/analisis (accessed on 5 April 2022).
32. Jefatura del Estado. BOE-A-2022-7843 Real Decreto-ley 10/2022, de 13 de Mayo, Por el Que se Establece Con Carácter Temporal un Mecanismo de Ajuste de Costes de Producción Para la Reducción del Precio de la Electricidad en el Mercado Mayorista. 2022. Available online: https://www.boe.es/buscar/act.php?id=BOE-A-2022-7843 (accessed on 20 May 2023).
33. Alderman, L. As Europe Quits Russian Gas, Half of France's Nuclear Plants Are Off-Line. *The New York Times*. 2022, pp. 5–18. Available online: https://www.nytimes.com/2022/11/15/business/nuclear-power-france.html (accessed on 30 May 2023).
34. OMIE. Evolution of the Electricity Market—Annual Report. 2021. Available online: https://www.omie.es/sites/default/files/2022-03/informe_anual_2021_en.pdf (accessed on 1 April 2023).
35. Nord Pool Key Statistics—July 2019. Available online: https://www.nordpoolgroup.com/en/message-center-container/newsroom/exchange-message-list/2019/q3/nord-pool-key-statistics{-}{-}july-2019/ (accessed on 12 June 2023).

36. OMIE. Details of the Intraday Market's Operation. 2019. Available online: https://www.omie.es/sites/default/files/inline-files/intraday_and_continuous_markets.pdf (accessed on 29 September 2021).
37. Bower, J.; Bunn, D. Experimental Analysis of the Efficiency of Uniform-Price versus Discriminatory Auctions in the England and Wales Electricity Market. *J. Econ. Dyn. Control* **2001**, *25*, 561–592. [CrossRef]
38. Xiong, G.; Okuma, S.; Fujita, H. Multi-Agent Based Experiments on Uniform Price and Pay-as-Bid Electricity Auction Markets. In Proceedings of the 2004 IEEE International Conference on Electric Utility Deregulation, Restructuring and Power Technologies (DRPT2004), Hong Kong, China, 5–8 April 2004; Volume 1, pp. 72–76. [CrossRef]
39. Rassenti, S.J.; Smith, V.L.; Wilson, B.J. Discriminatory Price Auctions in Electricity Markets: Low Volatility at the Expense of High Price Levels. *J. Regul. Econ.* **2003**, *23*, 109–123. [CrossRef]
40. Tierney, S.F.; Schatzki, T. Uniform-Pricing Versus Pay-as-Bid in Wholesale Electricity Markets: Does It Make a Difference? 2008. Available online: https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=c3562df03267aa6490e9552715f98169b0488bb7 (accessed on 24 June 2022).
41. Kahn, A.E.; Cramton, P.C.; Porter, R.H.; Tabors, R.D. Uniform Pricing or Pay-as-Bid Pricing: A Dilemma for California and Beyond. *Electr. J.* **2001**, *14*, 70–79. [CrossRef]
42. ENTSO-E. All TSOs' Proposal for the Single Methodology for Pricing Intraday Cross-Zonal Capacity in Accordance with Article 55 of Commission Regulation (EU) 2015/1222 of 24 July 2015 Establishing a Guideline on Capacity Allocation and Congestion Management. 2017. Available online: https://eepublicdownloads.entsoe.eu/clean-documents/nc-tasks/EBGL/CACM_A55.3_170814_%20170810_CZIDCP_Methodology_AllTSOs_approved.pdf (accessed on 11 April 2023).
43. Herrero, I.; Rodilla, P.; Batlle, C. Evolving Bidding Formats and Pricing Schemes in USA and Europe Day-Ahead Electricity Markets. *Energies* **2020**, *13*, 5020. [CrossRef]
44. OMIE. Consulta Pública Para Agentes de Mercado Sobre La Ofertas En El Mercado Diario Del MIBEL. 2023. Available online: https://www.omie.es/sites/default/files/inquiry_files/Consulta%20Publica%20productos%20de%20oferta%20SDAC%20MIBEL_4.pdf (accessed on 24 May 2023).
45. Timo, S.; Marja, E. Market Coupling Consultative Group Meeting. 2022. Available online: https://www.nemo-committee.eu/assets/files/mccg-presentation.pdf (accessed on 30 May 2023).
46. Gould, M.D.; Porter, M.A.; Williams, S.; McDonald, M.; Fenn, D.J.; Howison, S.D. Limit Order Books. *Quant. Financ.* **2013**, *13*, 1709–1742. [CrossRef]
47. Martin, H.; Otterson, S. German Intraday Electricity Market Analysis and Modeling Based on the Limit Order Book. In Proceedings of the 2018 15th International Conference on the European Energy Market (EEM), Lodz, Poland, 27–29 June 2018; pp. 1–6.
48. Baker, H.K.; Filbeck, G. *Portfolio Theory and Management*; Oxford University Press: Oxford, UK, 2013; ISBN 978-0-19-931140-8.
49. Frey, S.; Sandås, P. The Impact of Iceberg Orders in Limit Order Books. In *Proceedings of the AFA 2009 San Francisco Meetings Paper*; 2009. Available online: https://www.econstor.eu/bitstream/10419/41392/1/605038759.pdf (accessed on 13 June 2023).
50. NEMO Committee. Public Consultation on SDAC Products—Summary of Responses from MP and Answers from NEMOs. 2023. Available online: https://www.nemo-committee.eu/assets/files/2023-01%20Consultation%20on%20SDAC%20products%20-%20summary%20for%20publication-796cfa4870062e65e615900c9dddc33f.pdf (accessed on 13 June 2023).
51. Ehrenmann, A.; Henneaux, P.; Bruce, J.; Schumacher, L.; Küpper, G.; Klasman, B. *The Future Electricity Intraday Market Design*; Publications Office; Brussels, Belgium, 2019. Available online: https://data.europa.eu/doi/10.2833/004191 (accessed on 20 June 2023).
52. Comisión Nacional de los Mercados y la Competencia. Resolución de 23 de Febrero de 2023, de La Comisión Nacional de Los Mercados y La Competencia, Por La Que Se Aprueban Las Reglas de Funcionamiento de Los Mercados Diario e Intradiario de Energía Eléctrica Para Su Adaptación al Régimen Económico de Energías Renovables y Evolución Del Comité de Agentes Del Mercado. 2023. Available online: https://www.omie.es/sites/default/files/2023-03/BOE-A-2023-5582.pdf (accessed on 30 May 2023).
53. Budish, E.; Cramton, P.; Shim, J. Implementation Details for Frequent Batch Auctions: Slowing Down Markets to the Blink of an Eye. *Am. Econ. Rev.* **2014**, *104*, 418–424. [CrossRef]