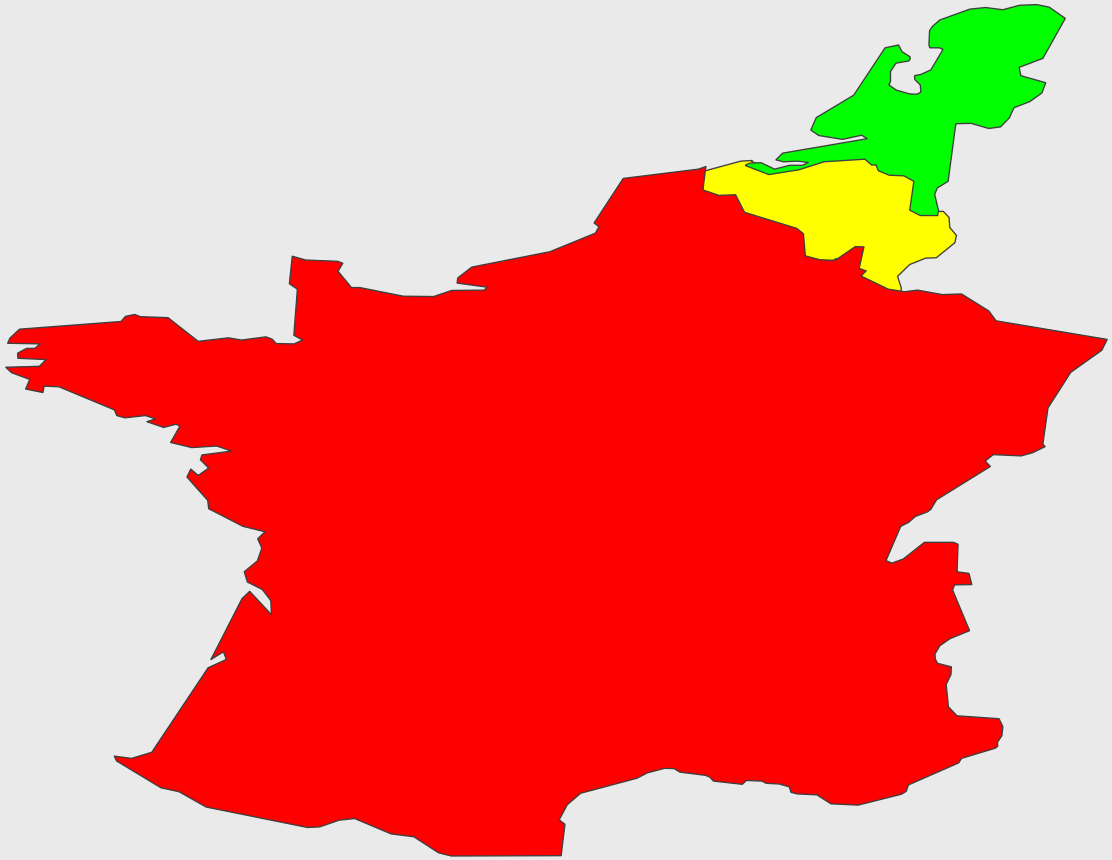
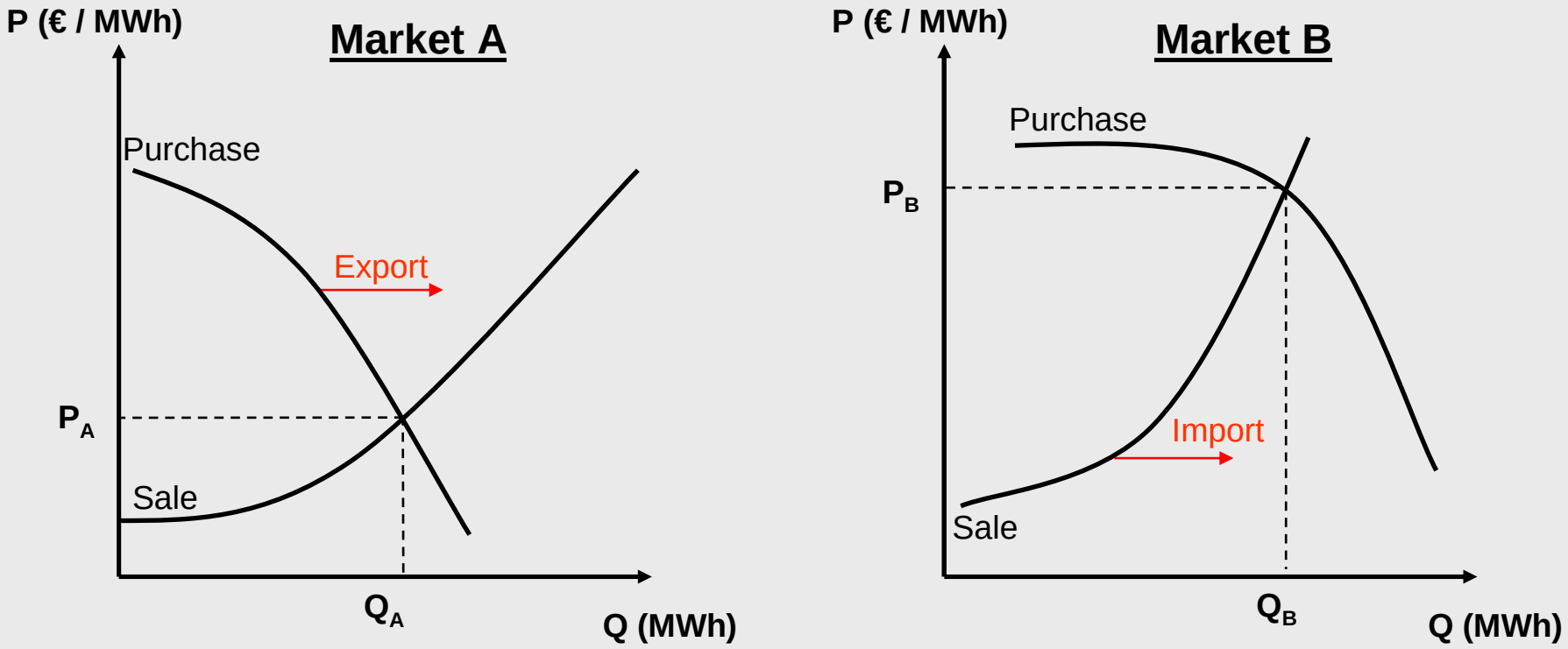
Trilateral Market Coupling

Introduction

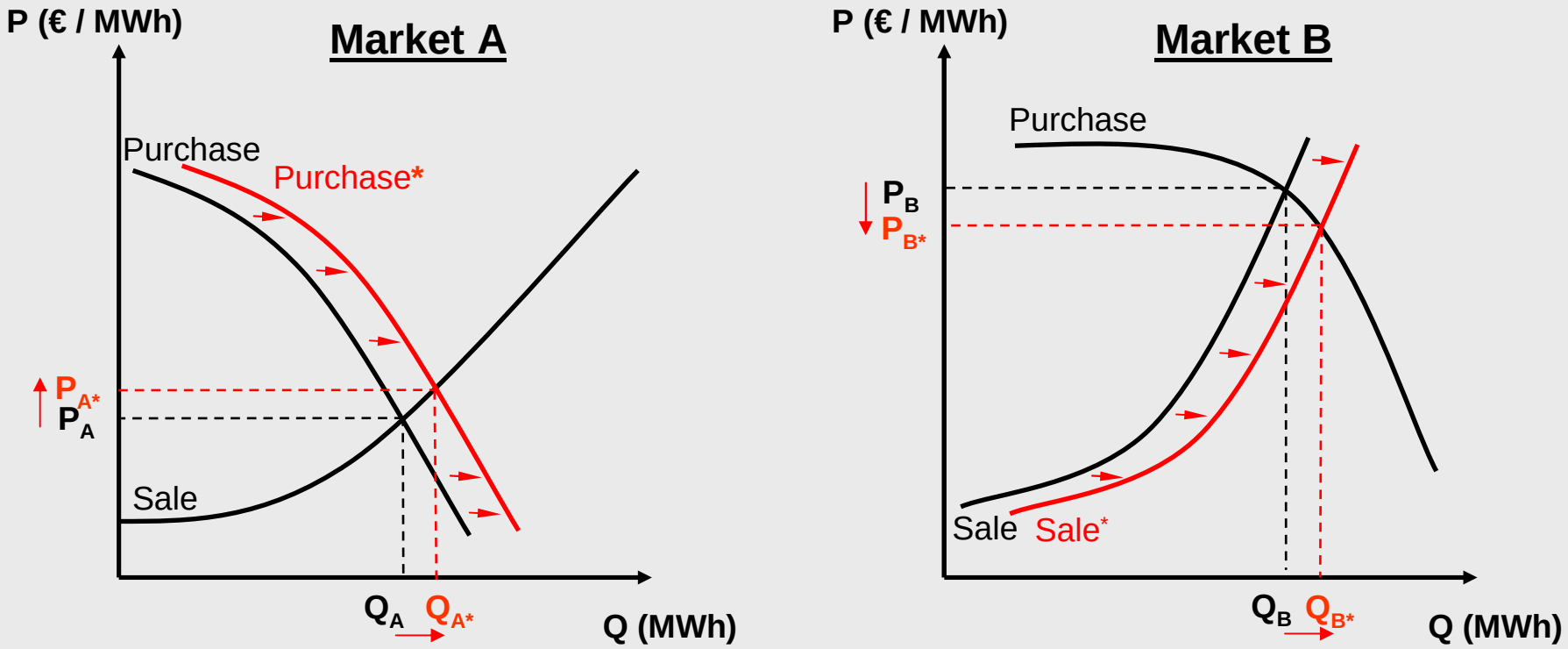


Market Coupling (basic concept)



- **Isolated price Market A > isolated Price Market B**
- **Market A can export to market B (purchase and sale curve shift)**

Market Coupling (basic concept)



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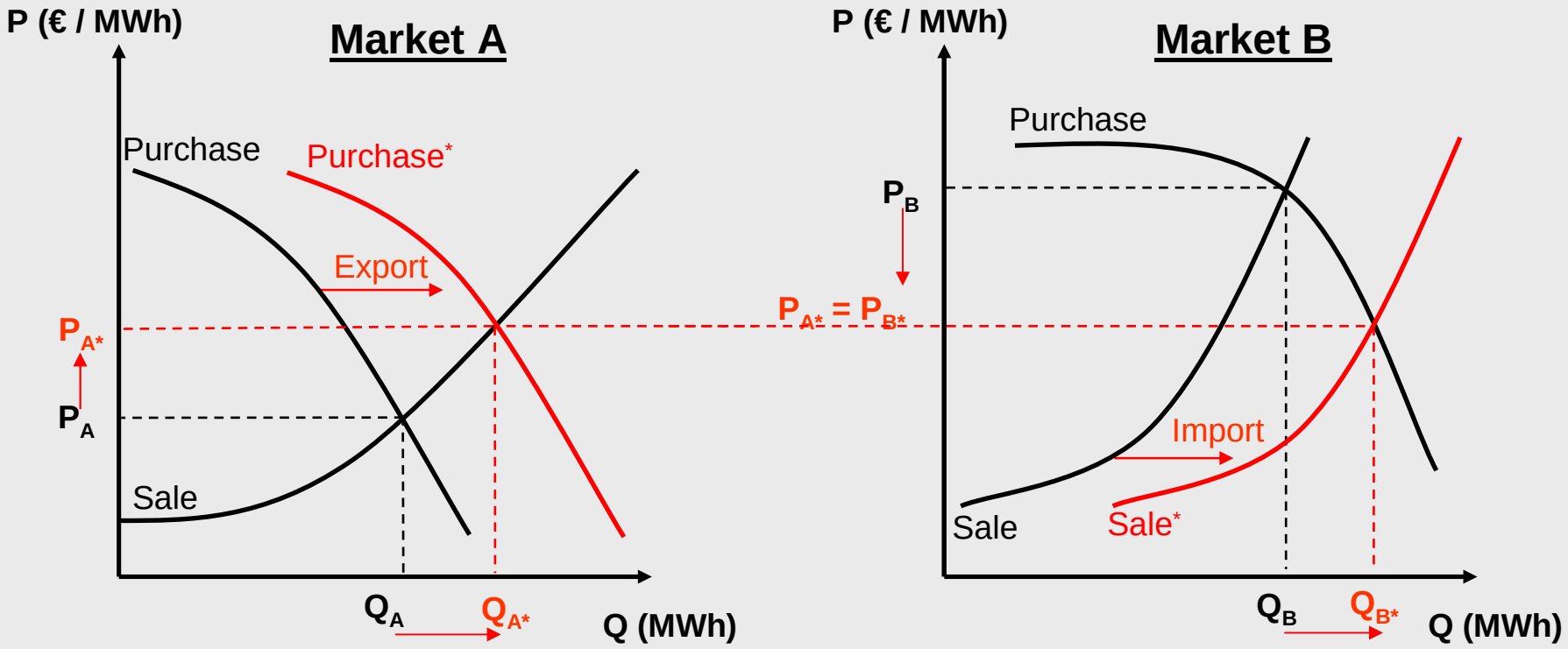
Market Coupling (basic concept)



- **Isolated price Market A > isolated Price Market B**
- **Market A can export to market B (purchase and sale curve shift)**
- **Prices market A and B converge till price market A = price market B**

	MCP < Price limit	MCP = Price Limit	MCP > Price Limit
Divisible Hourly Offer	Not contracted	Contracted (but volume may be curtailed)	Fully contracted
Divisible Hourly Bid	Fully contracted	Contracted (but volume may be curtailed)	Not contracted
Block Offer	Not contracted	Fully contracted (but possible it may be 'paradoxically' rejected)	
Block Bid		Fully contracted (but possible it may be 'paradoxically' rejected)	Not contracted

High Level Properties of Market Coupling

Criteria to be met by Market Coupling results

- **Market prices are positive**
- **Flows balance overall**
- **Flow consistent with published ATC**
- **Power flows from low price area to high price area**
- **Maximize flow until prices across link converge (or ATC limit reached)**

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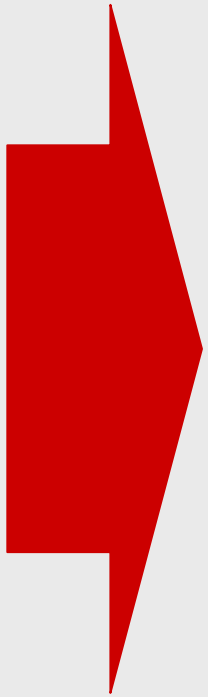
- **Respect participants' order price and volume conditions (normal exchange rules)**



Market clears: all possible trades executed

Efficient use of the available transmission capacity

Possible to verify this every day using publicly available data

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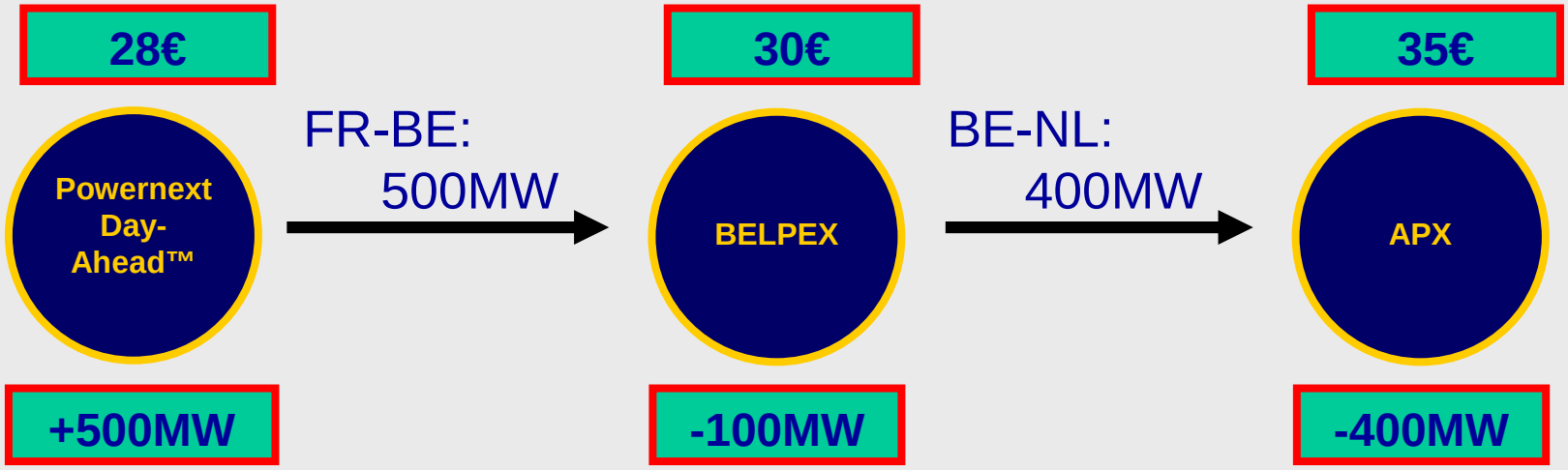
Other Features of the Market Coupling

Assumptions on the Market Model

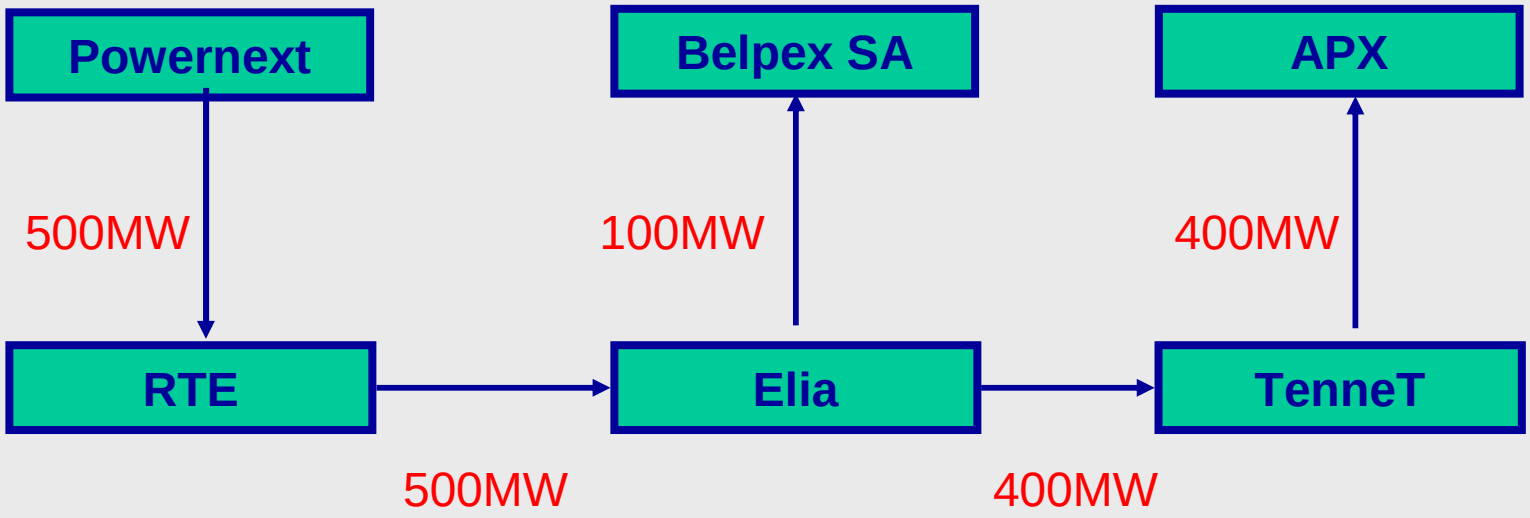
- **Exchanges can keep their mix of products and bidding conditions (i.e. block orders) unchanged and keep flexibility**
- **Exchanges can keep their current price and volume ticks and keep flexibility**
- **Bidding interfaces remain unchanged (SAPRI, Eurolight)**
- **Credit, clearing and settlement unchanged**
- **Illogical bidding is forbidden**
- **Maximum prices are harmonised (3000€)**
- **Minimum prices are harmonised (0,01€)**

Implementing a decentralised contractual approach (1)



- **What are the transactions required to ensure:**
  - **Delivery and payment of the cross-border transaction**
  - **Order book balance in each market**
  - **Collection and payment of the congestion revenues?**

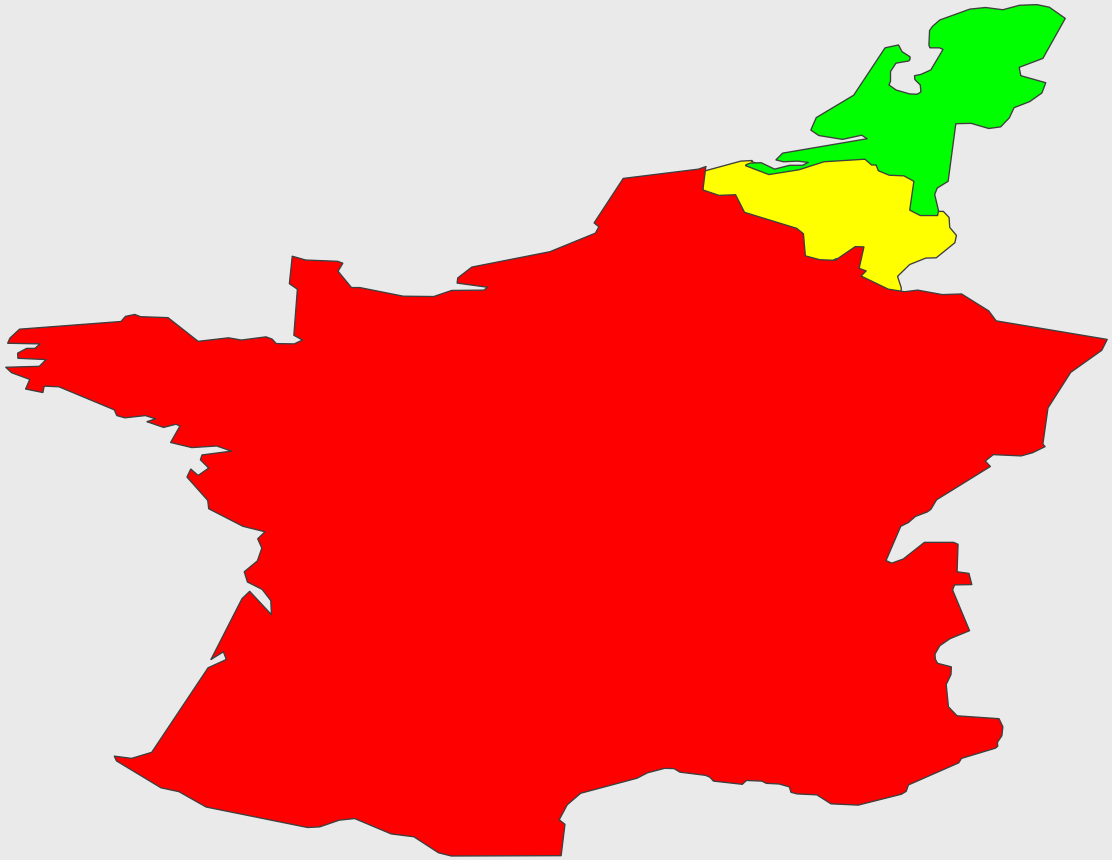
Implementing a decentralised contractual approach (2)



- **Transactions:**
  - **TSO/ market: Each TSO gives a permanent instruction to the Exchange operating in its system to execute a transaction at market price, with a volume determined by the Market Coupling algorithm on the basis of the ATCs.**
  - **TSO/ TSO: Cross-border transactions between TSOs to close positions and share congestion revenues**

Trilateral Market Coupling

Coupling Algorithm
(hourly calculations)



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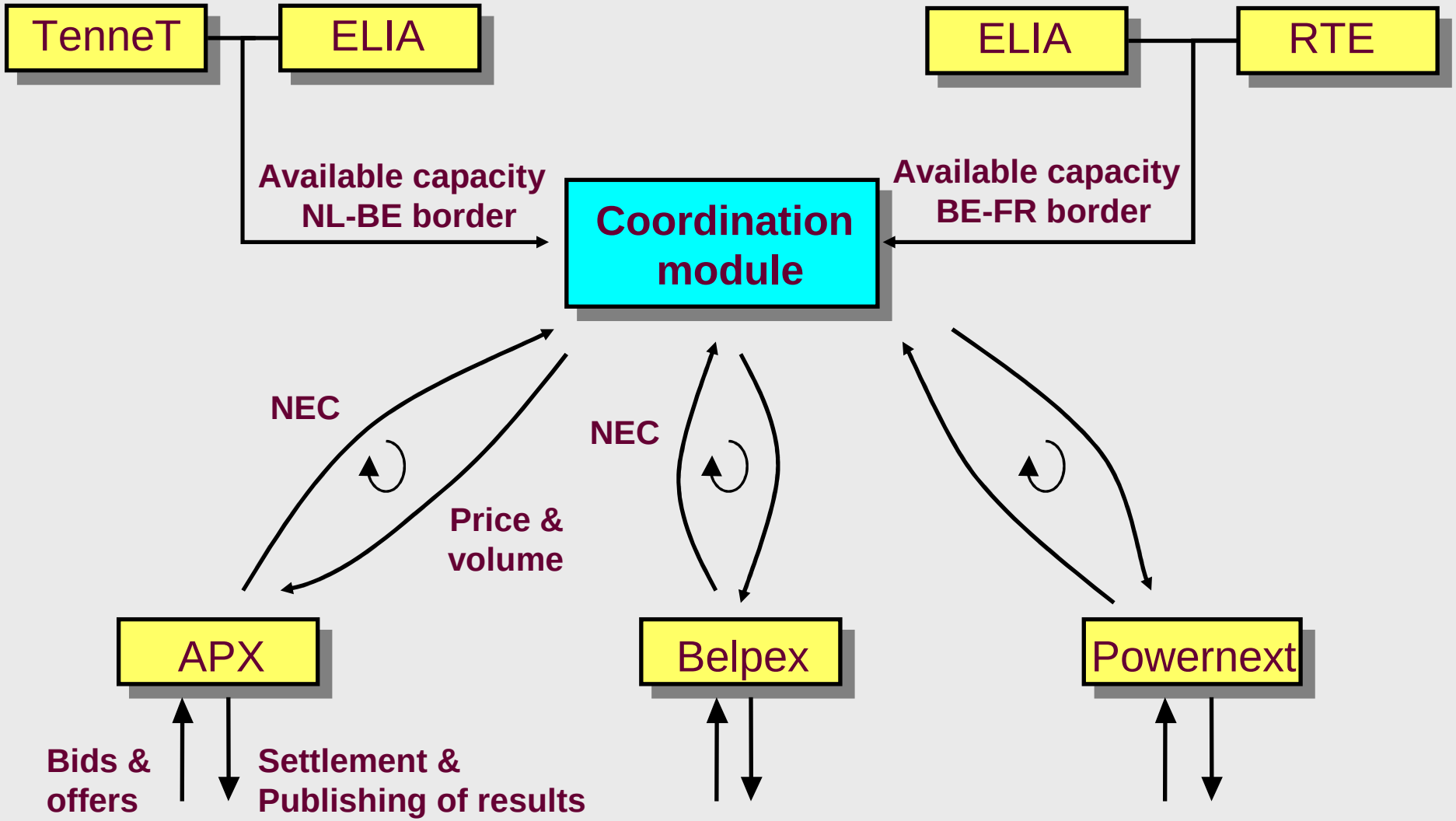
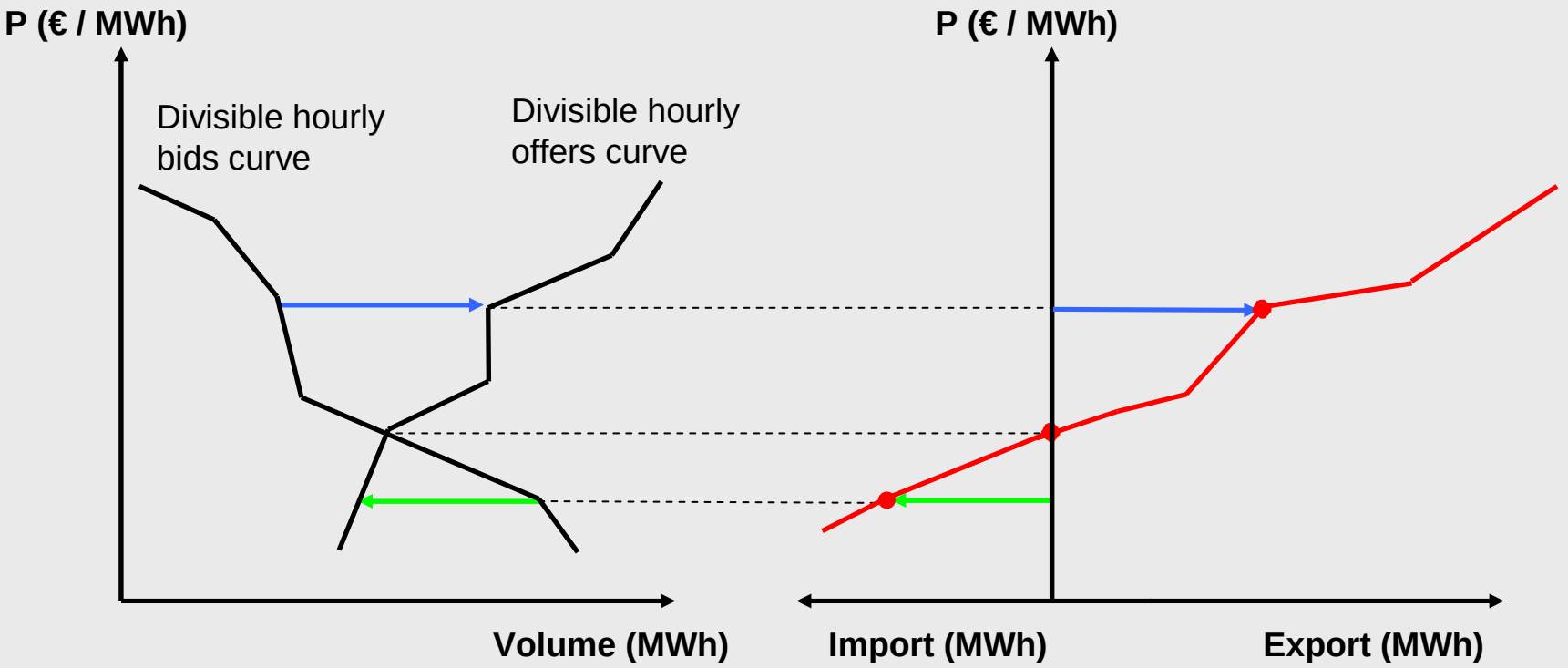
Trilateral Market Coupling (simplified picture)

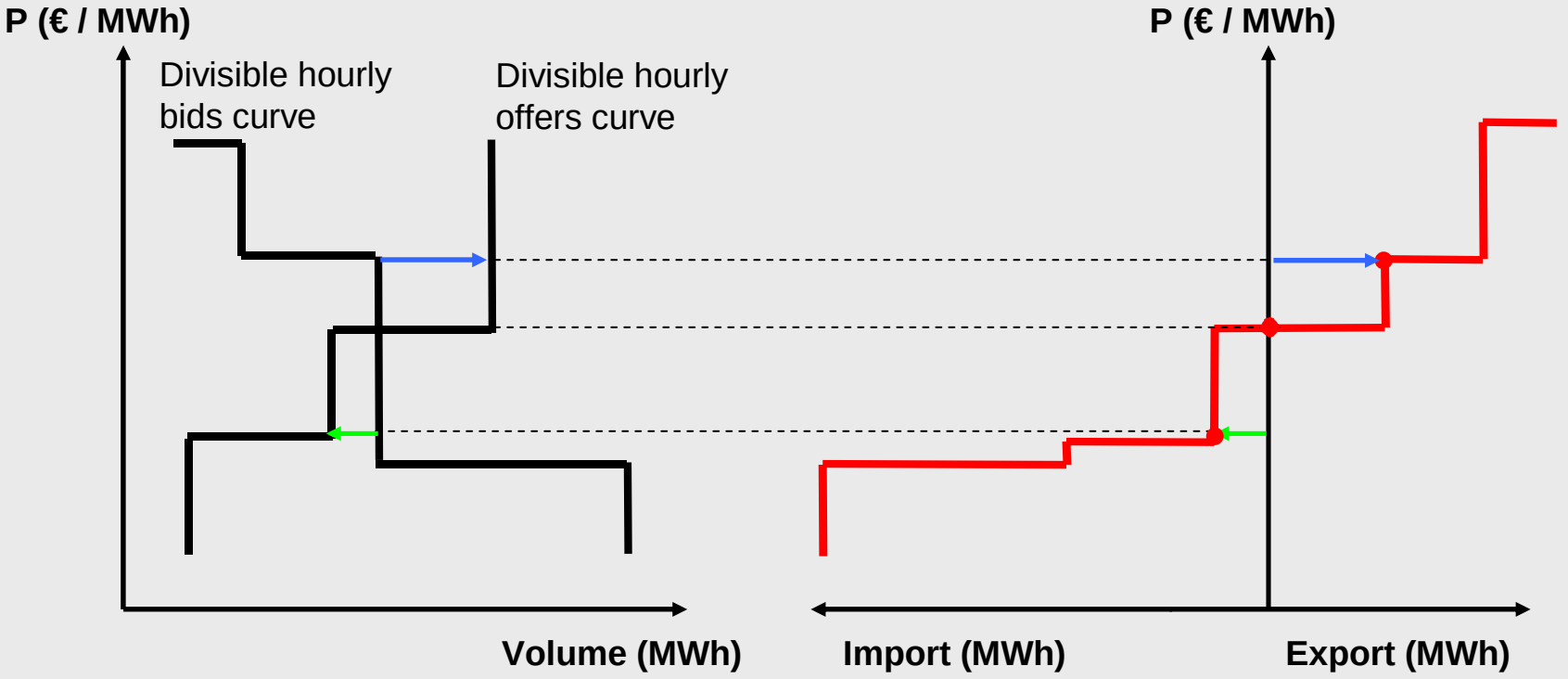


Net Export Curves (NEC)



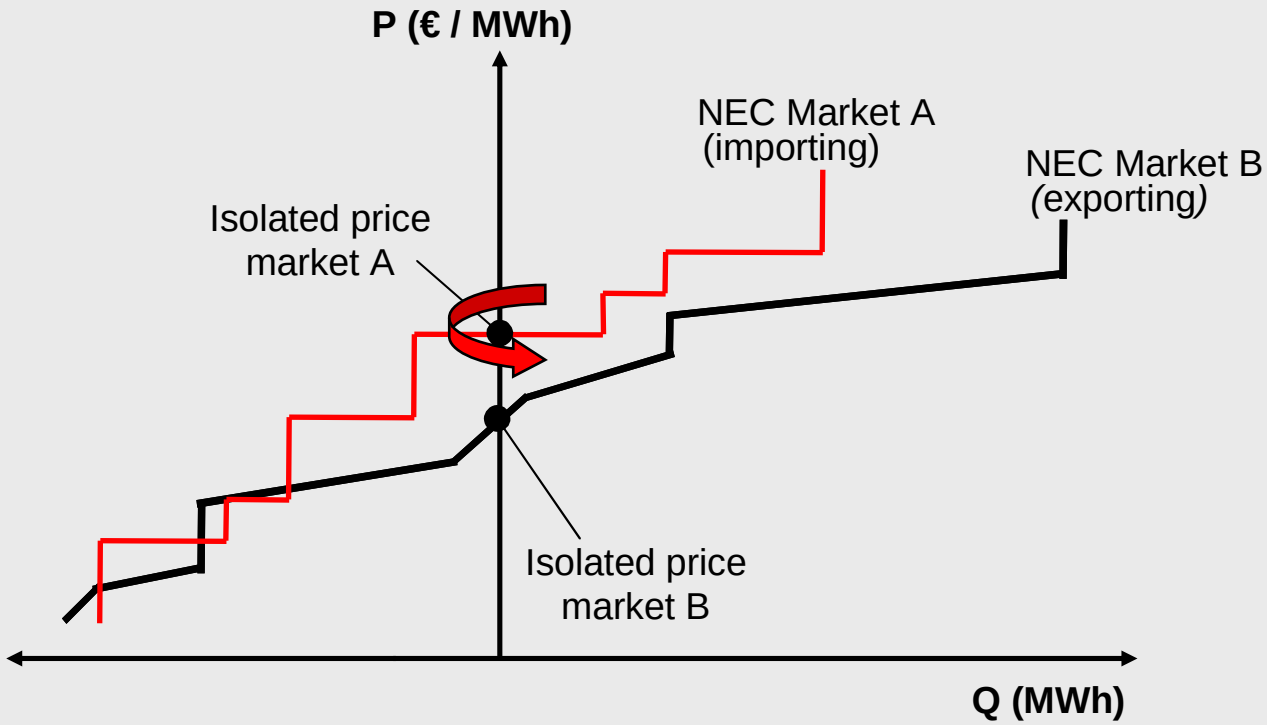
- **Depicting market's willingness to import or export at different prices**
- **Decentralized calculation by each individual exchange**
- **NEC constructed of divisible hourly bids and offers (block-bids treated differently)**
- **Linear NEC for French market (see example)**

Net Export Curves (NEC)



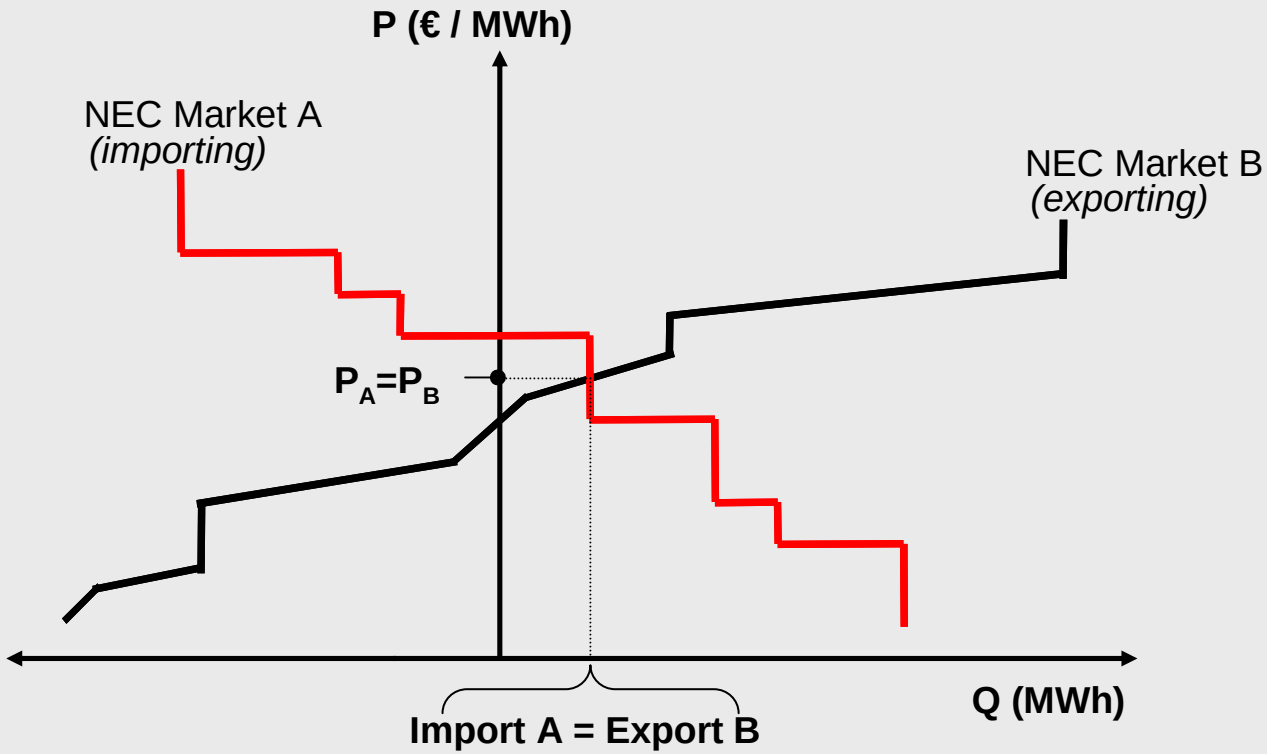
- **Depicting market's willingness to import or export at different prices**
- **Decentralized calculation by each individual exchange**
- **NEC constructed of divisible hourly bids and offers (block-bids treated differently)**
- **Linear NEC for French market**
- **Stepwise NEC for Belgian and Dutch markets (see example)**

Market coupling using Net Export Curves



- **NECs Market A and B**
- **Isolated price market A > isolated price market B**
- **Market B will be exporting market and market A importing market (flipped NEC)**

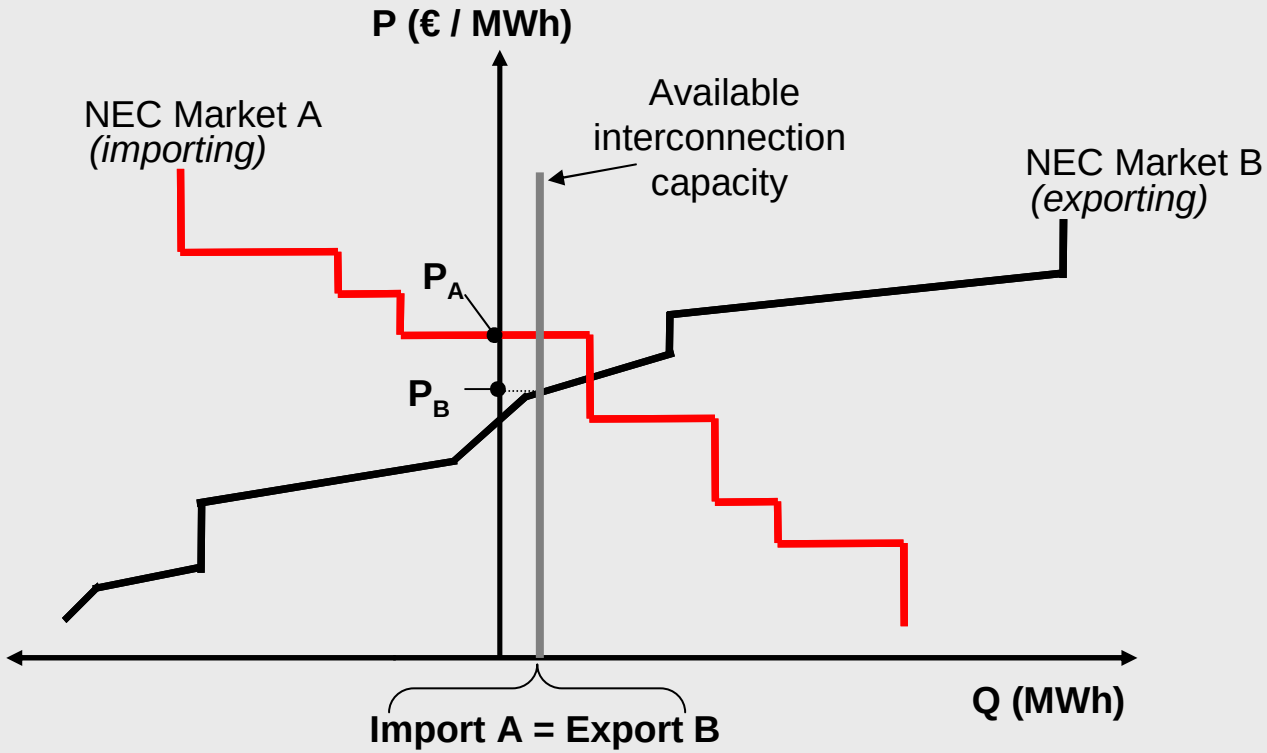
Market coupling using Net Export Curves



- **NECs Market A and B**
- **Isolated price market A > isolated price market B**
- **Market B will be exporting market and market A importing market (flipped NEC)**
- **Intersection of importing and exporting NECs is equilibrium price and volume**

Market coupling using Net Export Curves

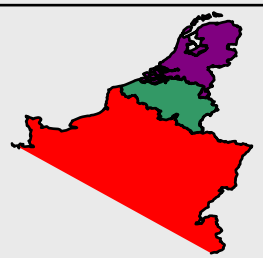
(congested case)



- **Market B will be exporting to market A**
- **Available interconnection capacity between market A and B is insufficient to export till full price convergence is reached**

Solving Trilateral Market Coupling

Different possibilities regarding border congestion

(1) No congestion	→ F = B = NL	
(2) BE-NL border congested	→ F = B ≠ NL	
(3) FR-BE border congested	→ B = NL ≠ F	
(4) BE-NL plus FR-BE borders congested	→ B ≠ NL ≠ F	

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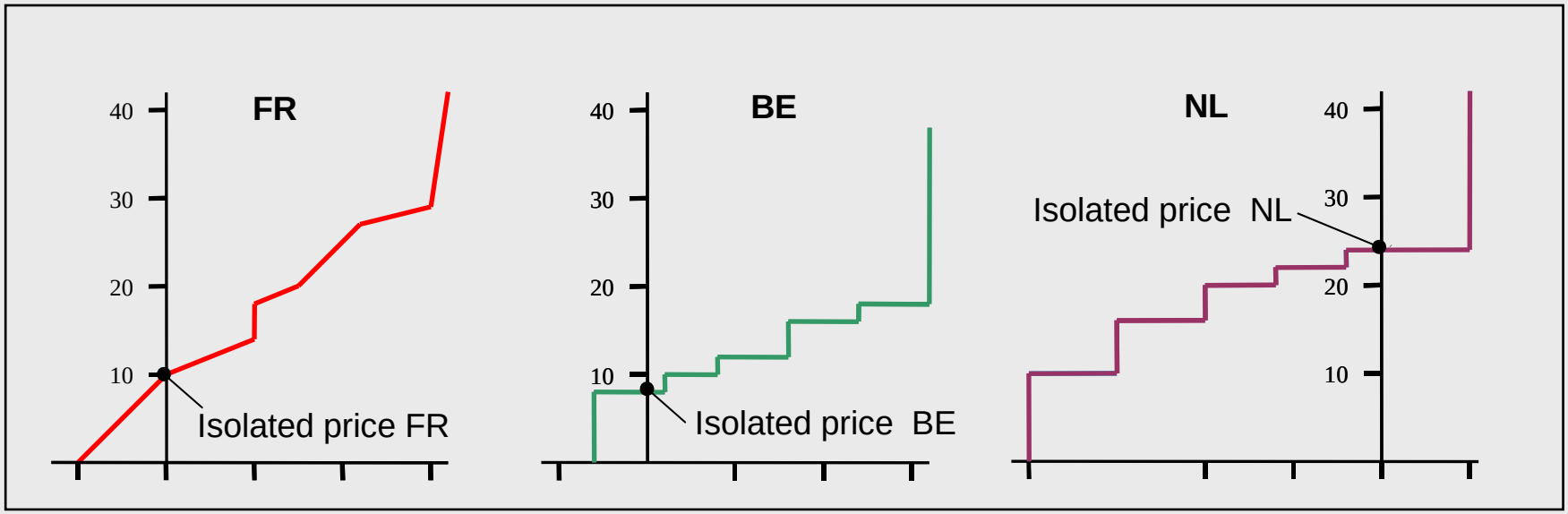
Solving Trilateral Market Coupling

Example (FR and BE jointly export to NL)

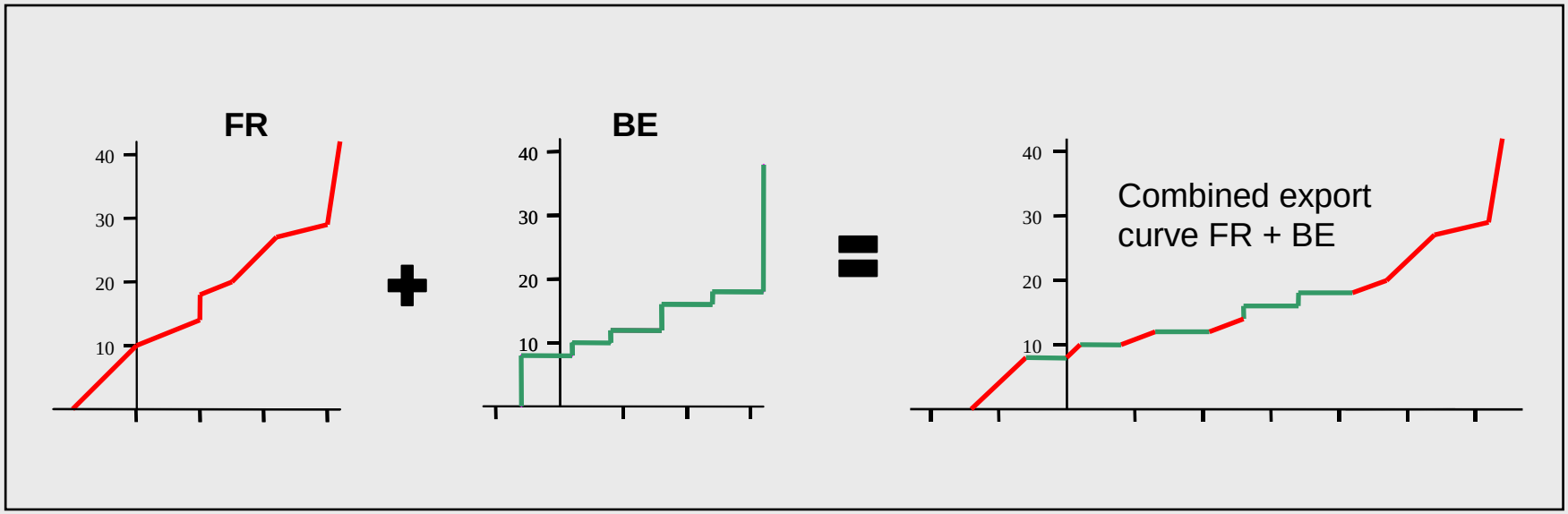


Next step:

- **Combine export curves of BE and FR**

Solving Trilateral Market Coupling

Combining export curves of M1 and M2

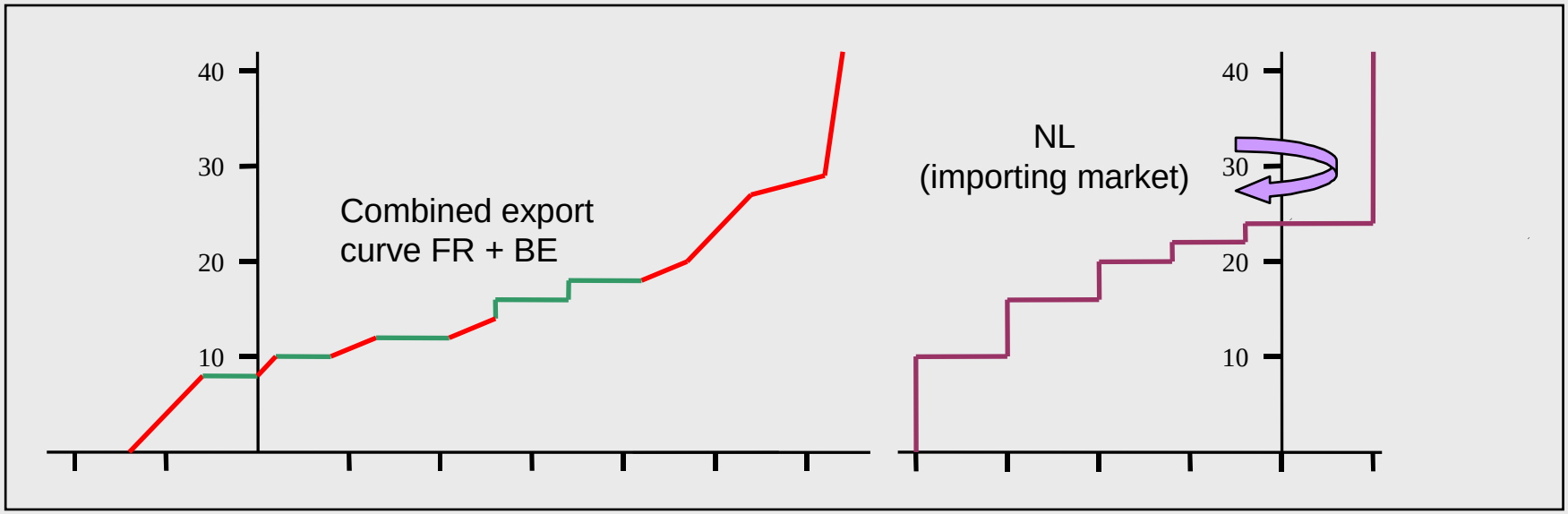


Next step:

- **Solve three market problem with individual import curve of NL plus the combined export curves FR + BE**

Solving Trilateral Market Coupling

Solving three market problem

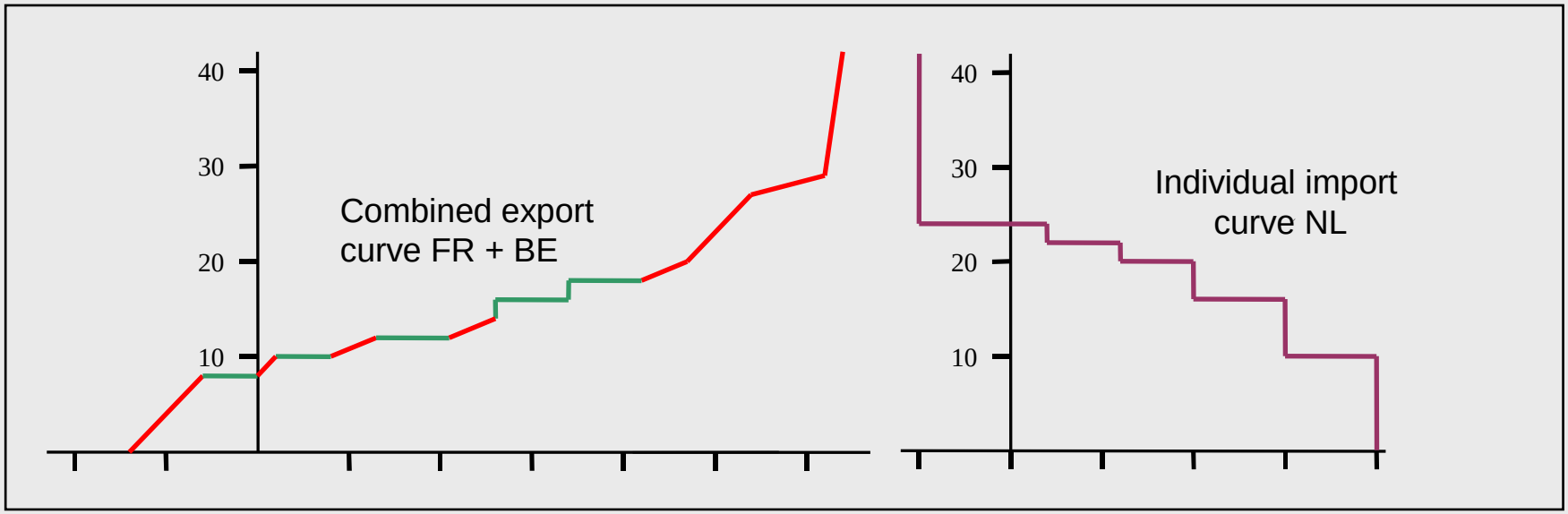


Next step:

- **NEC of NL to be flipped (importing market)**

Solving Trilateral Market Coupling

Solving three market problem



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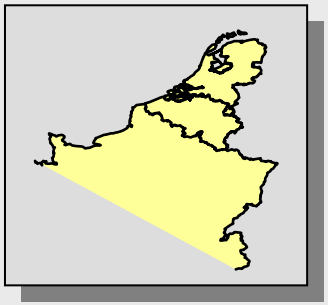
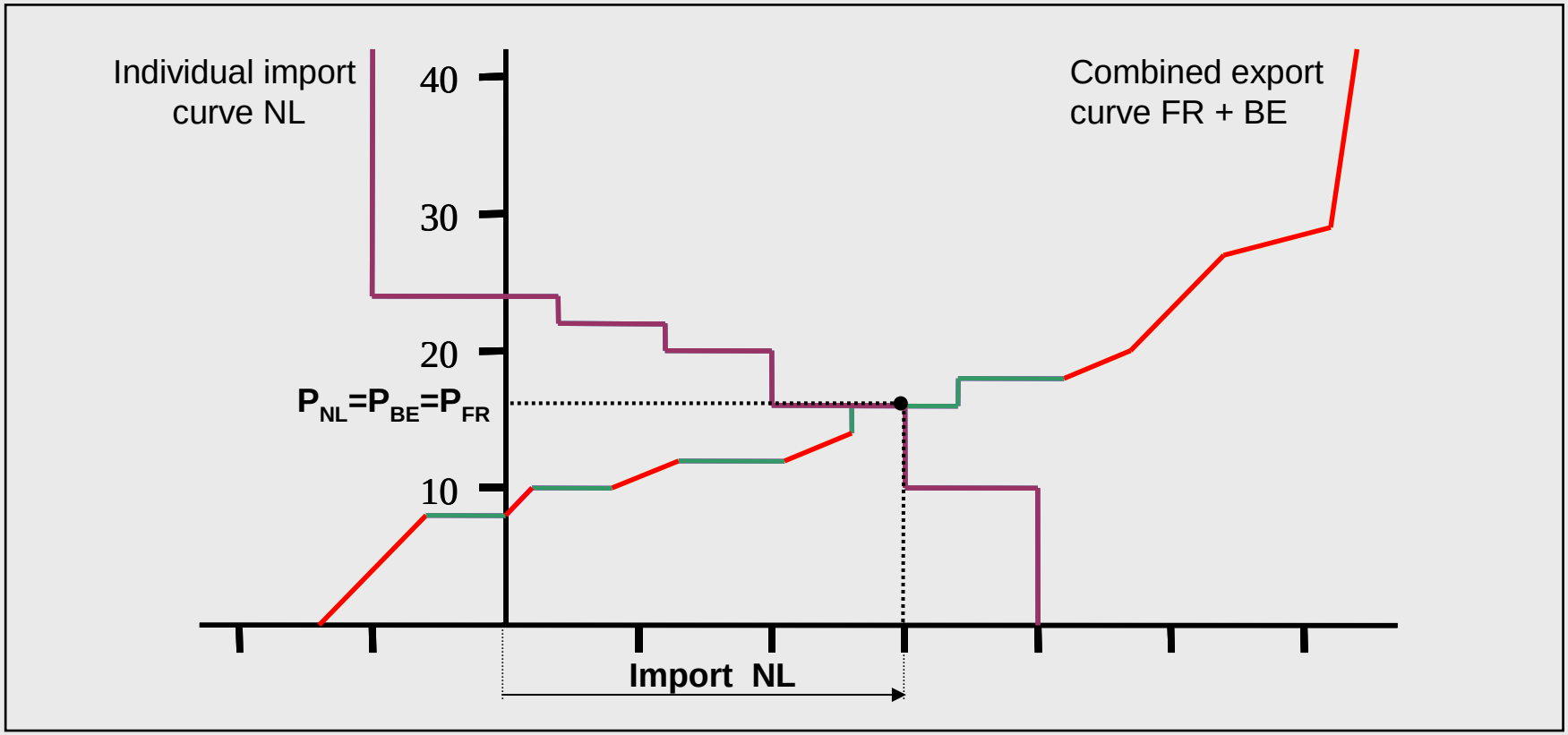
Solving Trilateral Market Coupling



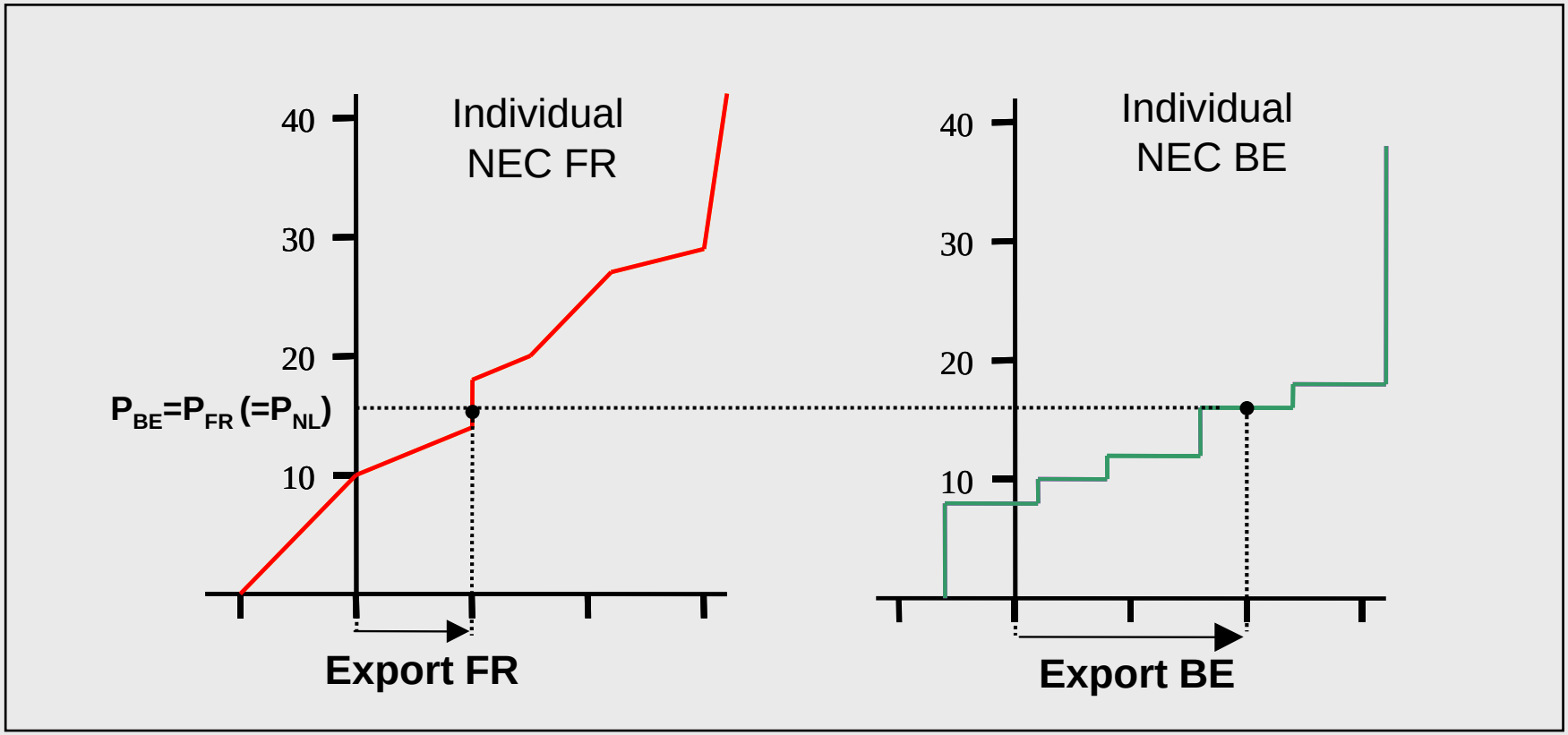
Solving three market problem (full price convergence)



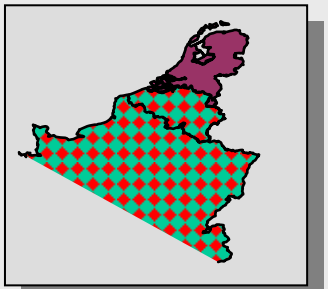
- **Individual (export) positions of FR and BE are the projection of P_{FR} and P_{BE} on individual NEC-curves**

Solving Trilateral Market Coupling

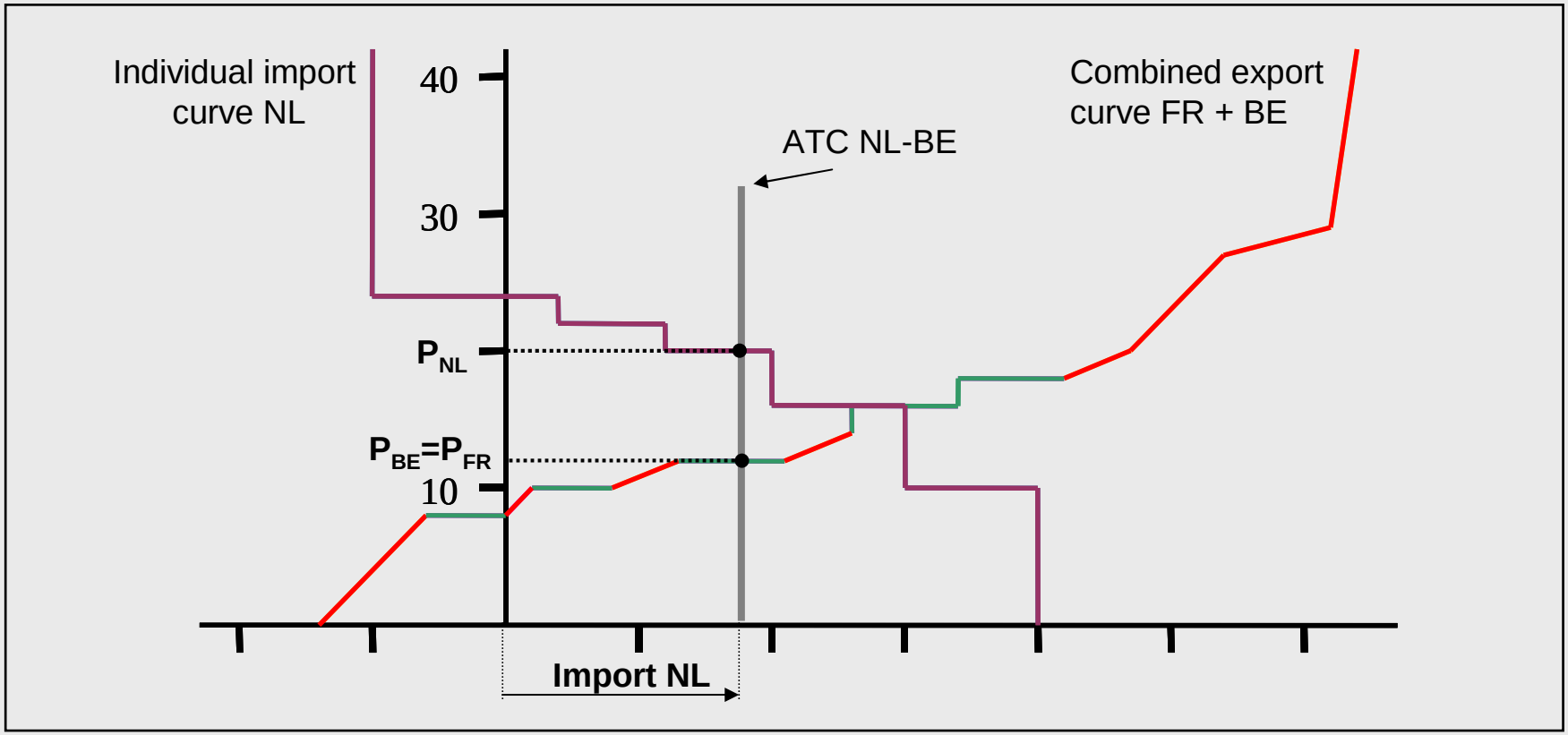
Solving three market problem (full price convergence)



Solving Trilateral Market Coupling



ATC-limitation between NL and BE, BE and FR full price convergence



Solving Trilateral Market Coupling

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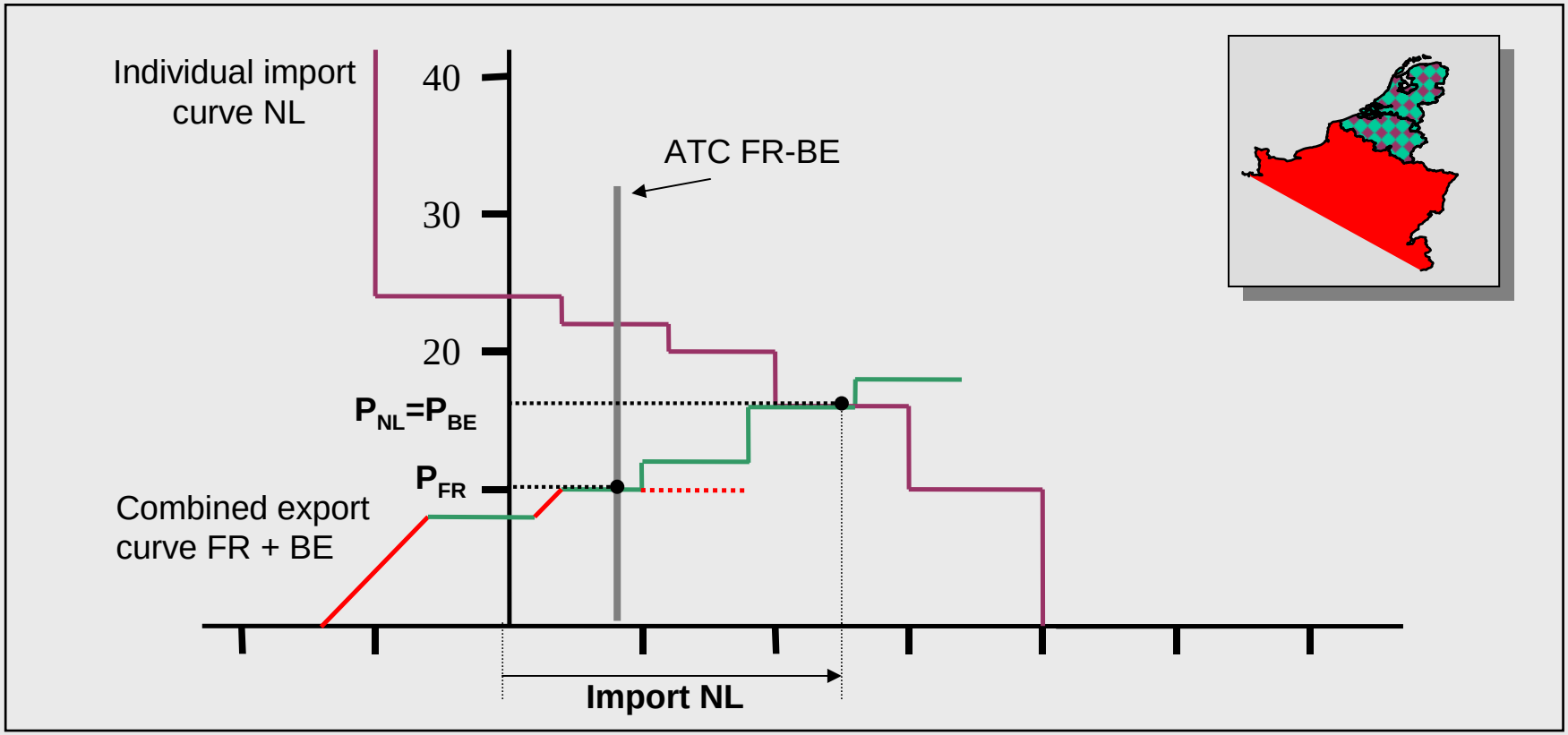
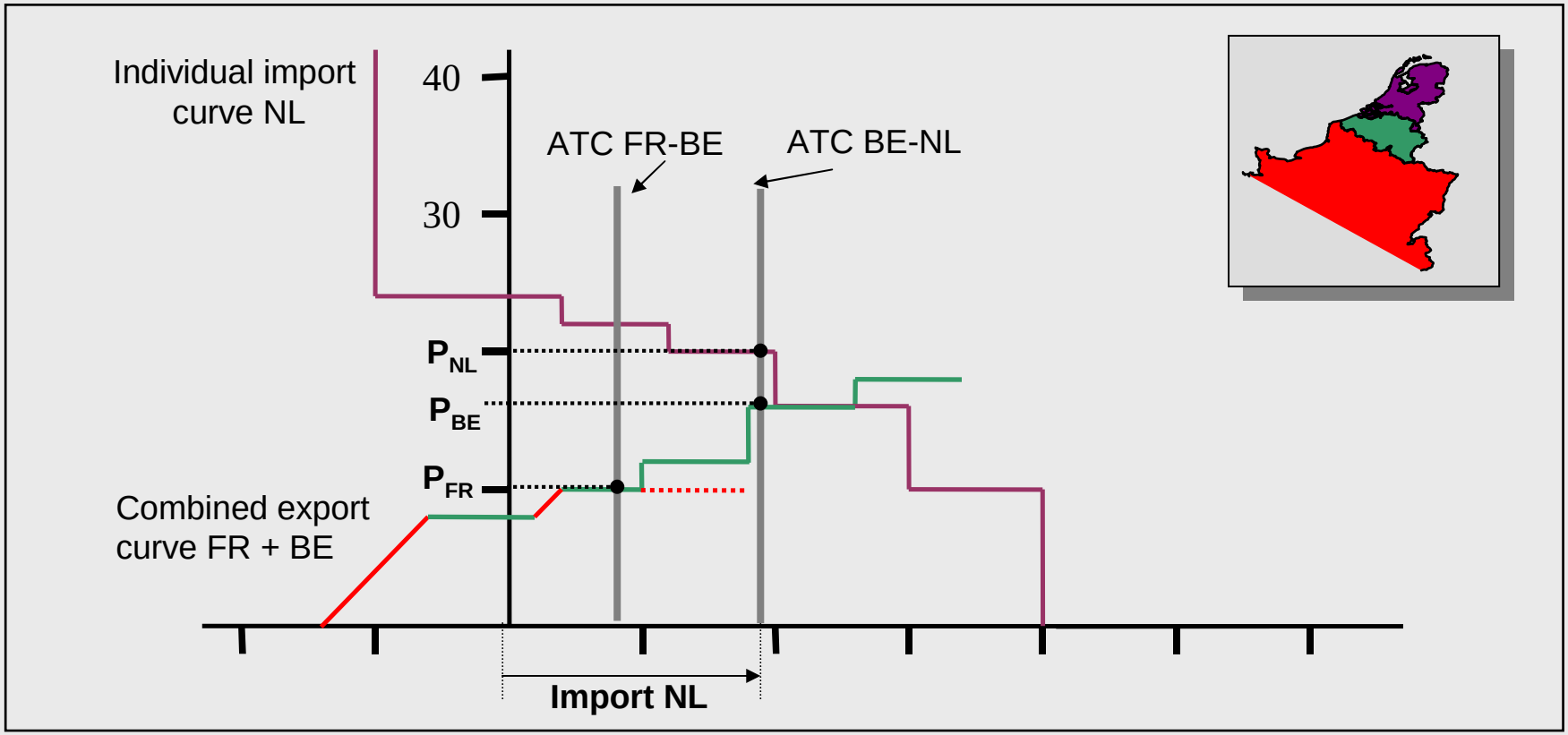


Solving Trilateral Market Coupling

ATC-limitations between FR and BE & between BE and NL, three different prices



Price and Quantity determination principles

- In some cases a range of prices or range of quantities are possible as a result of market coupling calculations
- Principles are required to end up with only one single combination of price and quantity

Quantity determination principles

(1) Maximize total executed volume

(2) Equitable treatment between markets

Price determination principles

(1) Determination based on HLPs

(2) Equilibrium price is middle of common part

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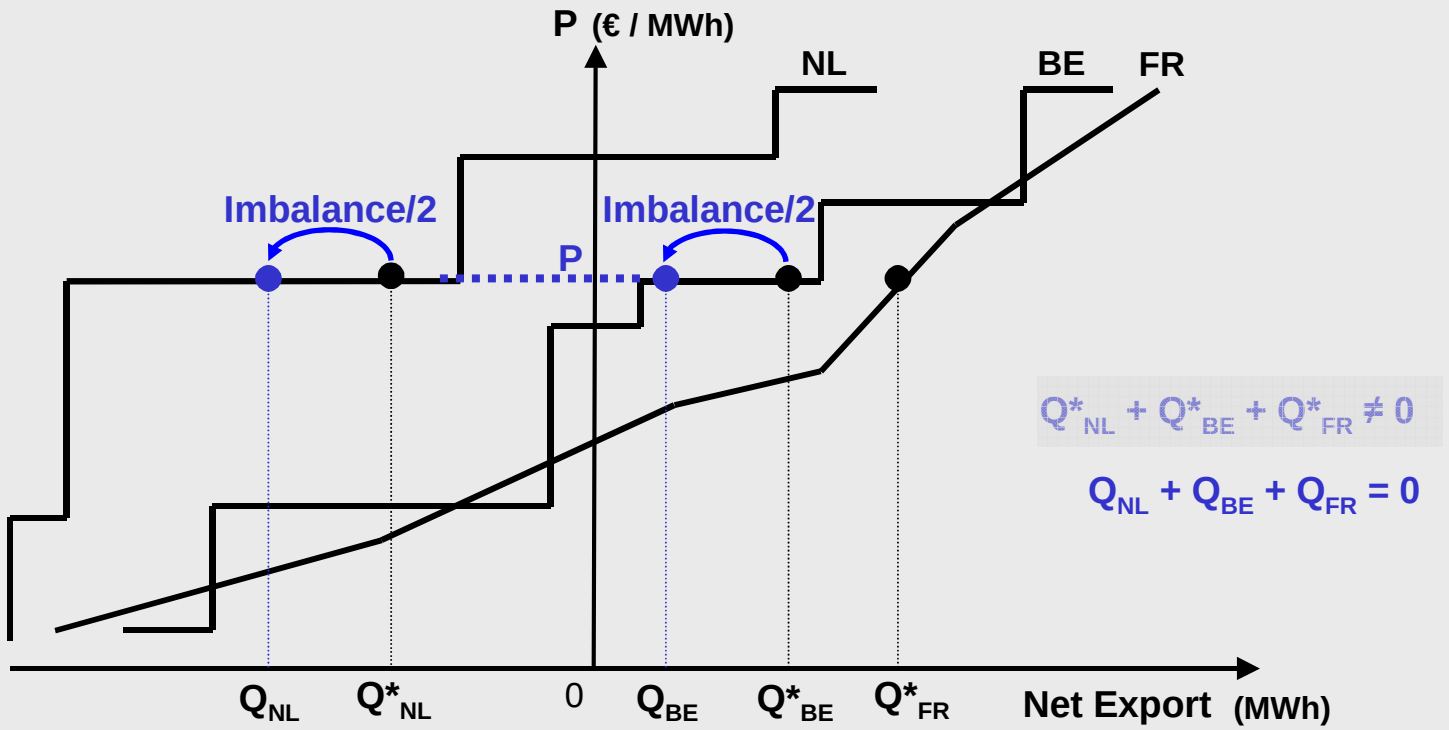
Quantity determination (example)

(1) Maximize total executed volume

(2) Equal volume division between markets when maximizing executed volume

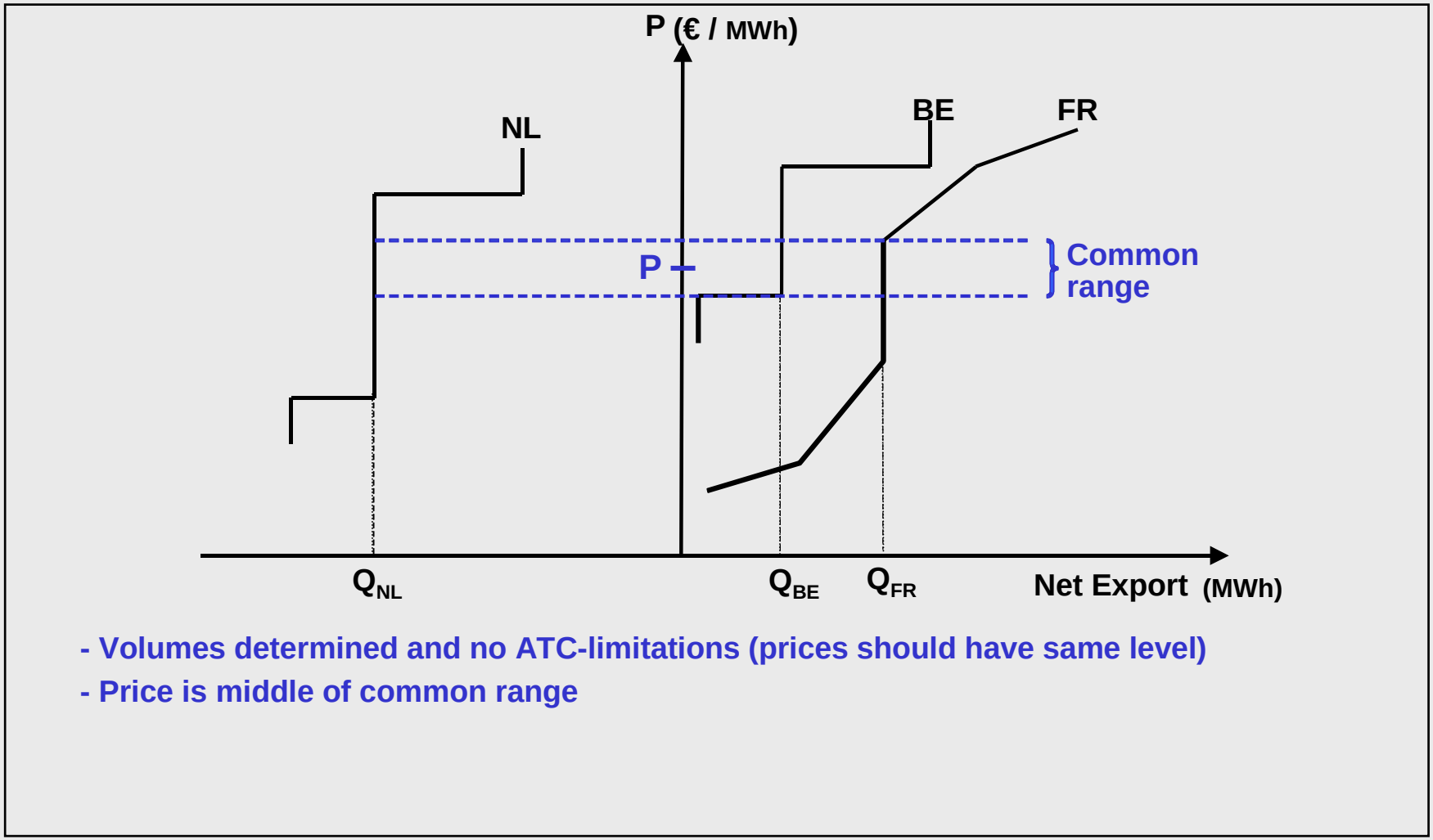


- For price P, different volumes are possible
- Q* is most optimal price-/volume pair for individual market (no orders are curtailed)
- $Q^*_{NL} + Q^*_{BE} + Q^*_{FR} \neq 0$ causes imbalance total net exports
- Divide imbalance over M2 and M3

Price determination (example 1)

(1) Determination based on HLPs

(2) Equilibrium price is middle of common part

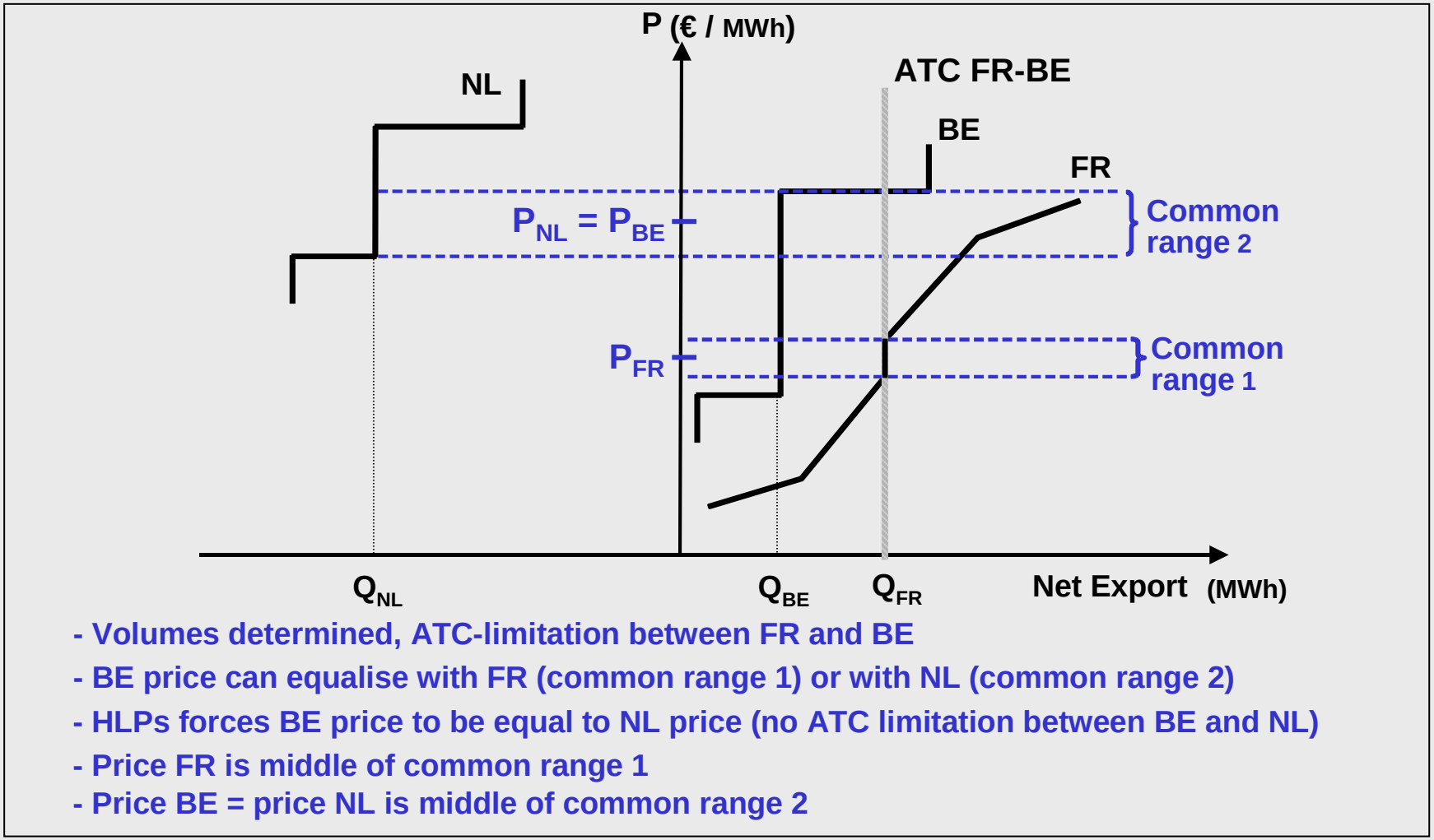


- Volumes determined and no ATC-limitations (prices should have same level)
- Price is middle of common range

Price determination (example 2)

(1) Determination based on HLPs

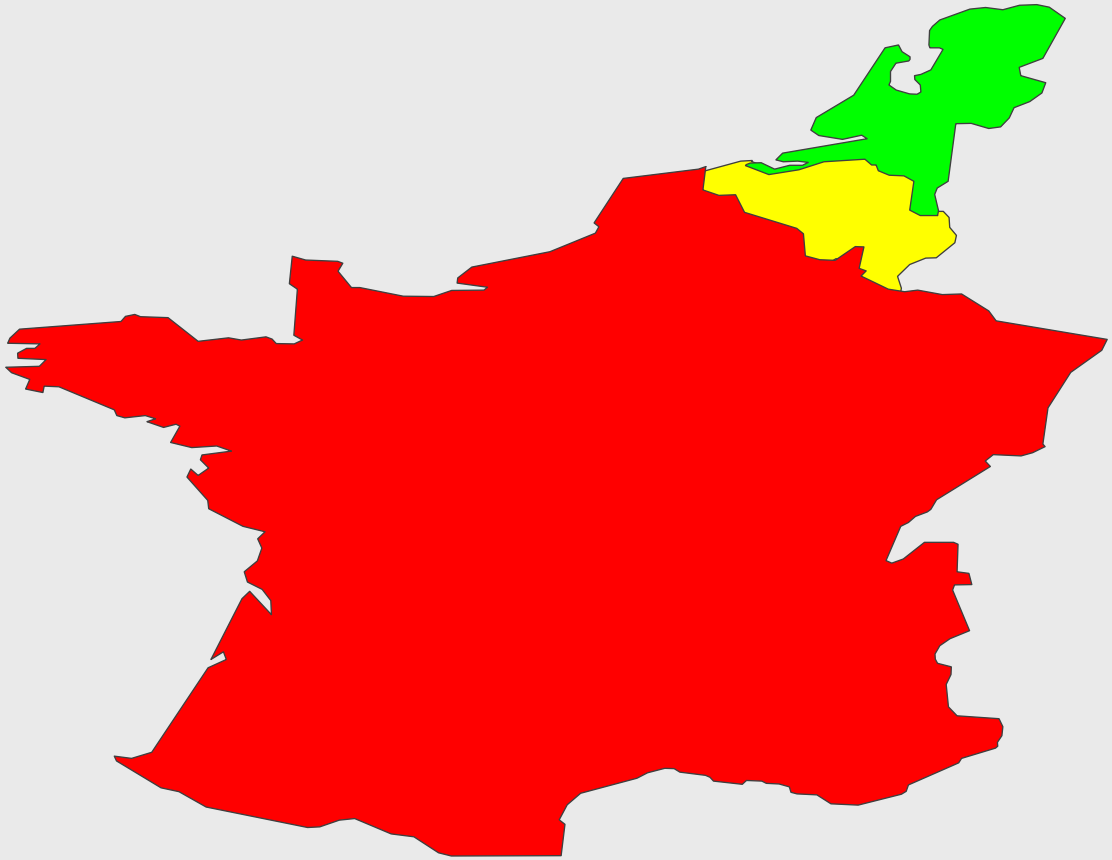
(2) Equilibrium price is middle of common part



- Volumes determined, ATC-limitation between FR and BE
- BE price can equalise with FR (common range 1) or with NL (common range 2)
- HLPs forces BE price to be equal to NL price (no ATC limitation between BE and NL)
- Price FR is middle of common range 1
- Price BE = price NL is middle of common range 2

Trilateral Market Coupling

Coupling Algorithm
(with block orders)



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Iterative calculations

Block orders

- make matching problems combinatorial
- introduce a coupling between different hours

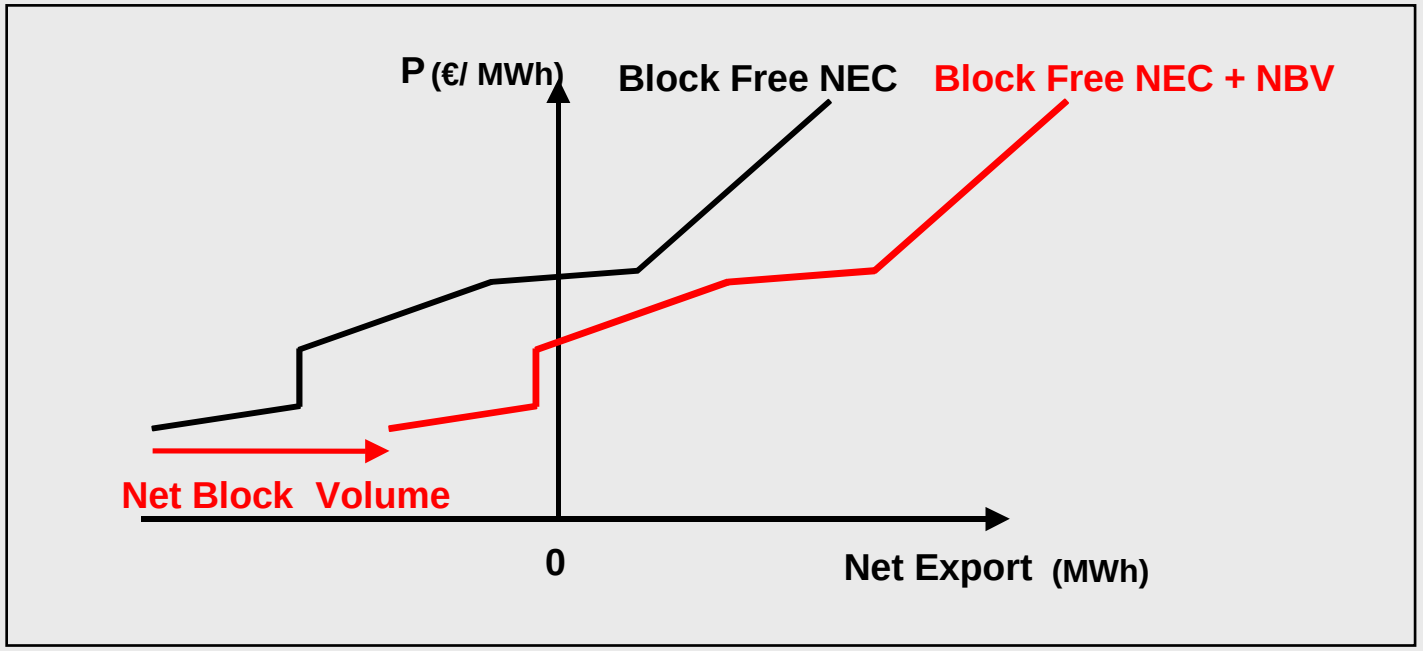
As a result

- NECs are not the exact price response of a market
- NECs are not independent from each other

Iterative calculation steps enable resolution of intertemporal and interzonal constraints

Iterative calculations

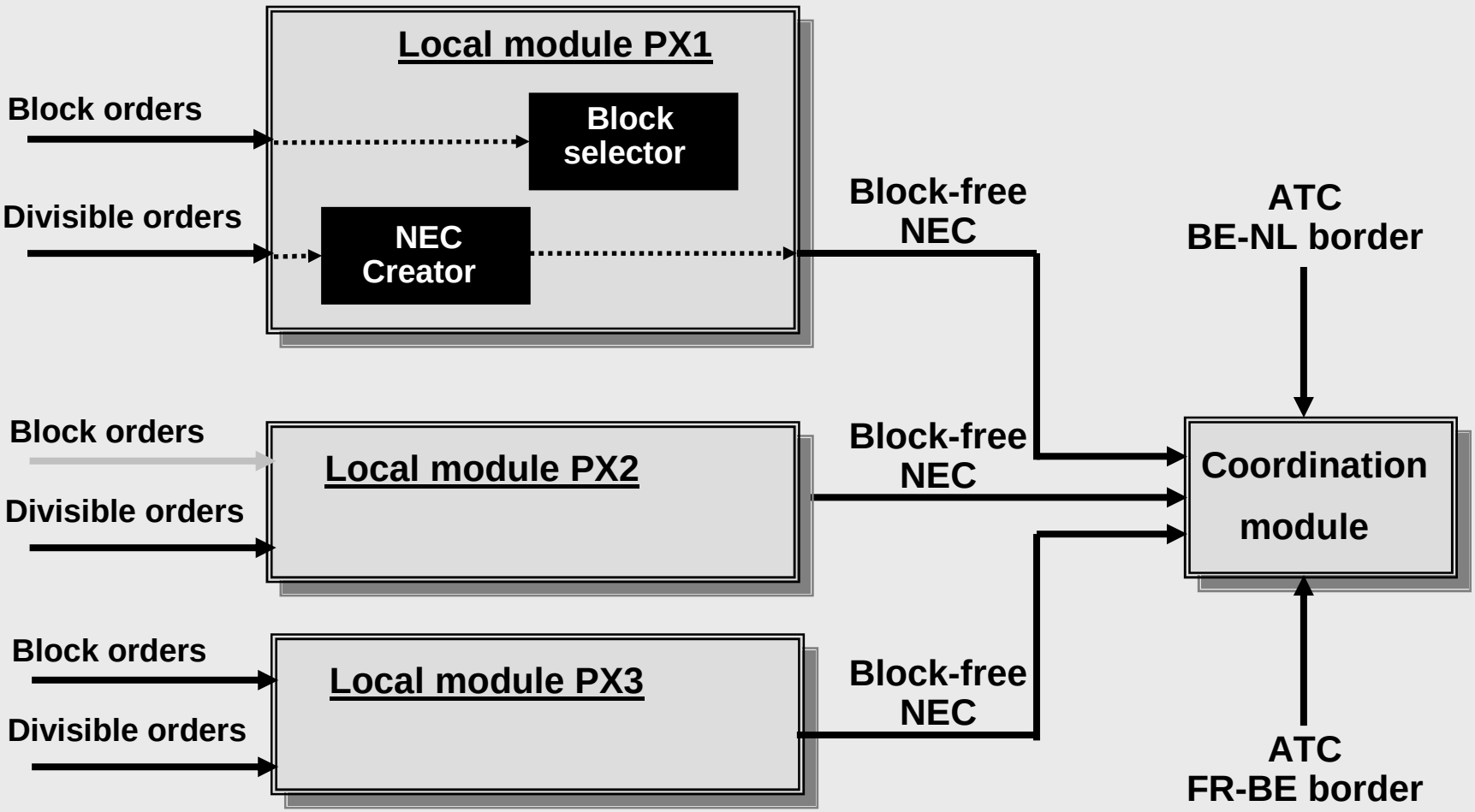
Block free NEC shifted by Net Block Volume (NBV)



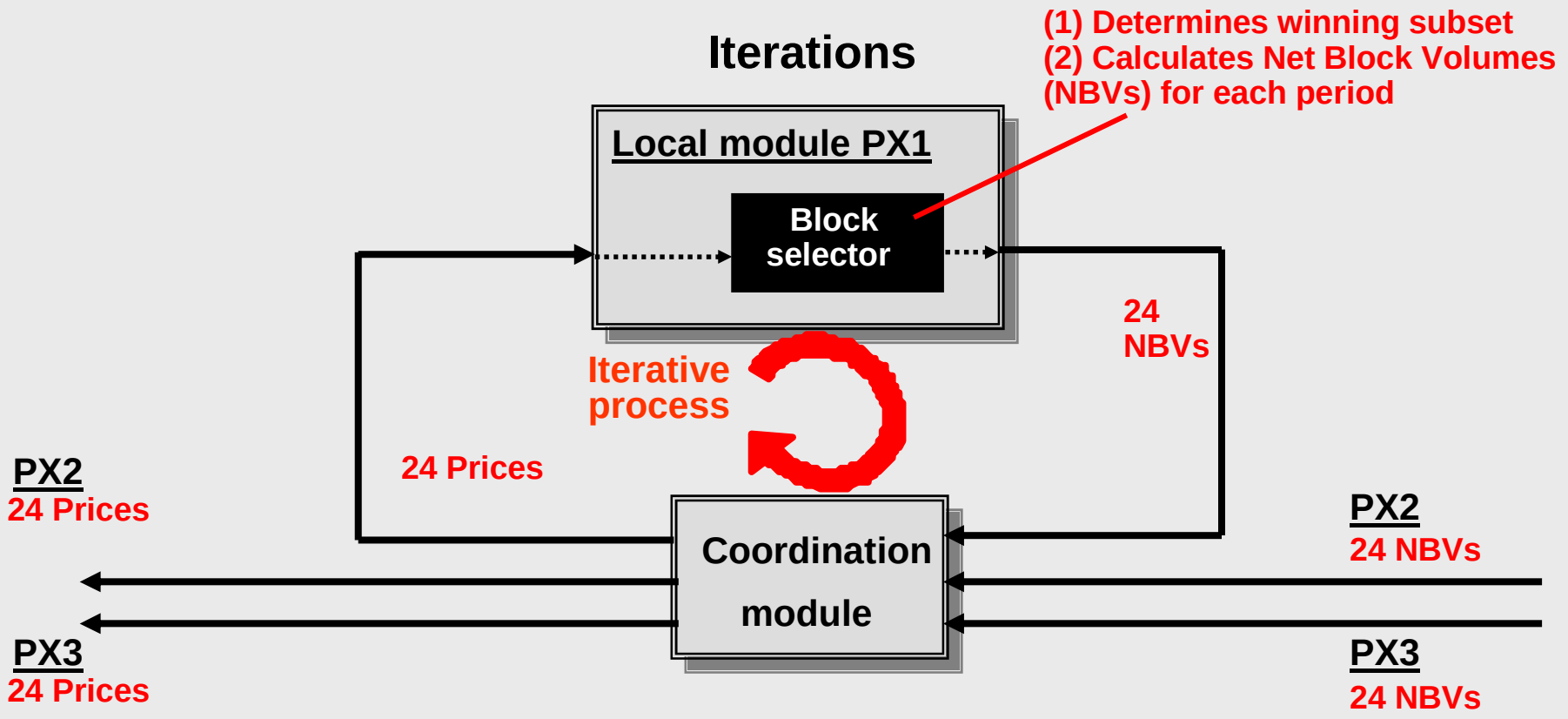
- NEC shifted by NBV is used for iterative steps
- Three markets calculate NEC shifted by NBV for new iteration round

Iterative calculations

Data collection



Iterative calculations



- Iterations stop when prices for each market and for each settlement period are equal to previous iteration
- At convergence Coordination module calculates Net positions for each market
- Each market determines schedules of its participants/ portfolios

Block selector functioning

First step: selection of the "pure winning subset"

- If the average market price is higher than, or equal to, a sale block order's price limit, then the block is accepted
- If the average market price is lower than, or equal to, a purchase block order's price limit, then the block is accepted
- All other blocks are rejected

But:

- This may not be sufficient because combinatorial problems may mean no solution without Paradoxically Rejected Block Orders (same for stand-alone markets)

Illustration:

→ Accept block offer order at iteration k
→ CM calculates lower MCP for iteration k+1
→ Block offer is rejected in iteration k+1
→ CM calculates new, higher MCP for iteration k+2
→ Block offer is accepted in iteration k+2

Block selector functioning

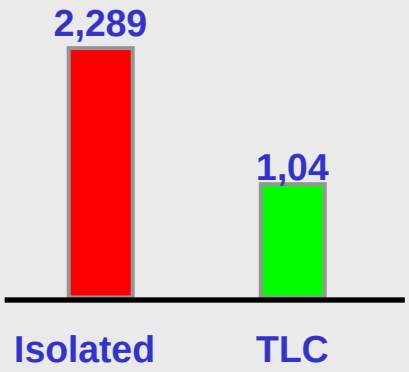
Second step: refinement of the "pure winning subset"

- **Heuristics are implemented in order to**
  - **allow for paradoxical rejection and avoid cycling**
  - **avoid large oscillations of the algorithm creating PRBs with large ΔP = | price limit – average MCP|**
  - **minimise the amount and severity of the PRBs in a limited time window**
- **Main principles**
  - **at each iteration, it is made increasingly difficult for BB to re-enter the winning subset**
  - **criterion for re-entering is based on ΔP**

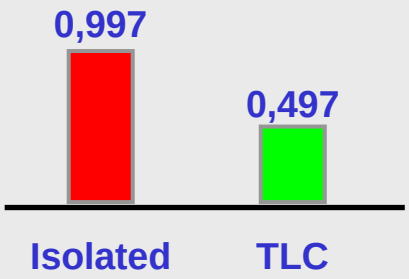
Block selector functioning

Performance TLC regarding # of PRBs and ΔP (simulation data 2004)

APX market

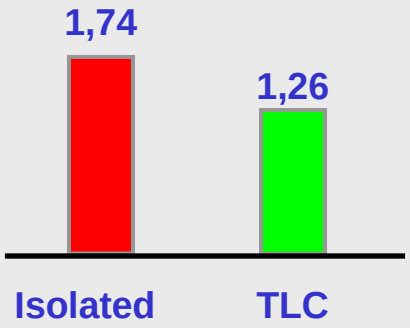


Average # of PRBs per day



Average ΔP (€)

Powernext market



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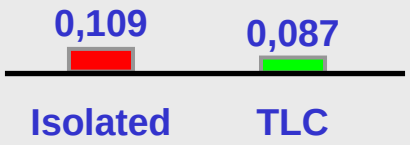

Average ΔP (€)

High Level Properties of Market Coupling

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- Maximize flow until prices across link converge (or ATC limit reached)

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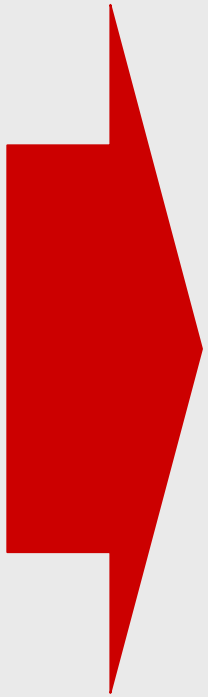
- Respect participants' order price and volume conditions (normal exchange rules)



Market clears: all possible trades executed

Efficient use of the available transmission capacity

Possible to verify this every day using publicly available data

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