Is Marginal Cost Pricing still the ideal Energy Market Design

Panel Session on

The Energy Market & The European Energy Crisis

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Outline

- The Marginal Pricing Based Market Architecture
- Benefits of marginal Pricing
- Marginal Pricing Challenges
- Marginal Pricing Under Emergencies
- Marginal Pricing in a RES-based System (Challenges and Solutions)
- A Roadmap Moving Forward
- Conclusions

EU Politicians' Comments

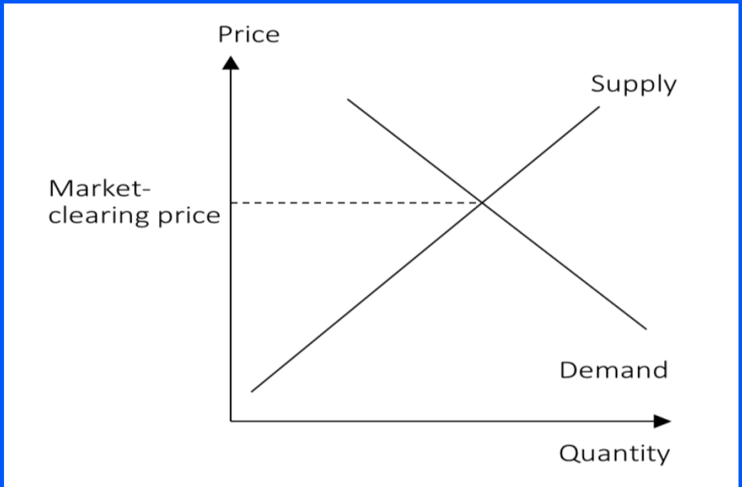
"We still have an electricity market that is designed in a way like it was necessary twenty years ago before we started to bring in the renewables. Today, the market is completely different and the system does not work any more." Ursula von der Leyen, 8 June, 2023

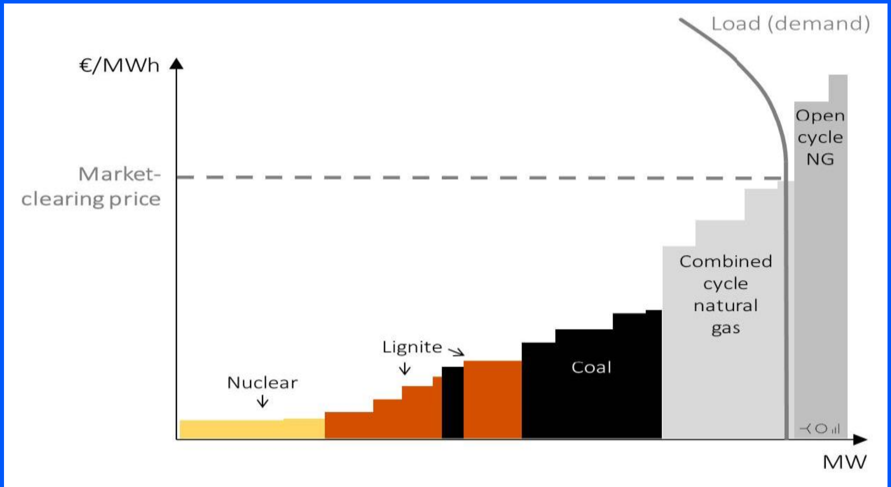
"People are being charged for their electricity prices on the basis of the top marginal gas price, and that is frankly ludicrous. We need to get rid of that system." Boris Johnson, 25 June 2022

"You have skyrocketing electricity prices that no longer have anything to do with electricity production costs, it follows gas, it's absurd" Emmanuel Macron, 28 June 2022

Marginal Pricing (1/4)

- Marginal pricing is not unique to power markets; consistent with economic theory; commodities such as oil, copper, milk, solar panels are priced on the margin; It's how prices emerge from decentralized decision making; it is based **on shadow prices of the load balance constraint in the dispatch optimization** which determine the marginal effect of perturbing the constraint on the objective function





Marginal Pricing (2/4)

- Provides incentives to bid close to the actual costs → **promotes efficiency**
- It supports (short run) **efficient market clearing**
  - Maximizes social welfare (short run)
  - Maximizes profit for each generator
- Incentivizes **optimal resource mix** in the long run
- Compatible with carbon pricing → **promotes decarbonization**
- Allows part of capital costs to be recovered → **reduces the need for subsidies or capacity mechanisms**
- Sends signal for investments in new technologies and where new investments would be required (e.g., storage, peak generation, hydrogen, etc.) → **promotes innovation** (Investments reduce margins)
- Transparent and understandable to market participants → **builds confidence in the market**

Marginal Pricing (3/4)

- Contributes to the financing of RES and reduces the need for subsidies → **supports decarbonization**
- Provides a signal for demand participation (through aggregators)→ **promotes demand participation in wholesale markets**
- Compatible with spatial and temporal marginal costs for delivering electricity → **facilitates spatiotemporal price discovery (LMPs)**
- Serves as a reference for risk hedging strategies for both producers and consumers → **enables end-customer shielding from price shocks**
- Serves as a reference for market coupling in EU (for DAM) → **facilitates cross-border trading, enhances price convergence**

Marginal Pricing (4/4)

- When generation capacity is at an optimum level, marginal pricing (set at VOLL during scarcity) will result in full recovery of fixed costs
- There are some unique characteristics of power markets; non-storability (in massive scale), perishability and uncertainty resulting in high market price volatility
- High price volatility motivates buyers to enter into long-term contracts to hedge their risk exposure and enable investments
- **Energy-Only markets** can work (ERCOT, Australia, etc.)
- **Convexity is required for marginal pricing to work**
- In reality non-convexity exists due to: cost monotonicity, binary decision variables, Unit Commitment costs, inflexible units, etc.
- Under non-convexity conditions marginal pricing sometimes cannot support an efficient dispatch (**need of uplift payments**)

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Marginal Pricing Challenges

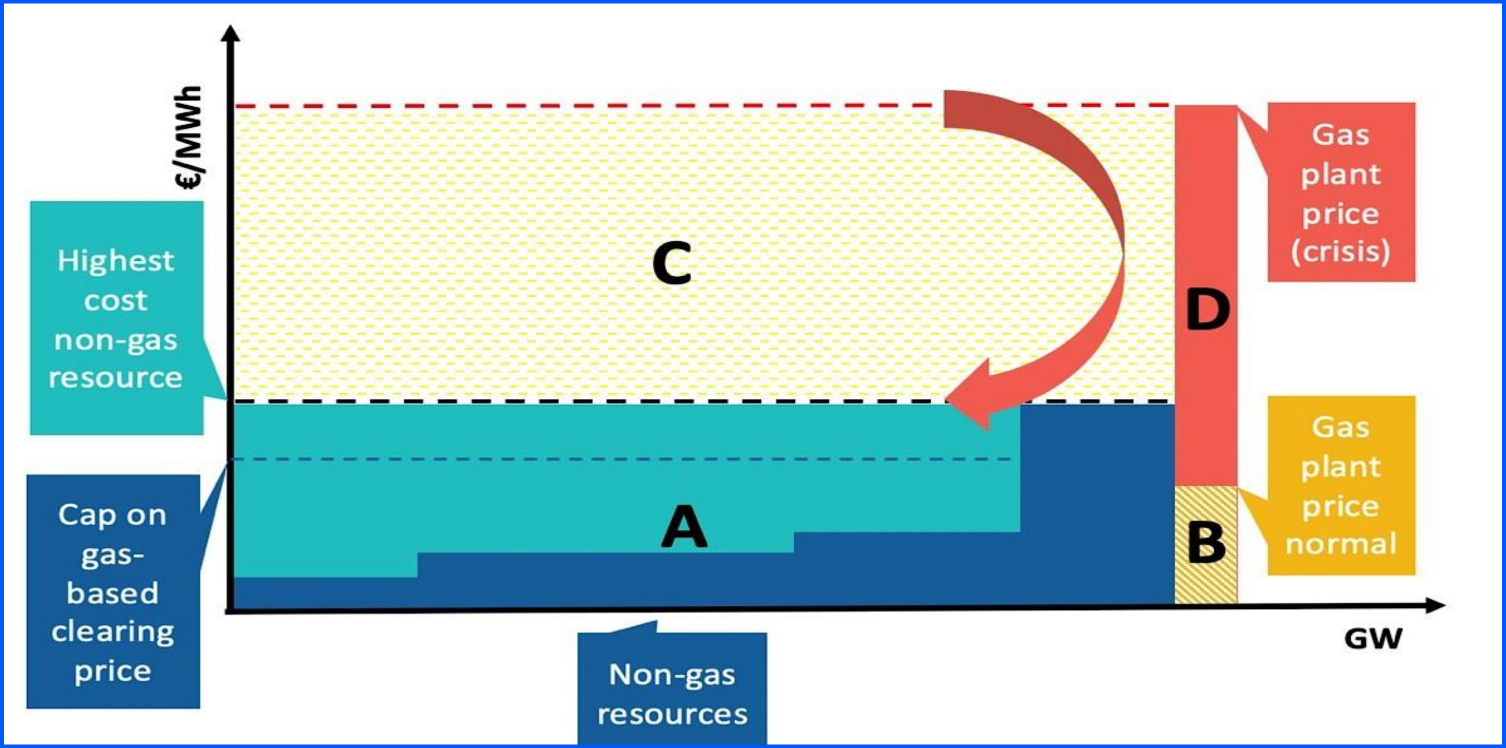
- Marginal Pricing under emergencies
- Renewable Energy based systems with zero marginal cost generation (Unit Commitment, Dispatch and Pricing)

Marginal Pricing Under Emergencies: The Price Shock Absorber Solution

- I support **'Price shock absorber**' mechanisms also called soft caps or circuit breakers; they trigger a temporary cap on the ability of gas generation to set the price as result of an extraordinary event (a 'shock')
- Under these conditions the accumulated **inframarginal rents** are deemed to reach a level beyond which they are no longer contributing to the **market's objective of maximizing the social welfare**
- It decouples wholesale electricity and gas prices
- It preserves to maximum extent the efficiency of the marginal pricing while protecting electricity consumers from the extreme impacts of extraordinary events

EU Energy Crisis: The Price Shock Absorber Solution

- Loads pay A + B + D BUT NOT C (no substantial transfer of wealth from consumers to generators)



Other Pricing Methods Under Emergencies

- **Windfall profit tax (implemented in many EU countries)**
  - **Mechanics**
  - collect the profits, cycle them through national coffers and pay out to consumers on a pre-determined basis
  - Decouple subsidies from consumption & caps technology agnostic
  - **The good**
  - It is used to raise funds to subsidize targeted users
  - It maintains production and allocative efficiency
  - It is economically sound, in principle
  - **The Bad**
  - Inefficiencies of many intermediate processes
  - Requires substantial creative accounting
  - Arbitrary politically-based decisions

Other Pricing Methods Under Emergencies

- **Bifurcation of the DAM into two markets**
- one for RES, hydro and nuclear and
- the other for coal and gas
- A terrible idea debunked in the US from all serious market designers
  - It kills the market signal and the inframarginal rents
  - It kills the maximization of social welfare and creates huge regulatory and investment uncertainty
  - Increases the cost of capital
  - Provides disincentives for long-term PPAs and Forward Markets

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Renewable Energy based Systems with Zero Marginal Cost Generation (1/4)

- Challenges in Renewable Energy based systems include increased:
  - Congestion
  - Uncertainty
  - Non-convexities
- Marginal pricing can effectively address these challenges / externalities
- Every study we have executed confirms that the price distribution has and will continue to change as RES generation penetrates the system

Renewable Energy based Systems with Zero Marginal Cost Generation (2/4)

- Challenges in Renewable Energy based systems include increased:
  - **Congestion**
- Congestion now becomes unsystematic and unpredictable
- The need to transition Zonal Model to Nodal LMP models is increasing
- LMPs reflect the marginal cost of congestion

Renewable Energy based Systems with Zero Marginal Cost Generation (3/4)

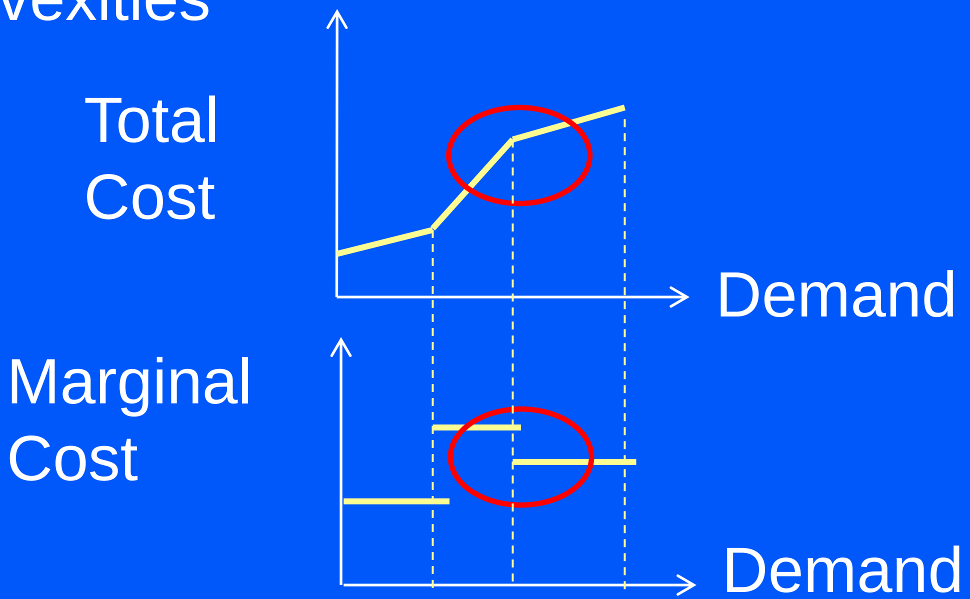
- **Uncertainty**
- Procurement of ancillary services (re-designed, including ramping, to address reliability concerns) is compatible with Marginal Pricing (through co-optimization)
- Pricing the marginal risk that assets impose on the system (**reliability externality**) and addressing the cost-causation argument (the “polluter” pays) is critical
- It reduces costs for consumers and provide signal for investment in technologies that support renewable integration

Renewable Energy based Systems with Zero Marginal Cost Generation (4/4)

- **Non-convexities**
- A long-standing issue that will be aggravated (frequent switching of units, more hours in technical minimum generation), and resulting uplifts would increase
- Approaches such as **Integer Relaxation**, **Average Incremental Cost**, **Convex Hull pricing** are all compatible with marginal pricing
  - Integer Relaxation is a "proxy" Convex Hull pricing
  - Average Incremental Cost adds on the LMP component to eliminate make-whole payments
  - Convex Hull pricing derives the marginal cost in a "convexified economy" (obtained from a convex combination of feasible schedules) and supports the market solution with minimum uplift

Marginal Pricing Under Non-Convexities

- Non-convexities



Unit Commitment, Dispatch and Marginal Pricing

- **Unit Commitment problem**

$$\min_{\mathbf{x},\mathbf{y}} f(\mathbf{x},\mathbf{y}) = \sum_i f_i(\mathbf{x}_i,\mathbf{y}_i),$$

subject to:

System constraints, e.g., power balance: $\sum_i x_{i,t} = D_t, \forall t,$

Generation unit constraints, e.g., min/max limits, ramp rates, min up/down times, etc.: $(\mathbf{x}_i,\mathbf{y}_i) \in \mathrm{Z}_i, \forall i.$

$f_i(\cdot)$: Cost function of unit *i*

$x_{i,t}$: **Continuous** variables, e.g., power output of unit *i*, at time period *t*

$y_{i,t}$: **Discrete** variables, e.g., status (on/off) of unit *i*, at time period *t*

D_t: Demand at time period *t*

Z_i: Set of unit *i* constraints

Unit Commitment, Dispatch and Marginal Pricing

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- **Integer Relaxation (λ)**

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D_t: Demand at time period *t*

Z_i: Set of unit *i* constraints

$$\min_{\mathbf{x},\mathbf{y}} f(\mathbf{x},\mathbf{y}) = \sum_i f_i(\mathbf{x}_i,\mathbf{y}_i),$$

s.t.: $\sum_i x_{i,t} = D_t, \forall t,$ $\longrightarrow$ $\lambda_t,$

$(\mathbf{x}_i,\mathbf{y}_i) \in Z_i, \forall i,$ **with** $y_{i,t}$ **relaxed to continuous variables**

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Unit Commitment, Dispatch and Marginal Pricing

- **Unit Commitment problem**

$$\min_{\mathbf{x},\mathbf{y}} f(\mathbf{x},\mathbf{y}) = \sum_i f_i(\mathbf{x}_i,\mathbf{y}_i),$$

subject to: $\sum_i x_{i,t} = D_t, \forall t,$

$$(\mathbf{x}_i,\mathbf{y}_i) \in \mathrm{Z}_i, \forall i.$$

- **Convex Hull Prices (λ)**

Lagrangian Dual

$$\max_{\boldsymbol{\lambda}} q(\boldsymbol{\lambda}),$$

where: $q(\boldsymbol{\lambda}) = \inf_{(\mathbf{x}_i,\mathbf{y}_i)\in \mathrm{Z}_i,\forall i} L(\mathbf{x},\mathbf{y},\boldsymbol{\lambda}),$

$$L(\mathbf{x},\mathbf{y},\boldsymbol{\lambda}) = \sum_i f_i(\mathbf{x}_i,\mathbf{y}_i) - \sum_t \lambda_t \left(\sum_i x_{i,t} - D_t\right).$$

Convexified Primal

$$\min_{\mathbf{x},\mathbf{y}} \sum_i f_i^{**}(\mathbf{x}_i,\mathbf{y}_i),$$

subject to: $\sum_i x_{i,t} = D_t, \forall t,$ ⟶ $\lambda_t,$

$$(\mathbf{x}_i,\mathbf{y}_i) \in conv(\mathrm{Z}_i), \forall i.$$

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Unit Commitment, Dispatch and Marginal Pricing

- The expanded Unit Commitment can provide convex hull prices with most constraints included, like ramping
- These approaches have not attracted too much attention in the industry
- An alternative approach is to maintain the standard unit commitment but apply either the well-known Dantzig-Wolfe decomposition or heuristics to accelerate Benders decomposition applied to the dual problem of the original unit commitment
- **Bottom Line: Greater penetration of renewables does not affect the basic theoretical issues, but it does reinforce the importance of improved pricing models**

Moving Forward

- Forward Markets and long-term markets **<u>based on expected real-time prices</u>** (stay deterministic for now); the basic structure of FM and contracts, which are mostly financial, stay the same
- They provide a valuable arbitrage function to address prices but not quantities
- Redesign Contracts for Differences (price, floors, etc.)
- Redesign of Short-term markets to accelerate deployment of Renewable Energy
- RA; Two connections with market design (**<u>incentive problem, incomplete markets</u>**)
- Transmission policy & infrastructure planning (**<u>need hybrid systems</u>**)
- Better Consumer Empowerment and Protection
- DR and DERs (DSO Markets) and Interface with wholesale markets
- Continue to improve price formation

Key Messages

- Electricity market are necessarily hybrid systems
- The basic framework of efficient spot electricity markets with marginal pricing remains solid (in theory and practice) despite the challenges
- Power is a commodity differentiated by time and space and marginal pricing offers the correct price signals for **operation** and **investment decisions**
- RES penetration clearly creates challenges but does not challenge energy market & RA theory & practice; to the contrary the spot market design is even more important in decarbonization efforts
- Reform efforts should focus on **efficient pricing models, scarcity pricing, improved capacity market models, flexible demand response**, **multi-period dispatch and pricing, Unit Commitment pricing issues and expansion of wholesale market to the distribution level (DSOs)**
- Maintain the classical Unit Commitment but apply the Dantzig-Wolfe Decomposition or heuristics to accelerate the Benders Decomposition