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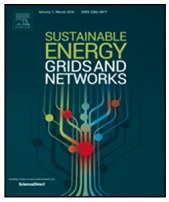

Research areas and methods of interest in European intraday electricity market research—A systematic literature review

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ABSTRACT

This paper establishes a robust foundation for the expansion of European intraday electricity market research through a systematic literature review. The review encompasses 132 primary studies from various libraries, categorizing them based on research area, methodologies, dataset context, and dataset date. The resulting taxonomy identifies six major research groups: Bidding, Market Modeling, Price Forecasting, Market Design, Forecast Errors, and Market Abuse. The analysis of the review results leads to actionable recommendations for future European intraday electricity market research. These recommendations include the utilization of close-to-live datasets to accurately reflect the impacts of the energy transition, the exploration of market abuse in the energy market industry, and the broadening of national electricity market studies beyond Germany. This systematic review aims to benefit various stakeholders, including academic researchers, industry participants, and European regulators, by providing a structured and objective compilation of existing research and offering insights into the identified gaps within the intraday electricity market research landscape.

1. Introduction

Within the power sector deregulation waves of the 1990s and early 2000s, electricity became a traded commodity akin to grain or coffee in Europe [1]. This marked a change in the motives driving power plant scheduling; scheduling behavior changed from a centrally optimized structure by the state to profit-maximizing structure by each market participant. European electricity has become even less centralized, and more heavily traded, in recent years. For instance, from 2010 to 2016, the volume of energy traded on the continuous German intraday (ID) market rose by about 400% [2]. Additionally, EPEX SPOT, one of the largest energy exchanges in Europe, hit record trading volumes of 621.5 terra-watt hours (TWh) in 2021 despite high prices [3].

The rise in ID trading activity is largely due to the increasing share of variable Renewable Energy Sources (vRES), such as wind and solar power plants. The increase in vRES production can be partially attributed to lower costs of necessary technological inputs [4]. Additionally, an increase of vRES production in Europe came from government mandates, such as European Directive 2009/28/EC which stated that, by 2020, 20% of the EU final energy consumption should be produced from vRES [5]. vRES generation is inherently more stochastic than fossil generation due to its reliance on natural factors, such as wind speed and solar irradiance. vRES shares have grown across major EU states during the century, such as Germany vRES share growing from 8.79% to 19.45% from 2010 to 2021 [6]. Increasing shares of less predictable electricity generation leave electricity market participants open to risks pertaining to supply/demand shocks and significant short-term price movement [7]. These factors have increased both the use of ID markets by market participants and its importance within research.

The ID electricity market serves as the platform for trading electricity products on the day of delivery. Contrary to its name, the ID market commences just hours after the day-ahead (DA) market clears. Over the past decade, this market has gained increasing importance within Europe. A significant policy and design change in recent years was marked by the completion of the Single IntraDay Coupling (SIDC) project. Launched in 2018 and concluded in 2023, the SIDC aimed to couple ID electricity trading across 23 countries [8]. Within the SIDC, trading has witnessed substantial growth, escalating from 3.5 million trades in mid-2018 to 34.22 million trades by early 2023 [8].

ID markets play a crucial role for market participants in mitigating risks associated with exposure to large volumes of stochastic vRES generation. These markets facilitate trading until very close to electricity delivery, with some, like the Netherlands and Belgium, allowing trades as close as 5 min prior to delivery [8]. This allows market participants to react to the most current supply/demand conditions. The increased trading flexibility offered by participation in the ID market has been demonstrated to enhance profitability by reducing balancing costs across various European ID markets [9–11]. Furthermore, the

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unique marketplace characteristics of electricity, given its unstorable nature on a mass scale, make the ID market a realm of 'forced' trading, driven by the necessity to distribute all generated electricity, or else balanced for a fee. Overall, ID markets provide commodity-focused researchers with a unique marketplace for study.

Although there is a significant body of literature on ID markets from various perspectives, this literature is currently scattered and lacks organization or structure. This absence of organization makes it challenging for new researchers to navigate and obscures novel methods from the intended industry audience. Therefore, the necessity for a systematic literature review (SLR) arises to map and categorize primary research on ID markets. This paper aims to address this research gap by compiling and analyzing journal articles and conference proceedings that explore the behavior and characteristics of European ID electricity markets. It establishes a taxonomy of major research areas related to ID markets, guiding future research in this domain. This SLR distinguishes itself from earlier literature reviews such as Weron (2014) [12] and Shinde & Amelin (2019) [13], both of which focus on aspects of European electricity markets with specific considerations for ID. It differs from these reviews in the following two main aspects.

Firstly, this review has a different goal than Weron (2014) [12] or Shinde & Amelin (2019) [13]. Weron (2014) [12] focused solely on price forecasting techniques with the goal of providing a comprehensive review of all techniques utilized in the price forecasting space as well as evaluating the effectiveness of the reviewed techniques. Shinde & Amelin (2019) [13] developed a detailed breakout of market condition reviews and price impacts, while also commenting on literature focused on bidding strategies utilizing the ID market. However, the review in [13] is not up to date regarding research post-2020, which is an inflection year for both EU policies and geopolitical realities. Furthermore, the review in [13] is not a systematic review and instead has the goal of summarizing research in major EU electricity markets equally. The SLR in this paper seeks to guide and shape further research, thus adopting a different focus and goal. Therefore, this SLR will not include comprehensive descriptions of techniques used in price forecasting or bidding strategies.

Secondly, this review encompasses multiple perspectives within the ID market research spectrum. Our analysis is grounded in a systematic search of journal papers and conference proceedings, resulting in an initial pool of 712 papers pre-validation and pre-scoring. Following validation, the number of included papers narrows to 170, and after post-scoring, the final count is 132 primary studies. This differs from the work in [12], which reviews over 300 journal papers, reviews, and books, yet focuses solely on price forecasting in response mostly to DA market concerns, given its larger research focus. While thorough, the review in [12] lacks a clearly defined systematic bibliographic approach to literature selection and transparent inclusion/exclusion criteria. The review in [13] covers 49 papers related to ID market research and also lacks a systematic literature selection procedure and clear inclusion/exclusion criteria.

The remainder of this systematic literature review is organized as follows: Section 2 describes the review process, Section 3 presents the review results, Section 4 addresses the research questions and offers a thorough discussion, and Section 5 summarizes the SLR, providing recommendations for future research on ID markets.

2. Methods

This study was performed as a systematic literature review based on guidelines proposed by [14], which have been retooled for use in the context of electricity markets. The goal of this review is to assess and categorize ID market research utilizing primary sources from European electricity exchanges, so this review is a secondary study. The steps in the systematic literature review are as follows: (1) Define goal of SLR and research questions, (2) Layout search process, inclusion criteria, and quality assessment schema, (3) Study collection and extraction of specified data, (4) Data analysis and results, and (5) Discussion of research questions. The specific rulesets and components of these SLR steps are summarized in Table 2.

Table 1
SLR research questions.

Research questions	RQ1: Which and how many journals or conference proceedings include papers focused on European ID electricity markets?
	RQ2: What are the major focus areas of European ID electricity market research and how have they changed over time?
	RQ3: What are the main methodologies employed by researchers and how have they changed over time?
	RQ4: What market datasets are employed in research and over which years?

Table 2
SLR inclusion criteria.

Inclusion criteria	Description
IC1	Full text is available or received from the authors upon request during the reading period.
IC2	Paper is written in English.
IC3	Paper is primarily focused on ID market aspects.
IC4	Paper is a primary study.
IC5	Paper was published by a journal, or from conference proceeding.
IC6	Paper is a not a duplication of a previously selected paper.
IC7	Paper uses a dataset from a European electricity exchange.

2.1. Research questions

Four research questions have been identified for this SLR, which are summarized in Table 1. These research questions were chosen with the purpose of developing a mapping of the broad and disconnected ID market research space. Additionally, these research questions aim to complement the broad mapping with detailed analysis of the mapped groups. This dual approach is in service of providing a knowledge base which is useful for the diverse set of identified stakeholders namely, academic researchers, industry participants, and European regulators.

2.2. Search process

The search process was a manual search through journal papers and conference proceedings published since 2003. This search was executed through three online libraries (Scopus, Springer, and IEEE Xplore) using the search query logic of the literature's Indexes, Abstract and/or Title must contain "Intraday" and "Market" and "Electricity". Each journal or conference proceeding was reviewed and papers which focused on European ID markets using primary data sources were deemed potentially relevant. The specific inclusion and exclusion criteria listed in the next section (Inclusion and Exclusion Criteria) were applied to the relevant articles.

2.3. Inclusion and exclusion criteria

Strict inclusion criteria were specified in order to select a subset of high-quality papers from the different libraries. By using carefully selected research to answer the research questions, a distinct level of validity is assured. Six inclusion criteria (see Table 2) were established and are based upon a foundational SLR [15].

The last inclusion measure is more subtle than the preceding six since there is transferability of research performed on American, Chinese, or Australian ID markets towards all ID markets. However, market rules and the mix of participants are of utmost importance for understanding effective pricing forecasting or efficient market designs, therefore it is necessary to limit variables, such as differing continental market locations which would confound research. A paper would only qualify for review if it was able to pass all seven of the listed criteria above in Table 2. This was done in an effort to simplify the review process and avoid misappropriating research focused on disparate electricity markets as equivalent in all cases.

Table 3
Distribution of primary studies collected by database prior to complete inclusion/exclusion criteria.

Database	Yield	Percentage of total
SCOPUS	410	58%
IEEE Xplore	175	25%
Springer	127	18%
Total	712	100%

2.4. Quality assessment

Each journal or conference proceeding paper was assessed along four criteria questions: (1) Is the focus of the paper on some aspect of ID market characteristics or activity of market participants? (2) Is the paper a primary study? (3) Are the methods and dataset used in analysis described? (4) Are the findings/conclusions/limitations clearly stated and/or consistent with the results?

The quality criteria are self-evident with regards to the goal of this SLR. This SLR aims to map and categorize primary research on ID markets. Thus, opinion papers, literature reviews, or papers focused solely on DA or balancing markets would distract from progress towards this goal. Similarly, a paper must make evident its methods and used data for the results to be validated and compared with other papers. A primary study receives one mark for each quality assessment criteria it contains, and a primary study must have at least three marks to qualify for contribution to the research questions.

2.5. Data collection

The data extracted from each primary study were: (1) The library where the article was sourced, (2) Journal or conference of publication, (3) Authors information, (4) Main research topic, (5) Sub-research area, (6) Main methods discussed or utilized towards achieving the research question, and (7) Electricity market data provider, geographic area of market participants, and years included used dataset. Table 3 shows a summary of the retrieved primary studies alongside their distribution per selected library.

In contrast to the prescribed approach in [14], all data gathering, and analysis was performed solely by the authors. Literature was not reviewed in a randomized process, but instead done chronologically following each library sources bibliographic ordering. Discussion on literature topic grouping and formulation of research questions was performed by the authors and validated through at least one expert interview with an electricity market researcher/industry member.

2.6. Data analysis

The data pertaining to the literature was tabulated in efforts to answer the research questions. The following were the key recorded metrics:

- Number of journal articles per year and their publishing source (RQ 1).
- Number of conference proceedings per year and the publishing conference (RQ 1).
- The number of studies in each major research (RQ 2).
- The topics studied and their electricity market scope based on the utilized dataset (RQ 2 and RQ 4).
- Keywords of methods utilized to answer study research questions i.e., neural networks, regression, or stochastic programming (RQ 3).

2.7. Threats to validity

The main threats to the validity of this review are as follows:

Table 4
Retrieved pool of primary studies by library.

Database	Search yield	Post validation	% Included
SCOPUS	410	116	28%
IEEE Xplore	175	32	18%
Springer	127	22	17%
Total	712	170	24%

Publication bias: The exclusion of multimedia and books is based mainly on practical concerns, including workload and lack of traceability on originality for multimedia productions. The exclusion of books would be more difficult to defend if this SLR was focused on broader economic concepts related to ID markets, e.g., fundamentals of the Merit Order curve and its relevance for ID markets. However, this SLR is interested mainly in properties of the research into ID market characteristics and aspects. Another potential publication bias is the exclusion phenomenon arising from unpublished ID market research due to the research having non-significant results, results that did not yield the desired outcome, or conflicts with company/exchange-confidential results. The latter cause related to confidentiality is quite significant since exchange operators, regulatory bodies, and market movers in the exchanges would be able to generate significant research due to their data holding positions.

Unfamiliarity with other fields: ID market research is a topic that is relevant to many fields; thus, it is possible that essential work and relevant journals published in another discipline using differing keywords and indexing (e.g., operational logistics, political science, or finance) have been overlooked.

Confirmation Bias: Since only one researcher performed the validation and scoring, there might be unintentional focus on confirming preconceived notions or beliefs about particular subjects within the space of ID markets, leading to confirmation bias. This could result in overlooking contrary evidence or alternative viewpoints.

Risk of Error: Human errors, such as misinterpretations or data entry mistakes, can occur during the validation and scoring process. The chances of these human errors grow when combined with the challenges discussed above.

Sub-optimal Keyword Selection: The choice of keyword selection was predicated on casting the widest net in efforts to gather ID market research from across many publications and research aims from the databases. However, this keyword selection may not use specific enough language to capture more detailed research. This lack of specificity may be the largest contributor to the exceedingly low number of market abuse-focused primary studies in the final grouped pool shown in Table 8.

3. Results

The synthesized literature data is reported in this section. First, the search results are reported and summarized. Afterwards, the more specific results are presented in order to illustrate the assessment of the literature under the quality assessment elements discussed in Quality Assessment.

3.1. Search results

The total amount of primary studies initially retrieved for this literature review is 712, shown in Table 3. Applying the inclusion criteria shown in Table 2 reduces the amount to 170 primary studies as shown in Table 4.

By applying the quality assessment criteria discussed above in Quality Assessment, the mean score of the primary studies was 3.35 with a standard deviation of 0.77. The distribution of scores is given in Fig. 1. The threshold score is a 3 and a total of 132 primary studies are finally extracted from the post-validation set of 170 which is shown in Table 5.

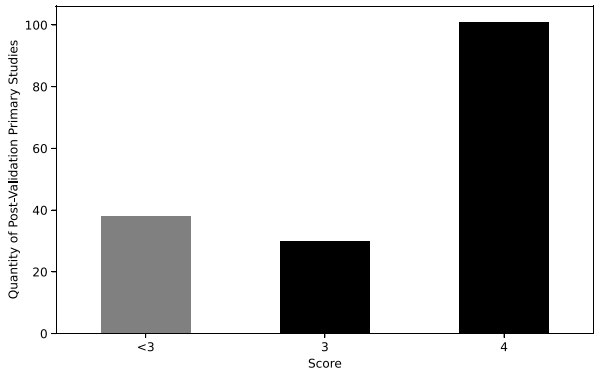

Fig. 1. Histogram of quality assessment scores for the retrieved primary studies. The collection of primary studies below the threshold are shown in gray.

Table 5
Final distribution of included primary studies by library.

Database	Post validation	Post scoring	% Abv. Threshold
SCOPUS	116	90	78%
IEEE Xplore	32	25	78%
Springer	22	17	77%
Total	170	132	78%

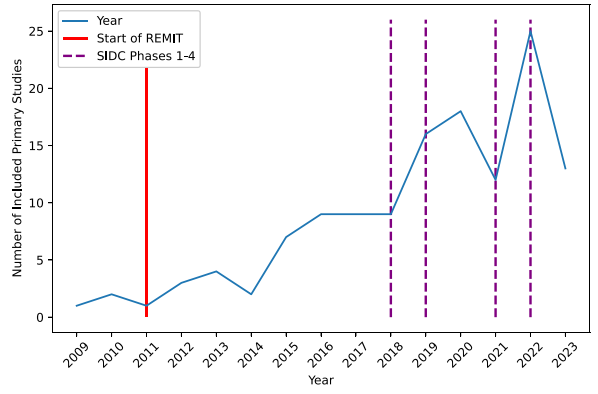

Fig. 2. Quantity of post-validation and post-scoring primary studies per publication year from 2009-June 2023.

The quantity of included primary studies per year is shown in Fig. 2. This figure shows that interest in the ID market among researchers has been steadily increasing over the past two decades following the growing usage of the ID market among market participants and, in turn, importance for regulators. The sharp dip of included primary studies in 2021 may be attributable to research focus being diverted during 2020 and 2021 to COVID related market research, but this is not verified in this SLR. However, the dip in 2023 is explainable since it is an incomplete year due to the primary study selection taking place in mid-2023.

4. Discussions

In this section, the answers to the research questions are discussed. The full research questions can be found in Table 1.

4.1. RQ1: Relevant ID market journals and conferences

Primary studies on ID markets were found across 44 journals. The top journals are listed in Table 6 alongside their corresponding quantity of included primary studies, proportion, and cumulative proportion of total journal primary studies. Ten journals are included in the top portion. These top journals comprise 58% of included journal primary studies on ID markets, which is 98 of the final 132 primary studies. Therefore, a researcher, regulator, or industry participant in the beginning phases of orienting within the research space can focus on a subspace of journals and feel confident they have exposure to a significant segment of research. However, an individual hoping to expand research horizons will need to access the broader frame of journals as they contain over 40% of the final primary studies. A list of all final primary studies and their publication source is in the Data Supplement.

Table 6
Top journals for ID marker research.

Journal	Count	Proportion	Cuml. Proportion (N=98)
Energy Economics	14	14%	14%
Energies	10	10%	24%
IEEE Transactions on Power Systems	7	7%	31%
Energy Systems	5	5%	36%
Applied Energy	5	5%	41%
European Journal of Operational Research	4	4%	45%
Energy Policy	4	4%	49%
SSRN Electronic Journal	3	3%	52%
International Journal of Forecasting	3	3%	55%
The Energy Journal	3	3%	58%

Table 7
Top conference proceedings for ID marker research.

Conference proceeding	Count	Proportion	Cuml. proportion (N=34)
International Conference on the European Energy Market (EEM)	12	35%	35%
IEEE workshop on complexity in engineering	2	6%	41%
IEEE PowerTech	2	6%	47%

In addition, primary studies on ID markets were found across 23 conference proceedings. The top conference proceedings are listed in Table 7 alongside their corresponding quantity of included primary studies, proportion, and cumulative proportion of total journal primary studies. Three international conferences are included in the top portion due to all other conference proceedings producing no more than 1 included primary study. These 3 conferences comprise 47% of included conference proceedings. However, the International Conference on the European Energy Market (EEM) produced 12 included primary studies on ID markets over 9 different years of proceedings, which comprises 35% of included conference proceeding primary studies. Therefore, EEM should be a yearly point of focus for researchers and industry members to interact and share thoughts. However, not all conferences list all of their papers for public access or through the utilized databases, which may have limited the scope and breadth of understanding of all the conferences contributing to ID market research.

4.2. RQ2: Major research areas

This section offers an overview of major research areas that aggregate to the reviewed primary study space. These research areas range from bidding strategies and price forecasting to understanding market modeling, market design, and market abuse. This categorization of market research areas aims to be as exclusive as possible to facilitate meaningful intra-area comparison of methodologies. For instance, price forecasting and forecast errors are treated as distinct topics. Price forecasting encompasses a broader range of primary studies, while forecast errors focus specifically on papers heavily emphasizing vRES

Table 8
Major research topics on ID electricity markets over time.

Research area	2008–2011	2012–2015	2016–2019	2020–2023	Total	Proportion
Bidding	1	4	12	24	41	31%
Market modeling	1	6	12	18	37	28%
Price forecasting	1	1	10	10	22	17%
Market design	2	3	6	7	18	14%
Forecast errors	0	3	3	7	13	10%
Market abuse	0	0	1	1	2	2%

forecast errors and their impacts on ID market activity and prices. Similarly, market design and market modeling are separated for similar reasons. Market design research explores topics, such as ID efficiency comparison between auction and continuous formats, or proposes novel market designs for theoretical 2050 market environments. Conversely, market modeling focuses more narrowly on primary studies detailing factors necessary for accurate market simulations or reconstructing the ID orderbook using derivative market datasets. Within each of these research areas, there are illuminating aspects that decompose the complexities governing modern ID electricity marketplaces for various stakeholders. Table 8 displays the distribution of research topics across four equal time periods and, collectively, over the included primary study timeframe.

4.2.1. Bidding

The bidding research area is defined by primary studies which focus on creating and/or evaluating market bidding and participation strategies for electricity markets. A bidding strategy is an approach or plan which is executed by an electricity market participant through placing of asks and bids. These strategies are executed across any number of marketplaces, such as the ID, DA or balancing markets, or some combination of electricity marketplaces. These strategies can vary from simple (e.g., placing updated bids and asks based on new weather forecasting [16]) to complicated algorithms leveraging reinforcement learning on outcomes of Markov Decision Process solutions [17]. All bidding strategy papers in the final primary study groupings shown in Table 8 involve participation in the ID marketplace, regardless of the depth of method employed.

The bidding modeling challenges are significantly amplified in the ID electricity market research compared to the DA and balancing markets. This heightened complexity arises from the substantially increased decision space and the dynamic nature of real-time price movements. Unlike the standardized auction system in the DA market, continuous ID markets lack such uniformity. Moreover, the ID market introduces additional complexities with multiple levels of delivery windows and products featuring real-time prices, a contrast to ex-post balancing prices. Consequently, navigating the intricacies of ID markets poses greater difficulty for bidding strategy researchers, often resulting in simplifications or exclusion in several bidding primary studies. For instance, in literature on bidding, ID markets are often excluded in the bidding strategy case studies as in [18,19], or assumed to be perfectly competitive, liquid markets as in [20].

4.2.2. Market modeling

The market modeling area is defined by primary studies which focus on evaluating ID market aspects across different dimensions (i.e., liquidity evaluation, trading behavior, imbalance costs, and price volatility). This research area also includes concerns around understanding supply and demand impacts on trading behavior and price formation for the ID market. This is the broadest area of research with researchers, regulators, and industry participants all able to leverage published research. Researchers may need techniques utilized here to effectively manipulate their own data sources for updated hypothesis testing, such as an adapted bid–ask spread, which is used to measure marketplace liquidity, for datasets containing only completed trades [21]. An industry participant may want to reconstruct an activity on a marketplace to estimate their own profitability ex-ante a financial quarter and would need marketplace simulation research to match their industry case [2,10,22]. While a regulator may have data access to observe all trades and participants, during turbulent price events such as those following the onset of the Russia–Ukraine war in 2022, effective communication with the public necessitates a nuanced understanding of the specific economic fundamentals driving price variability [10,23,24].

4.2.3. Price forecasting

The price forecasting research area refers to primary studies which focus on reconstructing the components for the price of an ID market product and attempting to forecast such a price over any horizon (i.e., quarter-hourly, half-hourly, or full hour electricity delivery products). Price forecasting horizons in this research area range from very short-term [25,26], which are important for understanding and trading quarter-hourly power products, to long-term such as multiple days ahead for DA hourly products [27]. Price forecasting research is mainly utilized as a key component of bidding strategies, which is of large importance for industry participants. Some bidding strategies utilizing price forecasts as a central component in the overall strategy are price arbitrage centered strategies [28–30]. However, regulators may find price forecasting research useful as supportive evidence for indicating if price formation is highly irregular from forecast trends and possibly due to bad market actors. These studies also focus on DA market price formation and forecasting due to the innate interactions between DA and ID market prices across multiple hourly power products and delivery days, such as in [31–33].

4.2.4. Market design

The market design research area is defined by primary studies which focus on evaluating ID market designs based on economic principles of efficiency and price equilibrium. These primary studies also recommend policy changes for regulators and exchange governance structures to address inefficiencies and imbalances within ID markets. This research has become increasingly important in the last decades as vRES integration has increased across Europe [6]. Since market design at the time of market liberalization was based on a small share of vRES generation, design updates and recommendations to increase market efficiency and stability have been, and still are, required. For instance, Weber discusses how to enable increasing integration of wind energy into European power systems through market design [34]. Henriot also focuses on wind power integration but from how to manage low-predictability and its impacts on the ID market [35]. Some recent research has even called for new marketplaces to be added alongside the major DA, ID, and balancing markets [36]. The rise of international trading for both DA and ID markets through programs, such as SIDC, have also increased the importance of market design research to evaluate the efficacy of coupling projects and if adjustments will be needed for long-term energy stability under a highly internationalized trading framework. Some work on this has already been sponsored and published through EU funding with mixed results on market efficiency across 18 EU member states [37].

4.2.5. Forecast errors

The forecast errors research area is defined by primary studies that assess the impact of vRES forecast errors on ID market activity. These evaluations concentrate on characteristics such as trading tendencies related to delivery time and price formation, in connection with forecast errors and updates in vRES. As vRES integration has increased across EU member states generation profiles, understanding how forecast errors related to vRES generation, mainly wind and solar, impact market fundamentals is important for a number of relevant ID market actors. For example, researchers focused on market design need to understand how forecast errors impact physical flows so that research on investment and political collaboration can be performed. This type of future vRES integration design was proposed for a hypothetical 2050 scenario in Europe and the greater Mediterranean area [38]. vRES forecast errors, especially as vRES integration increases, are likely to be a major factor in ID price formation and forecasting. [39] showed that larger wind and solar production forecast errors increase the absolute levels of imbalance on the grid and that larger imbalances influence subsequent ID market prices on the German market for quarter-hourly delivery products. Industry participants and regulators alike have a vested interest in understanding the value of these forecast errors as they relate to ID prices. A significant portion of the primary studies in this grouping focus on this vRES forecast to ID price formation formulation [40–42]. Industry participants would hope to leverage any forecast arbitrage for successful bidding strategy implementation, while regulators will need to convey to consumers how weather changes, which are increasing in variability, influence energy price fluctuations.

4.2.6. Market abuse

The Agency for the Cooperation of Energy Regulators (ACER) states that market abuse includes "performing false or misleading transactions, price positioning which secures or attempts to secure the price at an artificial level, as well as transactions involving fictitious devices or deception, and the dissemination of false and misleading information" [43]. Additionally, ACER publishes a specific list of targeted energy market abuse strategies as well as examples of each activity in action. Potential market abuse strategies in ID markets are: spoofing/layering, wash trades, capacity hoarding and insider trading. Full definitions of these activities, minus insider trading, due to its less technical nature, and examples provided by ACER can be found in the following guidance reports [44–46].

The literature found in the market abuse research area in ID markets is heavily focused on insider information possibilities of some market participants [47,48]. These primary studies also investigate price impacts of unplanned power outages and evaluate possible policy changes to reduce insider information impacts. These papers, however, clearly state that they lack the level of data granularity or investigative depth necessary to conclusively determine whether abuse has occurred. Instead, they focus their conclusions on implications for market level price impacts. These price impacts lead to discussion on including information asymmetry on capacity outages into the market design and the need to include information asymmetry in further price formation and forecasting research [47,48]. These studies do not attempt to reconcile with power exchange or regulator insider information thresholds, such as that published by Nord Pool [49]. Market abuse techniques extend far beyond insider trading using private generation outage information.

4.2.7. Research area trends over time

Several observations could be derived from Table 8. First of all, the bidding research area is on the rise and will most likely continue to be a central point of focus for researchers. Bidding strategy research has applicable uses for industry participants and with ID market trading activity rapidly growing industry interest will follow. Second of all, bidding strategies focus is following the growth of algorithmic trading which is growing across all trading platforms, such as security and other commodity exchanges [50].

Table 9
Distribution of methods utilized in post-scoring primary studies on ID electricity market.

Method	Count	Proportion	Cuml. Proportion (N=358)
Deterministic Optimization	35	10%	10%
Multiple Markets	35	10%	20%
Econometrics	25	7%	27%
Autoregression	25	7%	34%
Regression	24	7%	41%
Stochastic Programming	20	6%	47%
Model Comparison	17	5%	52%
Market Fundamentals	16	4%	56%
Algorithmic Trading	15	4%	60%
Neural Networks	15	4%	64%

In general, the distribution of research across the research areas has remained steady over time. The only exception to the relative stability is the large growth of bidding research in the last 3 years. Over the whole time period, market modeling has also been on a steady increase following the overall increase in ID research. This area of research will continue to be of importance for researchers and industry participants going forward as it delivers foundational updates on ID market behavior and characteristics.

The market abuse research area has remained underrepresented across the whole time period and will be a necessary point of growth in coming research. This research will become even more important for regulators as the ID market activity continues to increase going forward. Regulators will need to understand the strategies used for market abuse to enhance their detection and prevention mechanisms. Additionally, regulators can use empirical evidence from research efforts to shape effective policies that safeguard market integrity and increase investor confidence during this crucial period of energy transition.

4.3. RQ3: Main methodologies by research area

Table 9 shows the distribution of methodologies utilized across the final primary study space. Some of these methods require further clarification since they are non-standard methodologies. These methods include "Multiple Markets" and "Model Comparison". "Multiple Markets" as a method means that a primary study purposefully executed their analysis focus, whether it be within price forecasting or market design, across multiple marketplaces with differing actors. These marketplaces could be differing exchanges, such as Nord Pool and EPEX SPOT, or product marketplaces, such as balancing, ID, DA, or futures. "Multiple Markets" is less of a technical method compared to "Deterministic Optimization" or "Stochastic Programming", but it is a key method to identify because it helps researchers to understand that a significant portion of research being conducted is cross-sectional along marketplaces and exchanges. "Model Comparison" as a method refers to a bulk of analysis within a primary study being devoted to comparing differing modeling approaches. These comparisons can be executed with statistical measures, such as mean-square error, or financial, such as profit realized during a trading window. Defining "Model Comparison" as a distinct methodology to be tracked allows for researchers, regulators, and industry participants to parse more quickly through modeling approaches that could apply to their unique situation.

However, due to the broad nature of ID market research discussed in Section 4.2.7, a detailed discussion of methods will be conducted per research area.

4.3.1. Bidding methods

The distribution in Table 10 suggests that there are definitive concentrations of technical focus for researchers publishing bidding-focused primary studies. First of all, the methods with the bidding

Table 10
Distribution of methods utilized within primary studies focusing on the bidding research in ID electricity market.

Area	Method	Count	Proportion	Cuml. Proportion (N=102)
Bidding	Deterministic Optimization	23	23%	23%
Bidding	Stochastic Programming	17	17%	39%
Bidding	Multiple Markets	14	14%	53%
Bidding	Algorithmic Trading	9	9%	62%
Bidding	Neural Networks	7	7%	69%
Bidding	Markov Decision Process	7	7%	75%

Table 11
Distribution of methods utilized within primary studies focusing on the market modeling research area in ID electricity market.

Area	Method	Count	Proportion	Cuml. Proportion (N=109)
Market modeling	Econometrics	15	14%	14%
Market modeling	Market Fundamentals	13	12%	26%
Market modeling	Regression	13	12%	38%
Market modeling	Simulation	9	8%	46%
Market modeling	Descriptive Statistics	8	7%	53%
Market modeling	Deterministic Optimization	6	6%	59%
Market modeling	Probabilistic Forecasting	6	6%	64%
Market modeling	Autoregression	5	5%	69%

research area are highly concentrated within a few methods since the top 6 methods comprise 75% of all methods used in the 41 bidding-focused primary studies. Second of all, the contextualization of the bidding strategy problem is commonly based on a kind of optimization problem since "Deterministic Optimization" and "Stochastic Programming" comprise 39% of the method space. Stochastic Programming contexts can employ stochastic programming to enhance profits by minimizing imbalance costs or maximizing pricing, effectively managing the inherent randomness in vRES generation [51–54]. On the other hand, Deterministic Optimization can be performed with differing methodologies, such as with dynamic programming [55], or with differential equations leveraging the Markowitz mean–variance approach to portfolio management [56]. A smaller subset of primary studies has tackled Deterministic Optimization through physical systems control for dispatching generation across various control contexts, including transmission congestion or optimal delivery of a mixed-asset portfolio to meet real-time pricing [57–59].

Participating in trading across multiple markets has been successful for profitability increases, since profitability is the key metric of analysis for bidding-focused primary studies. These increases in profitability are the result of market participants paying less in imbalance costs, or achieving better prices on settled trades in the ID market. Bidding strategy papers utilizing the perspective of a electricity producer, such as a wind park, have found that participation across the DA, ID, and balancing market to be instrumental for increasing trading profitability since more opportunities are present to offset unfavorable vRES forecast errors [53,54,60–63].

"Algorithmic Trading" has become an increasing research trend within the bidding space, as discussed in Section 4.2.7, and now accounts for a significant portion of methodology in the bidding space. These trading algorithms can be performed with simple algorithmic looping centering around vRES forecast arbitrage to gain profitability under favorable forecast update positions, or limit costs under unfavorable positions [16,30,64]. "Neural Network" technique is commonly utilized to position the trading algorithm based on portfolio measures such as conditional value-at-risk or other financial measures. The common build for these neural network models within these papers is to combine a neural network within the context of deep reinforcement learning. This reinforcement learning could focus on learning through an actor-critic method [28], or through the lens of Markov Decision Process [17,65].

4.3.2. Market modeling methods

The distribution in Table 11 suggests that methods within the market modeling research area incorporate a wider frame of techniques than the bidding research area. These primary studies are less concentrated with the overarching regression-based approaches ("Regression" and "Autoregression") comprising only 17%. However, the prevalence of "Econometrics" supposes a shared lens of analysis that these papers share opposed to bidding-focused primary studies.

Considering the theoretical underpinnings behind "Market Modeling" primary studies, they often approach ID trading behavior from an economics focused lens (e.g., "Econometrics" and "Market Fundamentals" comprise 26% of methods). In many instances, research is focused on if market fundamental components, such as liquidity, input prices, and/or previous prices, are enough to explain a market element. Price variations are attempted to be decomposed and explained [10,21,66]. The work in [21] was able to explain 75% of price variation in the German EPEX SPOT ID market using load, demand, coal price, CO2 emission price, gas price, vRES generation, combined-heat-and-power (CHP) generation, power plant unavailability size in MW, and cross-border net export. While this may seem a long list of inputs, most of these inputs come from public information which is important for researchers with limited access to paid, industry sources and private information. Hourly Load, vRES generation, CHP generation, power plant unavailability and cross-border net export are all publicly available for EU countries.

Market modeling techniques have a distinct focus on understanding variation and detailing changes in behavior. Key methods in pursuit of this understanding are "Descriptive Statistics" and "Simulation". Market profiles built using descriptive statistics are important for researchers, regulators, and industry participants alike as the profiles provide key statistical details which may be inaccessible or cumbersome to create. For example, Mayer & Trück built a comparative framework of ID market prices, liquidity, and size across Europe and the world [1]. Baule & Naumann leverage descriptive statistics to provide a profile of volatility and price dispersion for hourly products within the EPEX SPOT market [67]. The facts found in these primary studies are able to quickly orient researchers or industry participants to a market in question. In tandem with a statistical profile, "Simulation" plays a crucial role in market modeling as they provide a flexible approach to understanding the complexities and variations of ID markets. Martin & Otterson showed that the true orderbook for EPEX SPOT can be reproduced through simulation and market fundamentals through only the limit-order book to within 90%–95% accuracy on aggregated metrics [2]. Furthermore, elucidating price formation through simulations of economically optimal trading can replicate various market peculiarities, such as spikes in trading value near delivery and correlations between price and vRES forecast errors [68]. Simulations, as discussed, empower stakeholders – researchers, regulators, and industry participants – to achieve a deeper understanding of market dynamics, make informed decisions, and/or mitigate potential risks.

"Regression" and "Autoregression" are used depending on empirical design within the primary study. "Regression" is often used to understand impacts of exogenous factors on key market metrics, such as the work by Hagemann composing price formation from external factors, such as fossil fuel prices and generation outages, using an ordinary least squares (OLS) regression method [21]. Similarly, Hirsch & Ziel seek to understand price distribution in terms of its shape, location, and size in the German EPEX SPOT market using a logit regression based on DA prices, ID day power outages, DA fundamentals, vRES forecast errors, and merit order shape [69]. Hirsch & Ziel were able to show their value-added regression model was able to explain more about

price distributions compared to the naïve approach, which provides a new tool to leverage existing price arbitrage trading strategies or optimization procedure [69]. In comparison, "Autoregression" is often used with autoregressive integrated moving average (ARMIA)-type models or vector-autoregression (VAR) models for problems characterized by substantial correlation, such as 15-minute contract pricing or other high-frequency datasets like ID trading time series [70–74].

4.3.3. Price forecasting methods

The distribution in Table 12 suggests that methods with the price forecasting research area are concentrated within a few methods. "Regression", "Autoregression", "Least Absolute Shrinkage and Selection Operator (LASSO)", and "Model Comparison" comprise 55% of all methods used in the 22 price forecasting-focused primary studies.

Research in price forecasting is split between two technical camps: regression-based approaches and machine learning approaches. Regression-based approaches comprise "Autoregression" and "Regression", while machine learning approaches would include "Ensemble Learning". While it seems that practitioners in both technical camps are comparing their results with those within and outside their camp as indicated by the prevalence of "Model Comparison".

Primary studies following regression-based techniques normally focus their forecast on hourly products since these products are shared between the DA and ID markets. Besides, these products are subject to both continuous trading and auction trading, while this is less common for 30-minute and 15-minute products. Narajewski & Ziel implement both a Generalized Additive Models for Location, Scale, and Shape (GAMLSS) and logit-LASSO model to assemble hourly price trajectories and understand their distribution across multiple dimensions. Using these trajectories they are able to show that the SIDC initiative has reduced price volatility in the German ID market by increasing liquidity and allowing for more accurate forecasting [75]. In comparison, Maciejowska & Weron targeted 30-minute contract prices using VAR models to forecast baseload pricing in the UK ID market and then compared performance across 54 distinct regression compositions [23]. Maciejowska & Weron were distinct in offering multiple forecast horizons across short-term (1 day) to long-term (50 days) [23]. This paper is distinct since other identified papers focusing on ID price forecasting utilize back-casting or out-of-sample testing to evaluate forecast results within point forecasting frameworks horizons [25,76–78].

There is a large focus in price forecasting research in decreasing the dimensionality of the forecasting model by eliminating explanatory variables. This is evidenced by the prevalence of LASSO across the method space. LASSO has shown success across many primary studies regardless of forecasting horizon by facilitating feature selection and reducing overfitting [26,31,75,78–80]. The continued usage and success of this technique in the price forecasting space is valuable for researchers since ID price problems are highly complex and can quickly balloon in dimensionality when all market modeling factors, discussed in above, are weighed.

As mentioned in the introduction of this SLR, Weron (2014) published a highly comprehensive literature review of price forecasting for electricity markets which considers primary studies that focus across all marketplaces. This review also discusses the history of price forecasting research and provides mathematical descriptions and proof sections of main techniques [12]. For these reasons, this SLR points to this review for readers highly interested in a deeper dive into price forecasting research.

4.3.4. Market design methods

The distribution in Table 13 suggests that methods with the market design research area are concentrated within a few analytical tools. This concentration is illustrated by the top 5 approaches comprising 63% of all methods used in the 18 market design-focused primary studies.

Market design research often utilizes international design since electricity markets have become increasingly interconnected since the beginning of market liberalization in the 1990s. Therefore, "Multiple Markets" is a key method of interest for researchers to evaluate current design efficiencies. Indicators to measure market efficiency across 18 EU members states result in two main indicators being proposed: (1) The ratio of high variance load hours to 1,000 h and (2) The median of the share of high variance load hours in relation to positive load variance [37]. This study also highlights how econometrics is utilized within the context of market design research area since these indicators are based on market phenomenon underpinned by market participant behavior in relation to forecast errors.

A number of primary studies also focus on how to increase market performance (i.e., by increasing liquidity or better integrating vRES production with its stochastic nature) by modeling physical occurrences, or "Physical Modeling". The physical modeling in these primary studies ranges from transmission line physical transfer capacity [81] to large-scale integration of theoretical solar farms in the Middle East and North Africa into the EU energy grid [38].

Finally, a number of studies focus their conclusions on recommendations of new electricity products, or "Product Recommendations". These range from introducing more sophisticated bidding formats, such as loop orders and freezing continuous market bids for volume spike accommodation [82], to products specifically designed for battery storage operators, such as volume constrained orders and cumulative volume constrained orders [11].

4.3.5. Forecast error methods

The distribution in Table 14 suggests that methods within the forecast error research area are highly concentrated within a few approaches since the top 6 techniques comprise 71% of all methods used in the 12 forecast error-focused primary studies.

These papers are focused on understanding the impacts increasing vRES integration has had on European electricity markets. For instance, papers utilizing "Autoregression" seek to quantify these impacts though VAR models. The authors of [41] illustrate through usage of a VAR model on a shifted DA generation supply curve that vRES forecast errors exhibit a statistically significant impact on ID prices in the German ID market. The work in [83] showed via a VAR model that the integration of wind energy into the Swedish ID market has been significant in size but also that it has a statistically causal relationship on price premia, load forecast errors, cross-border net exports of electricity across all four Swedish ID market zones. A similar study was conducted for the Danish ID market in [84], where the authors found that vRES forecast errors cause ID prices to differ significantly from DA prices for the same hour of delivery.

Table 12
Distribution of methods utilized within primary studies focusing on the Price forecasting research area in ID electricity market.

Area	Method	Count	Proportion	Cuml. Proportion (N=65)
Price forecasting	Autoregression	11	17%	17%
Price forecasting	Model Comparison	11	17%	34%
Price forecasting	Regression	7	11%	45%
Price forecasting	LASSO	7	11%	55%
Price forecasting	Ensemble Learning	5	8%	63%

Table 13
Distribution of methods utilized within primary studies focusing on the market design research area in ID electricity market.

Area	Method	Count	Proportion	Cuml. Proportion (N=48)
Market design	Multiple Markets	8	17%	17%
Market design	Physical Modeling	6	13%	29%
Market design	Product Recommendations	6	13%	42%
Market design	Econometrics	5	10%	52%
Market design	Policy Review	5	10%	63%

Table 14
Distribution of methods utilized within primary studies focusing on the forecast errors research area in ID electricity market.

Area	Method	Count	Proportion	Cuml. Proportion (N=30)
Forecast errors	Multiple Markets	7	23%	23%
Forecast errors	Autoregression	5	17%	40%
Forecast errors	Descriptive Statistics	3	11%	46%
Forecast errors	Model Comparison	3	11%	57%
Forecast errors	Econometrics	2	7%	64%
Forecast errors	Deterministic Optimization	2	7%	71%

Table 15
Distribution of methods utilized within primary studies focusing on the market abuse research area in ID electricity market.

Area	Method	Count	Proportion	Cuml. Proportion (N=4)
Market abuse	Regression	2	50%	50%
Market abuse	Econometrics	2	50%	100%

4.3.6. Market abuse methods

The market abuse research area, which was included in the final primary study set, was sparse and both leveraged similar techniques as shown in Table 15. Lazarczyk's study, focusing on the Nord Pool market from 2006 to 2009, highlighted the significance of last moment market-specific messages registered through the Urgent Market Message (UMM) framework in explaining the DA vs. ID premium in that market [47]. Building on Lazarczyk's research, Valitov & Maier conducted an analysis of the German EPEX Spot market, utilizing more recent market data (2014–2016) and providing meaningful updates to the existing body of knowledge [48]. The most significant update regarding market abuse by Valitov & Maier was the segmentation of last moment market specific messages registered through the UMM system into public vs. private capacity, revealing an asymmetric impact of information about power plant outages on the average ID price. However, within the scope of this SLR the market abuse research area and the associated techniques used did not extend beyond the thread of research conducted by Lazarczyk and Valitov & Maier based on the predefined research criteria used in this SLR. As mentioned in Section 2, the keyword selection protocol in this SLR could be a threat to the validity of the market abuse research area. Another avenue for developing a comprehensive knowledge base on market abuse topics could involve conducting an SLR that extends beyond the ID market space to encompass all electricity marketplaces (DA, balancing, futures, etc.), and potentially even other commodity markets where the market abuse research area is more mature.

4.4. RQ4: Datasets & ID markets of use

In an era defined by digital access, algorithmic trading and expanded ID market participation, the amount of ID electricity market data has grown exponentially. However, the analysis of primary studies considered in this SLR shows that data diversification is not present within the ID market research space. The German ID electricity market exerts immense gravity in this research space. Similarly, a distinct time-lag is apparent in this research space despite milestone external factors, such as the energy transition, COVID pandemic, and Russia–Ukraine war drastically changing the market background. Table 16 shows the count of exchanges and datasets used by researchers in the included primary studies. This sum of count in Table 16 will exceed the total number of included papers due to a number of primary studies leveraging multiple data sources. This table reveals a number of key insights about data usage patterns amongst ID market researchers and which national markets or European exchanges are most prevalent within research.

Table 16
Exchanges and datasets used by researchers in included primary studies on ID electricity market.

Exchange/Dataset of use	Count
EPEX SPOT	76
OMIE	21
Nord Pool	19
ENTSO-E	8
EPEX M7 Orderbook	5
ID3 (EPEX Product)	3
APX (Now part of EPEX)	3
E-SIOS	2
GB CID	1
IBEX	1
PXE	1
SMARD	1

EPEX SPOT is the dominant choice for ID market researchers utilizing European exchange data. EPEX SPOT, EPEX M7 Orderbook, and APX are all components of EPEX SPOT data. The M7 Orderbook is a derivative dataset of the main trading dataset which contains all orders submitted to the German continuous ID market [2]. Similarly, ID3 is an ID market price index derived from trades on SIDC (prior to SIDC the German EPEX SPOT was the market source). It represents the weighted average price of all continuous trades executed within the last 3 h before delivery of a contract, revealing the imbalance prices of electric offer and demand close to delivery [31]. Therefore, researchers can use ID3 as a proxy for market price imbalance and bid–ask spread close to delivery. APX was a separate exchange covering central European countries, such as Austria, which was fully absorbed into EPEX SPOT in 2016 [85]. EPEX SPOT and associated sources make up almost 60% of all data source choices within the included primary studies.

EPEX SPOT trading activity is heavily impacted by Germany since it is the largest energy market in both Europe and the EPEX SPOT marketplace [1]. This focus on Germany ID market characteristics is made explicit in numerous papers using EPEX SPOT data [7,40,65,86–88].

The Iberian Peninsula is the main southern European area of interest for ID market researchers, with E-SIOS and OMIE being data sources for Iberian ID market activity. OMIE, or Operador del Mercado Ibérico de Energía, is the nominated energy market operator for the Iberian Peninsula [89]. The market name for cross-border trade on the Iberian Peninsula is MIBEL, or Mercado Ibérico de Electricidad, which was established in 2004 [90]. E-SIOS, or Sistema de Información del Operador del Sistema, is the real-time energy transparency platform for Spain and can be compared to ENTSO-E in terms of operational duties and output [91]. The Iberian sources make up 16% of all data source choices within the included primary studies.

ENTSO-E, or the European Network of Transmission System Operators for Electricity, is a European wide association of Transmission System Operators (TSOs) across the differing member nations. Since ENTSO-E is a European level association it supports the European Union's energy and climate objectives, including the integration of renewable energy, the reduction of greenhouse gas emissions, and the development of a resilient and sustainable energy infrastructure. In terms of some of ENTSO-E data offerings, they provide daily updates on generation by production type, load, and vRES forecasts and actuals [92].

Nord Pool is a distinctly secondary choice for research found on northern and western European ID markets compared to EPEX, but this is expected since EPEX is the larger ID market (123 vs. 25 TWh traded on ID in 2021) [93,94]. This is a point of interest which should be followed as the markets continue to develop to ensure that research is not wholly confined within one market.

Trading platform data choice may matter less in the future with continued expansion of the SIDC initiative. However, this is speculative

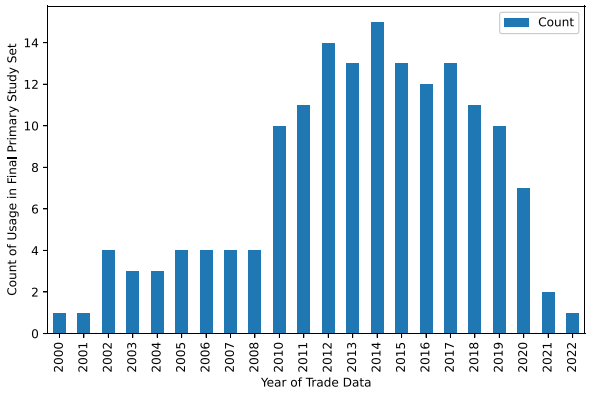

Fig. 3. Count of trading activity data (on yearly level) used in primary study analysis.

and requires significant research into comparative trading behavior across all major European energy exchanges.

Fig. 3 shows the years which the above data sources covered and their count across all included primary studies. This sum of bars in Fig. 3 will exceed the total number of included papers due to several primary studies leveraging multiple data sources. This table reveals a number of key insights about temporal coverage of ID market research.

A significant amount of research relies on trading activity which could be considered outdated in relation to current market conditions (i.e., completion of SIDC and ever increasing vRES share of generation). About 50% of the trading years covered are from a decade prior to this SLR and 87% of trading years covered are from 5 years prior to this SLR. Additionally, the lack of recent trading time coverage especially post-COVID, Russia–Ukraine war, and SIDC completion may be corrected in the coming years, but it will take concerted coordination between researchers and exchanges to make updated data available quickly and cost effectively.

5. Conclusions

In summary, this paper compiled 132 primary studies across three libraries, utilizing a taxonomy focused on classifying European ID electricity market research. This taxonomy and data collection process revealed six major research groups: Bidding, Market Modeling, Price Forecasting, Market Design, Forecast Errors, and Market Abuse. Additionally, methods and datasets were extracted from the final primary study set and thoroughly discussed. While the articles analyzed in this SLR have predominantly concentrated on Germany, the Nordics, and the Iberian Peninsula, noticeable research gaps exist in the exploration of other major EU energy markets, such as the Netherlands and France. The limitations in available datasets also present a challenge to conducting comprehensive research in this domain. Therefore, addressing these gaps and fostering more research in this area is crucial for advancing our understanding of the European ID electricity market.

The current number of prolific, active researchers is low compared to the breadth and importance of ID markets in Europe and variety of research avenues. Additionally, a number of the cited researchers in this paper focus on specific ID market characteristics. For example, Weron et al. have published extensively within the price forecasting area [26,31,32,95–97] and has even done an SLR on Price Forecasting research across DA and ID markets [12]. This is not the case for all researchers, such as Amelin et al. covering Bidding [54,98], Market Modeling [54,73,99], Market Design [100] and Forecast Error impacts [101]. A consequence of a strong concentration of researchers focused on the ID market means that a substantial portion of both authors and reviewers will be shorter-term researchers. The body of knowledge within the ID market is large and continuously growing in importance for market participants in Europe. Fresh researchers will struggle to meet research needs from regulatory agencies and market participants without supportive long-term environments providing best practices. For new researchers entering the field they are caught between a blessing and a difficulty. Since the ID market has a small concentration of highly productive researchers, they will likely have a strong reputation within the academic community. For young researchers able to associate with them, new researchers can gain credibility and recognition in their field. Additionally, they can utilize the experience of productive researchers to assist in establishing their own networks of academic and industry connections. While collaboration with the listed productive researchers can be advantageous, there is a risk that new researchers become overly dependent on them. This dependency may hinder their ability to develop independent research ideas and establish their own academic identity and adapt to newer needs in ID market research as the energy transition continues.

A notable research gap is the reliance on outdated trading activity data, which fails to account for current market conditions, including the completion of SIDC, the increasing share of vRES in electricity generation, and the Russia–Ukraine war. A significant portion of the trading years analyzed in the reviewed literature dates back a decade preceding this SLR, with 87% of the trading years falling within the five-year period before this SLR. This temporal discrepancy underscores the importance of updating research to accurately reflect recent market dynamics. Addressing this limitation would necessitate coordinated efforts between researchers and exchanges to swiftly and cost-effectively make updated data available.

Given the critical importance of understanding market abuse techniques and impacts, it is recommended that researchers conduct a hyper-focused SLR specifically targeting this aspect. Such a dedicated review should purposefully encompass research leveraging datasets from financial markets with more mature market abuse research bases, providing a broader perspective on market abuse beyond electricity markets. By highlighting gaps in existing research and underscoring the need for more comprehensive and up-to-date investigations, this SLR serves as a call to action for researchers to conduct further studies in this domain. Addressing these limitations and delving more extensively into market abuse research can enrich our understanding of electricity market dynamics in relation to the impacts of tactics employed by bad actors. Furthermore, this can contribute to more effective policymaking, regulatory measures, and enforcement in the future.

In general, ID markets are experiencing continuous growth in the number of trades and the volume of MWh traded, underscoring their increasing importance for researchers, market participants, and regulators to understand at a greater level of depth. A comprehensive and continual analysis of ID electricity markets is essential for identifying opportunities to enhance market efficiency and optimize energy resource utilization, which are both of paramount importance in Europe during the era of unstable energy partners and the climate-driven energy transition. Increased research into ID markets can lead to improved resource allocation, reduced costs, and enhanced overall system performance for market participants, regulators, and their stakeholders. Furthermore, there are discussions by ACER about transitioning all ID markets to an auction-based model across SIDC markets, suggesting potential continental changes in ID market design [102].

CRediT authorship contribution statement

Dane Birkeland: Writing – original draft, Resources, Methodology, Investigation, Data curation, Conceptualization. **Tarek AlSkaif:** Writing – review & editing, Supervision, Project administration, Methodology, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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