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Iberian-day-ahead-market-simulator: A Python package to simulate the MIBEL day-ahead market clearing

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ABSTRACT

The day-ahead market is the largest electricity market in Europe by traded volume, yet up-to-date simulation methodologies for reproducible research remain limited. This paper presents iberian-day-ahead-market-simulator, a Python package to reproduce and analyze day-ahead market clearing in the Iberian market (which includes Spain and Portugal), with out-of-the-box compatibility with public data. It enables reproducible experimentation with real day-ahead market data and provides a foundation for research on price formation, counterfactual scenarios, and policy analysis. We validated the package with more than 190 day-ahead market simulations, showing close agreement with observed outcomes in terms of prices, volumes, and cross-border exchanges.

Code metadata.

Nr.	Code metadata description	Please fill in this column
C1	Current code version	0.1.0
C2	Permanent GitHub link to code/repository used for this code version	https://github.com/EloyID/iberian-day-ahead-market-simulator/tree/v0.1.0
C3	Legal Code License	MIT
C4	Code versioning system used	git
C5	Software code languages, tools, and services used	Python
C6	Compilation requirements, operating environments & dependencies	Python 3.11, Gurobi or HiGHS, pyomo, pandas, matplotlib, pandera
C7	If available Link to developer documentation/manual	https://github.com/EloyID/iberian-day-ahead-market-simulator/blob/v0.1.0/README.md
C8	Support email for questions	einsunza@comillas.edu

1. Motivation and significance

The European day-ahead electricity market is the central trading venue through which most short-term wholesale electricity is scheduled in Europe, with more than 5 TWh traded per day on average across 27 countries [1]. Nevertheless, reproducible research on this market is hindered by the limited availability of simulation software that can accurately reproduce historical market outcomes and support counterfactual analyses.

The European day-ahead market is cleared through Euphemia algorithm. In this market, participants submit supply and demand bids for each delivery period, and the clearing process determines accepted quantities, cross-border exchanges, and zonal market-clearing prices [2]. The European market accepts simple bids and non-convex orders. Non-convex orders include:

- Block Orders. An energy profile at a limit price. All periods must be cleared at the same ratio.
- Exclusive Block-Order Groups. A set of Block Orders that are mutually exclusive, meaning that the sum of acceptance ratios of all orders in the group must be less than or equal to 1.
- Scalable Complex Orders. A group of bids linked by a Minimum Income Condition (MIC, fixed term) and/or a Minimum Acceptance Power (MAP, minimum power accepted each period).

The proposed software [3] focuses on MIBEL (the Iberian Electricity Market), a subset of the European market that covers Spain and Portugal

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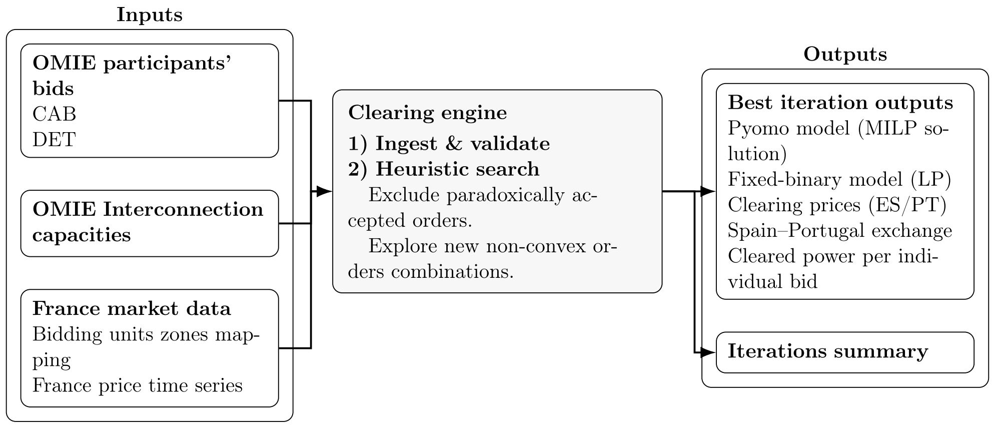

Fig. 1. Schematic overview of the package clearing workflow: inputs, iterative clearing engine, and outputs.

and with more than 1400 agents.[1] MIBEL is managed by OMIE. The software provides an open and reproducible implementation of the MIBEL day-ahead market-clearing process, with direct compatibility with real OMIE input data.

Reproducible simulation of day-ahead market clearing is important for several scientific problems. A first use case is market-optimal bidding. Bi-level formulations explicitly couple participants' bidding decisions with the market-clearing problem. These works could benefit from an open, reproducible market simulator that can be used to evaluate the impact of different bidding strategies on market outcomes [5,6]. A second use case is the integration with deep reinforcement learning bidding approaches that require repeated interaction with a realistic environment [7]. A third use case is helping with regulatory assessments and market design, where an Euphemia-based simulator can be used to evaluate rule changes, such as modified order conditions, and to quantify their impact on clearing outcomes [8–10].

The Euphemia clearing problem has been widely studied from a modeling and algorithmic perspective. The presented software is based on a detailed mathematical formulation provided by Chatzigiannis et al. [11], extended to include modern MIBEL order types. Other works have focused on decomposition methods [12], including balancing-market interactions [9] and additional grid constraints [13].

In parallel, several community implementations have appeared. OpenDAM [14] was developed for the Italian market, but due to a lack of maintenance, it is no longer compatible with current market rules. GECAD's market-clearing service proposes an electricity-market simulator [15] including several European markets, but it is not open source and has not been peer reviewed for the current market conditions. Some educational Euphemia implementations can be found [16], but they have not been peer-reviewed either and are not designed as an installable software.

Overall, the proposed software lowers the engineering barrier for researchers studying day-ahead market and facilitates reproducible research.

2. Software description

This section describes the design and main capabilities of iberian-day-ahead-market-simulator. First, we present the software architecture. Second, we summarize the main software functionalities. Fig. 1 provides a schematic overview of the package workflow, showing the main inputs, the iterative clearing engine, and the resulting outputs.

[1] This quantity was calculated from OMIE agents list. See [4] for the underlying data source.

2.1. Software architecture

The package is organized as a modular Python package that parses raw market data, builds and solves the corresponding market-clearing optimization problem combined with a heuristic search, and returns the results. The main public entry point is the function `run_iberian_day_ahead_market_simulator`, implemented in `clearing_process.py`.

The package is exposed through a Python API and documented through example notebooks, which provide reproducible workflows for data downloading, market-clearing replication, and application examples. A data book is also included in `data_book.md` to explain the structure of the main input and output data tables. The package is structured into three layers.

The first layer covers data ingestion and validation. The module reads raw OMIE input files. Data consistency is enforced through `Pandera` schemas located in the `schemas/` subpackage.

The second layer builds and solves the optimization model. The module constructs the market-clearing model as a `Pyomo` optimization problem from the validated input tables. The solver is selected by the user through a string argument, with support for Gurobi and HiGHS. The clearing process solves the mixed-integer model to determine the activation of non-convex orders and then re-solves the model with fixed binary variables to recover dual information used for price computation. The optimality gap is set to 0 since it can be solved in an acceptable time. Some clearing constraints depend on these same clearing prices, so the package implements an iterative heuristic search to explore different combinations of non-convex orders. This search is implemented in the third layer.

The third layer implements the heuristic search. In each iteration, the module generates new candidate sets of non-convex orders by removing low-contribution orders and reinserting promising excluded orders. Low-contribution orders are those that are accepted in the current iteration but have a small positive or negative contribution to the objective function. Promising orders are those that were previously removed but would have a high contribution to the objective function given the current clearing prices obtained by the best iteration so far. Candidate sets are evaluated using multiprocessing, which allows several combinations of non-convex orders to be explored in parallel. Every candidate set is evaluated by the optimization model, and the best solution across all iterations is returned as the final clearing outcome. The algorithm terminates in the first run if no paradoxically accepted non-convex product is present, or after a user-defined number of iterations otherwise. The heuristic search is reproducible, since the selection of non-convex orders to exclude and reinsert is based on a deterministic ranking of the orders.

Table 1
Absolute error for clearing prices, Spain-Portugal transmissions, and cleared energy of different Bid types. Scenario 1 corresponds to the case study where the France-Spain exchanges are fixed, while in Scenario 2 the exchanges are modeled with bids.

	Scenario	Unit	Granularity	Mean	Median	P75	P95	Max	rMAE (%)
Spain Clearing Prices	1	€/MWh	Hourly	0.07	0.00	0.00	0.49	5.50	0.14
Portugal Clearing Prices	1	€/MWh	Hourly	0.06	0.00	0.00	0.45	5.50	0.12
SP-PT Transmissions	1	MWh	Hourly	5.27	0.00	0.00	13.60	569.90	0.44
Simple Sell Bids	1	MWh	Daily	184.57	100.40	251.45	664.00	1772.60	0.03
Simple Buy Bids	1	MWh	Daily	170.70	98.80	243.15	603.30	1640.10	0.03
Block Orders	1	MWh	Daily	34.43	0.00	0.00	0.00	4609.60	0.92
SCOs	1	MWh	Daily	7.65	0.00	0.00	0.00	1444.30	0.02
Exclusive BO Group	1	MWh	Daily	20.58	0.00	0.00	0.00	3930.00	0.74
Spain Clearing Prices	2	€/MWh	Hourly	0.03	0.00	0.00	0.00	19.48	0.05
Portugal Clearing Prices	2	€/MWh	Hourly	0.03	0.00	0.00	0.00	19.48	0.05
SP-PT Transmissions	2	MWh	Hourly	13.16	0.00	0.00	87.79	796.20	1.11
Simple Sell Bids	2	MWh	Daily	679.26	289.25	849.28	2498.68	6485.30	0.12
Simple Buy Bids	2	MWh	Daily	248.20	164.85	334.58	769.89	1760.10	0.04
Block Orders	2	MWh	Daily	60.38	0.00	0.00	0.00	4609.60	1.61
SCOs	2	MWh	Daily	70.14	0.00	0.00	0.00	7595.00	0.21
Exclusive BO Group	2	MWh	Daily	62.29	0.00	0.00	0.00	3930.00	2.26

The package returns a dictionary containing the unfixed and fixed-binary models, iteration diagnostics, cleared bid-level data, clearing prices, Spain–Portugal transmissions, and an iteration summary.

2.2. Software functionalities

The software is designed as a counterfactual simulation environment for the MIBEL day-ahead market. Its central functionality is to run an optimization-based market-clearing process. The main Python API parses the data, constructs the market-clearing problem, solves it, and returns market outcomes in analysis-ready data structures.

The core inputs are the day-ahead bids submitted by each bidding unit. OMIE publishes these bids in two complementary files: the *Header of bids for Day-ahead Market* [17], and the *Day-ahead market bid details* [18]. In addition to bids, the clearing model requires OMIE files with interconnection information [19], which are used to model the Spain–Portugal exchange and the interaction with external areas (e.g., France). Optionally, users can also provide French price data to model the France–Spain interaction through a bid-based proxy representation.

The interaction with France can be represented through step bids reflecting the actual French residual demand. However, this information is not publicly available and demands additional modeling effort. Therefore, the package also proposes two alternative approaches for modeling the France–Spain interaction, depending on the user's preference and available data. Users can either fix France–Spain exchanges to observed historical values, or use a bid-based proxy representation based on French clearing prices and interconnection capacities. Both are generated out-of-the-box from the input data, and the user can select the desired representation.

The package exposes parsers for OMIE files, so users can modify input data. This allows counterfactual scenarios to be constructed directly from real market data. The example notebooks illustrate this workflow through several scenarios, including reproducing a historical clearing, deleting a bidding group, removing all minimum income conditions for a day, and modifying wind or solar production volumes.

Solver selection is configurable through a string argument, with support for Gurobi and HiGHS [20,21]. This allows users to choose between a commercial high-performance solver and an open-source alternative, depending on their computational environment and licensing constraints.

The main output of the clearing process is a dictionary containing data of the best solution: both Pyomo models (with and without fixed binary variables), clearing prices, Spain–Portugal exchange, and cleared bid-level quantities. Also a DataFrame summarizing the iterations of the heuristic search is returned.

Returning both aggregate results and model objects is useful for different user profiles. Users interested in market outcomes can work directly with the price, exchange, and cleared-energy tables. Users interested in optimization diagnostics can inspect the Pyomo models, objective values, and iteration-level information.

The tools provided make the package suitable for reproducible historical replication, sensitivity analysis, and user-defined counterfactual studies of the MIBEL day-ahead market.

3. Illustrative examples

We illustrate the use of the package through two sets of historical replication experiments. Both experiments simulate 195 day-ahead market sessions in the MIBEL region between 19 March and 30 September 2025. The objective is to assess whether the software can reproduce the main observable market outcomes from public market data and provide a reliable basis for counterfactual analysis. The two sets of experiments differ in the representation of the France–Spain interaction. Experiments have been run using Gurobi solver and 150 iterations. Table 1 summarizes the distribution of absolute errors obtained in both experiments. Since clearing prices and Spain–Portugal exchanges can be zero or negative, we also report the relative mean absolute error (rMAE) as defined in Eq. (1):

$$\mathrm{rMAE} = \frac{\sum_i |\hat{y}_i - y_i|}{\sum_i |y_i|} \times 100 \tag{1}$$

where $\hat{y}_i$ is the simulated value and y_i is the observed value. The rMAE provides a scale-free measure of error that is useful for comparing across different quantities.

3.1. Fixed cross-border exchanges with France

In the first experiment, France–Spain cross-border exchanges are fixed to their observed values. This setting minimizes external sources of variability and isolates the Iberian clearing problem.

The software reproduces clearing prices with high accuracy: the mean absolute error is 0.07 €/MWh for Spain and 0.06 €/MWh for Portugal. The mean absolute error of Spain–Portugal transmission is 5.27 MWh for a time series that typically ranges around ± 2000 MWh. These results indicate that, when external exchanges are controlled, the software reproduces the main price and exchange outcomes of the Iberian clearing process.

The same experiment also shows close agreement in cleared quantities. For simple bids, the mean daily error is 184.57 MWh for sell bids and 170.70 MWh for buy bids, which is negligible compared with total daily cleared volumes of around 5×10^5 MWh. For non-convex orders, the mean daily errors are 34.43 MWh for Block Orders, 7.65 MWh for Scalable Complex Orders, and 20.58 MWh for Exclusive Block-Order Groups. In most simulated days, the package reproduces the cleared non-convex orders exactly. No relative error is above one percent.

These discrepancies are informative because they identify the practical limits of the simulator. First, the heuristic search explores only a finite number of combinations of non-convex orders. Second, the simulator maximizes welfare within the modeled MIBEL system. By contrast, the official day-ahead clearing is part of the wider European coupled market and accounts for additional bidding zones. Therefore, the welfare-maximizing combination of non-convex orders within the modeled MIBEL subsystem may differ from the welfare-maximizing combination when taking into account the whole European market. As a result, the package should be interpreted as a reproducible approximation of the MIBEL clearing process rather than a complete reimplementation of Euphemia.

3.2. Bid-modeled cross-border exchanges with France

In the second experiment, France is represented through bid-based proxy orders. For each period, the model includes a simple sell or buy bid with quantity equal to the available import or export capacity and price equal to the observed French clearing price. This second configuration is more suitable for simulation studies because the France–Spain exchange can react to the simulated Iberian clearing. However, it remains an approximation, since it assumes that French prices are exogenous with respect to the MIBEL outcome.

The second experiment replaces fixed France–Spain exchanges with bid-based proxy modeling. This configuration reduces the mean absolute error of clearing prices to 0.03 €/MWh in both Spain and Portugal. The improvement is explained by the role of France as a strong marginal price signal. At the same time, error of Spain–Portugal exchanges remains small relative to the scale of the interconnection time series.

Cleared-energy errors are also larger in the bid-based experiment, but these errors remain moderate compared to total cleared energy. They reveal the trade-off associated with modeling an external coupled market using proxy bids.

Together, the two experiments show that the package provides a useful and transparent simulation environment. The fixed-exchange configuration validates the internal MIBEL clearing formulation under controlled external conditions, while the bid-based configuration illustrates how the same software can be used when cross-border exchanges must respond to Iberian conditions.

4. Impact

The main impact of iberian-day-ahead-market-simulator is to make reproducible experimentation with the MIBEL day-ahead market substantially easier for energy-market researchers. Until now, studies requiring day-ahead market-clearing outputs often had to rely on simplified market models, private implementations, or ad hoc scripts tailored to a specific case study. This limited the reproducibility of results and made it difficult to compare alternative assumptions about bids, non-convex orders, cross-border exchanges, or renewable generation. The software addresses this gap by providing a public Python package that contains the necessary logic for market-clearing simulation.

The software enables new research questions related to the role of non-convex orders in market outcomes. In particular, the inclusion of Block Orders, Exclusive Block-Order Groups, and Scalable Complex Orders allows researchers to study how these products affect price formation, cleared volumes, and economic surplus. This is especially relevant because Scalable Complex Orders are a recent product in the European day-ahead market and remain less studied than standard hourly bids or traditional Block Orders. The package makes it possible to analyze these questions using real market data and conditions.

A second set of research questions concerns counterfactual scenarios. By exposing file parsers, the package allows users to modify bids. For example, this makes it possible to evaluate how changes in wind or solar bid volumes affect clearing prices, cross-border exchanges, non-convex product activation, and cleared energy. These analyses are useful for studying the market impact of renewable penetration, curtailment, bidding assumptions, and price sensitivity under realistic order structures. Another application would be to evaluate the impact of different operating costs and carbon dioxide emission costs on the market-clearing outcomes via the modification of the bid prices. The example notebooks included with the software demonstrate this workflow by modifying wind and solar production volumes, removing bidding groups, changing bid prices, and eliminating minimum income conditions.

The software also improves the pursuit of existing research questions by reducing the engineering effort required to obtain reproducible market-clearing results. The package consolidates this logic into a maintained Python library with a single public entry point, reproducible example notebooks, tests, documentation, and a standard installation path through PyPI. Users can update the software with pip, reproduce the paper's experiments through the provided notebooks, and build new studies by modifying the parsed data structures.

At the time of writing, the software is publicly available on GitHub and PyPI under the MIT license. The repository includes a README, examples, tests, a citation file, and documentation. Early adoption indicators include 17 GitHub stars, approximately 300 PyPI downloads, and direct contacts from researchers through LinkedIn. The software is accompanied by a publicly available methodological preprint that describes the underlying market-clearing formulation, validation experiments, and modeling assumptions in greater detail [22]. The software has also been used in a conference paper, although no citable publication based on the package has yet appeared beyond the present paper. These figures indicate early-stage community interest, but the software should still be regarded as an emerging research tool rather than a widely adopted standard.

Code quality is checked with Ruff. The remaining reported issues correspond to unused-variable warnings caused by variables that are consumed inside pandas query/evaluation strings, which static analysis tools cannot reliably detect. Code formatting is enforced with Black. Data consistency is enforced with Pandera schemas, which validate the expected types, columns, and admissibility conditions of the main tabular inputs and outputs used throughout the simulation workflow.

Code coverage was measured with pytest-cov. The current test suite achieves 42% line coverage. The repository currently includes 122 pytest tests covering data parsing, preprocessing, model construction, and the iterative heuristic search. Continuous integration is implemented with GitHub Actions. The CI workflow installs the package and runs the pytest test suite in Python 3.11. The package is under active development, and future releases will expand the test suite to cover additional functionalities and edge cases.

The package may be useful in applied settings where transparent day-ahead market simulation is required, such as academic-industry collaborations, regulatory studies, bidding-strategy design and analysis, and training environments for electricity-market practitioners. Its immediate impact is therefore scientific and methodological: it provides an open, reproducible, and extensible basis for studying MIBEL day-ahead market clearing with realistic order data and modern non-convex orders.

5. Execution time and computational resources

All experiments were executed using the Gurobi solver on a machine running Ubuntu 24.04.2 LTS with an AMD Ryzen 9 PRO 8945HS CPU (8 cores, 16 threads; 16 logical processors) and 64-bit operating mode.

Fig. 2 reports the wall-clock time (in seconds) required to solve a single day-ahead market instance for both series of experiments. Each simulated market involved a median of 2576 bidding units and more than 66,000 individual bids. Overall, the runtime distributions are very similar across the two modeling approaches, although two clear clusters can be identified.

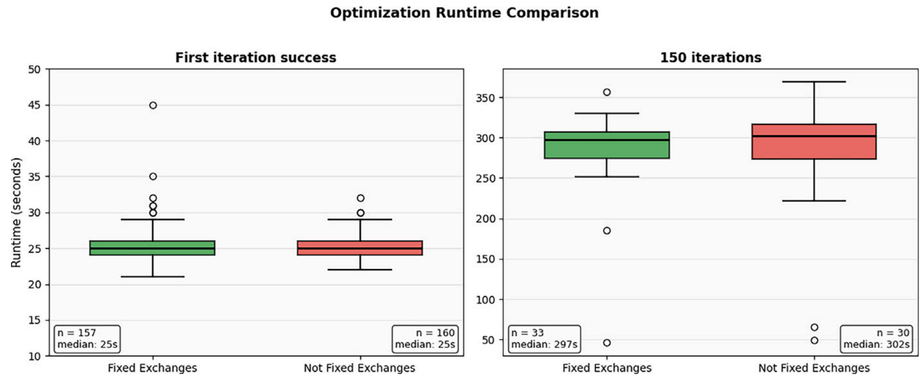

Fig. 2. Wall-clock time required to solve one DAM instance for the two series of experiments. Two runtime clusters appear: non-iterative instances (no paradoxically accepted group) and iterative instances (150 iterations).

The first cluster corresponds to markets in which no paradoxically accepted non-convex product is present. In these cases, the algorithm does not need to iterate: one solve is sufficient, combined with operations such as data consistency checks and summary generation. As shown in Fig. 2, these instances typically require between 20 and 30 s.

The second cluster corresponds to markets in which the algorithm must iterate. These instances run the full set of 150 iterations and require between 200 and 400 s per market, i.e., an order-of-magnitude increase in runtime. The increase is moderated by parallelization, which helps keep the scaling below what would be expected from a purely sequential execution.

6. Conclusions

This paper presented iberian-day-ahead-market-simulator, an open-source Python package for reproducing and analyzing day-ahead market clearing in MIBEL using real OMIE input data. The software provides an end-to-end workflow that parses market files, validates and preprocesses the data, clears the market with a heuristic search combined with an optimization model, and returns analysis-ready outputs. Outputs include clearing prices, Spain–Portugal exchanges, cleared bid-level quantities, solved models, and iteration diagnostics. By packaging these steps into a reusable Python API and documented notebooks, the software reduces the engineering effort required to perform reproducible electricity-market simulations.

The package is intended to support counterfactual analysis. The package tools allow users to modify parsed bid data and system constraints and rerun the clearing process. This makes the software useful for studying price formation, alternative renewable generation scenarios, the activation of non-convex orders, and the market impact of Scalable Complex Orders, Block Orders, and minimum income conditions.

The validation experiments over 195 day-ahead market sessions between 19 March and 30 September 2025 show that the package reproduces the main observable market outcomes with low average error. In a first experiment, France–Spain exchanges are fixed to observed values to reduce uncertainty. In this setup, the simulator achieves small mean absolute errors in Spanish and Portuguese clearing prices, Spain–Portugal exchanges, and cleared energy by order type. A second experiment using bid-based proxy modeling for France shows that the software can also support more flexible cross-border representations, although with the expected trade-off between historical replication accuracy and counterfactual flexibility.

The current implementation should be interpreted as a reproducible approximation of the MIBEL clearing process, not as a complete reimplementation of Euphemia. First, the price-determination procedure is simplified: clearing prices are obtained from the dual variables of the fixed-binary linear model, rather than through the full price-determination optimization subproblem used in Euphemia. This simplification can lead in some cases to price deviations, whose magnitude is quantified in the validation experiments reported in this paper. Second, the implementation does not reproduce all Euphemia tie-breaking and volume-indeterminacy rules. In particular, curtailment sharing and volume maximization procedures are not implemented, so bids located at or near the clearing price may be accepted or rejected differently from the official market outcome.

A further limitation concerns the finite heuristic exploration of non-convex product combinations. The number of iterations required to identify a high-quality solution may vary across market configurations and can be tuned by the user; the validation results in this paper are reported for 150 iterations. Moreover, the representation of France remains simplified. In the bid-based configuration, observed French market outcomes are used as inputs to the Iberian clearing process, even though the French and Iberian markets are interdependent in the coupled European day-ahead market. Additionally, the package is currently implemented for hourly rather than quarter-hourly clearing.

A final limitation concerns maintainability with respect to evolving market rules and data formats. The package has a hard dependency on the structure of OMIE input files, since this is precisely what allows users to work directly and easily with real market data. This design choice, therefore, involves a trade-off: direct compatibility with operational data improves reproducibility and usability, but it also requires the codebase to remain synchronized with future changes in OMIE files, market products, and clearing rules. In practice, OMIE data formats have shown substantial consistency, and electricity-market rules typically evolve through regulated processes rather than abrupt overnight changes. Moreover, the package is open source, so broader adoption can also support long-term maintenance through community contributions, issue reporting, and updates when market conventions change.

Future development will focus on improving external-market representation, extending support to quarter-hourly data, refining price and tie-breaking procedures, and expanding the treatment of additional order conditions. These extensions will further increase the value of the package as an open research infrastructure for reproducible day-ahead electricity-market analysis. Furthermore, France could be modeled with stepwise bids based on residual demand, which would allow for a more flexible representation of the interaction between the two markets. Additionally, the package structure could be applied to other electricity markets, like the Intraday Auction Market (IDAM), which also follows a marginal-pricing scheme, or to other bidding zones of the European Day-Ahead Market.

CRediT authorship contribution statement

Eloy Insunza: Writing – original draft, Visualization, Validation, Software, Methodology, Investigation, Formal analysis, Conceptualization. **José Portela:** Writing – review & editing, Supervision, Project administration, Methodology, Conceptualization. **Antonio Muñoz:** Writing – review & editing, Supervision, Project administration, Methodology, Conceptualization.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used OpenAI ChatGPT and GitHub Copilot to generate the LaTeX code and improve the writing. After using these tools/services, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

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.

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