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Future-Proofing Energy Trading

The New Algorithmic Trading Framework

Preface

The landscape for short-term and algorithmic power trading is currently undergoing significant changes, which are driven by three main trends. First, the energy transition is driving a fast build-out of renewable production and the deployment of flexible assets such as BESS, which need to be optimized and dispatched via short-term power markets. Second, increasing volatility has created trading opportunities, attracting new types of market participants, such as trading shops and hedge funds, which enrich the trading environment with varied strategies and approaches. Finally, regulators and policymakers have recently intensified their focus on short-term power markets, broadening the scope and depth of supervisory activities and extending complex regulatory requirements. These requirements, which were previously relevant only for financial instruments under MiFID II, are now being applied to trading activities in wholesale energy markets as well (for a discussion on REMIT II, finalized on 18 December 2024, see below).

This whitepaper, based on practical real-world examples using order-book data from various European markets, aims to equip decision makers with the insights needed to evaluate whether their business model for short-term power trading remains “fit for purpose” in this emerging world and addresses crucial questions about market dynamics, regulatory compliance, and technological integration. In particular, this whitepaper illustrates that more complex business requirements combined with more stringent regulatory demands will drive up the fixed cost of building and maintaining short-term power trading platforms. Moving forward, these rising costs, along with heightened regulatory and compliance risks, will compel decision-makers to reconsider whether managing the entire value chain of short-term power trading in-house is necessary or if outsourcing certain aspects (e.g., market access, maintenance of IT systems, etc.) can create more value for their business.

PwC’s work embodies a powerful synergy of expertise and innovation, paving a sustainable and profitable path forward. We invite you to explore the pages that follow, confident that the insights and frameworks provided will empower you to navigate the complexities of the European energy markets with renewed vigor and insight.

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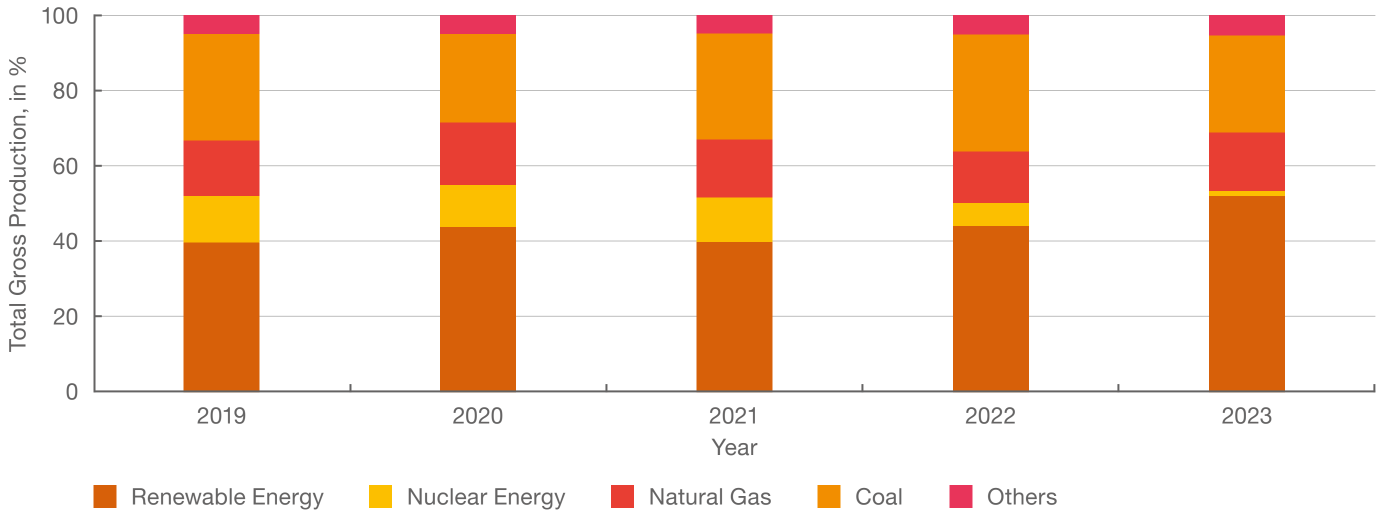
A Executive Summary

Since the liberalization of energy markets in Europe in the early 2000s, the energy trading landscape has undergone significant transformation due to several fundamental trends. Major external shocks, such as Brexit, the COVID-19 pandemic, and the Ukrainian crisis, have increased market volatility. These events present both risks and opportunities for market participants.

The energy transition and the growing penetration of renewable energy sources (RES) have further altered market dynamics (see Figure 1). The weather-dependent and intermittent nature of these sources requires new approaches to energy management. In response, market participants have developed sophisticated bidding and trading strategies. These strategies are increasingly supported by the adoption of advanced systematic procedures and trading solutions, moving away from traditional manual methods.

Fig. 1 Changes in the German production stack, 2019–2023.



Sources: Destatis, PwC Analysis.

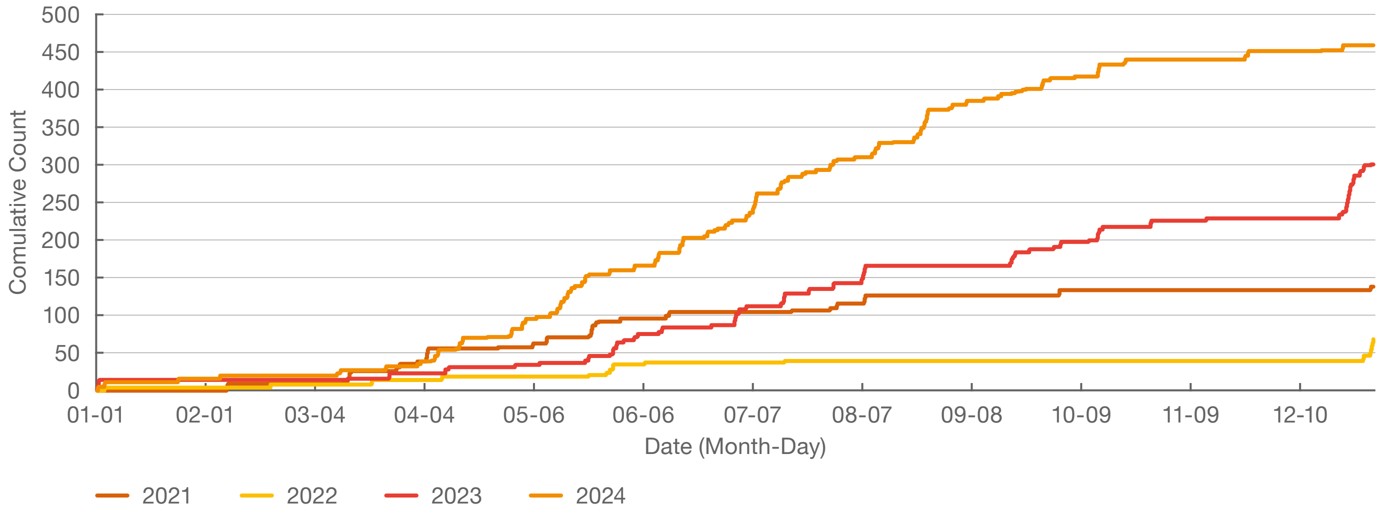
On the demand side, a similar transformation is currently underway. For instance, there has been substantial growth in behind-the-meter rooftop solar installations across many European countries. This trend may significantly impact wholesale power markets, as seen in the Dutch market over the past 24 months. Similarly, the expansion of decentralized flexibility solutions, such as heat pumps and e-mobility solutions, is expected to exert comparable influence on these markets.

To address these structural shifts, the European Union (EU) has implemented comprehensive adjustments in power market design. The Capacity Allocation and Congestion Management[1] (CACM) regulation aims to enhance cross-border electricity flows, streamline electricity balancing, and optimize congestion management across Europe. This regulation is intended to facilitate more efficient cross-border trading and reduce intraday coupled gate closure times. Additionally, the Commission Regulation on electricity balancing[2] sets the framework for the European platform for the exchange of balancing energy, with PICASSO specifically focusing on the automated activation of frequency restoration reserves[3].

[1] Commission Regulation (EU) 2015/1222 of 24 July 2015 establishing a guideline on capacity allocation and congestion management.
[2] Commission Regulation (EU) 2017/2195 of 23 November 2017 establishing a guideline on electricity balancing.
[3] The platform also includes other components such as IGCC (International Grid Control Cooperation), TERRE (Trans European Replacement Reserves Exchange), and MARI (Manually Activated Reserves Initiative), which collectively enhance the coordination and efficiency of balancing energy exchanges across Europe.

Furthermore, capacity mechanisms are currently under discussion in several European countries, such as Germany, and have already been implemented in others. These mechanisms are designed to incentivize market participants to maintain or expand their physical generation capacity, thereby enhancing system reliability during periods of peak demand. Simultaneously, local flexibility and congestion markets are emerging, exemplified by initiatives like Piclo Flex in the United Kingdom and GOPACS in the Netherlands. These markets enable localized power trading to manage grid constraints and optimize the use of distributed energy resources. By allowing active participation from demand-side response and distributed generation, local flexibility markets further contribute to a more resilient and efficient power system, effectively addressing RES congestion.

Fig. 2 Frequency of Negative Pricing Hours in the Power Day-Ahead SDAC Auction for Germany[1], 2021–2024.



[1] Market Area DE-LU.

Sources: ENTSO-E Transparency Platform, PwC Analysis.

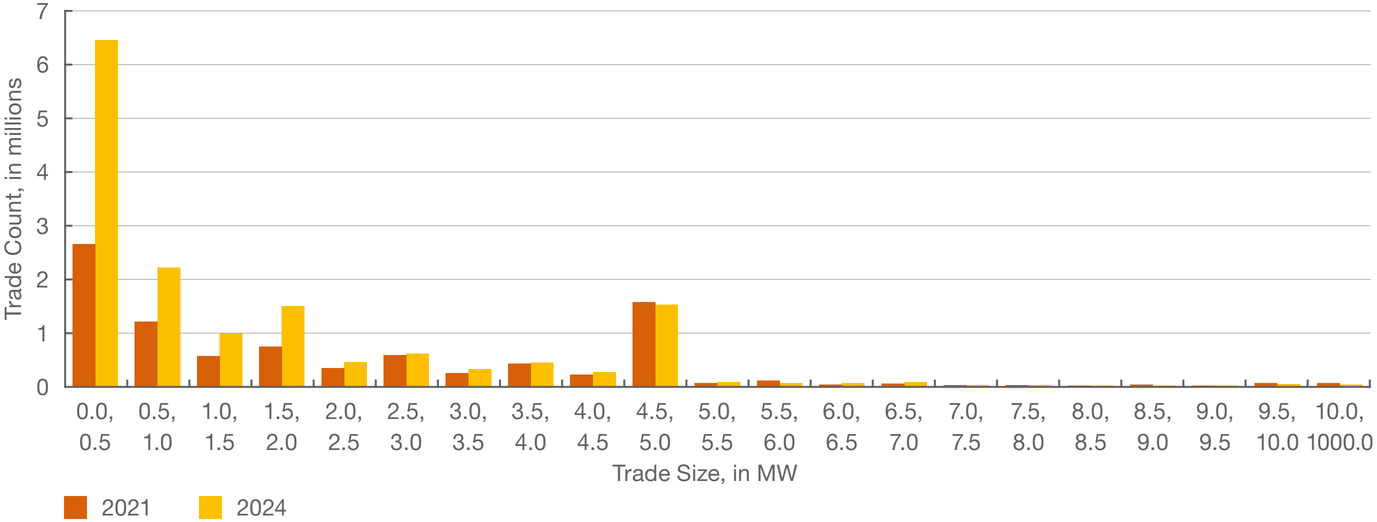
These changes have fostered a dynamic trading environment (see Figure 3), attracting a diverse array of participants, including proprietary trading firms, banks, asset optimizers, and hedge funds. The interaction between physical market fundamentals, grid balancing activities, and market liquidity drivers – such as the depth of the order book and hidden liquidity – has redefined price discovery processes. In this evolving landscape, advanced algorithmic trading solutions have become indispensable.

In this evolving environment, automated trading systems are essential for developing strategies in short-term power markets. These systems enable the conversion of technical and fundamental data into real-time trading signals, optimizing order execution with minimal market impact.

The development of more sophisticated trading strategies attracted the interest of supervisory bodies, which are increasingly[4] analyzing the compliance of suspicious trading behaviors, both locally and in a cross-country context. Regulatory breaches are now punished with significant fines and legal action.

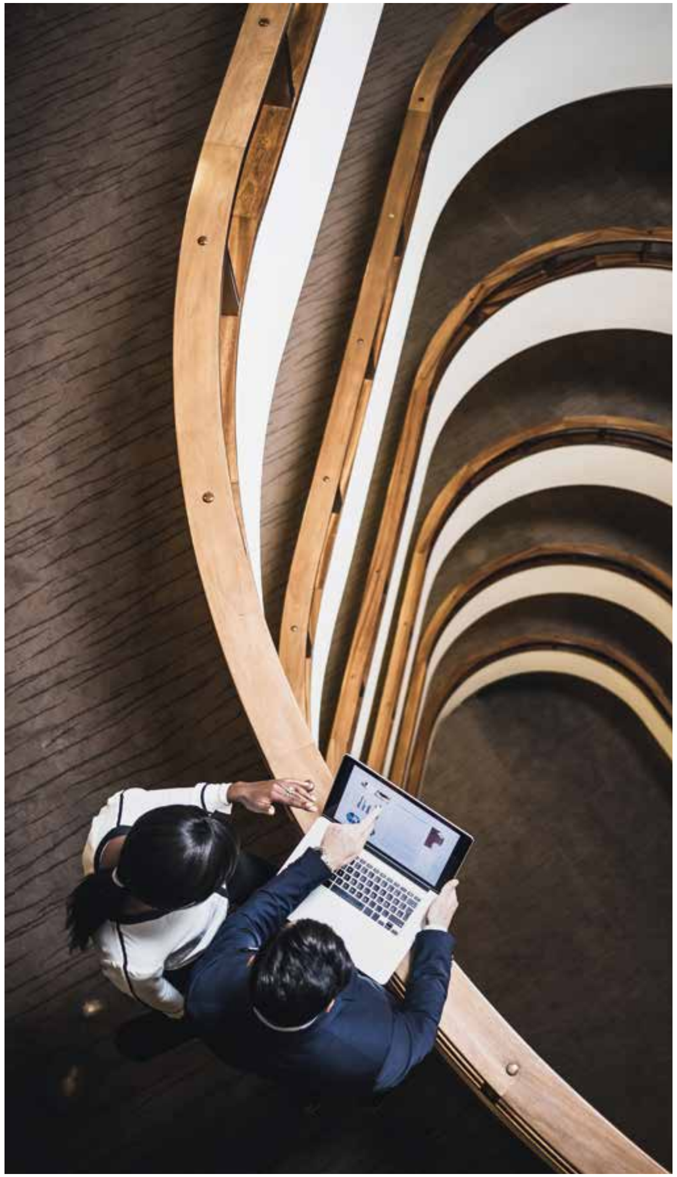
Fig. 3 Trade Sizes for hourly contracts in Germany, Amprion[1]: A Comparison between 2021 and January-November 2024.

The data reveals a rise in the total number of trades, accompanied by a notable shift towards smaller trade sizes, with a persistent clustering around 5 MW. This trend highlights the increasing prevalence of algorithmic trading and the sustained use of iceberg orders.



[1] 10YDE-RWENET---I.

Source: PowerBot Analysis.



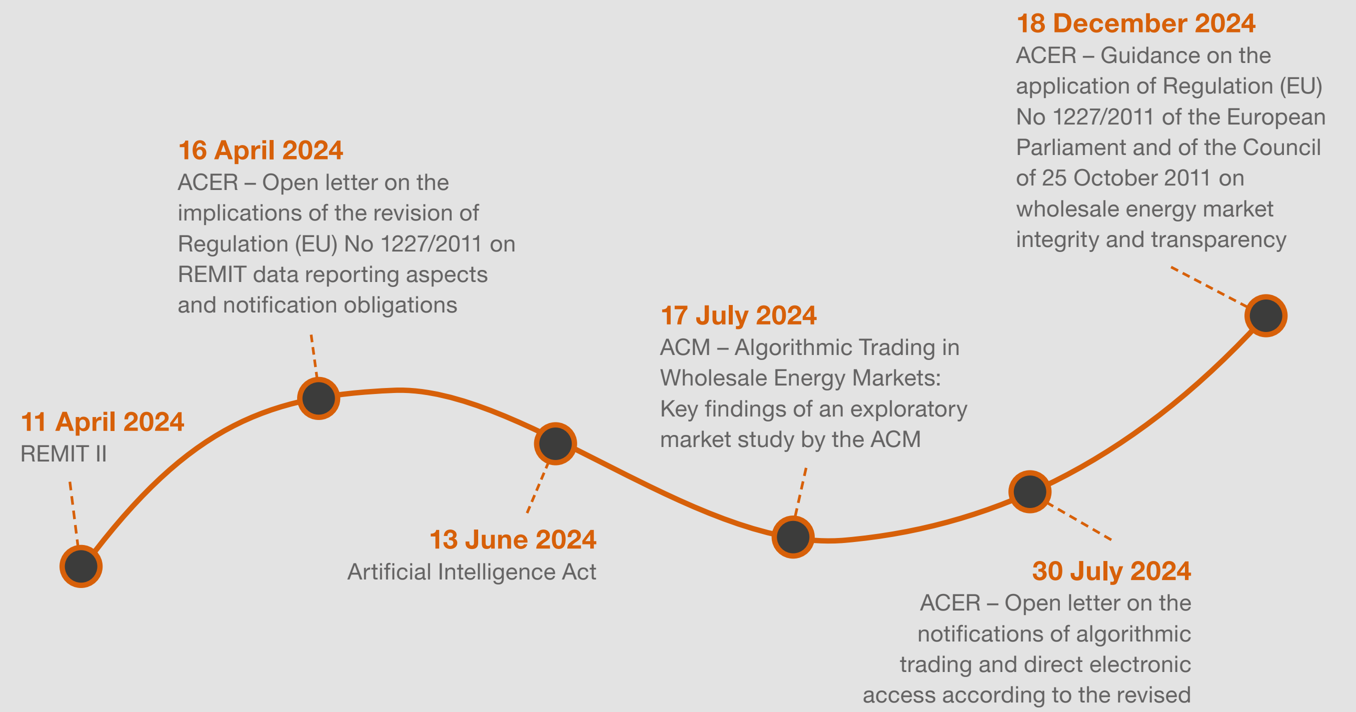
[4] ACER has programmed until 2027 to gradually improve the market surveillance as reported in the single programming document 2025–2027, released on 3rd January 2025.

The high level of automation and increased order volumes introduced by algorithmic trading can pose systemic risks, and in certain situations, lead to market dislocations. To mitigate these risks, EU policymakers have enacted several regulations.

As part of REMIT II[5]:

- The European Parliament has effectively extended the requirements of the Regulatory Technical Standards 6[6] (RTS 6), defined by MiFID II for algorithmic trading activities in financial instruments, to cover algorithmic trading in wholesale energy products.
- National Regulatory Authorities (NRAs) are provided with both regular and ad hoc supervisory roles over participants engaging in algorithmic trading activities.
- The Agency for the Cooperation of Energy Regulators (ACER) has been granted supervisory powers, particularly focusing on suspected cases of cross-border market manipulation.
- Market participants must implement systems and procedures to identify potential breaches of REMIT and detect and report suspicious orders and transactions.

Fig. 4 Recent Regulatory and Supervisory Activities.



Source: PwC Analysis.

The European Union has adopted the Artificial Intelligence Act[7] (AI Act) governing the deployment of artificial intelligence systems across various sectors, including the energy sector. The objective of this regulation is to ensure high standards of transparency, accountability, and risk management for AI systems and ensure that such systems operate safely and ethically. The AI Act's requirements for transparency and accountability are particularly relevant for models and AI-based solutions feeding trading, algorithmic execution systems, and asset optimization kernels, which must be designed to prevent biases, ensuring accuracy and robustness.

[5] Regulation (EU) 2024/1106 of the European Parliament and of the Council of 11 April 2024 amending Regulations (EU) No 1227/2011 and (EU) 2019/942 as regards improving the Union's protection against market manipulation on the wholesale energy market.

[6] Commission Delegated Regulation (EU) 2017/589 of 19 July 2016 supplementing Directive 2014/65/EU of the European Parliament and of the Council with regard to regulatory technical standards specifying the organizational requirements of investment firms engaged in algorithmic trading.

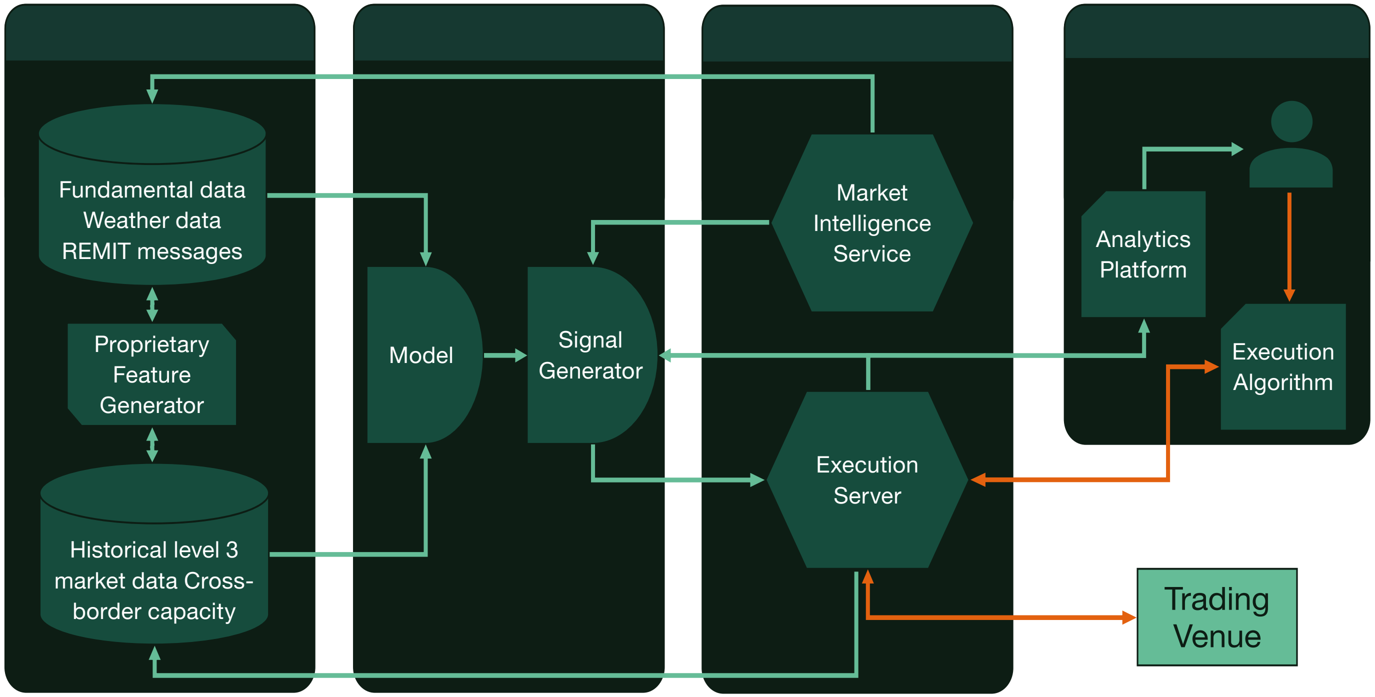
[7] Regulation (EU) 2024/1689 of the European Parliament and of the Council of 13 June 2024 laying down harmonized rules on artificial intelligence and amending Regulations (EC) No 300/2008, (EU) No 167/2013, (EU) No 168/2013, (EU) 2018/858, (EU) 2018/1139 and (EU) 2019/2144 and Directives 2014/90/EU, (EU) 2016/797 and (EU) 2020/1828.

Additionally, the European Union has enhanced the Network and Information Systems Directive[8] (NIS-2) to strengthen cybersecurity across critical sectors, including energy markets. This includes requirements on owners of such infrastructures that aim to protect against cyber-attacks, set up business continuity plans, protect sensitive data and prevent manipulation of trading outcomes.

Advanced algorithmic trading solutions can deliver the necessary capabilities if they are efficiently integrated within the overall IT-company architecture enabling seamless data flow, efficient processing, and real-time analysis (see Figure 5).

Navigating this complex regulatory landscape presents significant challenges for market participants. Achieving compliance with both overarching and local regulations demands more than just robust risk management, compliance, and IT frameworks. Effective data collection, reporting, and market abuse detection mechanisms are essential. To meet these requirements, participants must implement advanced control systems capable of comprehensive data management, analysis, and anomaly detection. These systems and procedures are vital for maintaining operational stability and compliance, mitigating potential risks, and ensuring sustainable market participation.

Fig. 5 Design for Modern Energy Trading Infrastructure.



Source: PowerBot Analysis.

Building and maintaining an in-house platform for short-term power trading that meets these requirements on a continuous basis entails a large amount of fixed costs. Thus, decision makers will need to re-evaluate on a systematic basis (see, for example, the framework described in section 5) the value-added by maintaining a fully-fledged short-term power trading platform in-house relative to these fixed costs or whether more value can be created by outsourcing specific capabilities. For instance, outsourcing functions such as "market access" or "maintenance of IT systems" may offer significant cost savings, while putting only small limitations on the scope of trading strategies that may be pursued by algorithms and the front office.

[8] Directive (EU) 2022/2555 of the European Parliament and of the Council of 14 December 2022 on measures for a high common level of cybersecurity across the Union, amending Regulation (EU) No 910/2014 and Directive (EU) 2018/1972, and repealing Directive (EU) 2016/1148.

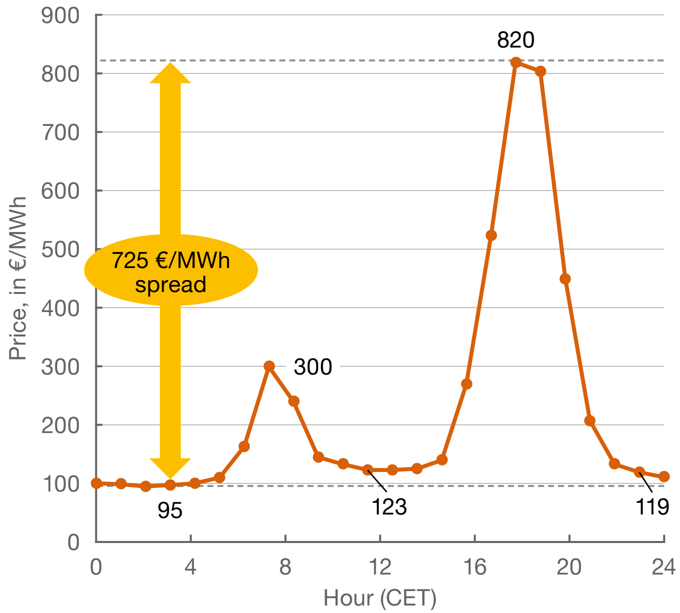
B Evolving Dynamics in Short-Term Power Markets

1 Overview of structural changes in driving dynamics of Short-Term Power Markets

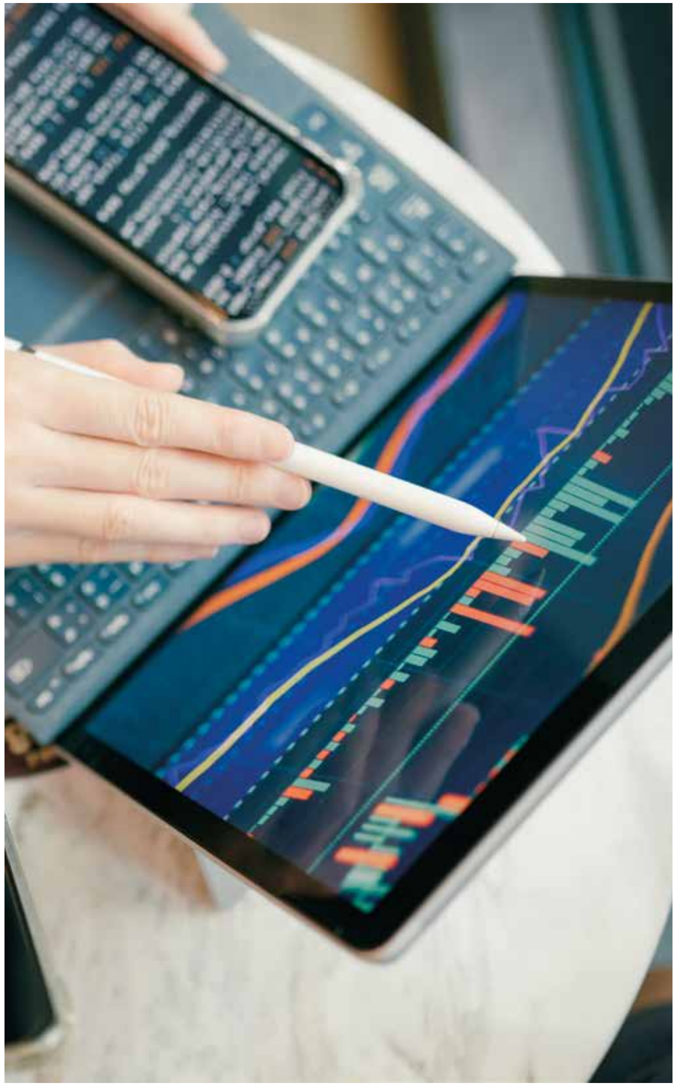
The dynamics of short-term power markets have become increasingly complex due to significant shifts in physical market fundamentals, exogenous events, market design adjustments, and the entrance of new market participants. These changes are further amplified by technological advancements that enable more sophisticated trading strategies.

One major development impacting European power markets is the growing penetration of renewable energy, which has substantially increased the volatility of the residual load – the difference between electricity demand and supply from renewable sources. In some countries, most notably Germany, this trend is compounded by lagging adjustments in the generation stack, where the accelerating phase-out of conventional generation assets is not matched by the necessary build-out of flexible generation assets and battery energy storage systems (BESS), creating spill-over effects into neighboring countries. These mismatches between the expansion of renewables and the development of flexible generation capacities (e.g. BESS) introduce new complexities in balancing the physical grid and dispatching available flexible capacities, leading to significant increases in price volatility during periods of renewable scarcity (see Figure 6).

Fig. 6 On 6 November 2024, a Power Day-Ahead SDAC Auction Price Spread of 725 EUR/MWh was observed in Germany due to a significant drop in wind power supply and a lack of available residual flexibility.



Sources: ENTSO-E Transparency Platform, PwC Analysis.

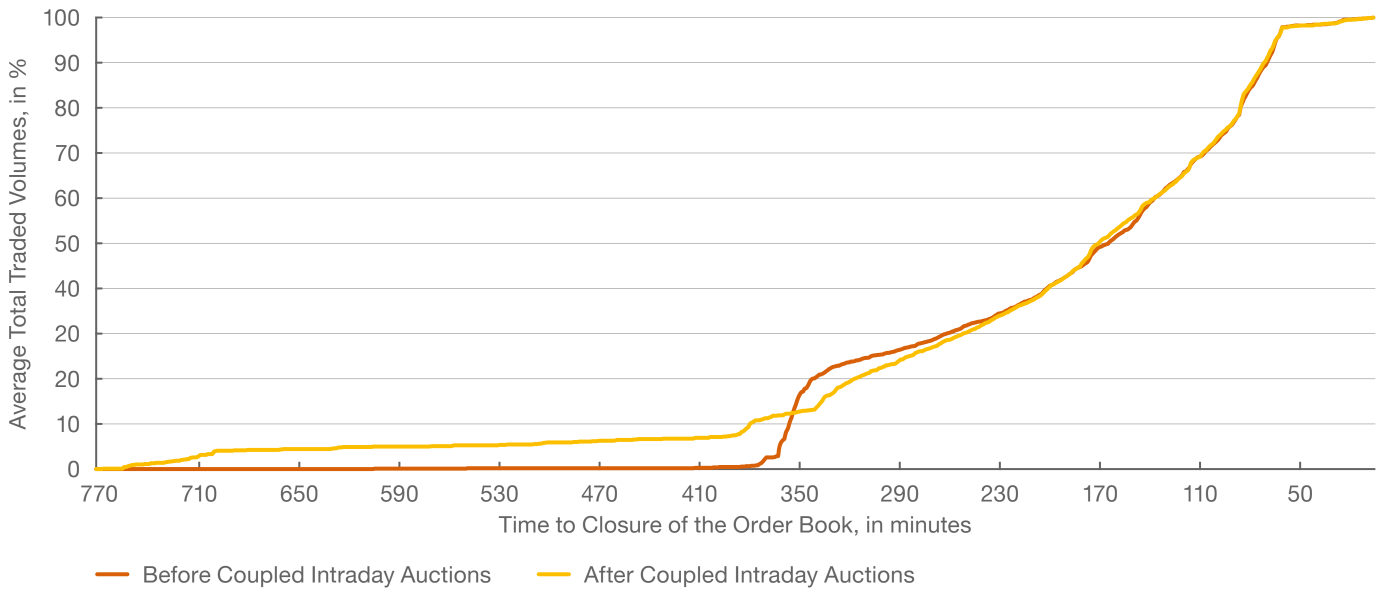


To facilitate the transition to renewable energy, policymakers have enacted various market design and infrastructure changes. These initiatives aim to balance regional and local power surpluses and deficits – imbalances that can occur in an energy system with a high share of renewables – by enhancing cross-border trading in wholesale power markets:

- The CACM Regulation, which governs cross-border power trading in intraday markets, has been introduced to optimize the use of transmission capacities, reduce congestion, and improve grid reliability. Adjustments to capacity calculation and allocation methodologies, along with streamlined procedures for releasing transmission capacity during intraday auctions, now ensure more transparent allocation of available capacity, thereby enhancing market liquidity and reducing congestion risks.
- Regulatory oversight, particularly by ACER, has been strengthened to prevent practices such as "capacity hoarding", where transmission capacity is acquired without effective utilization. Such practices can adversely affect the liquidity of cross-border trading.
- Looking forward, several topics demand attention, including capacity mechanisms and adjustments to renewable energy incentives. By 2026, renewable energy incentive systems must align symmetrically with EU regulations, which may necessitate reforms to existing frameworks such as Germany's Renewable Energy Sources Act.
- Moreover, local flexibility markets are playing an increasingly important role in managing physical constraints. These markets facilitate localized power trading, optimize the use of distributed energy resources, and effectively address grid bottlenecks.

Fig. 7 Comparison of cumulative volume curves for Hour 3 (H3) in France.

Comparing two months before and after the intraday auction coupling go-live. We can observe a smoother average volume curve after the go-live, due to changes in cross-border capacity release.



Source: PowerBot Analysis.

A diverse array of new market participants has been attracted by these changes in market structure combined with the strong increase in short-term market volatility between 2021 and 2024. These new players are keen to monetize different parts of the market and each employing distinct strategies to exploit market opportunities:

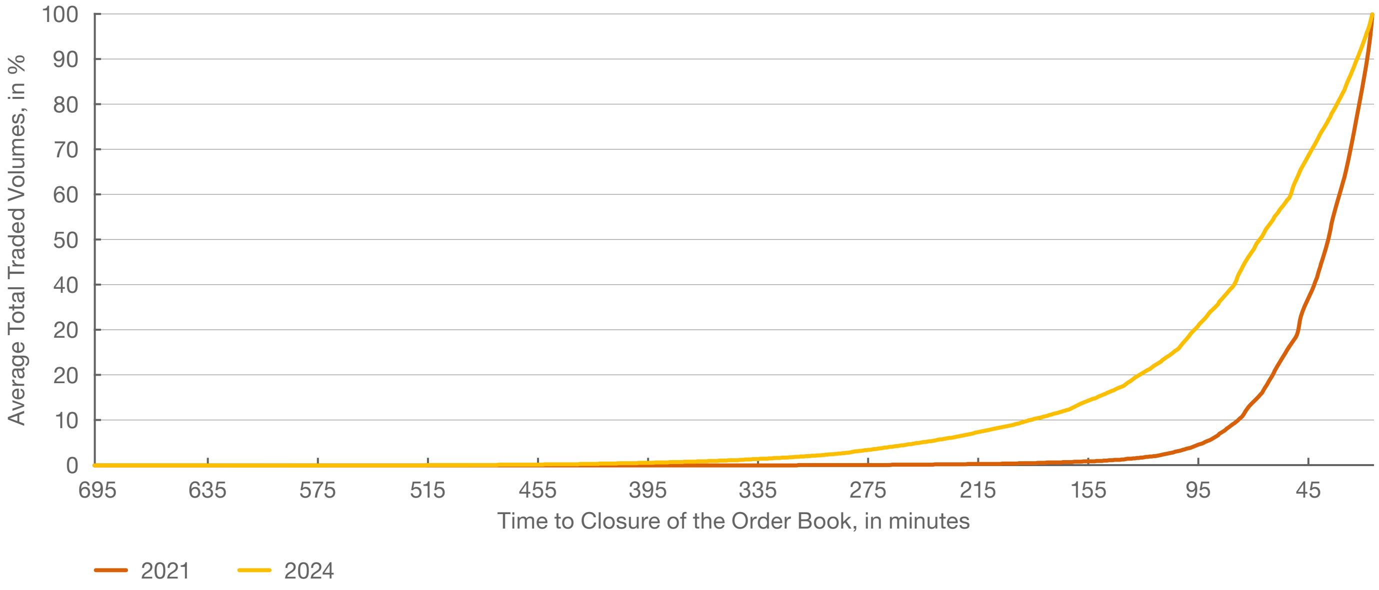
- Utilities, traditionally focused on energy generation and distribution, are now actively engaging in intraday trading activities to further optimize large asset fleets, consumption portfolios and manage gamma short positions from RES while hedging against market volatility. Consequently, the need for advanced systematic strategies and algorithmic trading platforms, capable of processing large volumes of data, optimizing execution costs and seamlessly translating positions into physical asset instructions, has become paramount.
- Many asset optimizers have emerged offering trading-as-a-service capabilities to owners of physical assets, including optimal merchant and balancing grid asset dispatch and management, exploiting asset flexibility against the market, offering at the same time market access, and regulatory reporting.

- Proprietary trading firms and hedge funds rely heavily on the accuracy and speed of their trading operations. These firms demand highly sophisticated algorithmic trading solutions to identify and exploit market inefficiencies, engage in market-making activities, and capitalize on low- and high-frequency arbitrage opportunities, even in the absence of physical assets to manage. An effective execution layer and near real-time fundamental and technical data analytics are essential tools for these participants, enabling them to maintain a competitive edge in an increasingly populated market environment.
- Banks increased their presence in the short-term market, enhancing their physical and financial market making, hedging, and trading capabilities.

The changes in market structure described in this section, together with exogenous shocks (COVID-19 and Ukraine war) have significantly changed the dynamics of market prices, price discovery processes and the dynamics of liquidity in the order books of spot power markets in Europe. For instance, longer volume distribution trading profiles have emerged (see Figure 8), reflecting the need to manage the variability of renewable energy sources and balance supply and demand over extended periods.

Fig. 8 Average cumulative traded volumes for August 2021 and August 2024 in Great Britain's half-hourly deliveries.

Historically, traded volumes in 2021 began to increase approximately 200 minutes before gate closure, whereas in 2024, market participants are acting roughly 200 minutes earlier.



Source: PowerBot Analysis.

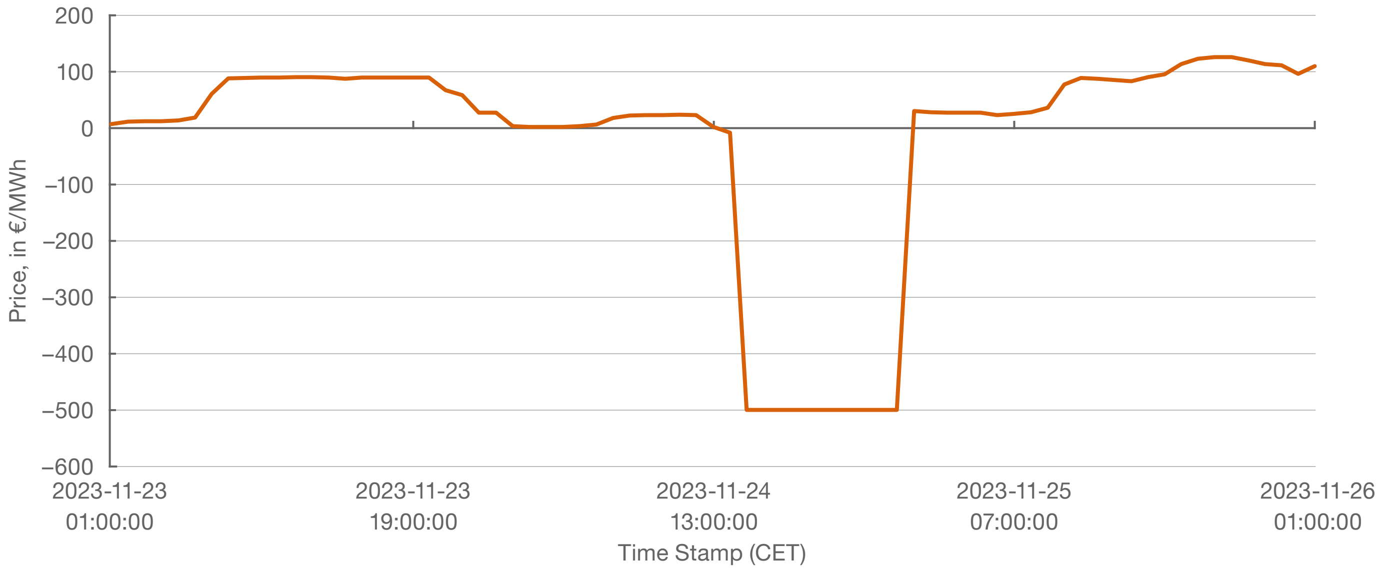
Changes in market fundamentals, adjustments in market design, and the influx of new market participants have led to more complex trading patterns. These patterns are characterized by fundamental price shifts, increased volatility, and trading dynamics, creating feedback loops that traders must navigate.

The enriched order book data – encompassing hidden liquidity, liquidity gaps, and book imbalance information – has provided fertile ground for traders to implement sophisticated strategies. Market participants leverage this granular data to inform their trading decisions and optimize execution.

To navigate this challenging landscape, traders and asset managers require structured systems that can process large volumes of data, generate accurate trading signals, and execute trades with minimal market impact. Advanced algorithmic trading solutions, incorporating machine learning and big data analytics, are essential for identifying and exploiting market inefficiencies, optimizing trading strategies, and ensuring operational excellence through process automation.

Fig. 9 Power Day-Ahead SDAC Auction Prices for delivery on 24 November 2023 in Finland.

Due to a human and RES forecasting error, Kinect Energy offered 5,858 MW of electricity to the market every hour, causing Finnish spot prices to crash to the –500 EUR/MWh price floor for 10 consecutive hours and leading to estimated losses in excess of 40 million EUR. Therefore, Nord Pool introduced stricter limits on individual market player bids to prevent similar incidents in the future.



Source: ENSTO-E Transparency Platform.

2 Case Studies for Order Books Dynamics in the New Market Environment

This section presents a series of market behaviors observed in the European continuous power spot market. Systematic analysis of these behaviors is crucial for achieving compliance with new regulatory requirements.

Manual Trading

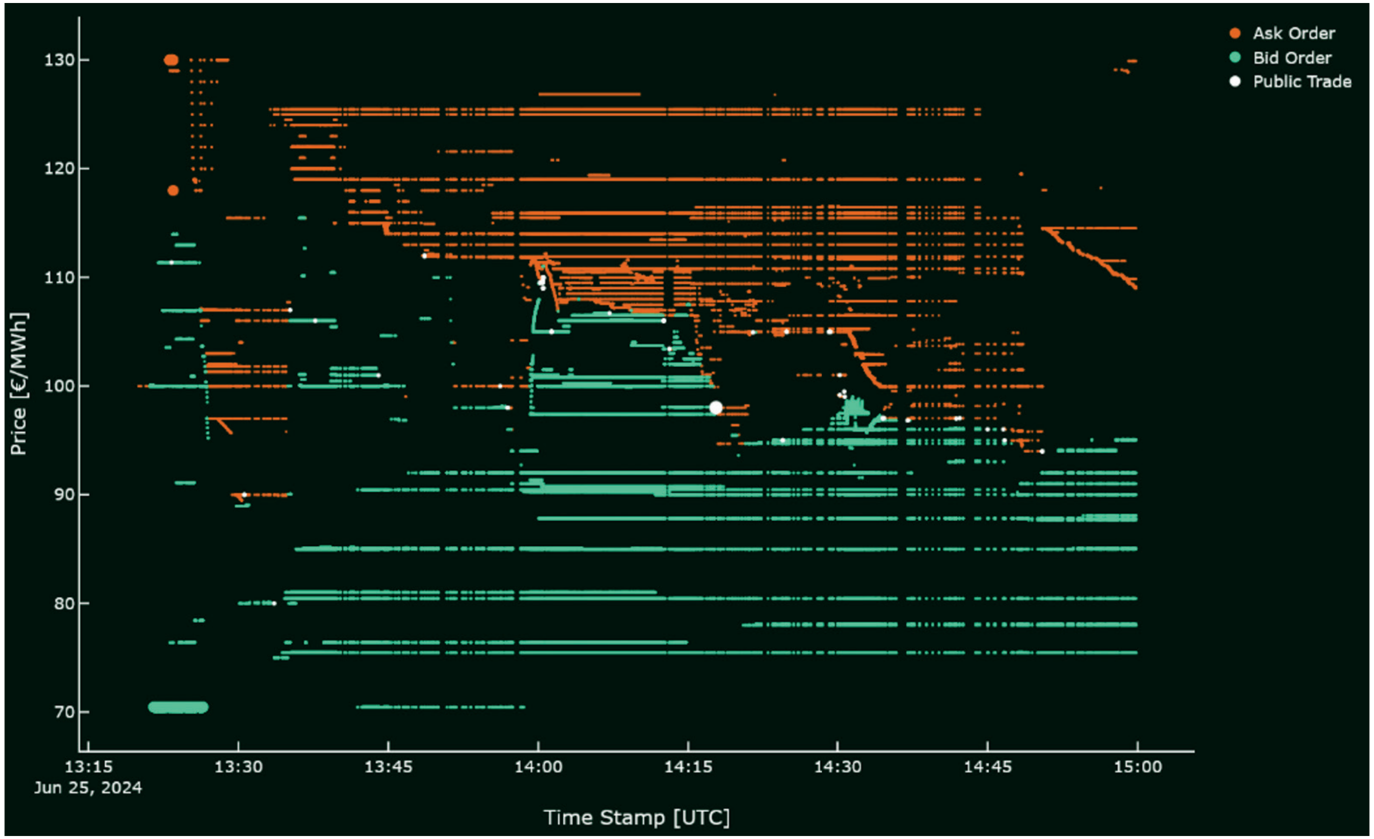
A remarkably large trade (600MW) has been executed in Amprion, though it is uncertain whether intentionally or unintentionally. No obvious sign for a trade this size can be found in prior order book states except for several larger orders (exceeding 100MW) on both sides near trading start and one bid order incrementally increasing in size from below 100MW to nearly 300MW over the course of a few minutes and subsequently vanishing from the order book approx. an hour before the 600MW trade.

Interestingly, spreads are already rather tight at the beginning of a contract. Normally, spreads would be expected to be wide at trading start and tighten up as trading progresses and order book density increases.

The 600MW trade appears to have absorbed a large fraction of the order book's ask or bid side. This behaviour warrants careful analysis, as it could potentially involve elements of market manipulation due to erroneous orders[9].

Furthermore, it is noteworthy how price formation is supported by static orders on both the bid and ask sides that remain in the order book even after top-of-the-book price improvements. This persistence suggests a deliberate manual strategy or a throttled algorithmic execution.

Fig. 10 Continuous order book for hourly delivery on 26 June 2024 06:00–07:00 UTC in Germany, Amprion on 25 June 2024 between 13:15 and 15:00 UTC.



Source: PowerBot Analysis.

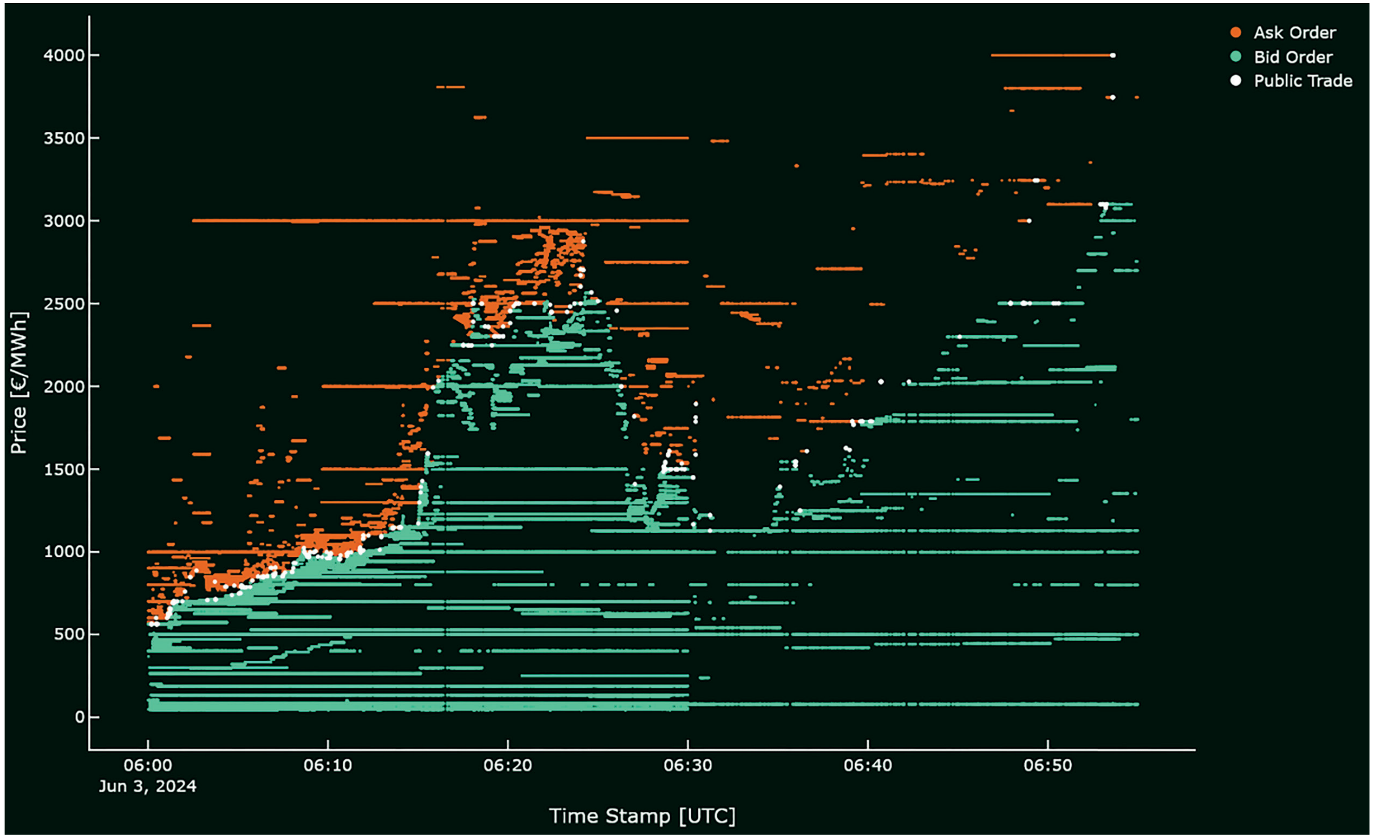
[9] A non-comprehensive list of types of practice of attempted market manipulation through giving or attempting to give false or misleading signals can be found in the latest ACER Guidance on the application of Regulation (EU) No 1227/2011 of the European Parliament and of the Council of 25 October 2011 on wholesale energy market integrity and transparency 6.1st Edition of 18 December 2024, 6.3.2 (315).

Algorithmic Trading activities with scarce Liquidity

This case in Germany highlights the exacerbation of a trend driven by algorithmic trading activity just before the order book closes. At the start of the local trading phase in the delivery area, the ask side of the order book noticeably thins out while dense buy pressure persists. This leads to sharp and rapid price increases, with buyers crossing significant spreads and reaching extraordinary price levels, peaking at 4,000 EUR/MWh. Such behavior warrants careful analysis, as it might indicate attempted market manipulation through an abusive squeeze or trend exacerbation.

It is also important to note the strategic role of static orders in the order book during the XBID session. These orders suggest, on one hand, opportunistic bidding to capitalize on capacity release and, on the other hand, an opportunistic physical optimization strategy. This dual strategy underscores the complexity of market dynamics and the need for vigilant monitoring and analysis.

Fig. 11 Continuous order book for hourly delivery on 3 June 2024 07:00–08:00 UTC in Germany, Amprion on the same day between 06:00 and 06:55 UTC.



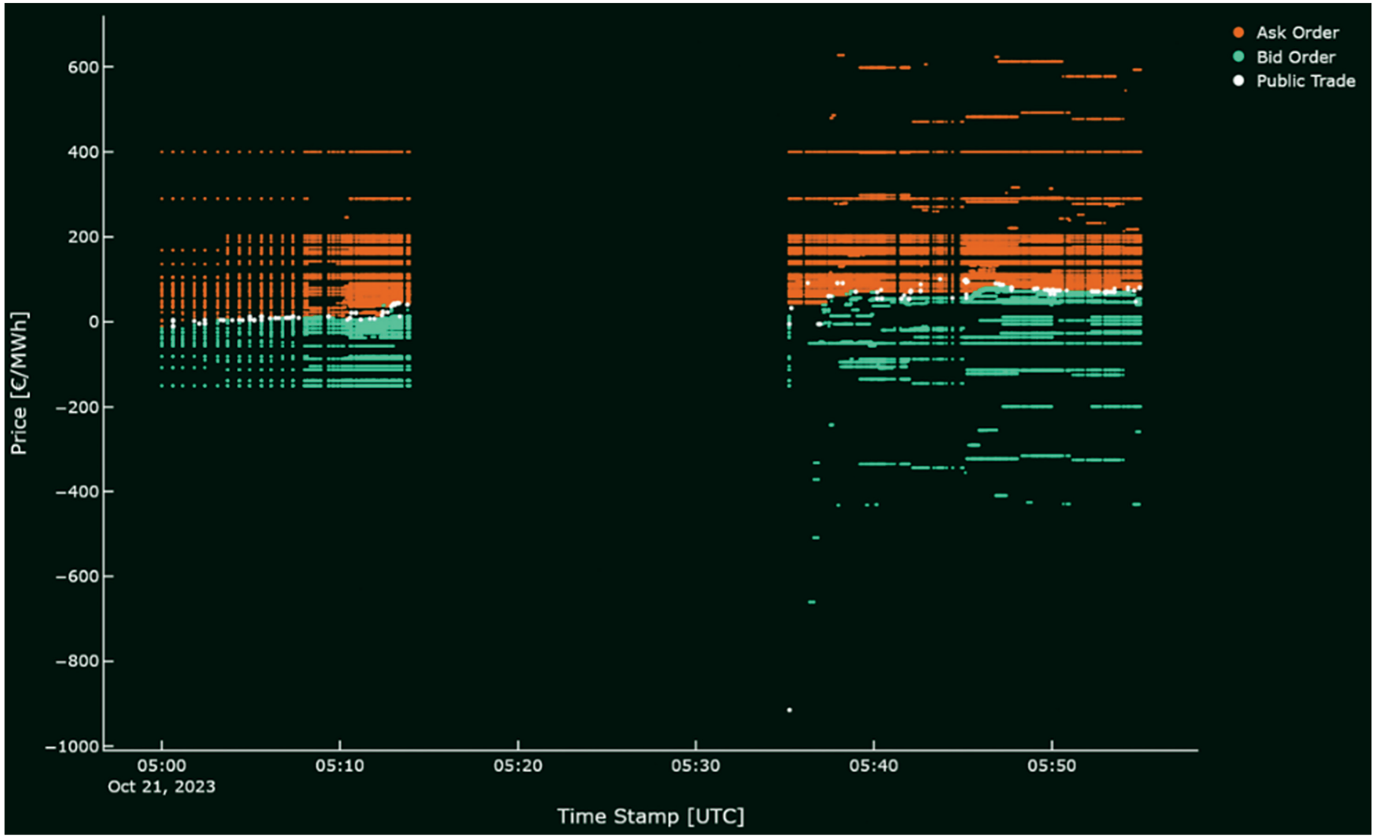
Source: PowerBot Analysis.

Market Maintenance and “out-of-market price” Trading

Following an exchange outage, we observe a case where algorithmic execution appears to be “catching up” on its distribution profile. It aggressively targets the best order in an almost empty bid side of the order book, without employing a limit price or pre-trade price control. As the bid side fills up again, trade price levels return to normal.

This situation underscores the importance of adhering to REMIT II regulations, which require price level controls during algorithmic trading execution to prevent such volatility and maintain market integrity.

Fig. 12 Continuous order book for quarter hourly delivery on 21 October 2023 06:00–06:15 UTC in Germany, Amprion on the same day between 05:00–05:55 UTC.

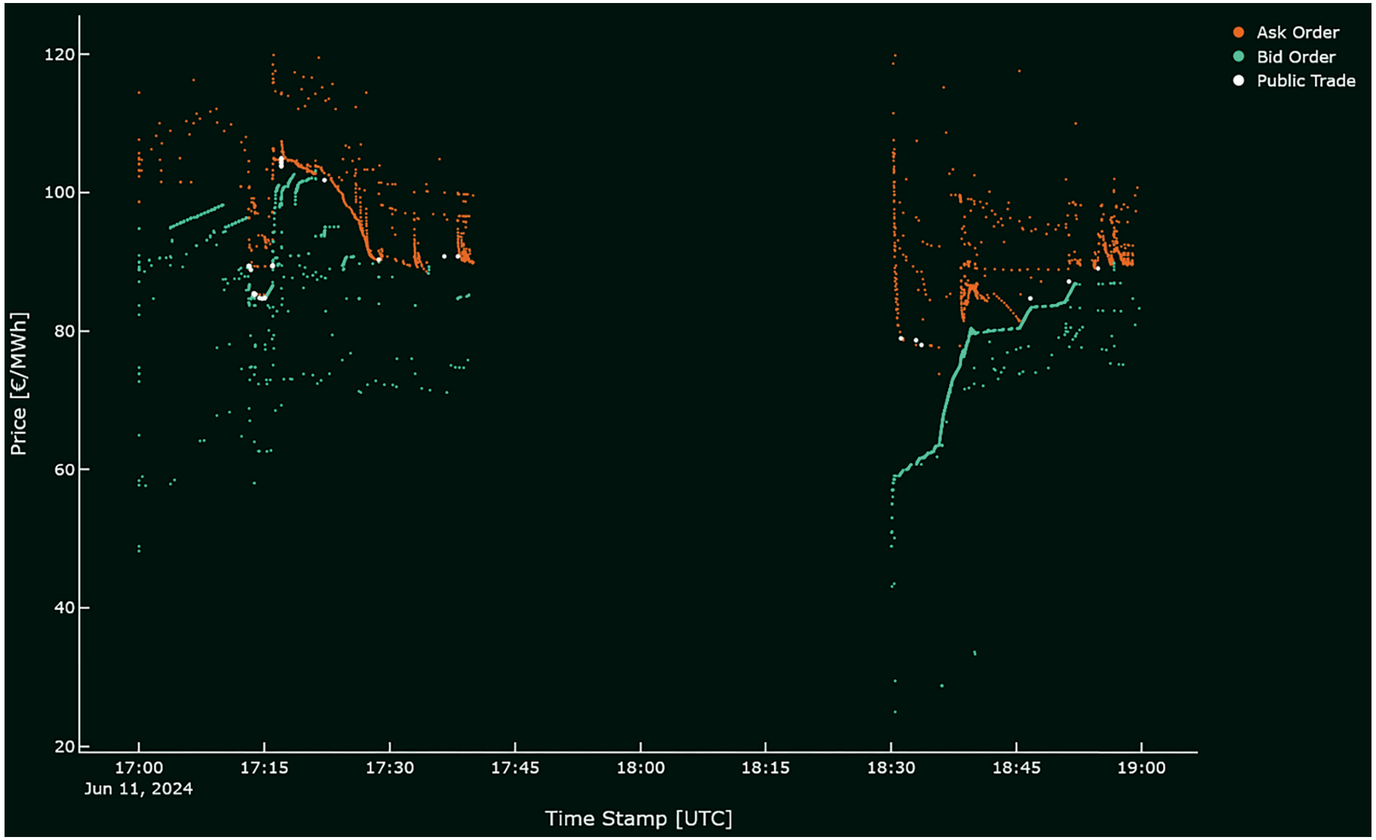


Source: PowerBot Analysis.

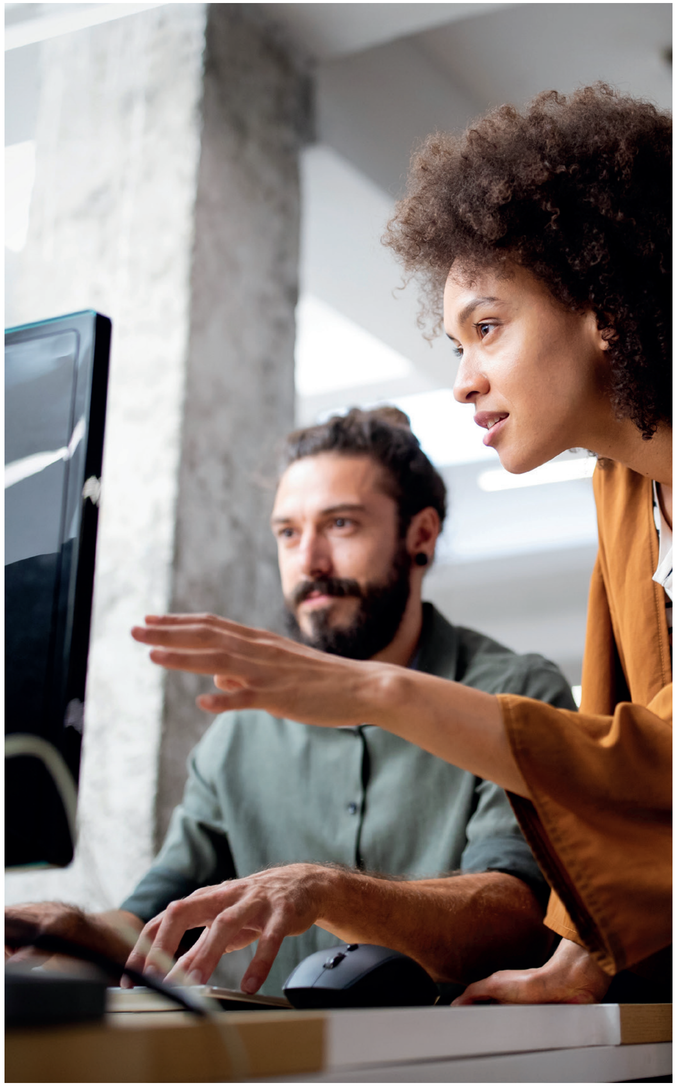
Feedback Loops

In this case study we observe two market participants fighting for the best ask position with one eventually resulting in a trade after an exchange outage. Such behaviour requires careful analysis as it might constitute a case of feedback loop, increasing market volatility and constituting an example of possible manipulative behavior, as recently pointed out by the Netherland Authority for Consumers & Markets (ACM).

Fig. 13 Continuous order book for quarter hourly delivery on 11 June 2024 22:15–22:30 UTC in Amprion on the same day between 17:00 and 19:00 UTC.



Source: PowerBot Analysis.



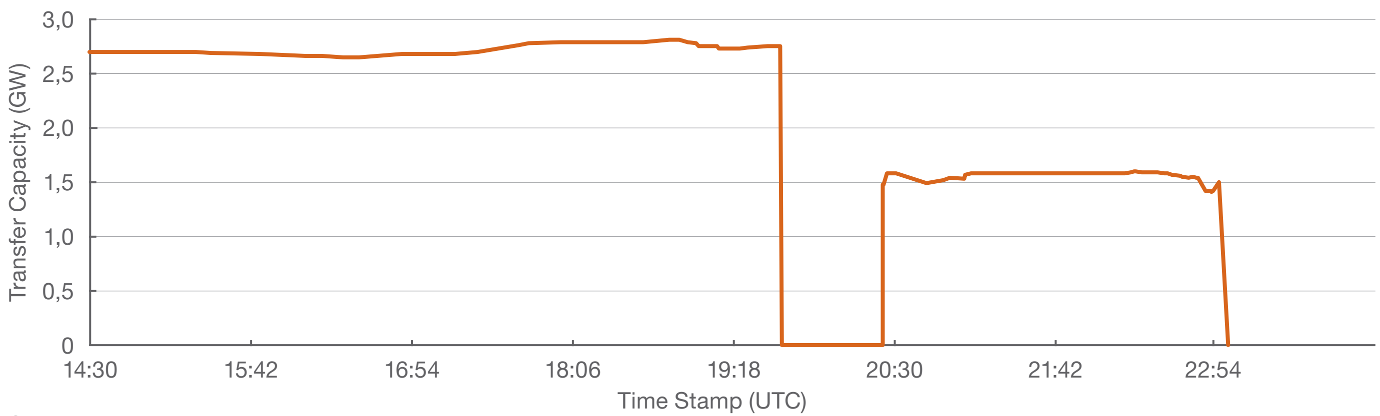
Self-Trades

In this example, we identified a case involving around 20 simultaneous cross-border self-trades from Amprion to TenneT (NL), likely executed in the form of iceberg orders. This activity took place in immediate temporal proximity to large cross-border capacity changes.

Such a scenario warrants careful analysis, as it may involve elements typical of wash trades. Wash trades are characterized by the absence of changes in beneficial interests or market risk, or where beneficial interest or market risk is transferred between parties acting in concert or collusion.

Fig. 14 Snapshot of executed transaction for hourly delivery on 29 July 2024 00:00–01:00 UTC in Amprion on 28 July 2024 at 20:26 UTC and NL Tennet – DE Amprion Cross-Border available capacity on 28 July 2024 between 17:00–21:30 UTC.

Trade Id	buyDeliveryArea	sellDeliveryArea	Execution Time	Quantity	Unit	Price	Currency	Updated at	selfTrade	Delivery Start	Delivery End
1737844529	10YNL----------L	10YDE-RWENET---I	2024-07-28T20:22:24.043Z	0,2	MW	74,01	EUR	2024-07-28T20:22:24.043Z	FALSCH	2024-07-29 00:00:00+00:00	2024-07-29 01:00:00+00:00
1737844567	10YNL----------L	10YDE-RWENET---I	2024-07-28T20:22:25.789Z	1	MW	74,39	EUR	2024-07-28T20:22:25.789Z	FALSCH	2024-07-29 00:00:00+00:00	2024-07-29 01:00:00+00:00
1737845363	10YNL----------L	10YDE-RWENET---I	2024-07-28T20:23:08.366Z	2,7	MW	75,4	EUR	2024-07-28T20:23:08.366Z	FALSCH	2024-07-29 00:00:00+00:00	2024-07-29 01:00:00+00:00
1737847376	10YNL----------L	10YDE-RWENET---I	2024-07-28T20:24:47.203Z	0,2	MW	76,46	EUR	2024-07-28T20:24:47.203Z	FALSCH	2024-07-29 00:00:00+00:00	2024-07-29 01:00:00+00:00
1737847392	10YNL----------L	10YDE-RWENET---I	2024-07-28T20:24:47.306Z	2	MW	76,71	EUR	2024-07-28T20:24:47.306Z	FALSCH	2024-07-29 00:00:00+00:00	2024-07-29 01:00:00+00:00
1737847983	10YDE-ENBW-----N	10YDE-RWENET---I	2024-07-28T20:25:22.862Z	0,1	MW	76,05	EUR	2024-07-28T20:25:22.862Z	FALSCH	2024-07-29 00:00:00+00:00	2024-07-29 01:00:00+00:00
1737848514	10YDE-EON------1	10YDE-RWENET---I	2024-07-28T20:26:45.695Z	6,3	MW	76,89	EUR	2024-07-28T20:26:45.695Z	FALSCH	2024-07-29 00:00:00+00:00	2024-07-29 01:00:00+00:00
1737848515	10YNL----------L	10YDE-RWENET---I	2024-07-28T20:26:45.695Z	4,9	MW	76,81	EUR	2024-07-28T20:26:45.695Z	WAHR	2024-07-29 00:00:00+00:00	2024-07-29 01:00:00+00:00
1737848516	10YNL----------L	10YDE-RWENET---I	2024-07-28T20:26:45.695Z	5	MW	76,81	EUR	2024-07-28T20:26:45.695Z	WAHR	2024-07-29 00:00:00+00:00	2024-07-29 01:00:00+00:00
1737848517	10YNL----------L	10YDE-RWENET---I	2024-07-28T20:26:45.695Z	5	MW	76,81	EUR	2024-07-28T20:26:45.695Z	WAHR	2024-07-29 00:00:00+00:00	2024-07-29 01:00:00+00:00
1737848518	10YNL----------L	10YDE-RWENET---I	2024-07-28T20:26:45.695Z	5	MW	76,81	EUR	2024-07-28T20:26:45.695Z	WAHR	2024-07-29 00:00:00+00:00	2024-07-29 01:00:00+00:00
1737848519	10YNL----------L	10YDE-RWENET---I	2024-07-28T20:26:45.695Z	5	MW	76,81	EUR	2024-07-28T20:26:45.695Z	WAHR	2024-07-29 00:00:00+00:00	2024-07-29 01:00:00+00:00
1737848520	10YNL----------L	10YDE-RWENET---I	2024-07-28T20:26:45.695Z	5	MW	76,81	EUR	2024-07-28T20:26:45.695Z	WAHR	2024-07-29 00:00:00+00:00	2024-07-29 01:00:00+00:00
1737848521	10YNL----------L	10YDE-RWENET---I	2024-07-28T20:26:45.695Z	5	MW	76,81	EUR	2024-07-28T20:26:45.695Z	WAHR	2024-07-29 00:00:00+00:00	2024-07-29 01:00:00+00:00
1737848522	10YNL----------L	10YDE-RWENET---I	2024-07-28T20:26:45.695Z	5	MW	76,81	EUR	2024-07-28T20:26:45.695Z	WAHR	2024-07-29 00:00:00+00:00	2024-07-29 01:00:00+00:00
1737848523	10YNL----------L	10YDE-RWENET---I	2024-07-28T20:26:45.695Z	5	MW	76,81	EUR	2024-07-28T20:26:45.695Z	WAHR	2024-07-29 00:00:00+00:00	2024-07-29 01:00:00+00:00
1737848524	10YNL----------L	10YDE-RWENET---I	2024-07-28T20:26:45.695Z	5	MW	76,81	EUR	2024-07-28T20:26:45.695Z	WAHR	2024-07-29 00:00:00+00:00	2024-07-29 01:00:00+00:00
1737848525	10YNL----------L	10YDE-RWENET---I	2024-07-28T20:26:45.695Z	5	MW	76,81	EUR	2024-07-28T20:26:45.695Z	WAHR	2024-07-29 00:00:00+00:00	2024-07-29 01:00:00+00:00
1737848526	10YNL----------L	10YDE-RWENET---I	2024-07-28T20:26:45.695Z	5	MW	76,81	EUR	2024-07-28T20:26:45.695Z	WAHR	2024-07-29 00:00:00+00:00	2024-07-29 01:00:00+00:00
1737848527	10YNL----------L	10YDE-RWENET---I	2024-07-28T20:26:45.695Z	5	MW	76,81	EUR	2024-07-28T20:26:45.695Z	WAHR	2024-07-29 00:00:00+00:00	2024-07-29 01:00:00+00:00
1737848528	10YNL----------L	10YDE-RWENET---I	2024-07-28T20:26:45.695Z	5	MW	76,81	EUR	2024-07-28T20:26:45.695Z	WAHR	2024-07-29 00:00:00+00:00	2024-07-29 01:00:00+00:00
1737848529	10YNL----------L	10YDE-RWENET---I	2024-07-28T20:26:45.695Z	5	MW	76,81	EUR	2024-07-28T20:26:45.695Z	WAHR	2024-07-29 00:00:00+00:00	2024-07-29 01:00:00+00:00
1737848530	10YNL----------L	10YDE-RWENET---I	2024-07-28T20:26:45.695Z	5	MW	76,81	EUR	2024-07-28T20:26:45.695Z	WAHR	2024-07-29 00:00:00+00:00	2024-07-29 01:00:00+00:00
1737848531	10YNL----------L	10YDE-RWENET---I	2024-07-28T20:26:45.695Z	5	MW	76,81	EUR	2024-07-28T20:26:45.695Z	WAHR	2024-07-29 00:00:00+00:00	2024-07-29 01:00:00+00:00
1737848532	10YNL----------L	10YDE-RWENET---I	2024-07-28T20:26:45.695Z	5	MW	76,81	EUR	2024-07-28T20:26:45.695Z	WAHR	2024-07-29 00:00:00+00:00	2024-07-29 01:00:00+00:00
1737848533	10YNL----------L	10YDE-RWENET---I	2024-07-28T20:26:45.695Z	3,8	MW	76,81	EUR	2024-07-28T20:26:45.695Z	WAHR	2024-07-29 00:00:00+00:00	2024-07-29 01:00:00+00:00
1737848534	10YNL----------L	10YDE-RWENET---I	2024-07-28T20:26:45.822Z	1,2	MW	76,81	EUR	2024-07-28T20:26:45.822Z	FALSCH	2024-07-29 00:00:00+00:00	2024-07-29 01:00:00+00:00
1737848535	10YNL----------L	10YDE-RWENET---I	2024-07-28T20:26:45.822Z	0,8	MW	76,81	EUR	2024-07-28T20:26:45.822Z	FALSCH	2024-07-29 00:00:00+00:00	2024-07-29 01:00:00+00:00
1737848544	10YDE-EON------1	10YDE-RWENET---I	2024-07-28T20:26:45.907Z	1,5	MW	76,5	EUR	2024-07-28T20:26:45.907Z	FALSCH	2024-07-29 00:00:00+00:00	2024-07-29 01:00:00+00:00
1737848545	10YDE-VE-------2	10YDE-RWENET---I	2024-07-28T20:26:45.907Z	0,5	MW	76,36	EUR	2024-07-28T20:26:45.907Z	FALSCH	2024-07-29 00:00:00+00:00	2024-07-29 01:00:00+00:00
1737849718	10YDE-RWENET---I	10YDE-VE-------2	2024-07-28T20:28:49.451Z	0,1	MW	77,2	EUR	2024-07-28T20:28:49.451Z	FALSCH	2024-07-29 00:00:00+00:00	2024-07-29 01:00:00+00:00



Source: PowerBot Analysis.

Cross-Border Capacity Halt

Immediately following the cross-border capacity release, buy pressure in the German delivery area penetrates the ask side of the order book in France, potentially "triggering" French iceberg orders. Price levels momentarily decrease as the German buy pressure stabilizes. Throughout this process, multiple phases of wide spreads and trades crossing the spread are observed. Eventually, as further aggressive buys are executed, increased selling pressure drives down price levels, fully utilizing the available cross-border capacity.

This case requires careful analysis, as it might involve elements typical of capacity hoarding. Such activities are a focus of investigations by ACER.

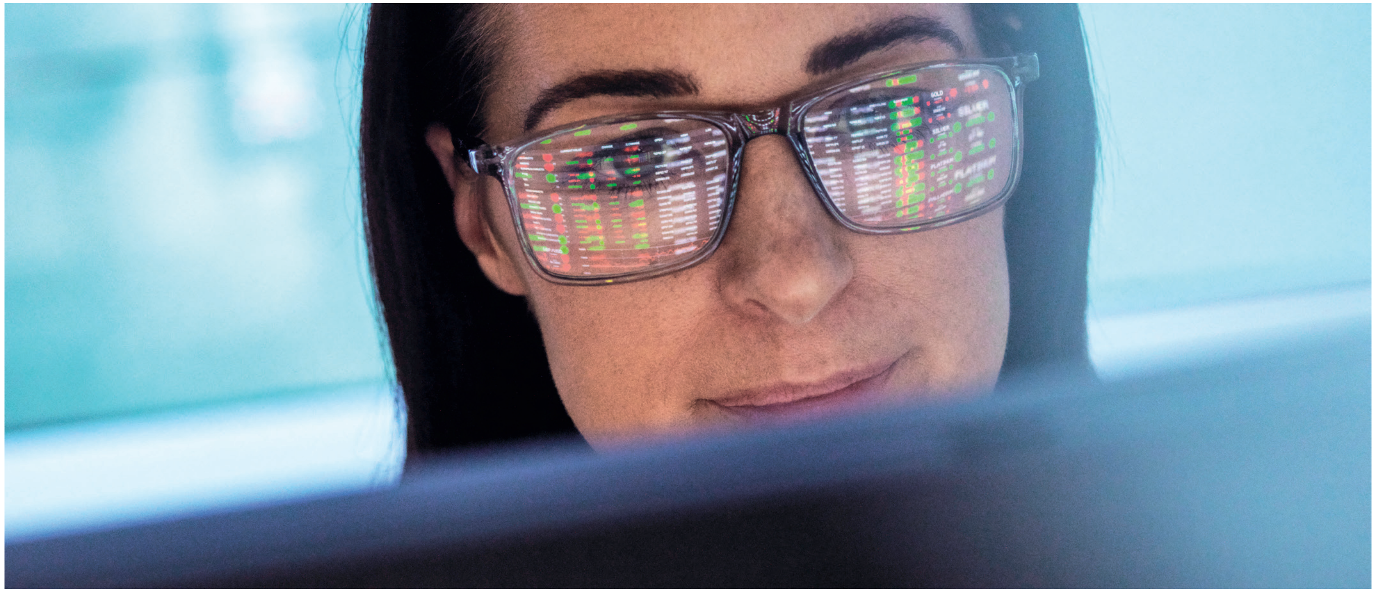
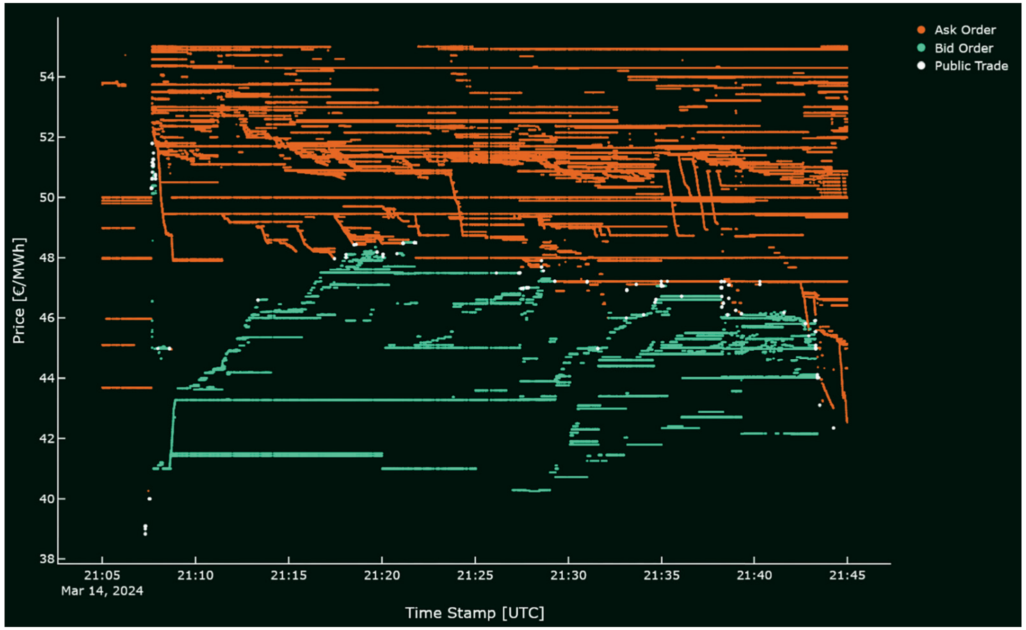
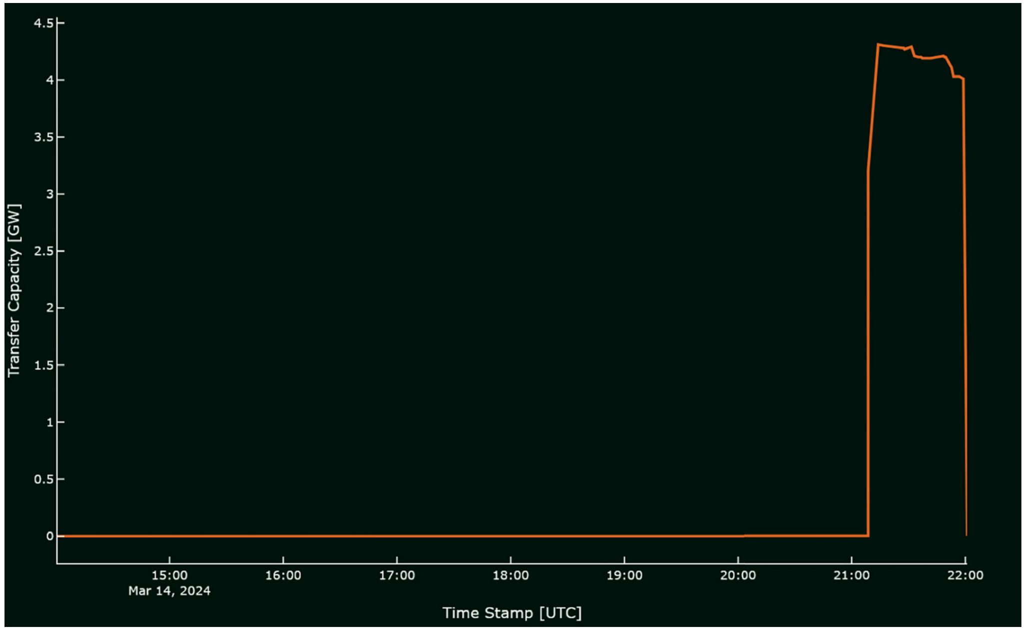


Fig. 15 Continuous order book for hourly delivery on the 14 March 2024 23:00–15 March 2024 00:00 UTC in France on the same day between 21:05 and 21:45 UTC and DE Amprion – RTE cross-border available capacity on 14 March 2024 between 14:00–22:00 UTC.





Source: PowerBot Analysis.

C Market Regulatory and Supervisory activities regarding Short-Term Power Trading

As illustrated by the case studies in section B.2, the trading process in short-term power markets is complex and can sometimes easily be affected by the trading behavior of individual market participants. Therefore, to protect market integrity and to ensure that market participants do not exploit these vulnerabilities, the EU has regulated in REMIT, Article 5, that “any engagement in, or attempt to engage in, market manipulation on wholesale energy markets shall be prohibited”. In light of these concerns, REMIT II introduces Article 2(18)[10] to define algorithmic trading in the context of wholesale energy products[11] as “trading, including high-frequency trading, in wholesale energy products where a computer algorithm automatically determines individual parameters of orders to trade such as whether to initiate the order, the timing, price or quantity of the order or how to manage the order after its submission, with limited human intervention or no such intervention at all” and Article 5a, containing provisions aiming to mitigate the level of operational risks inherent in algorithmic trading.

The REMIT II definition excludes certain types of algorithms and systems. Specifically, algorithms that do not automatically determine individual parameters of orders to trade, such as initiation, timing, price, or quantity, are not considered within the scope of algorithmic trading. This includes external order types offered by exchanges (e.g. Iceberg orders, stop-limit orders), order routing systems, order confirmation and post-trade processing and signal generators where the final trading decision is made by a human[12]. It is also important to note that algorithmic trading does not automatically fall under the scope of the AI Act.

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[10] The REMIT definition of algorithmic trading replicates the Art. 4(39) MiFID II definition introduced in May 2014 for financial instruments.

[11] It is to be noted that wholesale energy products do not limit to spot and forward contracts for supply of electricity, hydrogen or natural gas with delivery in the EU but also include balancing, transportation and storage agreements irrespective of how and they are traded (therefore also including contracts traded bilaterally or over the counter).

[12] REMIT Guidance, v6.1, 7.2 (353).

Amendments of REMIT[13] extend the supervisory role of ACER and NRAs for algorithmic trading in cooperation with NRAs. NRAs enforce REMIT II within their jurisdictions, ensuring market participants report their algorithmic trading usage and maintain compliance. This enhanced collaboration addresses cross-border regulatory breaches and promotes a harmonized regulatory approach. As an example, it is exemplary the recent activity of the ACM, conducting an exploratory market study on algorithmic trading in the wholesale energy markets. The study, examining trends and potential market impacts, highlighted the growing prevalence of algorithmic trading and machine learning modeling, emphasizing the importance of compliance with the REMIT II regulations to ensure market integrity and transparency.

The role for coordinating the implementation of the regulatory framework has been given to ACER[14]. ACER has addressed various market behaviors over the years that could constitute market manipulation under REMIT Article 5, as for example Capacity Hoarding[15], Layering and Spoofing[16] and Wash Trades[17]. Moreover, exchange surveillance monitors algorithmic trading based on the REMIT Regulation and exchange Rules and Regulations[18]. In addition, participants in physical markets also need to ensure compliance with local grid codes and balancing rules. In April 2023 the arrest of eight traders in Aarhus in Denmark on allegations of market manipulation of Wholesale Energy Products constituted the first known arrest for breaches of REMIT.

Additionally, Article 15 of REMIT II delineates the obligations for individuals professionally arranging or executing transactions in wholesale energy products, also within the context of algorithmic trading, which must establish and maintain effective mechanisms to identify potential breaches of market integrity provisions under Articles 3, 4, or 5 of REMIT II. These requirements should be considered in the development of a compliant algorithmic trading framework. Furthermore, the obligations extend to maintaining compliance with both REMIT and other relevant EU regulations, such as market abuse regulation[19].

Due to the complexity of these regulations, industry reviews[20] have emphasized the importance of having a robust risk and compliance framework to detect and prevent such manipulative practices and that algorithmic trading activities are compliant with regulatory standards. These frameworks, also advocated by ACER[21], should include advanced monitoring systems capable of identifying suspicious trading patterns, comprehensive internal controls, and regular audits to ensure compliance with REMIT regulations.

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13 Art. 5a, 7 and 13 REMIT II.
14 Art. 16 REMIT II.
15 Guidance Note 1/2018 on the application of article 5 of REMIT on the prohibition of market manipulation transmission capacity hoarding.
16 Guidance Note1/2019 on the application of article 5 of REMIT on the prohibition of market manipulation layering and spoofing in continuous wholesale energy markets.
17 Guidance Note 1/2017 on the application of article 5 of REMIT on the prohibition of market manipulation wash trades.
18 For example, EPEX SPOT's Market Surveillance monitors e.g. prohibition to enter orders without a due economic justification and to place orders without the intention of executing them (Article 2 EPEX SPOT Code of Conduct) and responsibility for ensuring that their technical environment does not disrupt or interfere with EPEX systems (Section 4 EPEX SPOT Operational Rules).
19 REGULATION (EU) No 596/2014 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 16 April 2014 on market abuse (market abuse regulation) and repealing Directive 2003/6/EC of the European Parliament and of the Council and Commission Directives 2003/124/EC, 2003/125/EC and 2004/72/EC.
20 E.g. "REMIT Best Practice A sector review on how to comply with REMIT related to inside information and market abuse" and "Question and Answers on EPEX SPOT Code of Conduct and REMIT regulation understanding".
21 ACER Guidance on the application of Regulation (EU) No 1227/2011 of the European Parliament and of the Council of 25 October 2011 on wholesale energy market integrity and transparency 6th Edition 22 July 2021.

D Market Resilience – Regulation of Trading Operations and IT Infrastructure

Market participants using algorithmic trading solutions, i.e. involving no or limited human intervention, rely on sophisticated data analytics tools, machine learning algorithms and complex IT infrastructures when processing vast amounts of data (e.g. cross-market prices, order book data, weather, and grid data etc.) in "near real time". Such set-ups entail elevated levels of operational risks at the level of individual market participants, which can easily trigger adverse repercussions at the market level.

To mitigate these systemic risks, several regulations have been adopted, to ensure that market participants engaged in algorithmic trading set up their processes and systems in a resilient way:

1 Mitigation of Operational Risk inherent Algorithmic Trading Processes (REMIT II, Article 5a)

Once market participants have such algorithmic trading activities falling into the scope of REMIT, Art 5a mandates that market participants operating algorithms in physical power markets must meet similar regulatory requirements as financial players according to MIFID II.[22] This obligation has recently been also stressed in latest REMIT Guidance[23].

MiFID II, through RTS 6, outlines detailed requirements for algorithmic trading systems, as summarized in Figure 16.

Fig. 16 The five pillars of RTS 6.

Article 1–5: ALGO – Organizational Requirements	Article 6–11: ALGO – Development, Testing and Validation	Article 12–18: ALGO – Control and Resilience Framework	Article 19–23: DEA – Direct Electronic Access	Article 24-27: Clearing
Definition of roles	Conformance Testing	Kill-Functionality	Controls of DEA Provider	System and Controls
Definition of tasks	Testing Environments	Automated Surveillance	System Specification and Requirements	Due Diligence Assessment
Role of Compliance Function	Controlled Deployment	Business Continuity	Due Diligence Assessment	Position Limits
Staffing	Annual Review	Pre-Trade and Post-Trade Controls	Review of DEA Clients	Disclosure Requirements
Outsourcing & Procurement	Stress Testing	Real-time Monitoring		
	Management of material changes	IT-Security		

Sources: RTS 6, PwC Analysis.

[22] Note: very similar wording of REMIT II, Art 5a and MiFID II, Art 17.
[23] ACER Guidance on the application of Regulation (EU) No 1227/2011 of the European Parliament and of the Council of 25 October 2011 on wholesale energy market integrity and transparency 6.1st Edition, 18 December 2024, 2.4.(iv) (54).

The first pillar "Organizational requirements" introduces a formalized governance framework setting clear rules of responsibility and separations of duties as well as requiring the acquisition and maintenance of a set of minimum skills for its workforce, with a focus on risk and compliance functions.

The second pillar "Development, Testing and Validation" mandates a rigorous testing and validation of algorithmic trading systems, evaluating the performance and behavior of their algorithms under various scenarios, including stress testing scenarios. The results of these tests must be documented, and any identified issues must be addressed before deploying the algorithms in live trading environments. An annual self-assessment and validation process is also required to review its algorithmic trading strategies, governance framework, business continuity arrangements, and compliance with current regulation.

The third pillar "Control and Resilience Framework" entails several layers impacting day-to-day operations and technical set-up of algos:

- One of the primary requirements of the control framework is the establishment of pre-trade controls. These controls include limits on order entry, which are designed to prevent the submission of erroneous orders that could disrupt market activity. Firms must implement price collars, maximum order value, and volume thresholds to ensure that orders are within acceptable parameters to automatically reject orders that exceed predefined risk limits or exhibit unusual trading patterns.
- In addition to pre-trade controls, RTS 6 emphasizes the importance of real-time monitoring, ensured through a set of safeguards to avoid disruption (Kill-Switch and business continuity plans).
- Finally, firms are required to implement post-trade monitoring systems to detect suspicious trading activity, such as market manipulation or potential breaches of regulatory requirements. This involves the surveillance of trading patterns, order flow, and market conditions to identify and mitigate potential risks.

The fourth pillar "DEA" translates the requirements of the first three pillars to the context of DEA clients. Such requirements are particularly relevant for trading companies offering trading-on-behalf services or trade in cooperation with third parties. The market participant is always responsible for the requirement implementation.

The fifth pillar "Clearing" defines due diligence, controlling and monitoring requirements for systems of firms acting as clearing firms.

It is also important to note that the investment firm remains fully responsible for its obligations if it outsources or procures software or hardware used in algorithmic trading activities.

In conclusion, the evolving landscape of energy markets and the increasing reliance on renewable energy sources necessitate sophisticated internal control mechanisms. Regulatory requirements emphasize the importance of robust risk management, advanced monitoring systems, and comprehensive compliance frameworks to ensure market integrity and transparency. By implementing these controls, market participants can effectively navigate the complexities of algorithmic trading, mitigate potential risks, and contribute to a fair and stable market environment, preserving the profitability and sustainability of the algorithmic business case.

2 Monitoring and Surveillance obligations for Market Participants (REMIT II, Article 15)

REMIT II additionally introduced monitoring and surveillance obligations for persons professionally arranging or executing transactions. Such persons shall establish and maintain effective arrangements, systems and procedures to identify potential breaches of REMIT (insider trading, obligation to publish inside information, and market manipulation) guaranteeing independence of employees carrying out surveillance activities in order to detect and report suspicious orders and transactions without further delay and in any event no later than four weeks from the day on which that person becomes aware of the suspicious event.

REMIT Guidance also provides a non-comprehensive list of practices of attempted market manipulation through giving false or misleading signals and/or securing the price at an artificial level, including wash trades, phishing, layering, spoofing, quote stuffing, advancing the bid (also implying improvements loop in the algorithmic trading context), placing orders with no intention of executing them etc.

Such cases are already analyzed and enforced by NRAs as for example through the recent action of the Comisión Nacional de los Mercados y la Competencia published on 20 December 2024, imposing a cumulative €7.5 million fine for breaching REMIT Art. 5 manipulating the Spanish electricity market between 30 September and 30 December 2022 giving false or misleading signals regarding the supply of wholesale energy products, through behavior known as quote stuffing as well as issuing non-genuine orders to be in an advantageous position to execute cross-border trades with France.

Surveillance processes require in the context of algorithmic requires the post-trade processing of significant amount of data and adoption of trading pattern detection and analysis, as highlighted in section 2.b.

3 Mitigation of Operational Risks inherent IT Backbone/Infrastructure and AI Applications

The scalability and flexibility provided by cloud infrastructures are critical for supporting the computational demands of algorithmic trading. Cloud platforms enable real-time data processing, high-frequency trading, and large-scale simulations without the limitations of traditional on-premises systems. In addition to the requirements of REMIT II, some aspects of operational risks related to IT backbone and infrastructure and the usage of AI applications are covered by the NIS-2 regulation and the AI Act.

NIS-2 enhances the original NIS Directive by strengthening cybersecurity in critical sectors like energy. It introduces stricter requirements, such as mandatory security assessments, intrusion detection systems, and incident response protocols to protect against cyber-attacks. Firms must promptly report incidents to authorities to ensure quick threat response and prevention of further disruptions.

Emphasizing supply chain security, NIS-2 requires firms to ensure that their partners adhere to stringent cybersecurity standards through due diligence and contractual obligations. It also mandates enhancing operational resilience with redundancy and backup systems, including regular testing of disaster recovery plans to ensure continuity during cyber incidents. Overall, NIS-2 emphasizes comprehensive protective measures to secure digital infrastructures and maintain resilience against cyber threats.

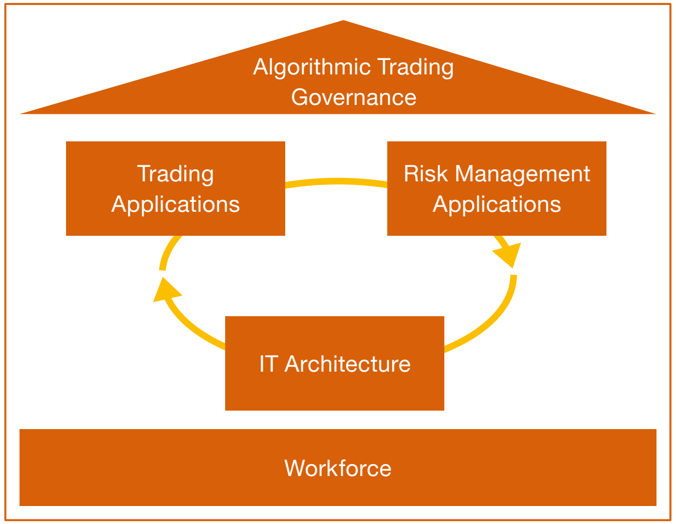
The AI Act, proposed by the European Commission, aims to regulate AI systems, including in the energy sector, by categorizing them based on risk. Algorithmic trading is deemed high-risk, requiring stringent transparency, explainability, and accountability measures. Firms must ensure AI models are auditable and appoint individuals to oversee compliance and governance. Rigorous testing under various market conditions is essential to confirm AI systems' robustness, alongside implementing safeguards to prevent disruptions and establishing strong data governance to maintain data integrity. Both the AI Act and NIS-2 significantly impact algorithmic trading, demanding substantial investments in technology, infrastructure, and skilled personnel. Firms must build advanced risk management and cybersecurity frameworks to comply with regulations and protect against threats.

The increasing technological sophistication in algorithmic trading, coupled with evolving regulatory frameworks like the AI Act and NIS-2, underscores the importance of robust internal controls and advanced technological solutions.

E Advanced Algorithmic Trading and Risk Management Frameworks

The evolving energy trading landscape described in the previous sections requires market participants to re-evaluate the set-up of their business model to ensure that this is still "fit-for-purpose" in the new landscape for short-term power trading. This review needs to cover the following areas as described in the framework for short-term power trading:

Fig. 17 The New Algorithmic Trading Framework.



Source: PwC Analysis.

Trading Processes & Applications

Successful trading in complex, highly dynamic energy markets requires market participants to significantly enhance the capabilities of their front office processes and systems to enable traders to successfully execute complex trading strategies. Market participants need to build up the following capabilities:

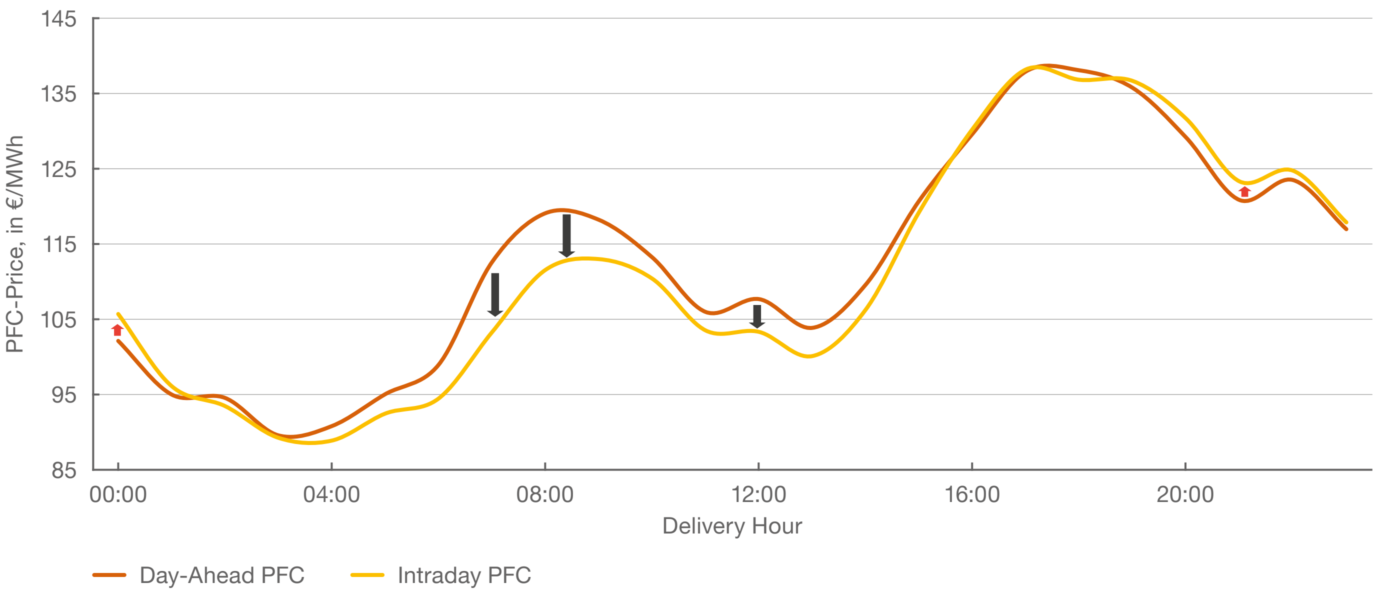
- Access to a rich data backbone including historical and near-real time order book data, weather data, unplanned physical unavailability, cross-border residual capacity and grid balancing activities, etc. which can be readily accessed by front office teams for developing and back-testing new trading strategies.
- Highly efficient DevOps processes enabling front office teams to quickly bring newly developed algorithmic prototypes into production, i.e. deploying new algos with new trading strategies and enhancing already existing algos with new data feeds, estimation techniques, forecasting models etc. ensuring compliance with regulatory requirements.
- Front-to-end automation of all pre- and post-trade processes, systems and, if applicable interfaces to physical assets and nomination systems, tracking trading and asset positions in real-time to ensure that algos can execute their trading strategies based on an accurate view on the portfolio traded.

Risk Management Processes & Applications

Algorithmic trading necessitates a shift in risk management from an end-of-day focus to a more dynamic, intraday approach. Market participants must develop a clear understanding of the unique risk exposures created by algorithmic trading.

First, focusing on financial risks, trading positions in short-term power markets can lead to significant market risks, especially when new weather data causes fluctuations in the market values of hourly or quarterly products. These fluctuations may deviate considerably from expected values, as indicated by historical price forecasts. Additionally, fundamental changes are often exacerbated by movements in the order book due to price discovery processes and imbalances.

Fig. 18 Intraday shifts of the hourly Price Forward Curve (based in the figure on Day-Ahead price data on 26 December 2024 in Germany) are affected both by intra hourly shaping effects as well as residual load shifts against Day-Ahead forecast.



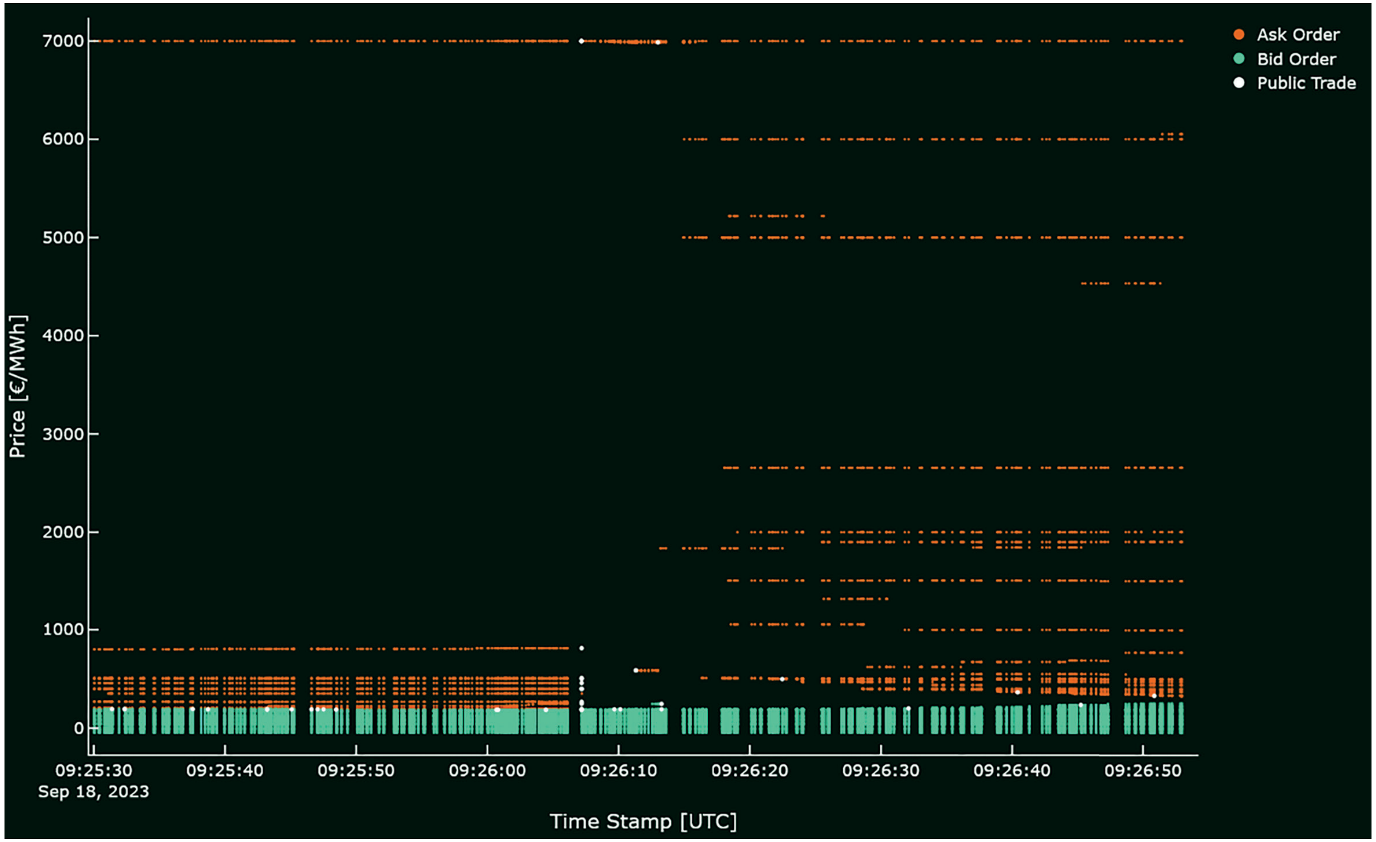
Source: PwC Analysis.

Thus, market participants should measure the mark-to-market of expected open spot positions as of 14 days before delivery by building a short-term price curve covering the next 24 delivery hours. The associated volatility can be used to calculate risk metrics such as "value-at-risk," which helps in assessing the risks from renewable positions and the potential benefits of flexibility. These risk metrics inform dynamic limit settings, allowing algorithms to adjust their trading strategies based on market volatility and order book liquidity. Real-time pre-trade risk checks are essential to prevent erroneous order entries, validating positions, cash limits, and other risk scenarios instantaneously. Speed and accuracy in these checks are crucial to avoid missed trading opportunities, requiring advanced low-latency infrastructures. Dynamic pre-trade controls serve in this context not only to prevent market disruptions but also to optimize execution strategies.

Second, risk management for algorithmic trading cannot rely only on tracking financial risks as captured in risk reports. Instead, risk management for algorithmic trading also needs to put a strong focus on "physical and operational risks" in case that the algorithm is used for managing physical asset positions. Thus, risk manager needs to ensure real-time access to availability data, have a good understanding of forecasting models for measuring asset positions (both point and interval estimates), key value drivers of assets, logistical risks inherent in trading strategies (e.g. restriction on scheduling across balancing areas) as well as a basic understanding of the underlying IT-processes and system to properly manage operational failures.

Fig. 19 Continuous order book for quarter hourly delivery on 18 September 2023 10:00–10:15 UTC in 50Herz on the same day between 09:25 and 09:27 UTC.

Example of execution strategy in active regime crossing a temporarily empty order book. Proper price limit calibration avoids cases of "out-of-market price" trading.



Source: PowerBot Analysis.

While such risks also exist in conventional trading approaches, the potential impact of such issues is significantly compounded by the speed at which algos execute their trading strategies and the interaction with other systems. At the same time, however, having an appropriate framework for managing algorithms provides more options for managing/measuring such risks, ensuring real-time monitoring and effective remediation measures (e.g. Kill-Switch).

Third, algorithmic trading strategies significantly increase compliance risks. As highlighted by regulatory and supervisory bodies, discovery (e.g. improvement loops) or aggressive execution strategies might mislead the wholesale energy market and hence might be identified as potential market manipulation under REMIT. This requires market participants to set up appropriate pre-trade controls, properly calibrate trade surveillance systems and introduce post-trade analysis, to verify that operations align with best practices, particularly when using custom algorithms.

Finally, the risk manager owns subject matter expertise and can assess within the daily risk management cycle liquidity dynamics, track the flexibility and availability of the traded physical asset base, ensuring robust IT and data interfaces, evaluate forecast errors in the models used and monitor risk concentrations across different algorithms. New ad-hoc tasks include back and stress of algorithm behavior in various market environments, with specific dataset requirements, assess the accuracy and variance of fundamental data forecasts and evaluate operational risks in pre-trade and processes, such as the transmission of forecasts and pattern analysis.

This structured approach to risk management not only addresses the complexities of algorithmic trading but also positions participants to navigate the evolving landscape effectively and compliantly.

IT Backbone

More, faster, and reliable data is crucial for algorithmic trading market participants. Therefore, cloud-based SaaS solutions are the most popular way to reduce time-to-market and operating risk for the market entry, the solution set-up, and the corresponding operation procedures. Most of the players are adopting a Dev-Ops methodology, which enables them to react immediately to market changes. Adoption of algorithms and corresponding coding should be enabled on a daily basis (e.g., in a CI/CD framework), including rigorous regression testing and deployment procedures. One main reason for this trend is the missing capability of “standard” ETRM solutions to provide or enable this kind of service/capability. The other advantage is related to scalability and high performance of cloud-based solutions (to handle the increasing volumes of short-term and intraday trades).

In those operating models, the overall responsibility for trading results and trading impact on market behavior remains on the trader’s side and cannot be transferred to the SaaS provider. That means that the activity split of operating procedures/IT management processes needs to be defined and established by the two partners in a clear and transparent role model to avoid any kind of organizational fault.

In addition to that, business continuity and disaster recovery procedures are essential to reduce any kind of default risk and should be considered within the trader’s algorithmic trading policy or framework. Again, this obligation cannot be transferred completely to the SaaS provider.

A robust approach to record-keeping is also needed. Trading systems must generate detailed logs of relevant activities, from order entries to execution and input parameters, ensuring comprehensive audit trails for investigations and regulatory reviews. The challenging management of the sheer volume of data while ensuring its long-term accessibility and usability should be taken into consideration within the IT integration. Scalable storage solutions and advanced retrieval systems are essential to meet these demands without compromising performance.

Finally, the integration of AI into algorithmic trading systems has further transformed how traders approach the market. Machine learning algorithms, leveraging techniques such as supervised learning, reinforcement learning, and anomaly detection, can predict market movements and optimize trading strategies by learning from historical and real-time data. However, the use must align with regulatory frameworks, which in turn requires an advanced technological platform.

These systems should be capable of integrating diverse datasets, including fundamental data (e.g., weather forecasts, energy demand), technical data (e.g., order book dynamics, hidden liquidity), and regulatory data (e.g., compliance requirements), to provide comprehensive insights into market conditions and potential risks as well as introduce safety measures against operational risks.

Based on a review covering the dimensions of this framework, decision makers can gain the required understanding to decide whether the value added of having a fully-fledged in-house short-term power trading platform justifies its increasing fixed costs or whether specific parts of the value chain should be externalized to outside service providers.

F Conclusion

The European energy market is on the brink of a transformative era, driven by innovation, regulatory evolution, and the integration of renewable energy sources. Advanced algorithmic trading solutions are poised to address multifaceted challenges and unlock new opportunities for market participants, marking a significant leap forward in trading capabilities.

In the face of unprecedented global events and rapid technological advancements, structured algorithmic frameworks offer a competitive advantage and operational excellence, empowering market participants to navigate volatility and capitalize on emerging opportunities with renewed confidence. The shift towards advanced trading strategies sets the stage for a more dynamic and resilient energy market.

Regulatory reforms have highlighted the critical role of compliance, reporting and sophisticated detection mechanisms. The integration of real-time data analytics, cloud infrastructure, and machine learning models is becoming crucial for achieving operational resilience and market responsiveness. These advancements provide a clear path for meeting regulatory requirements while maintaining a competitive edge.

The successful implementation of algorithmic trading business cases hinges on the ability to leverage these frameworks. By adopting advanced algorithmic solutions, market participants can automate and optimize trading strategies, manage risk more effectively, and ensure compliance with evolving regulations. The convergence of technology and strategic innovation holds the promise of a more efficient, transparent, and liquid market.

As we stand on the threshold of this exciting new era, the tools and methods discussed here are designed to equip stakeholders to thrive in an ever-evolving landscape. Algorithmic trading solutions offer unparalleled advantages, from enhanced decision making and operational excellence to competitive edge and sustainable profitability.

The future of energy trading is promising, characterized by significant potential for innovation and growth. Embracing advanced algorithmic solutions will enable market participants to achieve greater resilience, transparency, and prosperity. The prospective trajectory is favorable, with substantial opportunities for success in the algorithmic trading sector. Implementing these frameworks successfully will not only modernize trading operations but also propel the energy market towards a more innovative and sustainable future.

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As Germany's leading audit and consulting firm, PwC offers unparalleled expertise and comprehensive support in algorithmic and systematic trading. Our services are grounded in deep industry knowledge, designed to help clients navigate the complexities of modern energy markets and optimize performance through advanced trading solutions.

To effectively define, develop, and implement algorithmic business cases, we employ our proprietary framework for short-term power trading, guiding clients end-to-end throughout their algorithmic trading journey.

Our offering includes:

- Algorithmic Trading Compliance and Risk Framework Development, Implementation and Review.
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