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APE
APPUNTI DI ENERGIA

EUPHEMIA – European Day-Ahead Market Clearing Algorithm

October 2025

What is it

Euphemia public description

APE on DAM

The Italian electricity market is integrated with other European markets: an operator (producer or consumer) trading on the market of a particular country thus has access to other European markets, with the possibility of freely exchanging energy between different states (while respecting the transport capacities of the grid). The price established for each individual market is therefore calculated simultaneously throughout Europe and intrinsically depends on the offers submitted in other countries as well.

The calculation of prices takes place thanks to the initiative called Price Coupling of Regions (PCR), which aims to develop a single solution for the European day-ahead market. **One of the key elements of PCR is the creation of a single coupling algorithm known as Euphemia** (an acronym for Pan-European Hybrid Electricity Market Integration Algorithm). Euphemia thus calculates the energy prices for each market zone and defines the quantities of energy that must be exchanged between the zones for the following day.

Price coupling of Regions

EPEX SPOT: *Austria, Belgium, Denmark, Germany, Finland, France, Luxembourg, Netherlands, Norway, Poland, Sweden, United Kingdom, and Switzerland.*
GME: *Italy*
HEnEx: *Grecia*
Nord Pool: *Nordic, Baltic, British, German, Polish French, Dutch, Belgian, and Austrian markets. It also provides trading platform and market coupling services in Croatia, Bulgaria, and Georgia.*
OMIE: *Spain e Portugal*
OPCOM: *Romania*
OTE: *Czech Republic*
TGE: *Poland*

The Price Coupling of Regions (PCR) is an initiative involving eight Energy Exchanges: EPEX SPOT, GME, HEnEx, Nord Pool, OMIE, OPCOM, OTE, and TGE. The PCR covers electricity markets in the entire of Europe as shown in figure 1. This initiative is aimed at calculating electricity prices throughout Europe and allocating interconnection capacity on the Day-Ahead Market (DAM).

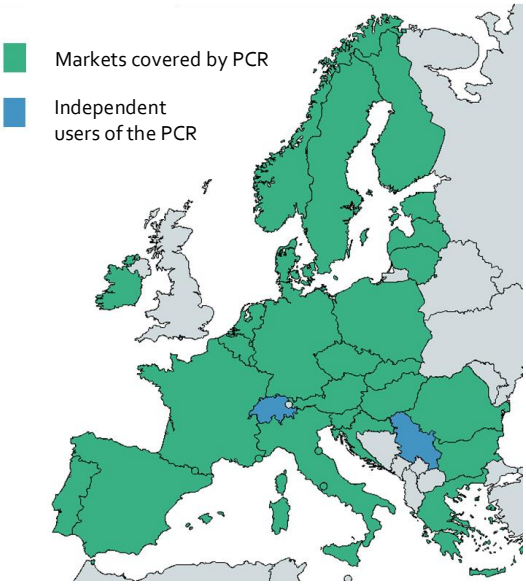


Figure 1 - Countries covered by PCR

How Euphemia works

Euphemia: description and funcioning (PCR)

Euphemia is the algorithm that solves the market coupling problem within the PCR perimeter. To function, each market participant submits their order to their respective Energy Exchange. All these orders are collected and sent to Euphemia, which must decide which offers to accept and which to reject, with the goal of maximizing the social welfare (calculated as the sum of consumer surplus, buyer surplus, and congestion rents between market zones).

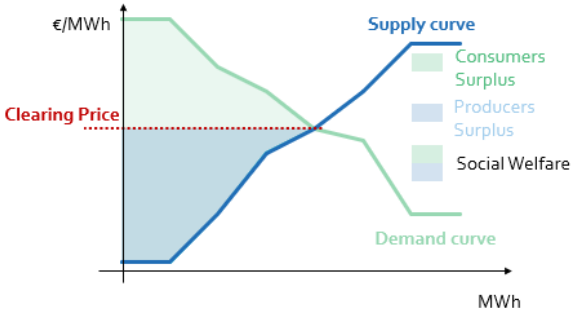
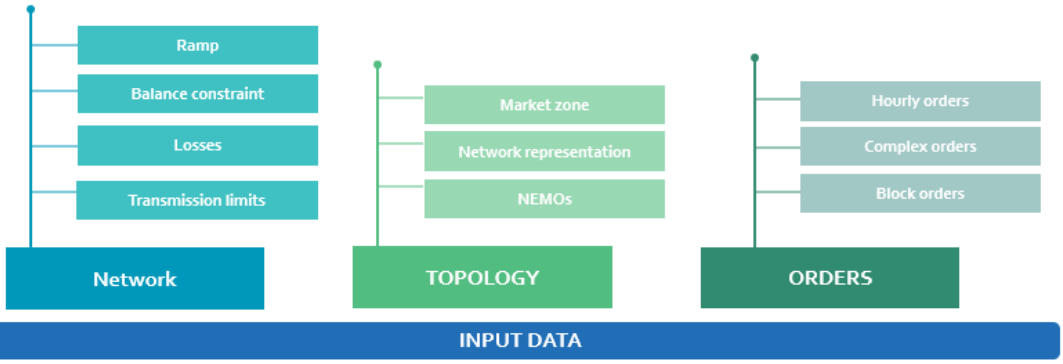


Figura 2 - Consumer surplus and producer surplus; their sum represents social welfare

The input to Euphemia

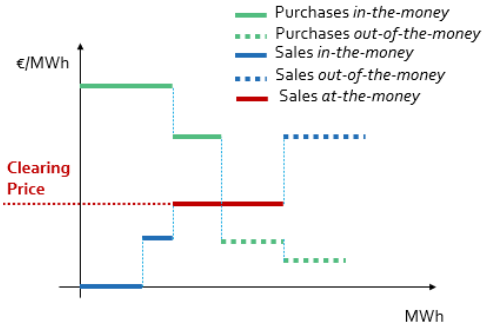
The algorithm analyzes all market zones (bidding zones) simultaneously, returning a price for each individual zone. The solution emerges after processing a wide variety of data.



Simple orders

The purchase (sale) orders of all market participants belonging to the same zone are aggregated into a single curve called the purchase (sale) curve. Purchase orders are sorted from the highest to the lowest price, while sale orders are sorted from the lowest to the highest price.

A purchase (sale) order is considered *in-the-money* if the market price (Clearing Price) is lower (higher) than the order price.
A purchase or sale order is considered *at-the-money* if the Clearing Price is equal to the order price.
A purchase (sale) order is *considered out-of-the-money* if the Clearing Price is higher (lower) than the order price.



Each *in-the-money* order must be fully accepted. Each *out-of-the-money* order must be fully rejected. *At-the-money* orders may be accepted (partially or fully) or rejected.

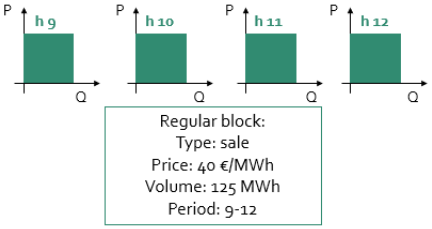
Block orders

Regular block orders

Regular block orders are defined by:

- type (purchase or sell)
- single price
- single volume
- period: consecutive hours to which the block applies.

A regular block order cannot be partially accepted. It is either fully rejected or fully accepted (*kill-or-fill* condition).

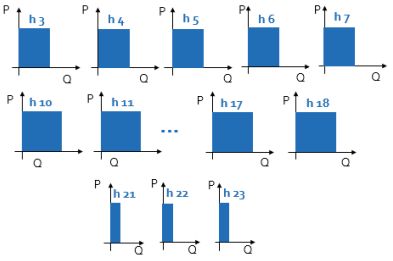


Profile block orders

Profile block orders are defined by:

- type (purchase or sell)
- single price
- *Minimum Acceptance Ratio*
- period: hours over which the block extends
- a quantity for each period.

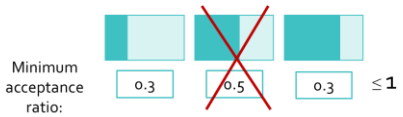
A *profile* block is accepted if the acceptance ratio (accepted volume / total offered volume) is greater than or equal to the *Minimum Acceptance Ratio*.



Block *profile*
Type: purchase
Price: 50 €/MWh
Minimum acceptance ratio: 0.5
Periods: 3-7, 10-18 e 21-23
Volume: 80 MWh (1° period), 220 MWh (2° period), 40 MWh (3° period)

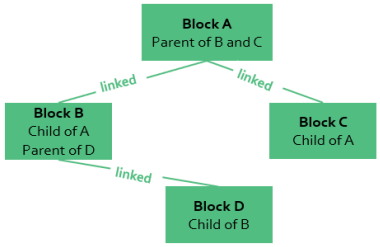
Exclusive block orders

An exclusive group is a set of block orders for which the sum of the acceptance ratios cannot exceed 1. In the specific case of blocks with a *Minimum Acceptance Ratio* of 1, this means that at most one of the blocks in the exclusive group can be accepted. Among the different valid combinations of accepted blocks, the algorithm chooses the one that maximizes the optimization criterion.



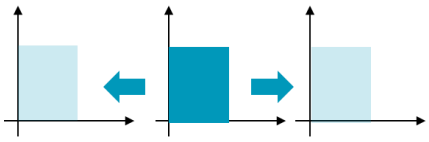
Linked block orders

Block orders can be linked to each other, meaning that the acceptance of individual block orders can be made dependent on the acceptance of other block orders. The block whose acceptance depends on another block is called the "child block", while the block that conditions the acceptance of other blocks is called the "parent block".



Flexible block orders

A flexible order is a regular block order with a fixed price limit, a fixed volume, a minimum acceptance ratio of 1, and a duration of 1 period. The period is not defined by the participant but is determined by the algorithm (hence the name 'flexible'). The period in which the flexible order is accepted is computed by the algorithm and determined according to the optimization criterion.



Complex orders

A complex order is a set of simple step orders (all either sell or buy) from a single market participant, covering multiple time periods and subject to various conditions that affect the entire set of orders.

Minimum Income Condition

Minimum Income Condition (MIC) orders are simple orders subject to a specific economic condition to be accepted. The MIC constraint requires that the total revenue across all periods must cover the production costs of the order, which are defined by a fixed term (FT – calculated in euros, representing the start-up costs of a power plant) and a variable term multiplied by the total allocated energy (VT – representing the operating cost per MW produced per period in a power plant).

$$Revenue\ MIC \geq FT + VT \cdot MWh_{accepted}$$

Maximum Payment Condition

Maximum Payment (MP) orders are like MIC orders, but with a constraint on purchasing. The MP constraint requires that the total payment across all periods be lower than the sum of a fixed term and a variable term multiplied by the total allocated energy.

$$Payment\ MPC \leq FT + VT \cdot MWh_{accepted}$$

Scheduled Stop

The Scheduled Stop condition applies only to MIC orders to prevent a plant from being shut down in case the economic condition is not met. The use of a Scheduled Stop modifies the non-acceptance of the MIC, which will instead be treated as a simple order by accepting the first (i.e., the most economical) of its orders. Scheduled Stop periods must be consecutive, may start in the first period of the day, and can extend up to the first three hours of the day. No Scheduled Stop can be defined for complex MP orders.

Load gradient

The load gradient constraint links the energy quantity of a given period to that of the previous period. A maximum increase/decrease is allowed (the same value applies to all periods). Period 1 is not constrained by the matched energy of the last period of the previous day.

Merit orders and PUN

Merit orders are numbers uniquely associated with simple orders to classify them according to acceptance priority. The lower the *merit order* number, the higher the priority for acceptance. More precisely, when, within a non-congested set of adjacent bidding zones, different orders with *merit orders* have an offer price equal to the market price, the order with the lowest *merit order* number should be accepted first, unless other network constrains have to be taken into account.

APE on PUN

The **Unique National Price (PUN)** is a purchase price that Italian buyers have been subject to regardless of the zone in which they are located. The PUN was introduced at the inception of the Electricity Market in order to eliminate, from the buyer's perspective, the price differences between various zones. This was intended to prevent imbalances among consumers caused mainly by the uneven geographical distribution of generation plants across the country—plants which also differ in efficiency—as well as by the limited transmission capacity of the grid, which is not always able to carry the required energy from low-price zones to high-price zones.
As of January 1st, 2025, the PUN has been phased out and replaced by a zonal pricing system, meaning that each "electricity zone" now has its own wholesale energy price.
The *"old PUN"* has not disappeared entirely; it has been redefined as the **PUN Index GME**. It is calculated ex post as the average of zonal prices weighted by zonal demand, and serves as a reference, including for the application of a transitional mechanism established by ARERA resolution 304/2024/R/eel, which provides for its duration "at least until December 31, 2025". This mechanism is intended to shield consumers from the differences between zonal prices and the PUN Index.

Euphemia network

Transmission System Operators (TSOs) provide Euphemia with information about the transmission network that must be considered as input constraints in calculating the final solution.
A *bidding zone* corresponds to a geographical area to which network constraints are applied. Bidding zones can exchange energy with each other through three different models:

Net position refers to the difference between the supplied and demanded quantities fulfilled within a given bidding zone.

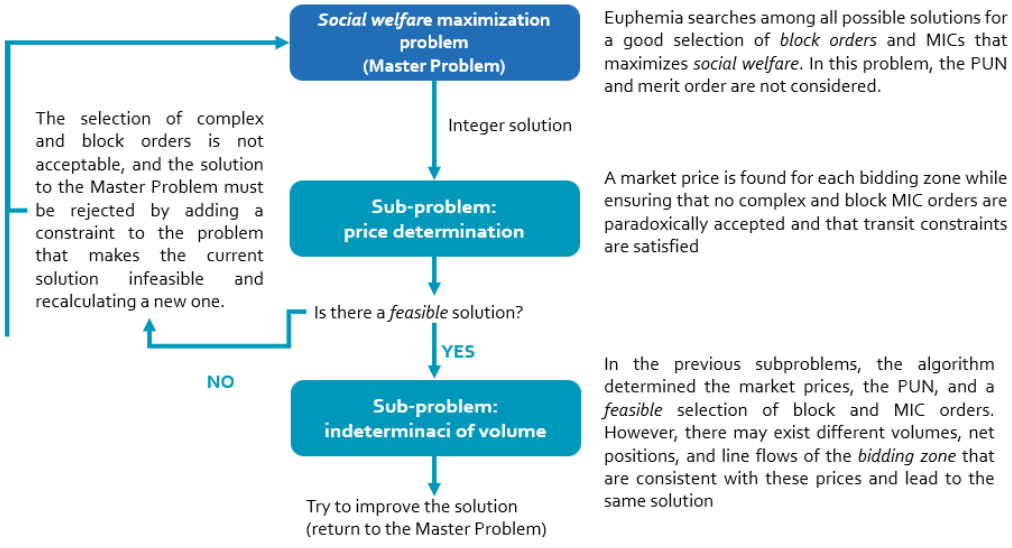
Contingency scenario refers to grid faults that must be controlled by the TSO must

ATC model	*flow-based* (FB) model	Hybrid model
The network is described as a set of lines interconnecting the *bidding zones*. Energy from one bidding zone to an adjacent zone can only flow through these lines and is limited by the *available transfer capacity* (ATC) of the line.	It allows for a more accurate modeling of physical flows, expressing the constraints arising from Kirchhoff's laws and the physical elements of the grid under the different contingency scenarios considered by the TSOs. The FB constraints are provided through two components: • *Remaining Available Margin* (RAM): the number of MW available for exchanges • *Power Transfer Distribution Factor* (PTDF): coefficient that indicates the incremental change in real power flow on a transmission line resulting from a power transfer between two nodes or zones of the electrical system.	Combination of the two previous models. Some *bidding zones* are connected through the *flow-based model*; the remaining ones through the ATC network model.

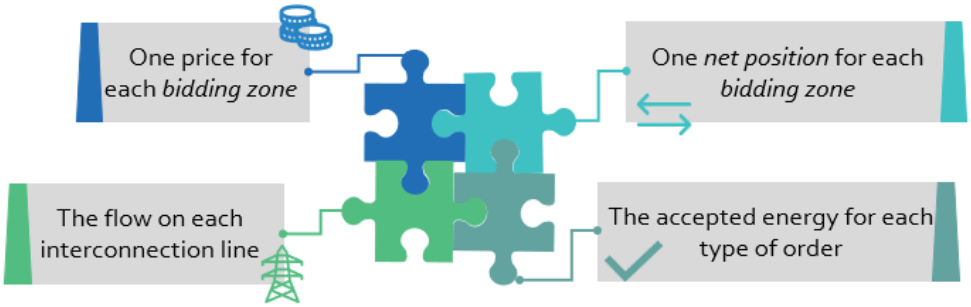
Euphemia also considers a set of transmission-related constraints: ramping limits between consecutive hours (for single lines or groups of lines), line losses, and ramping limits of the hourly and daily net position for the *bidding zones*.

Algorithm features

If block orders, complex orders and *merit order* were not present, the *market coupling* problem could be modeled as a quadratic program (QP) and solved using commercially available solvers. However, the presence of these orders makes the problem more complex. In fact, the *kill-or-fill* property of block orders and the *minimum income condition* (MIC) of complex orders require the introduction of binary variables (for example, 0/1). Additionally, the *merit order* and the PUN further increase the complexity of the problem.
To solve this complexity, Euphemia performs a combinatorial optimization process, solving a *social welfare* maximization problem (also called the *Master Problem*) and two interdependent subproblems: the price determination subproblem and the volume indeterminacy subproblem. In Euphemia, it may happen that some bids are paradoxically accepted; this particular situation refers to an order that, according to apparent economic or technical logic, should not be accepted, but is nonetheless accepted to ensure the overall consistency and feasibility of the optimal solution.



Euphemia output



The goal of the algorithm is to find the best possible solution within the boundaries set by market and network rules, and to do so as quickly as possible. The process continues until certain convergence criteria are met, the most important being time: the algorithm has about 12 minutes to complete its calculation[1].

Euphemia is designed to deliver transparent and efficient results. Among the feasible solutions it identifies, the one that maximizes overall economic welfare is selected ensuring that energy is distributed fairly, resources are used efficiently, and costs are minimized for both producers and consumers, all while respecting market and network rules.

The main outputs generated by Euphemia include:

- **Electricity prices**: For each bidding zone, the algorithm calculates the market price in €/MWh. This price reflects the balance between supply and demand, while also considering network constraints;
- **Net position**: This shows whether a bidding zone is importing or exporting electricity, based on the difference between energy bought and sold;
- **Flows across interconnections**: These represent the physical movement of electricity between zones via transmission lines. Flows are limited by network capacity and influence local prices.

From October 1, 2025, the European Day-Ahead market (SDAC) will move from hourly resolution to a 15-minute resolution. In this new framework, market participants will be able to submit orders with 15-minute granularity, while hourly (and in some cases half-hourly) orders will continue to be supported through cross-product matching (i.e. orders of different durations can be combined with each other during the clearing process). This will allow for more granular bidding, better reflecting intraday variations and supporting greater flexibility in the power system.

[1] *For the complex scenarios, Euphemia algorithm may not be able to find the optimal solution within the expected time frame (about 12 minutes, which represents the "stopping condition"' as specified in the official Euphemia documents, so that the output can be used in downstream markets). When this happens, it continues searching for at least one valid solution during a second time window.*

Notes by:

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We would like to thank Federica Davò (Senior Associate – Energy Scenario and Market Regulation, MBS Consulting) for her valuable contribution to the analysis and discussion of this APE.

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This work has been financed by the Research Fund for the Italian Electrical System under the Three-Year Research Plan 2025-2027 (MASE, Decree n.388 of November 6th, 2024), in compliance with the Decree of April 12th, 2024