PCR
PRICE COUPLING OF REGIONS

EUPHEMIA:
Description and functioning

Date: May 2014

EPEXSPOT GME Gestore Mercati Energetici nordpool spot omie opcom OTE TGE POLISH POWER EXCHANGE

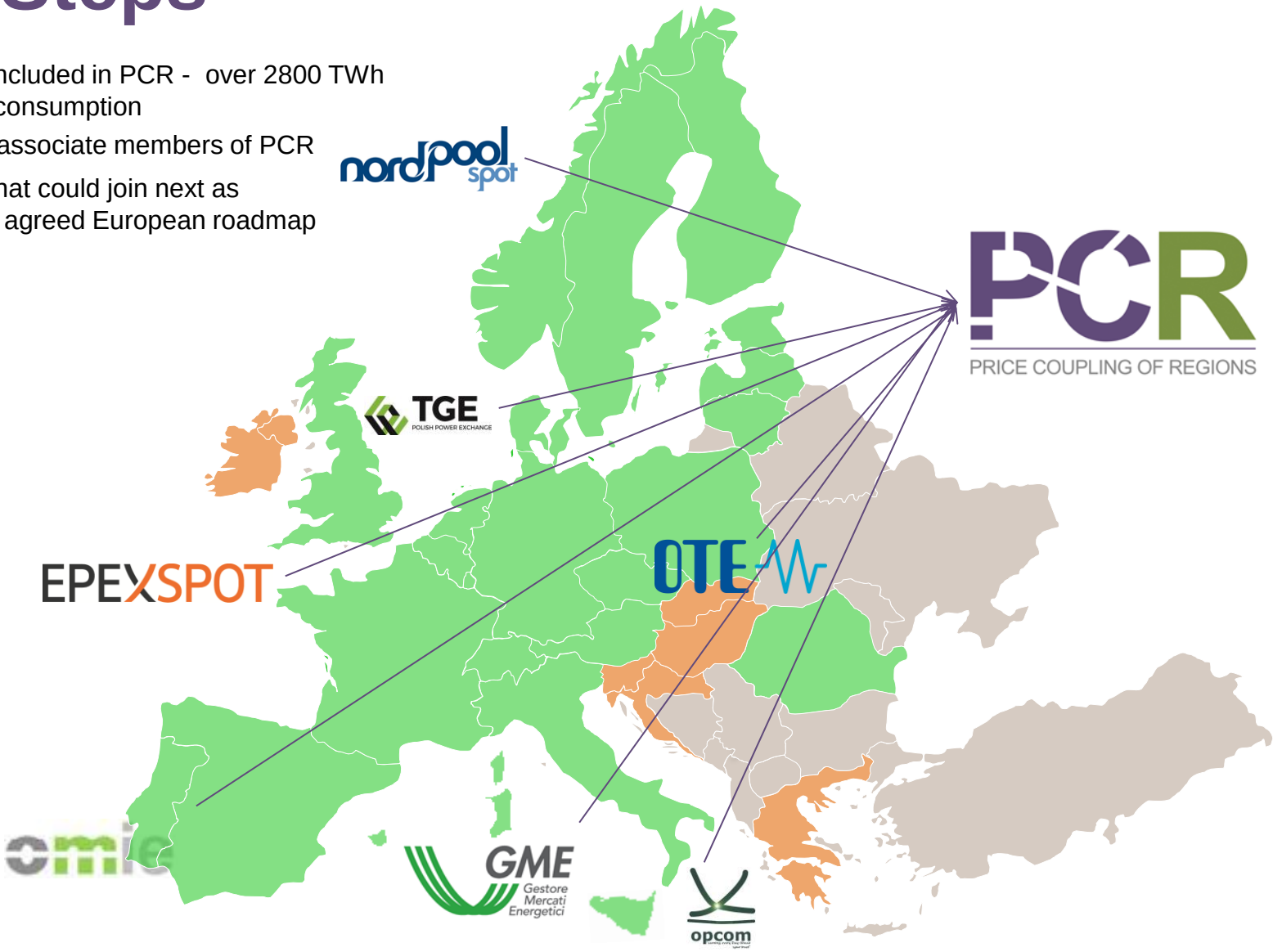
Supported by: europex association of european energy exchanges

Towards Single European Market: Next Steps

Markets included in PCR - over 2800 TWh of yearly consumption

Markets associate members of PCR

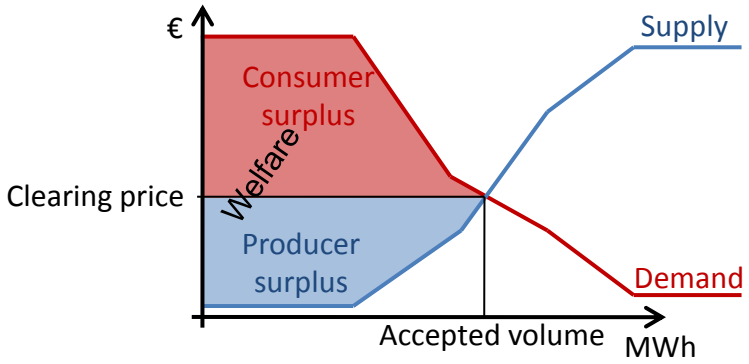
Markets that could join next as part of an agreed European roadmap



ALGORITHM EUPHEMIA

- EUPHEMIA is an algorithm that solves the market coupling problem on the PCR perimeter.
  - EUPHEMIA stands for: EU + Pan-european Hybrid Electricity Market Integration Algorithm.

- It maximizes the welfare of the solution
  - Most competitive price will arise
  - Overall welfare increases
  - Efficient capacity allocation



Algorithm has been tested using real 2011/2012/2013/2014 daily order books (around 50 bidding areas and 60 ATC lines)

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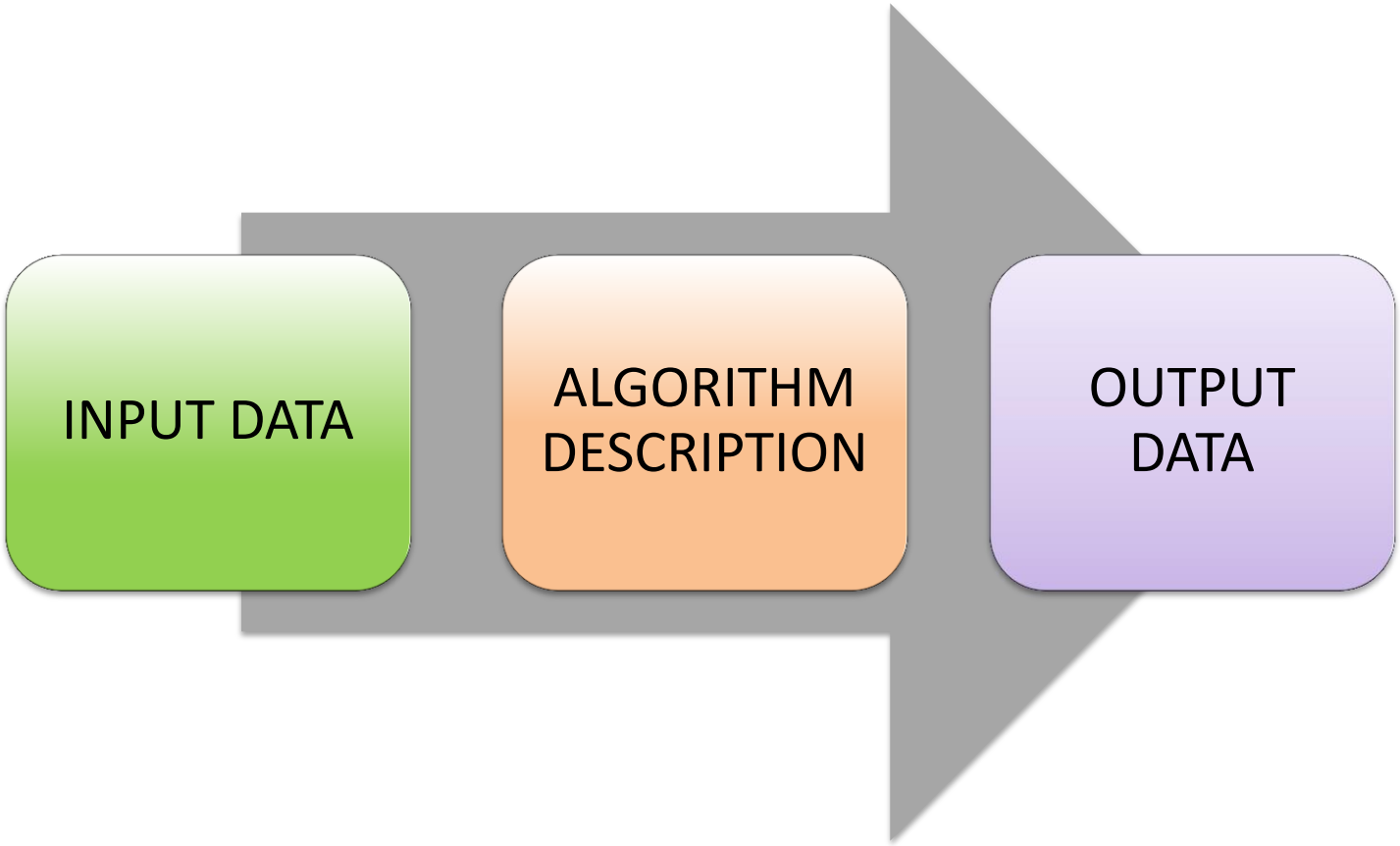
GENERAL DESCRIPTION



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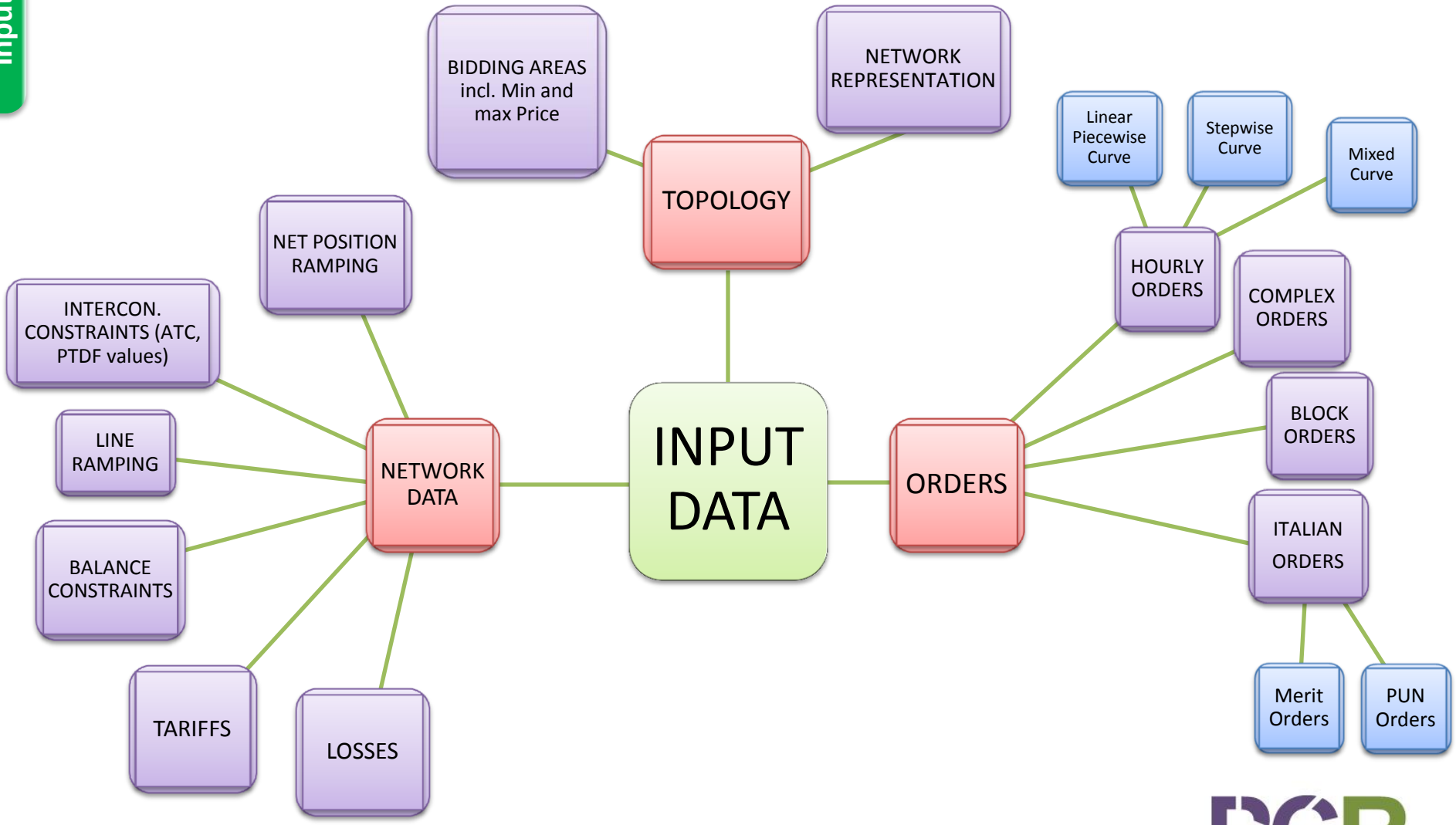
INPUT DATA



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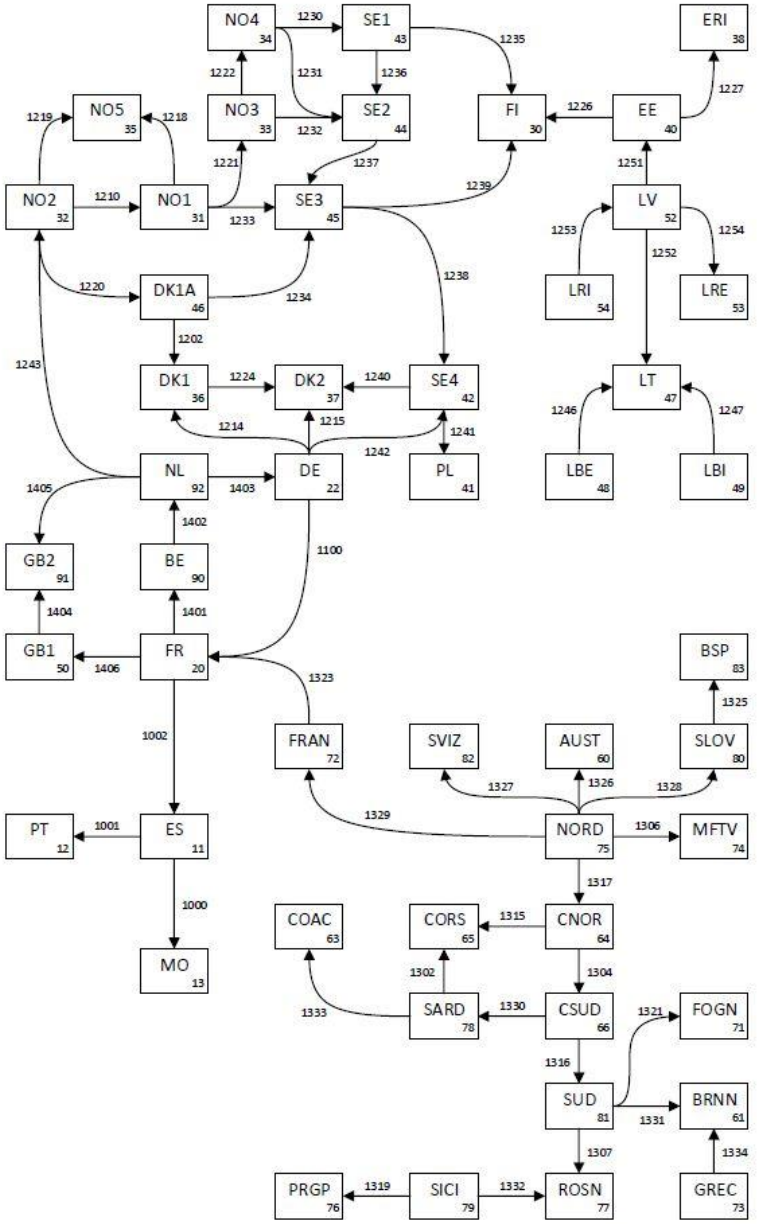
MARKET DATA

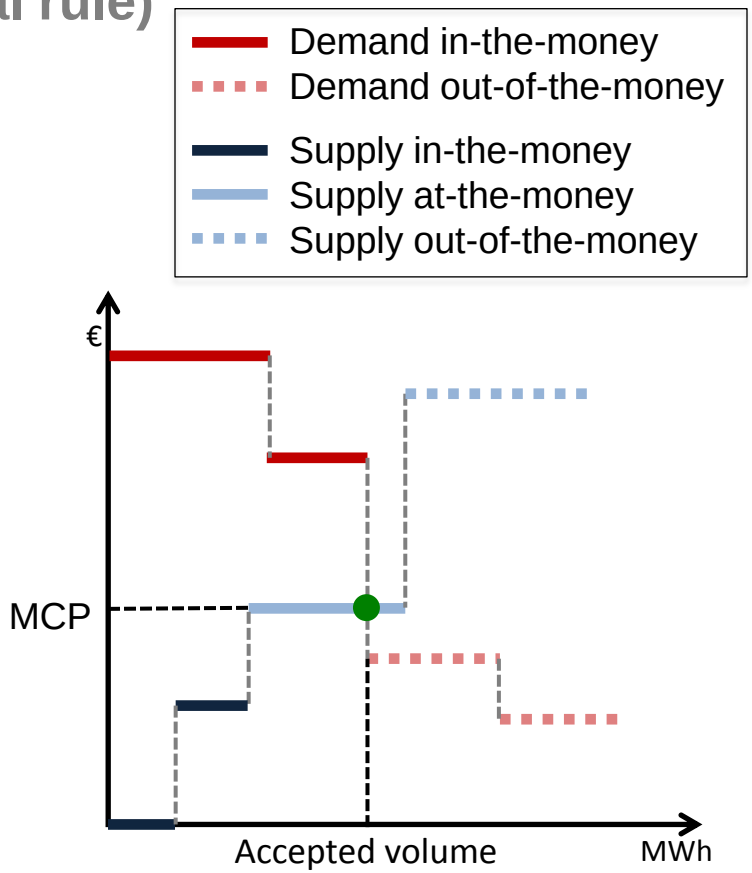
- Each PX (Market) operates several bidding areas.
- All bidding areas are matched at the same time.
- A different price can be obtained for each bidding area.
- The price for the bidding area must respect maximum and minimum price market boundaries.



HOURLY STEP ORDERS (general rule)

- Hourly step orders are defined by
  - A type (buy or sell)
  - A volume
  - A limit price

- EUPHEMIA provides solutions such that
  - Orders in-the-money are fully accepted
    - Supply at price < MCP
    - Demand at price > MCP
  - Orders out-of-the-money are fully rejected
    - Supply at price > MCP
    - Demand at price < MCP
  - Orders at-the-money can be curtailed



OMIE, APX, Belpex, GME and OTE use this kind of orders.

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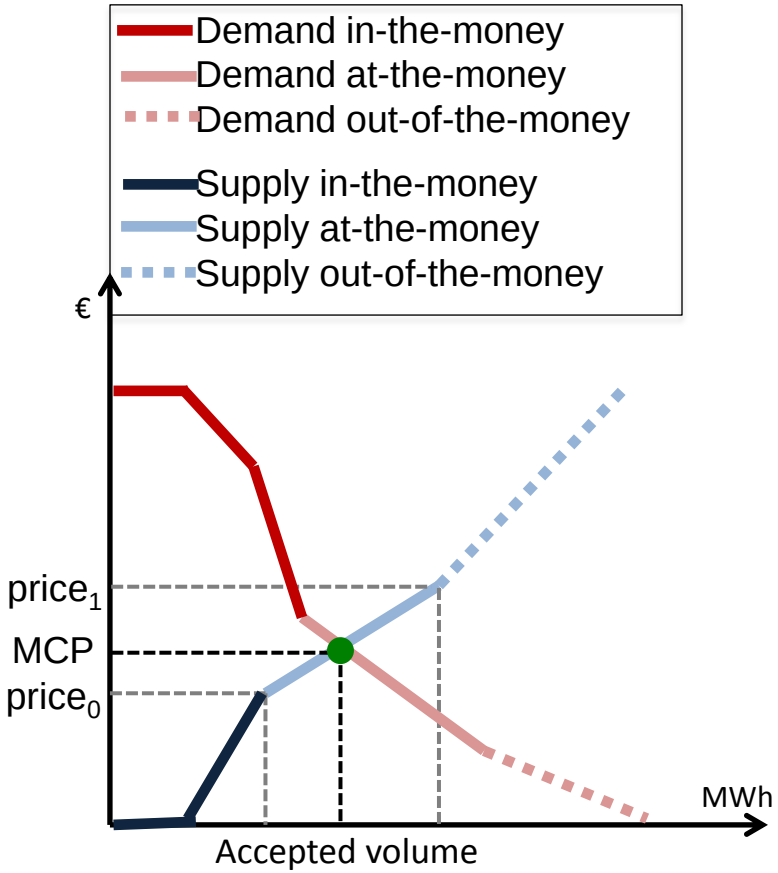
HOURLY LINEAR PIECEWISE ORDERS (general rule)

- Hourly piecewise orders are defined by
  - A side (buy or sell)
  - A volume
  - $price_0$: at which the order starts to be accepted
  - $price_1$: at which the order is totally accepted ($price_1 > price_0$)
- EUPHEMIA provides solutions such that
  - Orders in-the-money are fully accepted
    - Supply where $price_1 < MCP$
    - Demand where $price_1 > MCP$
  - Orders out-of-the-money are fully rejected
    - Supply where $price_0 > MCP$
    - Demand where $price_0 < MCP$
  - Orders at-the-money are accepted to the corresponding proportion

    Acceptance ratio = $(MCP-price_0) / (price_1-price_0)$



NORDPOOL and EPEX use this kind of orders.

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REGULAR BLOCK ORDERS

Regular Block orders are defined by

- Type (buy or sell).
- one single price.
- one single volume.
- Period: consecutive hours over which the block spans.

A regular block order cannot be accepted partially. It is either totally rejected or accepted (Fill-or-Kill condition).

PROFILE BLOCK ORDERS

Profile Block orders are defined by

- Type (buy or sell).
- one single price.
- Minimum Acceptance Ratio.
- Period: hours over which the block spans.
- Volume for each hour

The Profile Block orders can only be accepted with an acceptance ratio higher or equal than the minimum acceptance ratio.

Examples :

Type	PERIOD	PRICE	VOLUME
BLOCK BUY	Hours 1-24	40 Euros	200 MWh
BLOCK SELL	Hours 8-12	40 Euros	50 MWh

Type	PERIOD	PRICE	MIN. ACCEPT. RATIO	VOLUME
BLOCK SELL	Hours 1-7 Hours 16-24	40 Euros	**50%**	80 MWh 220 MWh

Acceptance Criterion :
a regular or profile block order out-the-money cannot be accepted

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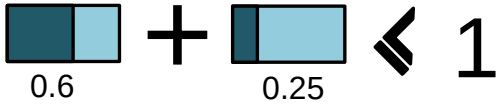
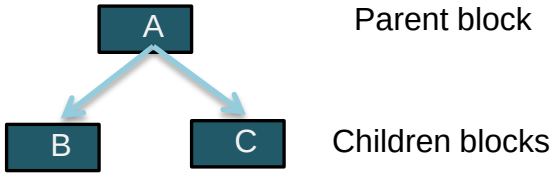
EXCLUSIVE BLOCK ORDERS

- Exclusive Group = Set of Block Orders in which the sum of the accepted ratios cannot exceed 1.
- Acceptance rules of Block Orders totally apply.

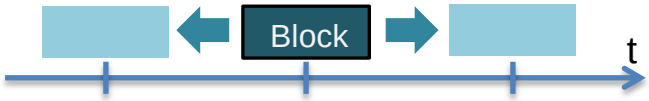


LINKED BLOCK ORDERS

- Several Block orders may be linked together in a parent-child relationship
- The acceptance of a child Block Order is conditional to the acceptance of its parent.
- However a loss giving parent can be saved by a child as long as the combination of accepted block orders is not making a loss.



FLEXIBLE HOURLY BLOCK ORDERS



- A Flexible Hourly Order is a Regular Block Order which lasts for only one period.
- If accepted, the block will be executed once and the period is determined by the algorithm such as the welfare is maximized.
- Acceptance rules of Regular Block Orders apply fully.

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COMPLEX ORDERS & MIC ORDERS

MIC (Minimum Income Orders) are Stepwise Hourly Orders under an economical condition defined by two terms:

- FT: Fixed Term in Euros which shows the fixed costs of the whole amount of energy traded in the order.
- VT: Variable Term in Euros per accepted MWh which shows the variable costs of the whole amount of energy traded in the order.

The same acceptance rules for Stepwise Hourly Orders are applied to MIC Orders and the revenue received by an activated MIC must be greater or equal to the Fixed Term plus Variable Term times the energy matched.

SCHEDULED STOP CONDITION

- It only applies to deactivated MICs.
- It applies to periods declared as Scheduled Stop by the MIC.
- A MIC order can declare a maximum of three periods as Scheduled Stop interval. (Periods 1, 2 or 3).
- The hourly sub-orders in the periods declared as Scheduled Stop interval must have decreasing energy as period increases.
- The first hourly sub-order will remain active (although the MIC is deactivated).
- For a deactivated MIC, its active hourly sub-orders corresponding to Scheduled Stop periods will be accepted if they are in/at the money (as any other hourly order).

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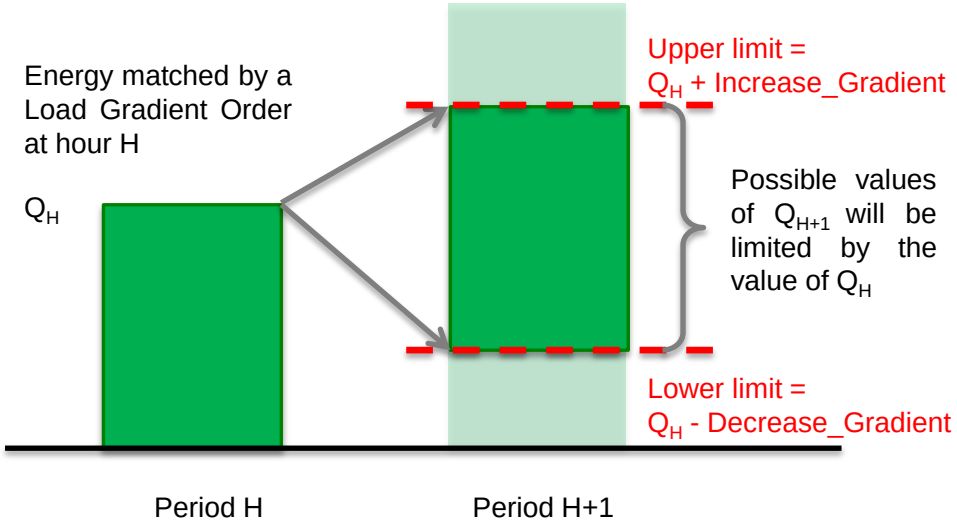
COMPLEX ORDERS & LOAD GRADIENT

The load gradient condition limits the variation between the accepted volume of an order at a period and the accepted volume of the same order at the adjacent periods.

A Load Gradient Order (LG) is defined by the next terms:

- ***Increase Gradient:*** Maximum increase gradient in MWh.
- ***Decrease Gradient:*** Maximum decrease gradient in MWh.



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PREZZO UNICO NAZIONALE (PUN) REQUIREMENT

- National demand of Italy (with the exception of storage pumps) is matched to a single purchase price (PUN), regardless of its location
- Expenses coming from the consumers paying the PUN must be equal to the expenses that would have come from consumers with zonal prices (minimum tolerance accepted)
- Acceptance/rejection of buying bids subject to PUN must respect the following conditions
  - Buying bids in-the-money (Offered price > PUN) are fully accepted
  - Buying bids out-of-the-money (Offered price < PUN) are fully rejected
  - Buying bids at-the-money (Offered price = PUN) can be curtailed
- In order to respect the aforementioned requirements, PUN and bidding area prices must be calculated simultaneously (PUN cannot be calculated ex-post)

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PUN AND MERIT ORDERS

In GME:

- Supply Merit orders are selling offers. They are cleared at their bidding area price.
- Non-PUN demand orders (pump plants and buying bids on cross-border long term capacities) : Buying Bids from pump plants and buying bids in non-Italian national zones* are demand Merit Orders. They are cleared at the price of their bidding area.
- PUN Merit Orders : the rest of the buying bids (the ones related to national consumption) are cleared at the common national PUN price (which is different from their bidding area price).

This PUN price is defined as the average price of GME marginal market prices for its bidding areas, weighted by the purchase quantity assigned to PUN Orders in each bidding area (subject to a tolerance, ϵ). That is:

$$P_{PUN} * \Sigma_z Q_z = \Sigma_z P_z * Q_z + \epsilon$$

* «Non Italian Zones» are limited poles of productions (available production capacity is bigger than ATC) and zones where holders of crossborders capacities rights submit bids .

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NETWORK DATA AND BALANCE CONSTRAINTS

The energy balance concept is defined as : The global supply minus the losses must be equal to the global demand of all markets involved. Depending on the manner the interconnections are modeled, there are the following:

- ***ATC network model:*** The network is described as a set of lines interconnecting bidding areas. The nomination of the line can be made up to its Available Transfer Capacity (ATC).

- ***Flow-based network model:*** Also known as PTDF model, with all bidding areas connected in a meshed network. It expresses the constraints arising from Kirchhoff's laws and physical elements of the network in the different contingency scenarios considered by the TSOs. It translates into linear constraints on the net positions of the different bidding areas.

- ***Hybrid network model:*** Some bidding areas are connected using the Flow-based network model; the remaining using the ATC network model.

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NETWORK DATA AND RAMPING LIMITS

- EUPHEMIA supports a wide range of network restrictions:
  - Ramping limit for individual or sets of lines between consecutive hours.
  - Line tariffs.
  - Line losses.
  - Hourly and daily net position ramping limits for bidding areas.

EUPHEMIA USES BRANCH-AND-CUT

- Branch-and-Cut method is a way to
  - Search among all block and MIC selections in a structured way
  - Find feasible solutions quickly
  - Prove early that large groups of these selections cannot hold good solutions

- The idea is as follows
  - Try first without the fill-or-kill requirement
  - If the solution happens to have no partially accepted block ➔ OK
  - If it has, then
    - Select one block which is partially accepted
    - Create two sub-problems (called *branches*)
      - One where the block is killed
      - One where the block is filled
  - Continue to explore until there is no unexplored branch

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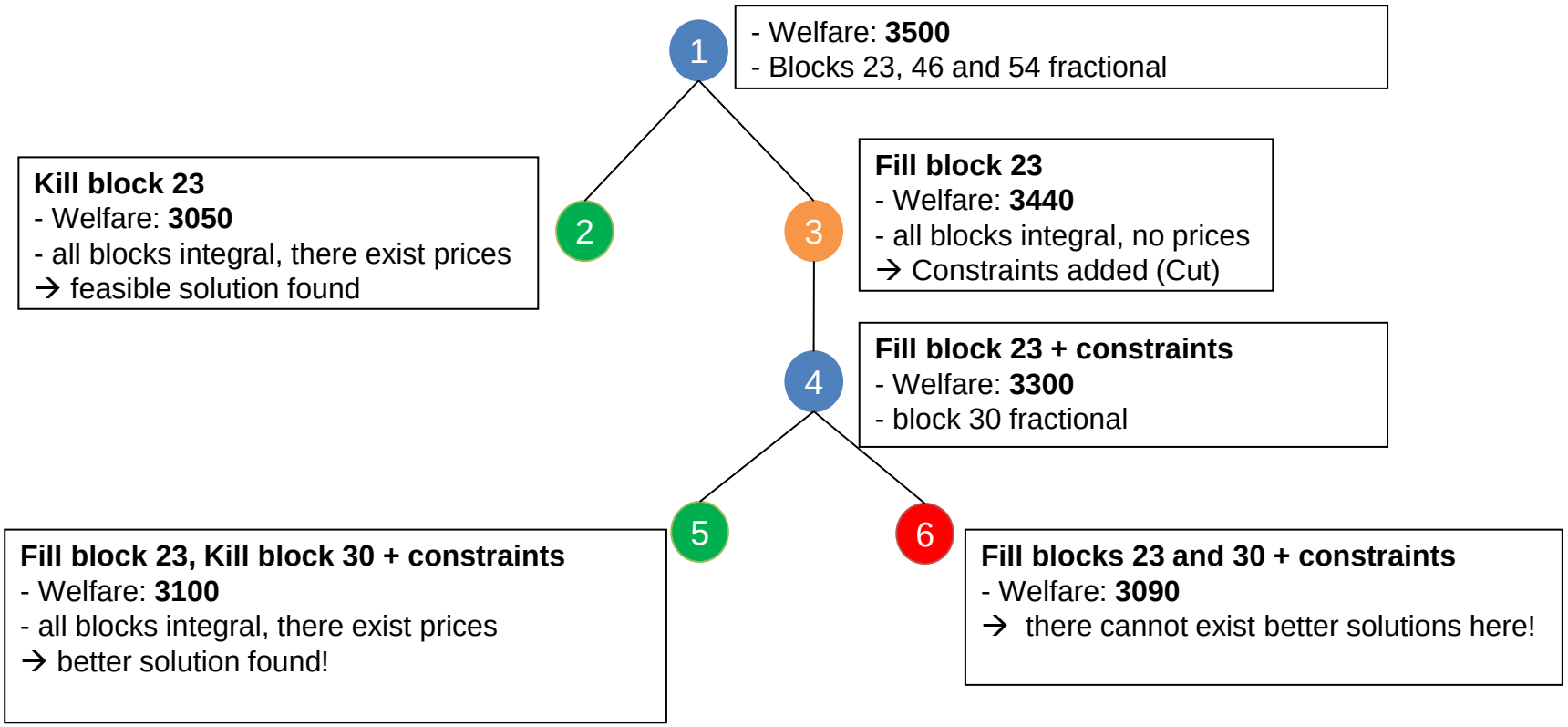
BRANCH-AND-CUT



fractional | New solution found | Integral, no prices | Pruned by bound

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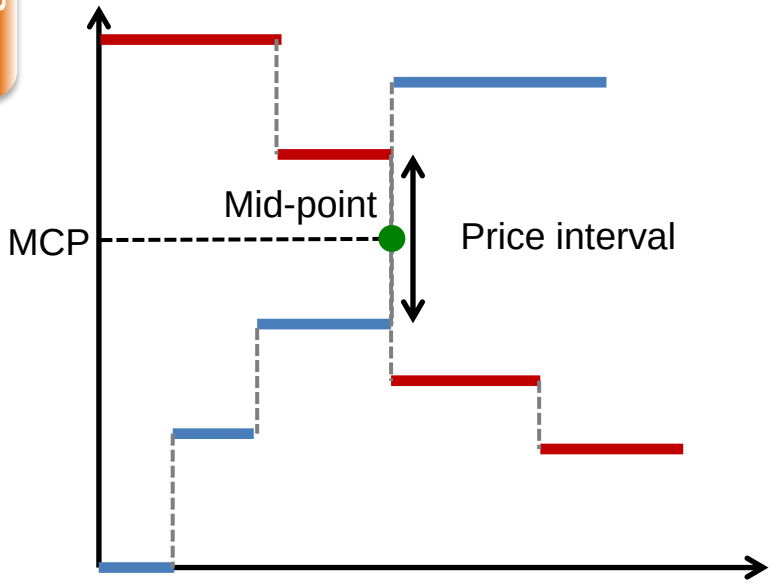
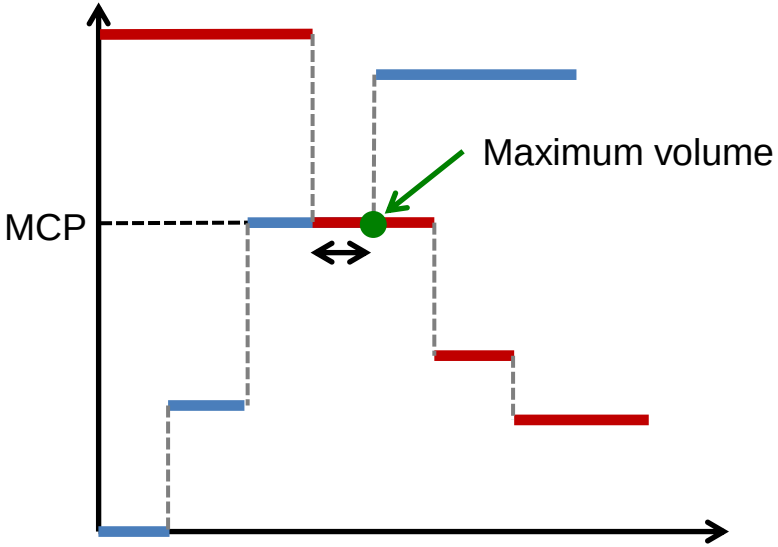
PRICE AND VOLUME INDETERMINACY RULES
(general rule)

PRICE



Minimize the distance to the middle of the price interval

VOLUME



Maximize traded volume

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STOPPING CRITERIA

In production, the algorithm will stop calculating whenever one of the following situations is reached:

- The algorithm has explored all nodes.
- The time limit has been reached.

OUTPUT DATA

EUPHEMIA results:

- Price per bidding area
- Net position per bidding area
- Flows per interconnection
- Matched energy for each block, MIC and PUN orders

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Thank You

For more information, in particular on the treatment of special cases, please refer to the extensive public description (available for download).

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