Can a Joint Energy and Transmission Right Auction deliver well-functioning long-term cross-border electricity market in Europe?

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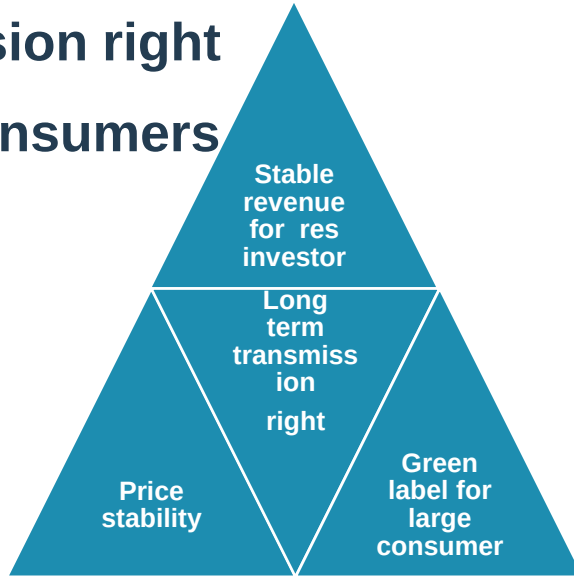
Background of research question

- ❑ Decarbonisation in power, transport and building sector, electricity demand increases, cross border electricity trade expects substantial increase
- ❑ Stable revenue for RES in zero subsidy era
- ❑ Green electricity labels for industrial consumers and retailers
- ❑ Price stability for consumers
- ❑ Cross-border PPA + long-term wholesale market + long term transmission right
- ❑ Long-term transmission right: win-win-win for renewable investors, consumers and grid users



History and status quo

Long-term priority access on interconnection capacity for vertically integrated utilities

Three Energy Packages with a focus on unbundling

Long-term priority access had been examined with critical view by EU institutions

Short term dominant market with implicit auctioning for interconnection capacity

Reimagination of the future market design

- Long-term cross-border electricity market several years prior to delivery
- Bilateral contract combined with transmission right or standardized contract in wholesale market that implicitly includes transmission access
- Financial transmission right and physical transmission right that hedge congestion costs
- Multi settlement system that links markets in different time frames
- Joint energy and transmission right auction proposed by O'Neil et al (2013)
- Research question: With energy and transmission use simultaneously optimized in the long-term market, will the zonal market design in Europe deliver the same level of economic gains in comparison with that of the nodal pricing?

Joint energy and transmission right auctioning

- Model description
- $Max\ b_1 t_1 + b_2 t_2 + b_3 t_3 + b_g g$
- $\beta_1 t_1 + \beta_2 t_2 + \beta_3 t_3 + \beta_g g \leq F)$ $\mu)$
- $\alpha_2 t_2 + \mu g = 0$ $\lambda)$

Objective function: Maximize the bid values

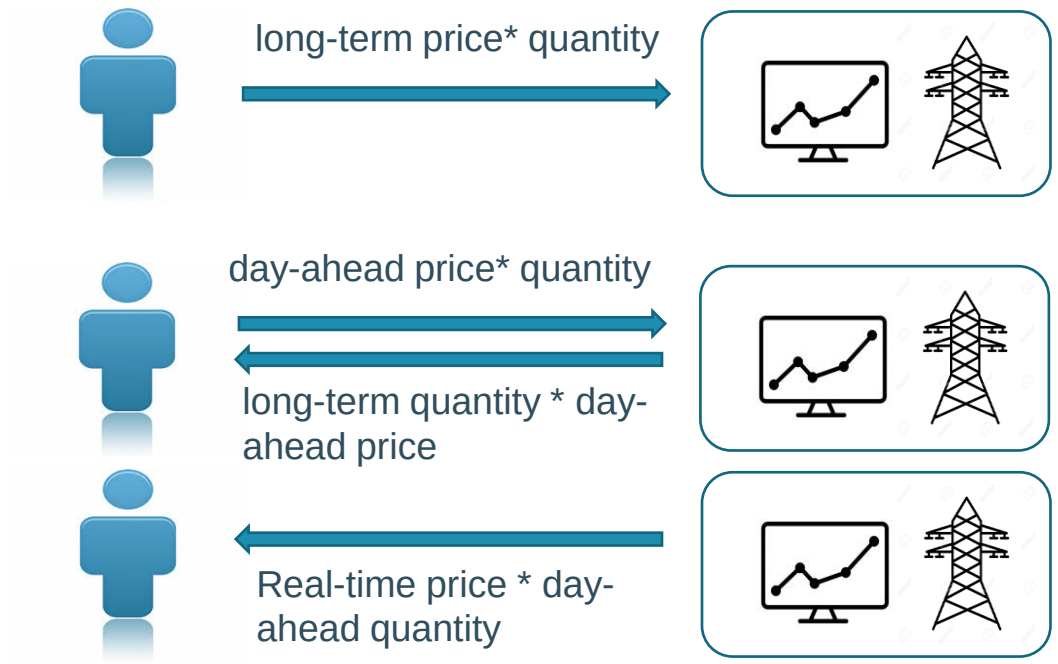
Flow constraints: DC flow constraints in nodal network ➔ dual as shadow price of the congested lines ($\boldsymbol{\beta_1, \beta_2\ , \beta_g}$ is a vector of the transmission rights needed on each transmission element per unit of each bid type)

Energy balance constraint: energy sell and purchase equal ➔ dual as hub price (cost of supply energy at the assumed hub in PTDF calculation)

Nodal pricing: financial or physical dispatch in different timeframes

- Consistent nodal network representation under nodal pricing works with the ISO responsible for market and network operation in all time frames.
- All bids are liquidated after each round of auction.
- Revenue adequacy is always achieved for the system operator

Nodal	• Long-term auctioning: Financial
Nodal	• Day-ahead auctioning: Financial
Nodal	• Real-time market clearing: Physical



Zonal market and institutions

Zonal pricing market in Europe is devised to be centered around day-ahead market, featuring interaction between national TSOs and power exchange.

Zonal	• Long-term auctioning: Financial
Zonal	• Day-ahead auctioning: Physical
Nodal	• Redispatch and balancing: Physical

TSOs
- Calculate zonal grid model based on estimation on market clearing result
- Prior to market clearing

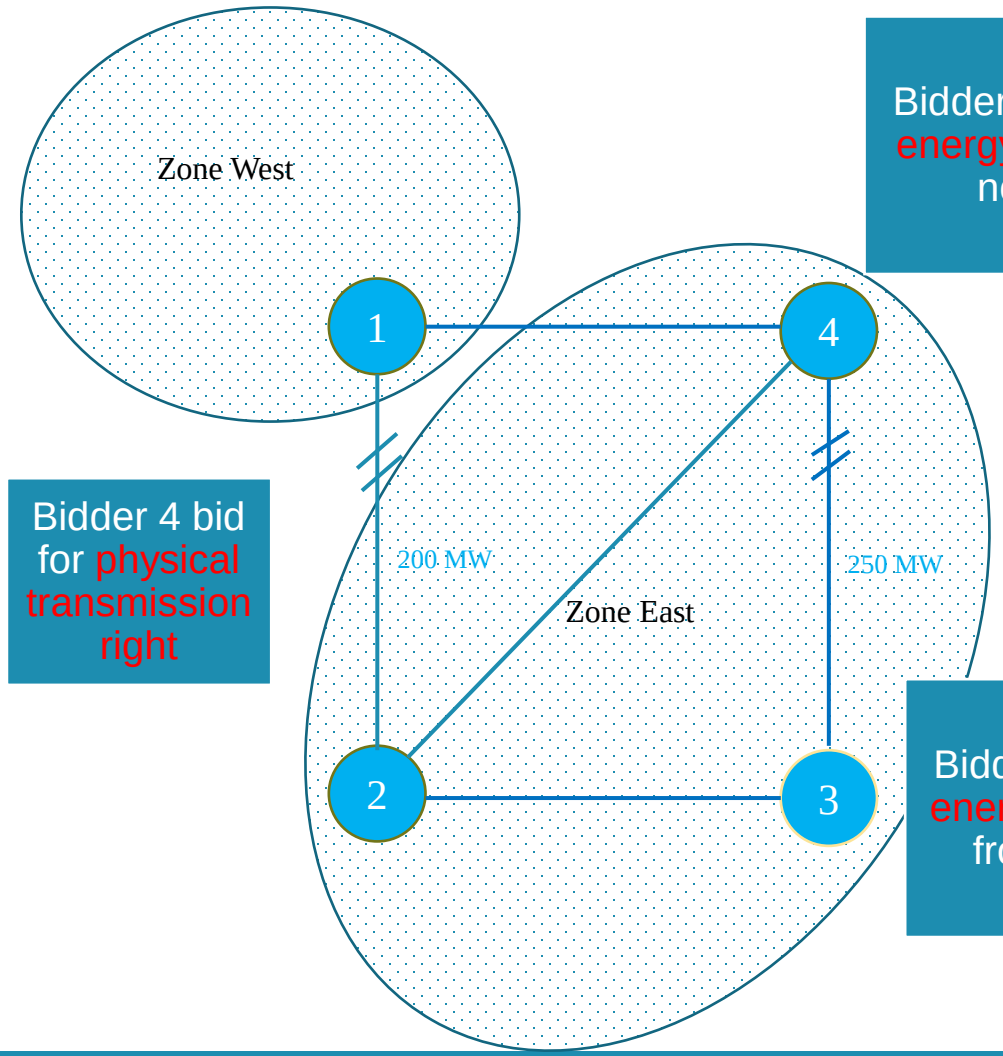
Power exchanges
- Accept supply and purchase bids
- Clears the long-term and day-ahead market with auctioning algorithm

TSOs
- Redispatch & Balancing
- After market closure

Nodal pricing: a case study

Bidder 1 bids for financial transmission right from node 1 to node 3

Bidder 3 bids for energy sell from node 4



Bidder 4 bid for physical transmission right

Bidder 2 bids for energy sell from node 2

Bidder 5 bids for energy purchase from node 3

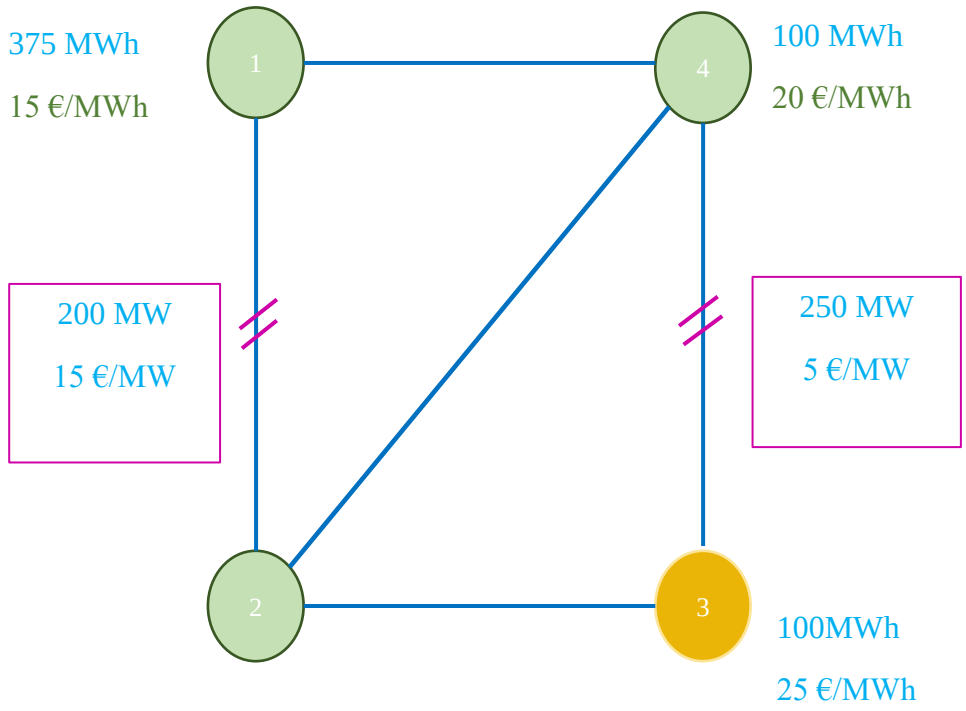
PTDF of bid 1: transmission capacity needed on each transmission element per unit of FTR between node 1 and 3

	Bid 1	Capacity (MW)
Line 1-2	0.5	200
Line 2-1	-0.5	200
Line 1-4	0.5	400
Line 4-1	-0.5	400
Line 2-3	0.5	400
Line 3-2	-0.5	400
Line 2-4	0	400
Line 4-2	0	400
Line 3-4	-0.5	250
Line 4-3	0.5	250

Calculation under nodal pricing: long-term auction

Payment from bid winners to SO in long-term time frame

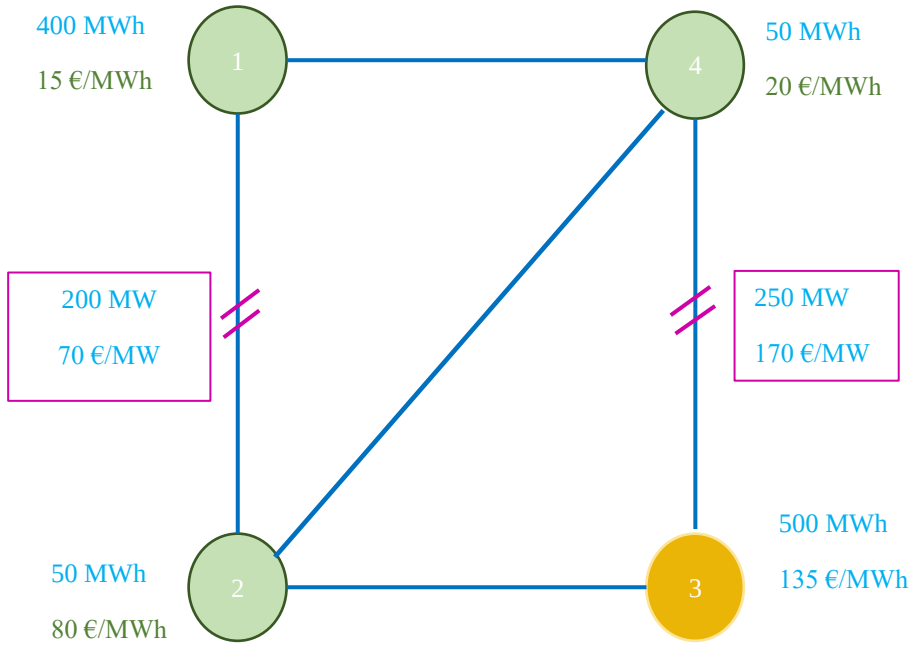
	Bidder 1	Bidder 2	Bidder 3	Bidder 4	Bidder 5
Type	Financial transmission rights	Energy sale	Energy sale	Physical transmission rights	Energy purchase
Upper bound (MW)	500	150	300	100	300
Lower bound (MW)	200	0	0	0	0
Bid price €/MWh	10	35	20	10	25
Result quantity (MWh)	375	0	100	0	100
Result price (€/MW)	10	0	20	0	25
Payment to SO (€)	3750	0	-2000	0	2500



Nodal pricing: real time market

Payment from SO to the day-ahead bid winners at real time market

	Bidder 1	Bidder 2	Bidder 3	Bidder 4	Bidder 5
Type	Financial transmission rights	Energy sale	Energy sale	Physical transmission rights	Energy purchase
Quantity (MW)	375	0	100	0	100
Price (€/MW)	120	0	20	0	135
Payment to SO (€)	45000	0	-2000	0	13500



Calculation results

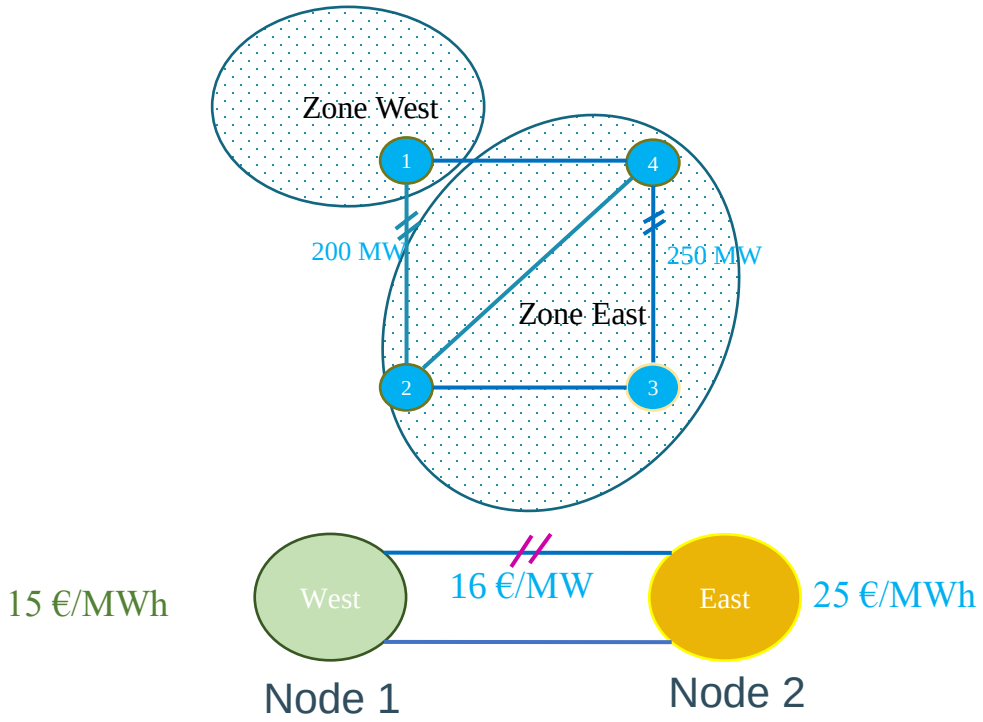
- Real time market: Load at node 3 pays 67500 € € to SO, SO pays 6000 € to generator at node 1, 4000 € to generator at node 2 and 1000 € to generator at node 4. Surplus of 56500 €.

  Bid 1 gets paid 45000€, bid 5 gets paid 13500€, bid 3 pays 2000 € to SO. Net payment 56500 €.
- Revenue adequacy for the system operator in all time frames by comparing load payment – generation costs versus payment to the auction winning bidders.
- Payback to the user 58500 € in real time market for the FTR and energy purchase contract rewarded in day-ahead market.
- Long-term market bid 1 wins 375 MWh FTR, bid 5 100MWh energy purchase

  Payment: bid 1 pays 3750 € to SO, bid 5 pays 2500 € to SO.
- Day-ahead market clearing and settlement the same as long-term.
- Total costs for the user at node 3, which is assumed to represent bid 1 for FTR between node 1 and node 3 and bid 5 who purchases energy in forward market: 15250€.

Long-term auctioning in zonal pricing market

- Worst case scenario to determine the zonal PTDF in long-term market
- Transaction node 1 to node 2 to represent zone west to zone east transaction

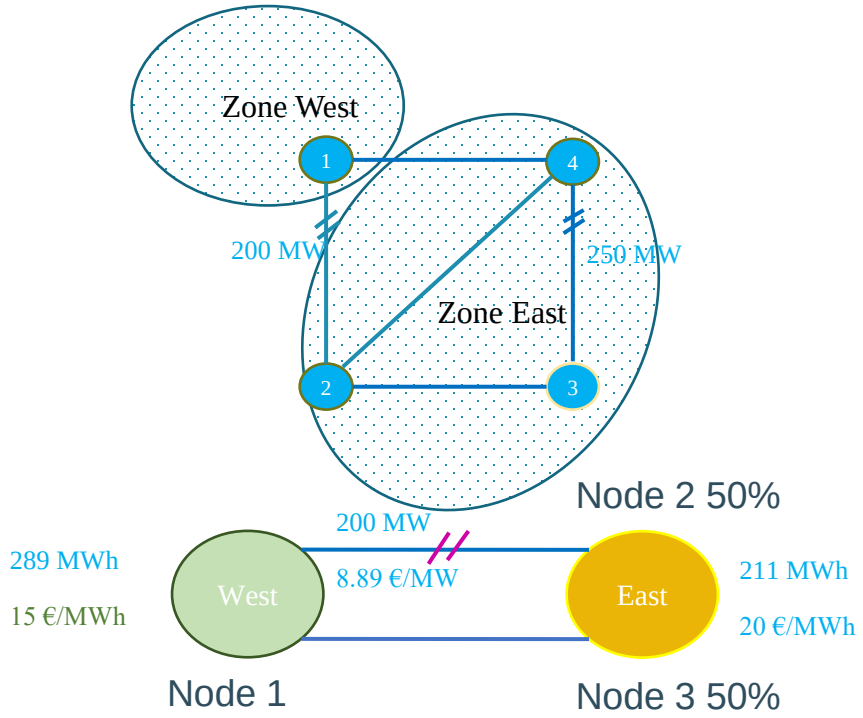


	Capacity (MW)	Bid 1	Bid 2	Bid 3	Bid 4	Bid 5	Shadow price (€/MW)
Line 1-2	200	0.625	0.125	0.125	1	0	16
Line 2-1	200	-0.625	-0.125	-0.125	0	0	0
Line 1-4	400	0.375	-0.125	-0.125	0	0	0
Line 4-1	400	-0.375	0.125	0.125	0	0	0

Bid 1 pays 2600 € for 260 MWh of FTR (<375 MWh in nodal pricing)
Bid 5 pays 7500€ for 300 MWh energy purchase

Zonal pricing day-ahead market coupling

- Heuristic method for PTDF determination in day-ahead market
- 50% transaction from node 1 to node 2 and 50% transaction from node 1 to node 3 (Interzonal PTDF on line 1-2 for bid 1 is 0.5625)



Payback to the long-term auction bid winners

	Bidder 1	Bidder 2	Bidder 3	Bidder 4	Bidder 5
Type	Financial transmission rights	Energy sell	Energy sell	Physical transmission rights	Energy purchase
Quantity (MW)	260	0	300	0	300
Price (€/MW)	5	0	20	0	20
Payment to SO (€)	1300	0	6000	0	6000

Transaction from zone west to zone east is 289 MWh. Generation, load surplus 1445€, net payment to bidders 1300 €. SO with 145 € surplus.

National and integrated redispatch & balancing

- Day-ahead market clearing results in 276.4 MW on line 4-3 that exceeds 250 MW limit
- Redispatch national: node 4 with 105.6 MWh↓, node 2 with 105.6 MWh↑
- Redispatch integrated: node 1 with 111 MWh↑, node 2 with 50 MWH↑, node 4 with 161 MWh↓

Redispatch cost: 1) National 6336 €; 2) Integrated 2445 € . Both exceeds 145 € surplus.

Break of revenue adequacy for system operator during this period

- No hedging opportunity for the costs incurred at this period

❑ Nodal network representation in the redispatch & balancing

❑ Market participants can not take part anymore as buyer

❑ TSO acts as the single buyer to the services

Total cost in the zonal pricing across different time frames national redispatch 19136 € , integrated redispatch 15245 €. Higher total costs and weaker hedging function for the users under zonal pricing in three scenarios.

Conclusions

- Joint energy and transmission auction from long-time market provides market participants hedging opportunity
- Zonal pricing cases deliver weaker hedging function and higher cost for market participants associated with demand than that of nodal pricing

➢ Volume of FTR made available to market participants between the same injection and withdrawal location in the long-term auction is much more constrained under zonal pricing as opposed to that of nodal pricing

➢ Inconsistency of zonal and nodal network model in different time frames

Moving towards nodal pricing is the prerequisite for development of effective hedging products and successful long-term market.

Main reference

- O’Neill, R. P., Helman, U., Hobbs, B. F, Stewart, W. R, & Rothkopf, M. (2002). A joint energy and transmission rights auction: proposal and properties. IEEE Transactions on Power Systems, 17(4), 1058–1067. https://doi.org/10.1109/tpwrs.2002.804978
- O'Neil, R. P., Helman, U., Hobbs, B. F., Rothkopf, M. H., & Stewart, W. R. (2013). A Joint Energy and Transmission Rights Auction on a Network with Nonlinear Constraints: Design, Pricing and Revenue Adequacy. In Financial transmission rights analysis, experiences and prospects, Springer.
- De Hauteclocque, A. (2013). The problem of long-term contracts in decentralized electricity markets: an economic perspective. In Market Building through Antitrust, Edward Elgar.
- Glachant, J. M., & Ruester, S. (2014). The EU internal electricity market: Done forever? Utilities Policy, 31, 221–228. https://doi.org/10.1016/j.jup.2014.03.006
- D’Aertrycke, G., & Smeers, Y. (2013). Transmission Rights in the European Market Coupling System: An Analysis of Current Proposals. In Financial Transmission Rights: Analysis, Experiences and Prospects (Lecture Notes in Energy, 7) (p. 549). Springer.