Bremer Energie Institut

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Large-scale integration of renewables and generation adequacy:

Design options for a European Capacity Market

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Work in progress.
Please do not quote!

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A changing environment

Towards low-carbon energy supply

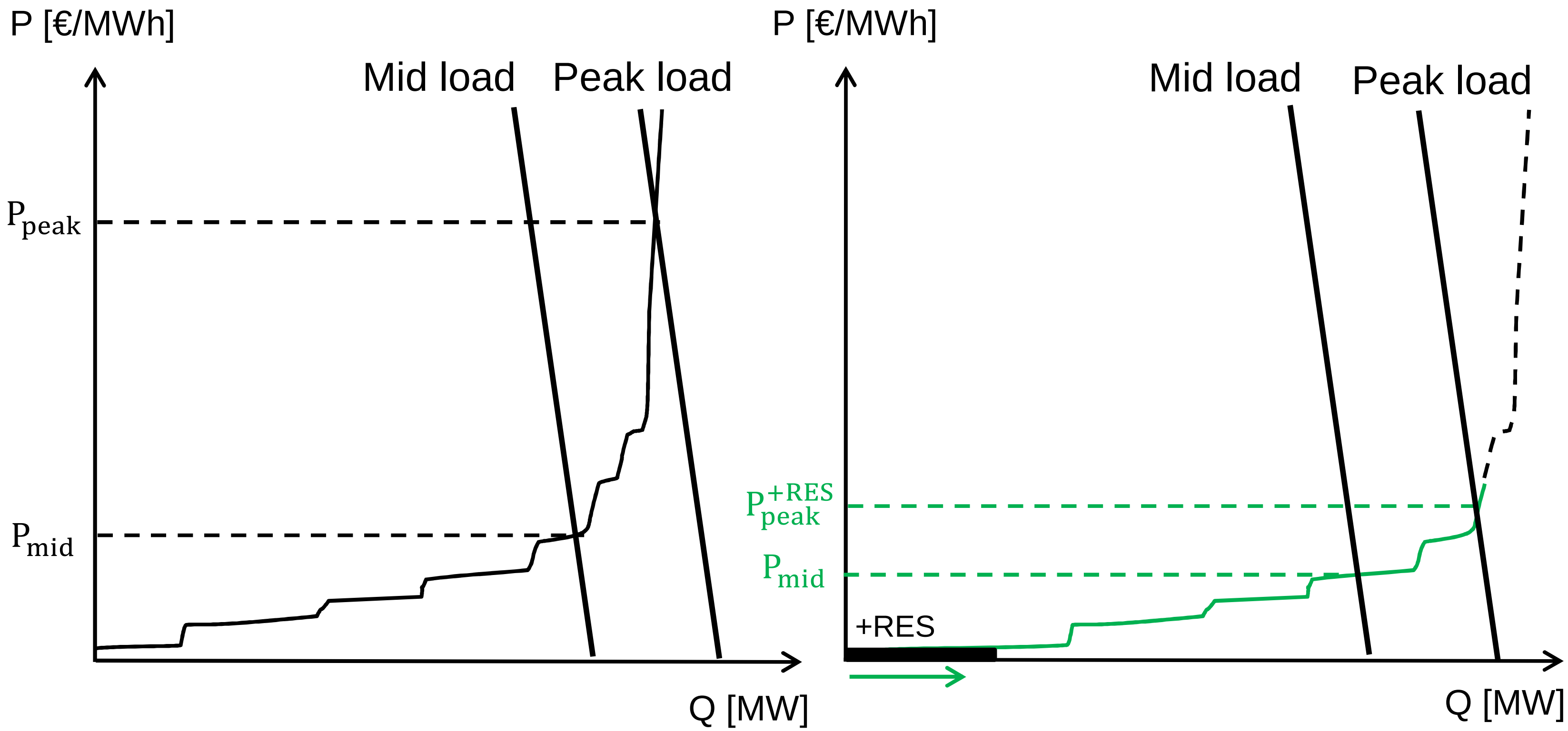
- Transformation towards large-scale integration of renewable energy sources (RES)
- Different (partly out-of-market) support schemes for RES
- E.g. Germany
  - Priority feed-in
  - Fixed feed-in tariffs
- But intermittent supply of RES
  - Conventional generators needed as reserves in case of low wind and solar generation
  - “Missing money problem”: Does the market provide sufficient investment incentives?
- Traditional market design: *energy-only market*
  - Generators receive revenues for *produced energy [€/MWh]* and not for holding *capacity reserves [€/MW]*

Is energy-based remuneration adequate for a world of *50+ percent RES*?

A changing environment

The merit-order-effect

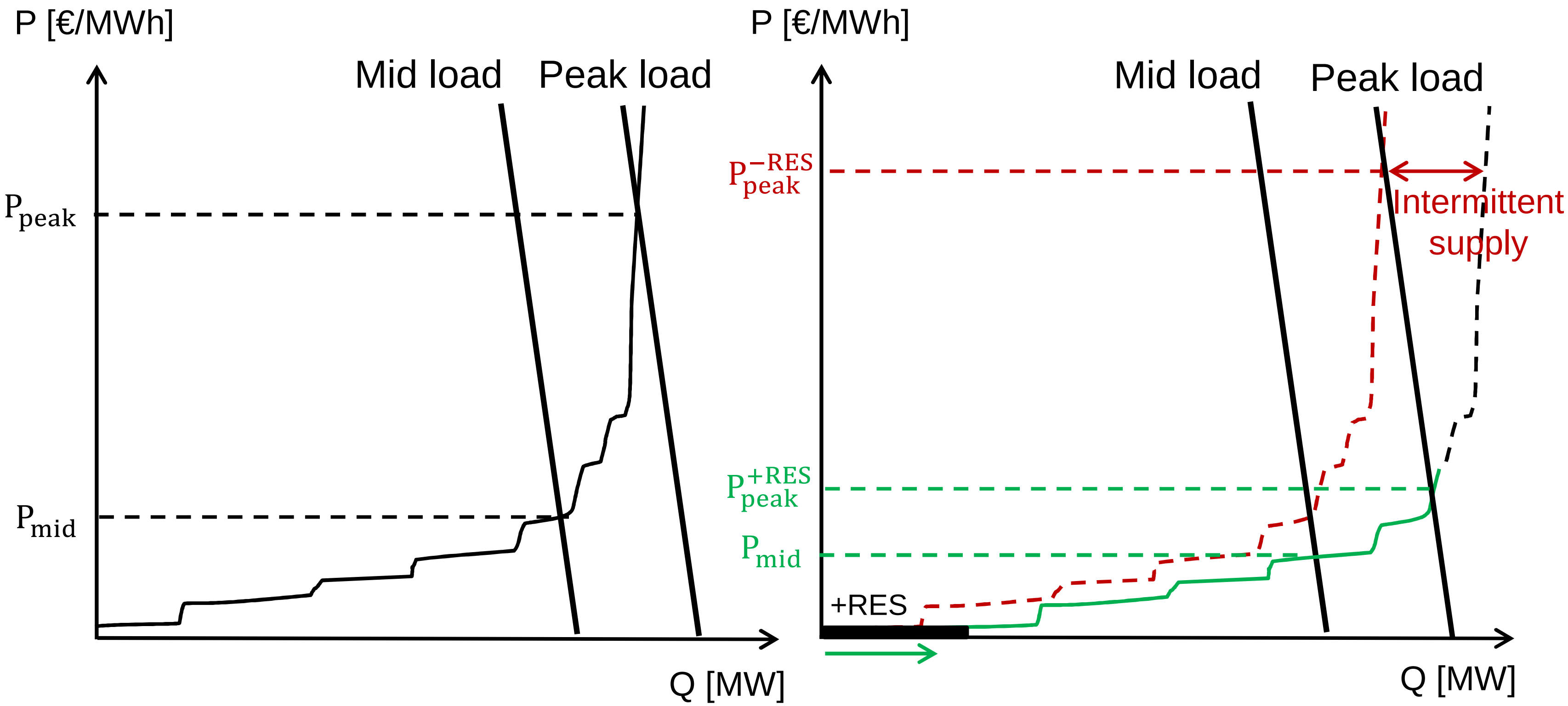
- Price-decrease (on average) reduces utilization / inframarginal rents
  → Insufficient recovery of fixed cost



A changing environment

The merit-order-effect

- Intermittent RES-supply increases volatility
  → higher investment risk



Capacity markets

Goals and design options

- Capacity-based revenues [€/MW] in addition to energy-only market revenues
- Main goal: generation adequacy
  - More stable and certain revenues lower investment risk
- Comprehensive vs. selective capacity markets
  - Selective capacity market: only selected units receive capacity payments (e.g. peaking units, gas plants)
  - Selection process may be based on auctioning for lowest capacity price
- Quantity-based vs price-based mechanism
  - Quantity-based: Regulator/TSO determines quantity of capacity selected

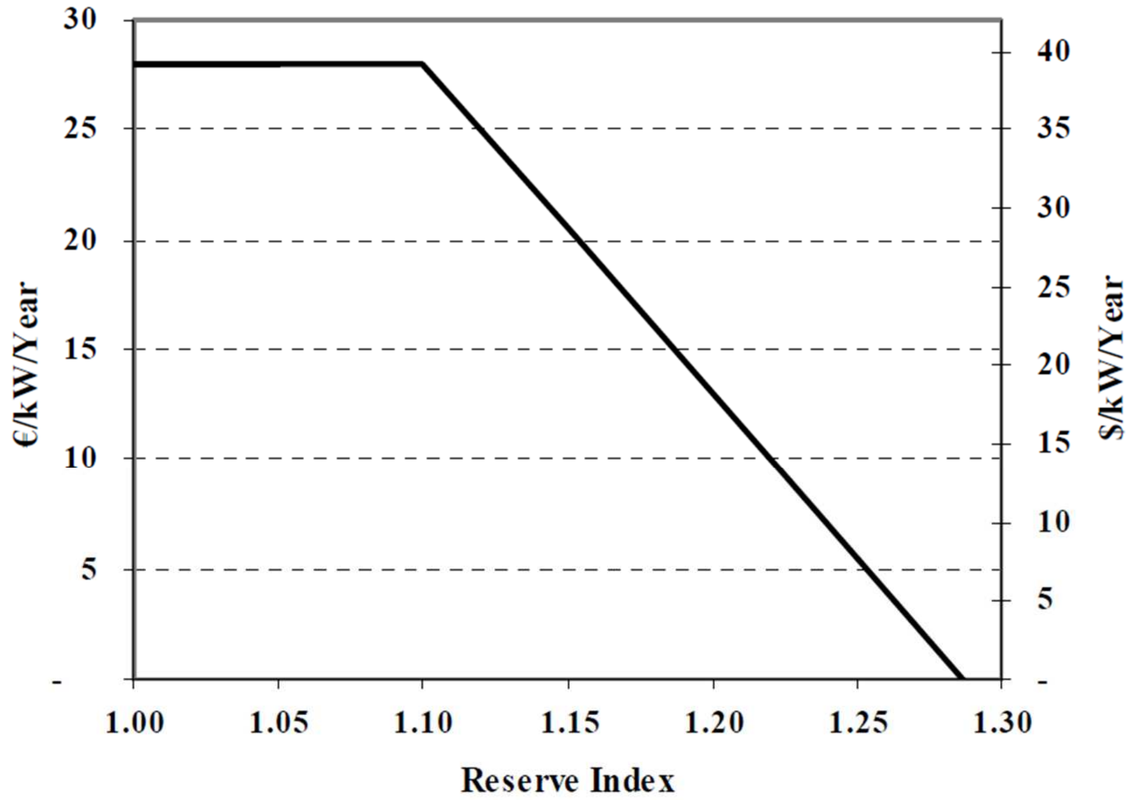
    → Capacity price is determined by market
  - Price-based: Capacity-price is set administratively

    → Quantity (and hence level of generation adequacy) is determined by the market

Capacity markets

I. Capacity Payments

- Example: Spain. Two forms of payments:
  - Availability payments
  - Investment incentive → Investment Incentive Curve



Sources and Notes:
From Federico and Vives (2008), pp. 59-60.
Based on exchange rate of 1.400 $/€ from FRB (2009).

Note:

Payments are fixed for 10 years

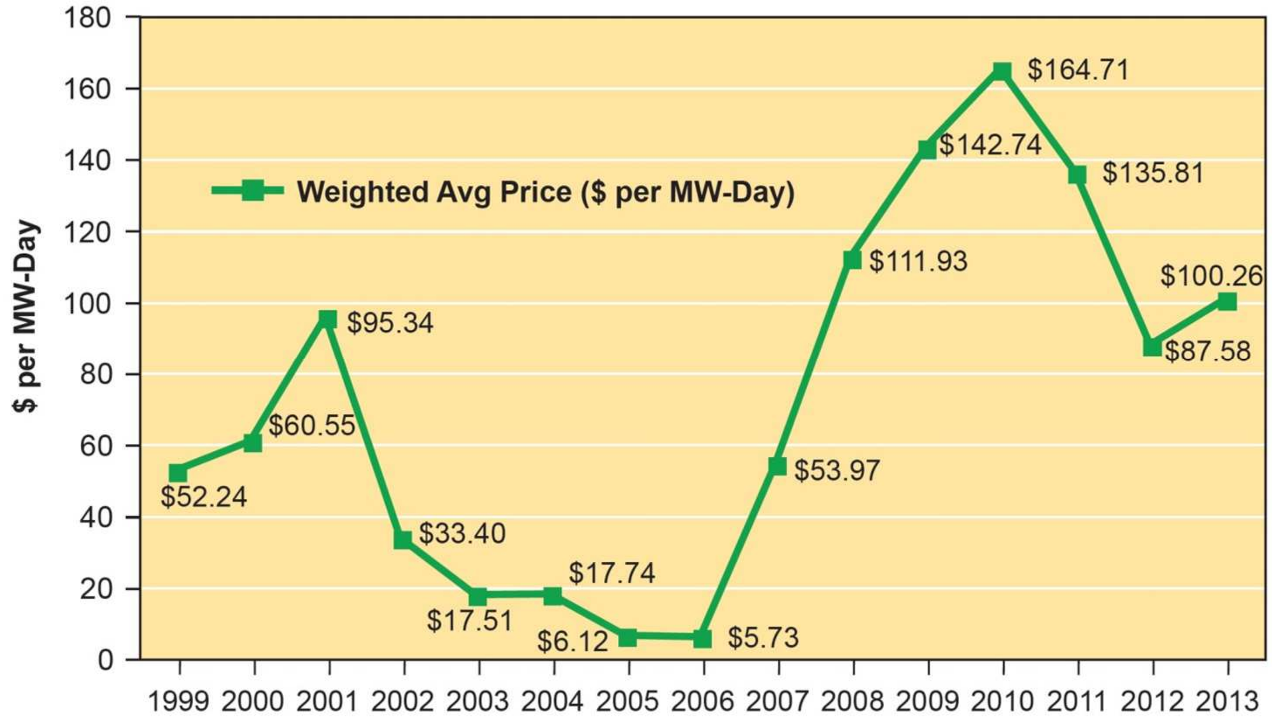
Capacity markets

II. Capacity Credits

- Example: PJM market (US). Similar form to be established in France
- Suppliers have to acquire capacity: peak demand + 15% reserve margin

  → Separate capacity market

Figure B-1 Average Annual PJM Capacity Prices



Source: Monitoring Analytics, "2010 State of the Market Report for PJM," March 10, 2011.

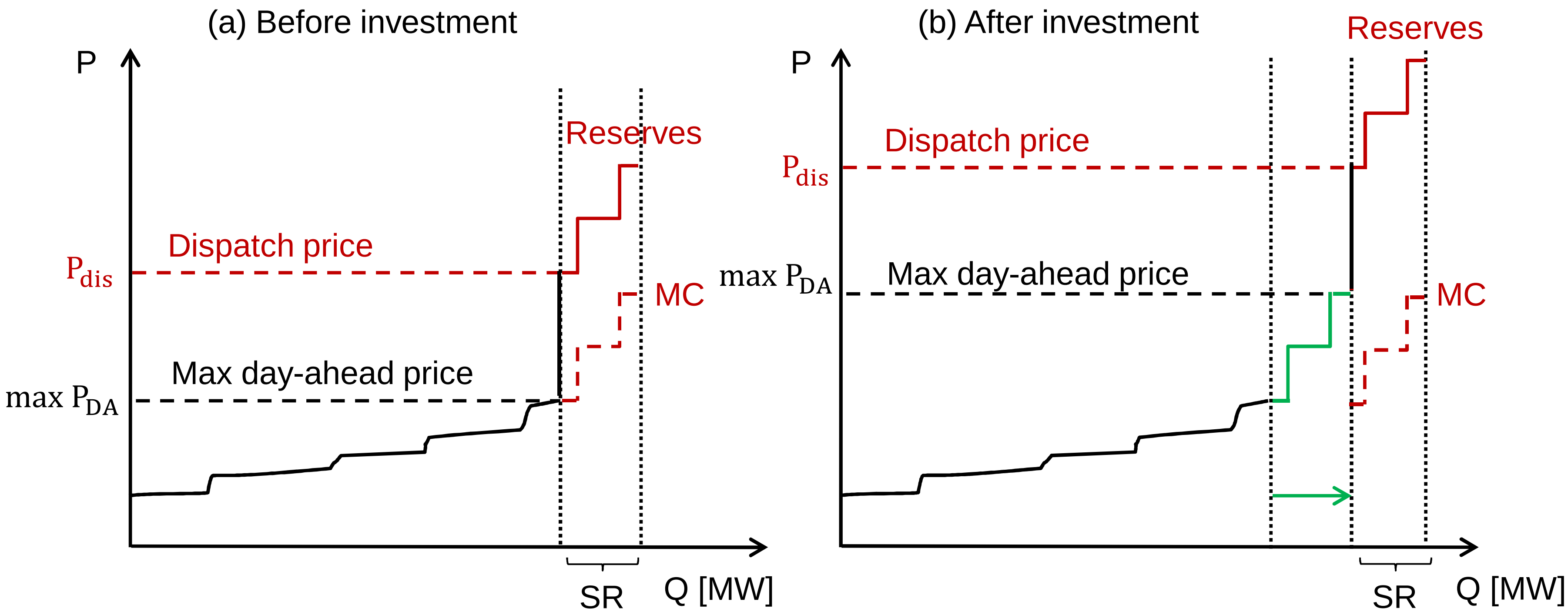
Note:

Volatility of capacity prices!

Capacity markets

III. Strategic reserves (SR)

- Example: Sweden, Finland
- TSO acquires max. *2000 MW* of reserves (units with a utilization below 40 hours/year)
  - Gas, Oil (2011: 1309 MW)
  - Demand response. (2011: 583 MW)

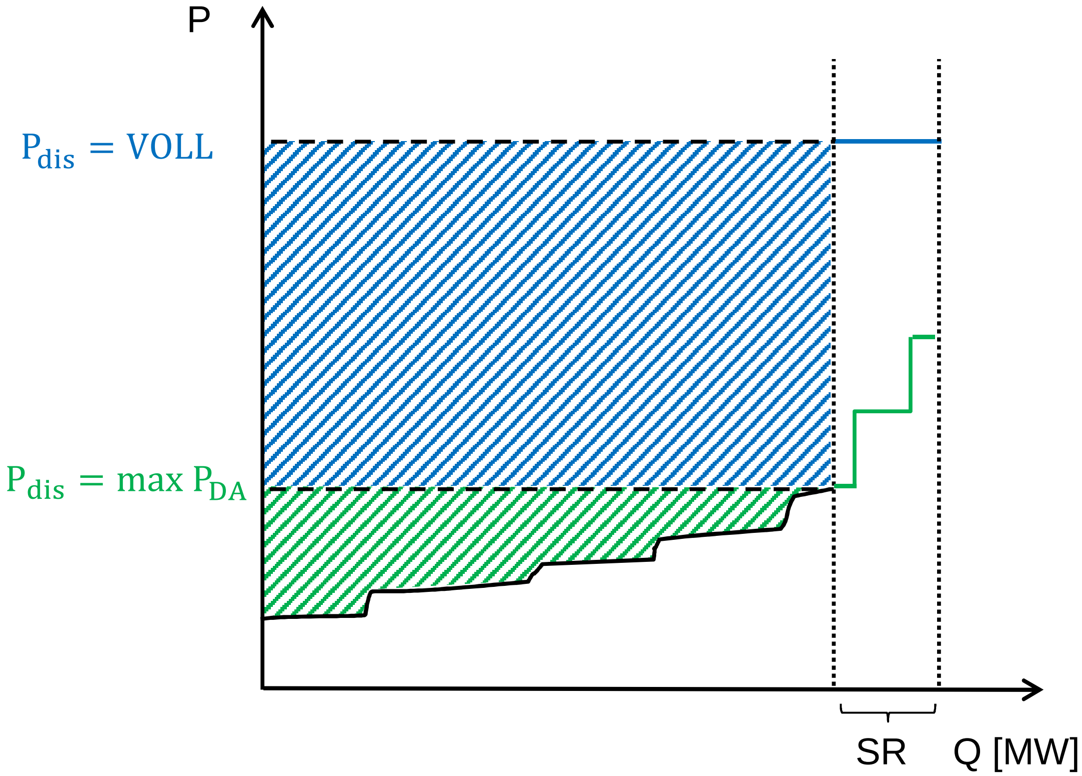


Reserve dispatch price = highest day-ahead price (min. 800 €/MWh) + variable cost

Capacity markets

III. Strategic reserves (SR)

- Investment incentives depend on reserve dispatch price



Extreme cases:

1) Dispatch price = VOLL

→ Large inframarginal rents

→ Strong investment incentives

2) Dispatch price = day-ahead price

→ Little inframarginal rents

→ No investment incentives (reserves ineffective)

Capacity markets

Which capacity model to choose?

- **Capacity payments** are rather inefficient
  - Difficulty to avoid windfall profits
  - Result (level of generation adequacy) difficult to predict: Price-based approach delivers uncertain amount of reserve capacity)

- **Capacity credits** are efficient but complex
  - Requires separate capacity market
  - Market power problems
  - Possible volatility of capacity prices

- **Strategic reserves**
  - Can be implemented rather quickly (no major market intervention)
  - Do not harm the market if not needed.
  - Efficient model if reserves are selected in a competitive auction process.

Auction design issues

Efficient selection and dispatch of reserve capacity

An auction design model (work in progress)

- TSO as auctioneer aims to minimize reserve costs by selecting the cheapest units
- Generators bid a certain amount of capacity for a give time period
  - Capacity is withdrawn from the day-ahead market
  - Time period normalized to 1
  - The bids of each unit i consists of
    - A capacity bid b_i^K [€/MW]
    - An energy bid b_i^C [€/MWh]
  - Assuming a *first-price*, *pay-as-bid auction*, each bidder receives its own bids if selected for the reserve market:

$$\pi_i = b_i^K + \rho_i \cdot b_i^C$$

with $0 \leq \rho_i \leq 1$ dispatch duration of unit i

  - Furthermore: $E(\pi_i) = \pi^{opp}$ (π^{opp} = opportunity costs on day-ahead market)

Auction design issues

Analysis of different scoring rules

- The auctioneer‘s problem of cost minimization is to find an optimal *scoring rule* to choose the cheapest bids.
- We consider two types of scoring rules:

1. **Simultaneous scoring rule**: Both capacity and energy bids are combined to a single score according to:

$$SR = b_i^K + \Omega_i \cdot b_i^C$$

   – Choosing the units with the lowest scoring values is cost minimal if the weights of the energy bids (Ω_i) are equal to the actual dispatch duration of the units (ρ_i).
   – However: Actual dispatch is *not known a priori* to the auctioneer, as it depends on *uncertain reserve demand* and *all bids received*.

→ Prediction errors of ρ_i and strategic bidding behavior may lead to cost inefficient selection and dispatch of reserve units.

Auction design issues

Analysis of different scoring rules

2. Sequential scoring rule:

– First stage: selection of cheapest unit only considers capacity bids:

$$SR = b_i^K$$

– Second stage: Forming of merit order among chosen units according to the energy bids b_i^C.

– This auction design corresponds e.g. to the German balancing market

– Problem is stategic bidding of generators.

– Chosen units face less competition on the second stage. Hence, they behave as in a single-stage game under Cournot competiton.

→ Energy bids (b_i^C) become “strategic variables” to maximize profits, while capacity bids (b_i^K) are “residual variables” which are set a low as possible to enter the reserve market.

→ Note that *expected reserve costs* (= π^{opp}) are equivalent to simultaneous bidding, but sequential bidding favors units with higher energy and lower capacity costs (peaking units).

Conclusions

- Large-scale integration of (subsidized) renewables may require an adjustment of the current energy-only market design
- Given uncertainty about the missing money problem, a *strategic reserve* may be a reasonable option due to its easy implementation.
- Main issues of an adequate *market design*:
  - How to set the dispatch price for reserves to incentivize efficient investment?
  - How to deal with cross-border effects (Leakage problem)?
  - How to determine the time-frame of a reserve market?
    - Daily, monthly or yearly auctions?
- What is the optimal *auction design*?
  - Simultaneous scoring auction may be efficient but involves risks of prediction errors and strategic behavior (including inefficient selection of units and distortion of the merit order)
  - Sequential scoring auction leads to strategic energy bidding, favoring “peaking technology“ with low capacity and high energy costs.

Thank you for your attention !
Questions, please?

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