On the Role of Electricity Storage in Capacity Remuneration Mechanisms

Christoph Fraunholz, Dogan Keles, Wolf Fichtner | IAEE Online Conference – 8 June 2021
Agenda

1. Storage Participation in Capacity Mechanisms
2. Theoretical Discussion on Relevant Design Parameters
3. Selected Results of a Large-Scale Simulation Study
4. Conclusion and Policy Implications
Regulatory framework

- Capacity mechanisms are used around the world to secure sufficient firm capacity.
- Formally, technology neutrality is a requirement in Europe and the US (European Commission, 2013; Sakti, Botterud, and O’Sullivan, 2018).
- In practice, rules for storage participation differ:
  - PJM: like conventional units (Chen et al., 2017)
  - CAISO: full output for 4 h (Usera et al., 2017)
  - Ireland & UK: derating factors (National Grid, 2017; Single Electricity Market Committee, 2016; Single Electricity Market Committee, 2018).

⇒ In what way does the parametrization of capacity mechanisms affect the future technology mix and long-term generation adequacy?
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Central buyer mechanism with reliability options (used in, e.g., Italy, Ireland)

**Characteristics**
- Regulator determines firm capacity requirement and other parameters
- Successful participants are rewarded with the marginal capacity price of the auction
- Capacity derating factors may be used, e.g., for storage units
- Combination with call options
  - Price cap on the day-ahead market
  - Regulator collects peak energy rent
  - Implicit penalty for non-availability during scarcity periods

**Bidding strategy**
Capacity remuneration should cover the difference costs $DC$:

$$DC = \max (-NPV, 0)$$

With some simplifications follows the indifference bid price $p^{CRM}$:

$$p^{CRM} = \frac{k_1}{f^{derate}} \cdot \max \left( k_2 \cdot c^{invest} - CM(p^{limit}), 0 \right)$$

The resulting technology mix is driven by the relation of
- investment expenses $c^{invest}$,
- contribution margin $CM$ (indirectly: strike price $p^{limit}$),
- derating factor $f^{derate}$.

⇒ Focus of this talk: Combination with call options and variation of the strike price
Combination with Call Options

Contribution margins in a stylized example of the day-ahead market in the future

Under some reasonable assumptions, storage units counterintuitively benefit from a strike price:

$$CM^{stor} > CM^{conv} \iff \begin{cases} p^{\text{high}} (1 - \eta^{stor}) < c^{\text{var}}_{\text{CONE}}, \text{ for Cases 1/2a} \\ p^{\text{limit}} (1 - \eta^{stor}) < c^{\text{var}}_{\text{CONE}}, \text{ for Case 2b} \end{cases}$$

where $p^{\text{limit}}$ is the strike price of call option, $c^{\text{var}}_{\text{CONE}}$ is the variable cost of new entry, $CM$ is the contribution margin, and $\eta^{stor}$ is the storage efficiency.
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Agent-Based Electricity Market Simulation Model PowerACE

- **Selected characteristics**
  - Time horizon 2020–2050 with 8760 h/a
  - Day-ahead market simulation (daily)
  - Investment decisions (yearly)

- **Input**
  - Power plant fleets of the base year
  - Fuel and carbon prices
  - Hourly electricity demand
  - Hourly renewable feed-in
  - Transfer capacities between market areas

- **Output**
  - Hourly day-ahead market prices
  - Hourly dispatch (power plants, storages)
  - Investment decisions (power plants, storages)
Model Assumptions and Scenario Setup

Some key assumptions

- Simulation period: 2020–2050 at hourly resolution (8760 h/a)
- Regional scope: Selection of ten European countries with diverse electricity market designs
- Renewable share in electricity demand reaching 80% by 2050
- Carbon prices increasing to 150 EUR/tCO₂ in 2050

| Scenario       | Electricity market designs | Strike price          |
|----------------|-----------------------------|-----------------------|
| EOM            | European EOM                | n/a                   |
| CRM            | National CRM policies       | none                  |
| CRM-limit_high | National CRM policies       | $1.5 \cdot \var{CONE}$ |
| CRM-limit_low  | National CRM policies       | $\var{CONE}$          |

\(\var{CONE}\) – variable cost of new entry, CRM – capacity remuneration mechanism, EOM – energy-only market
Reference Scenario (European Energy-Only Market)

Simulated development of conventional power plant and storage capacities in France

⇒ Fuel switch towards gas-fired power plants and expansion of utility-scale storages
Capacity Auctions Bundled with Call Options

Simulated development of conventional power plant and storage capacities in France

- CCGT —combined cycle gas turbine
- OCGT —open cycle gas turbine
- Electric thermal storage
- Li-ion battery
- Total storage
- Total conventional

Delta of capacities [GW]

- (a) no strike price
- (b) high strike price
- (c) low strike price

⇒ Technology composition affects both renewable integration and generation adequacy
## Deterministic indicators describing generation adequacy level in France (2020–2050)

| Scenario            | Strike price | No market clearing | Energy not served |
|---------------------|--------------|--------------------|-------------------|
| EOM                 | n/a          | 10.7 h/a           | 60.5 GWh/a        |
| CRM                 | none         | 0.0 h/a            | 0.0 GWh/a         |
| CRM-limit_high      | $1.5 \cdot \frac{\text{var}}{\text{CONE}}$ | 1.6 h/a | 3.7 GWh/a  |
| CRM-limit_low       | $\frac{\text{var}}{\text{CONE}}$ | 5.1 h/a | 16.2 GWh/a |

$c_{\text{var}}^{\text{CONE}}$ – variable cost of new entry, CRM – capacity remuneration mechanism, EOM – energy-only market

⇒ *Nameplate capacity of electricity storage should be adequately derated (for details see paper)*
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Conclusion and Policy Implications

Key take-aways of this talk

- Design of capacity remuneration mechanisms inevitably creates a bias towards one technology or the other
- Linking the capacity auctions with call options increases the competitiveness of storages against conventional power plants
- Determining the capacity credit of non-conventional resources is challenging and can strongly affect generation adequacy
- For additional details see paper on the right (open access)

Contact details – feel free to get in touch

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⇒ Thank you for the attention! Any questions or comments?

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Literature I

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