‘The change in need for a capacity market if demand response and electrical energy storage are available with growing share of RES-E

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Introduction

- Background: discussion about capacity markets (CM).

- Improved Demand Response (DR) and electrical energy storage (EES) may also improve system adequacy.

- Will DR and EES obviate the need for a capacity mechanism?
- If a capacity market is implemented, how does this affect DR and EES?

Approach: ABM/EMLab

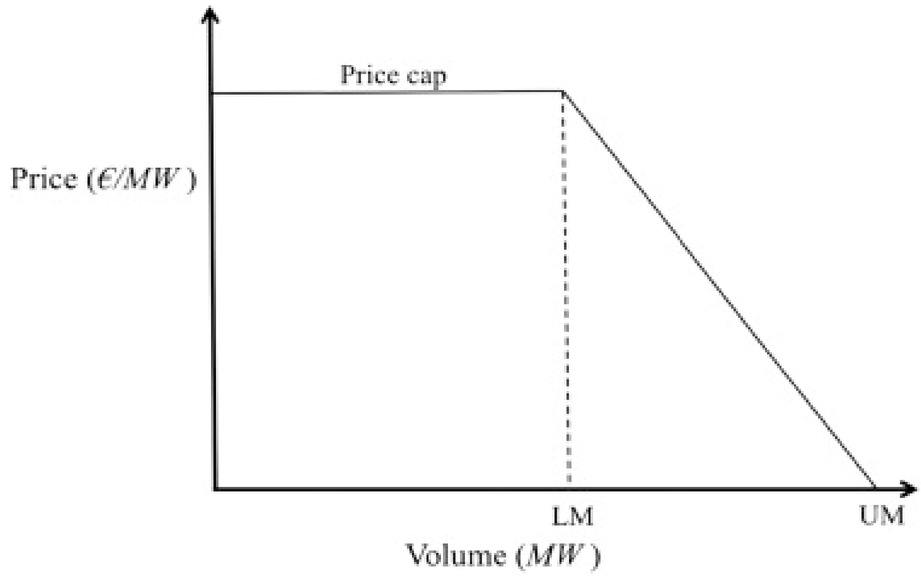
- Capacity markets are supposed to correct imperfect investment decisions.
- Therefore we need to model imperfect investment.
  - Imperfect foresight + time delay → investment cycle.

- EMLab: hybrid optimization and agent-based model
  - Investment decisions are agent-based: myopic
  - Generator dispatch, storage operation and DR are optimized.

TUDelft's Energy Modelling Lab [EMLab-Generation Version 2.0]

- Single node electricity market (for this experiment)
- Power companies as agents
  - Bid into pool
    - spot market cleared hourly
  - Invest based on forecasted Return on investment (RoI)

Capacity Market (CM): based on NYISO and PJM

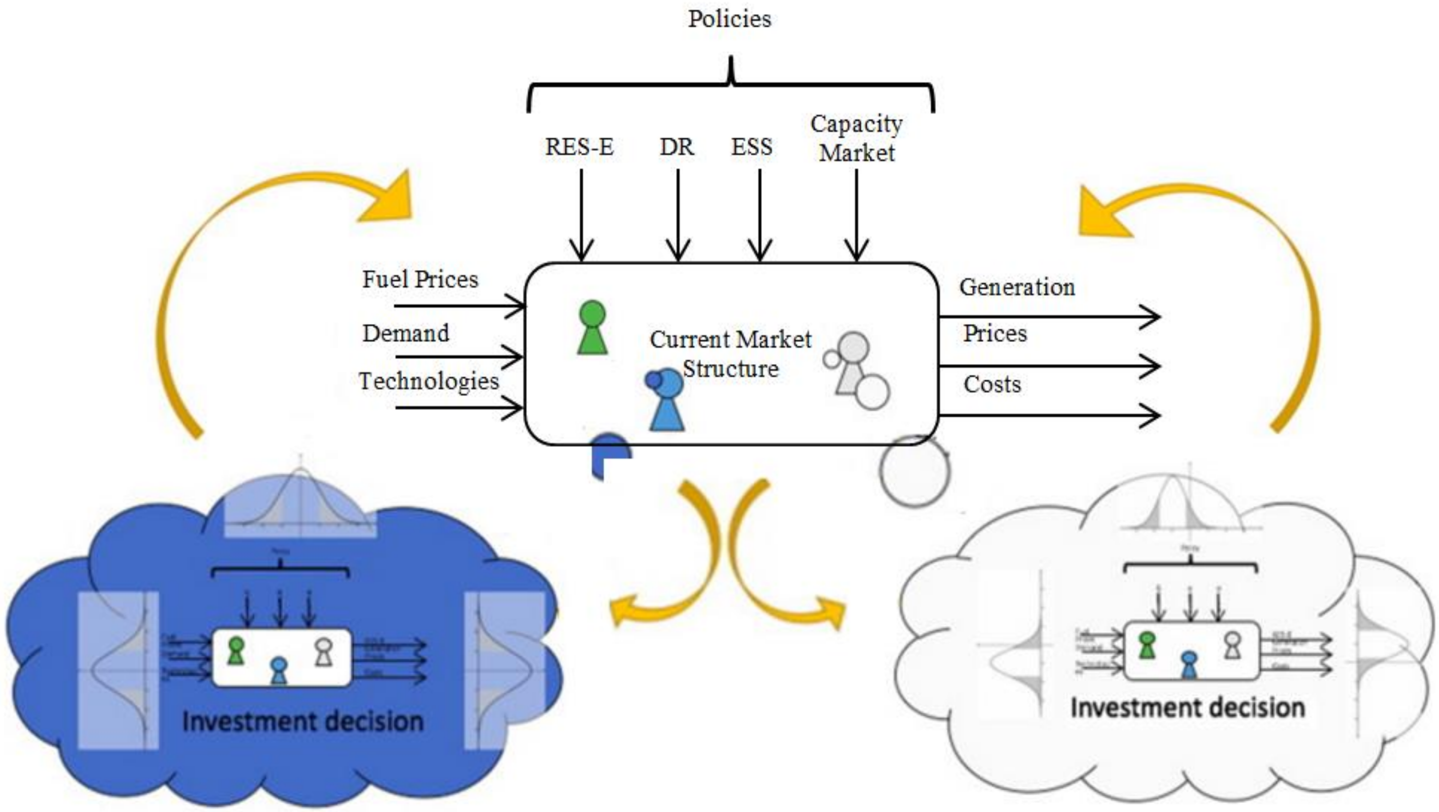


Sloping demand curve used for clearing the capacity market. Adapted from (P. C. Bhagwat et al., 2017)

Capacity Market (CM)

- Bid Price = Annual Fixed O&M Cost – Projected Annual Net Revenue from Energy Market.
- Market clearing is based on uniform price auction.
- Energy storage participation in capacity markets enabled.

Investment



In addition, investment in non-profitable RES according to external (government) targets.

Stakeholder Dividends

- Stakeholder dividends are paid on the basis of:
  - Annual return on investments for the power production company
  - Share of stakeholders (70%)

Payment of stakeholder dividends ensures that the cash state of all agents is somewhat balanced.

Dismantling of power plants

- Subsidized RES units: end of economic life (end of subsidy).
- Competitive power plants are dismantled depending on their profitability in the past years and their expected profits in the future year.
- The operation and maintenance costs of power plants increase as they age beyond their technical life time.

Demand Response (DR)

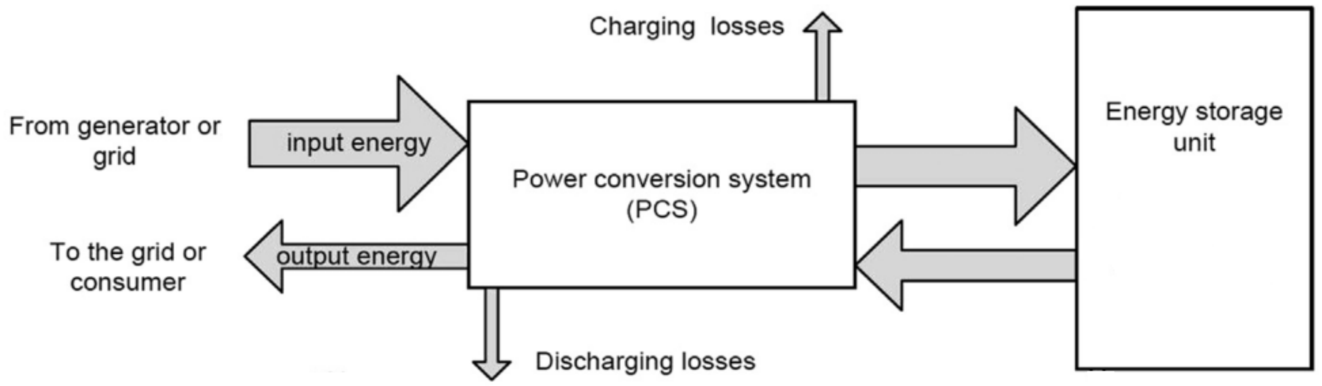
- The consumers are incentivized to shift demand to off peak hours where the spot market prices are lowest in a given period.

- The idea is to reduce peak demand and shift it to off peak hours.

- Constraints:
  - the volume of flexible demand;
  - the time period within which it must be consumed.
- Assumption: cost to consumers is 0 (within these constraints).

Electrical Energy Storage (EES)

- EES is implemented using the principle of cost minimization



- Constraint:

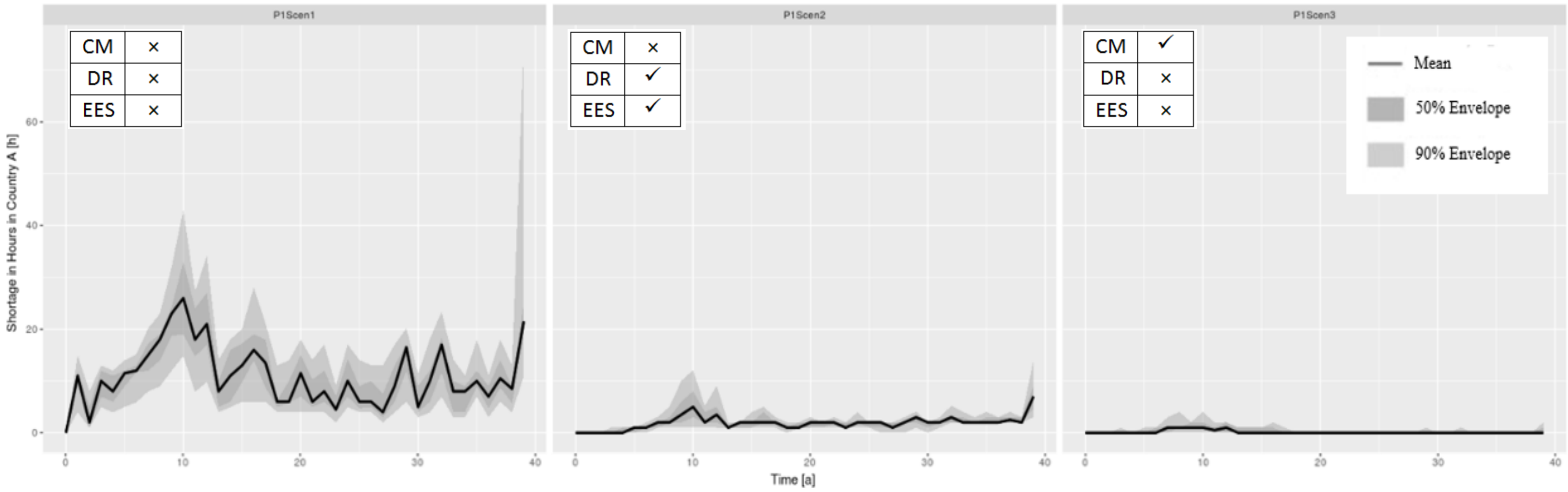
$$StateofChargeInStorage_t = \left(-\frac{1}{\eta}\right) * StorageDischarging_t + (\eta) * StorageCharging_t + StateofChargeInStorage_{t-1} \quad \forall t$$

- (Dis)investment: marginal changes depending on (un)profitability

Experiment design

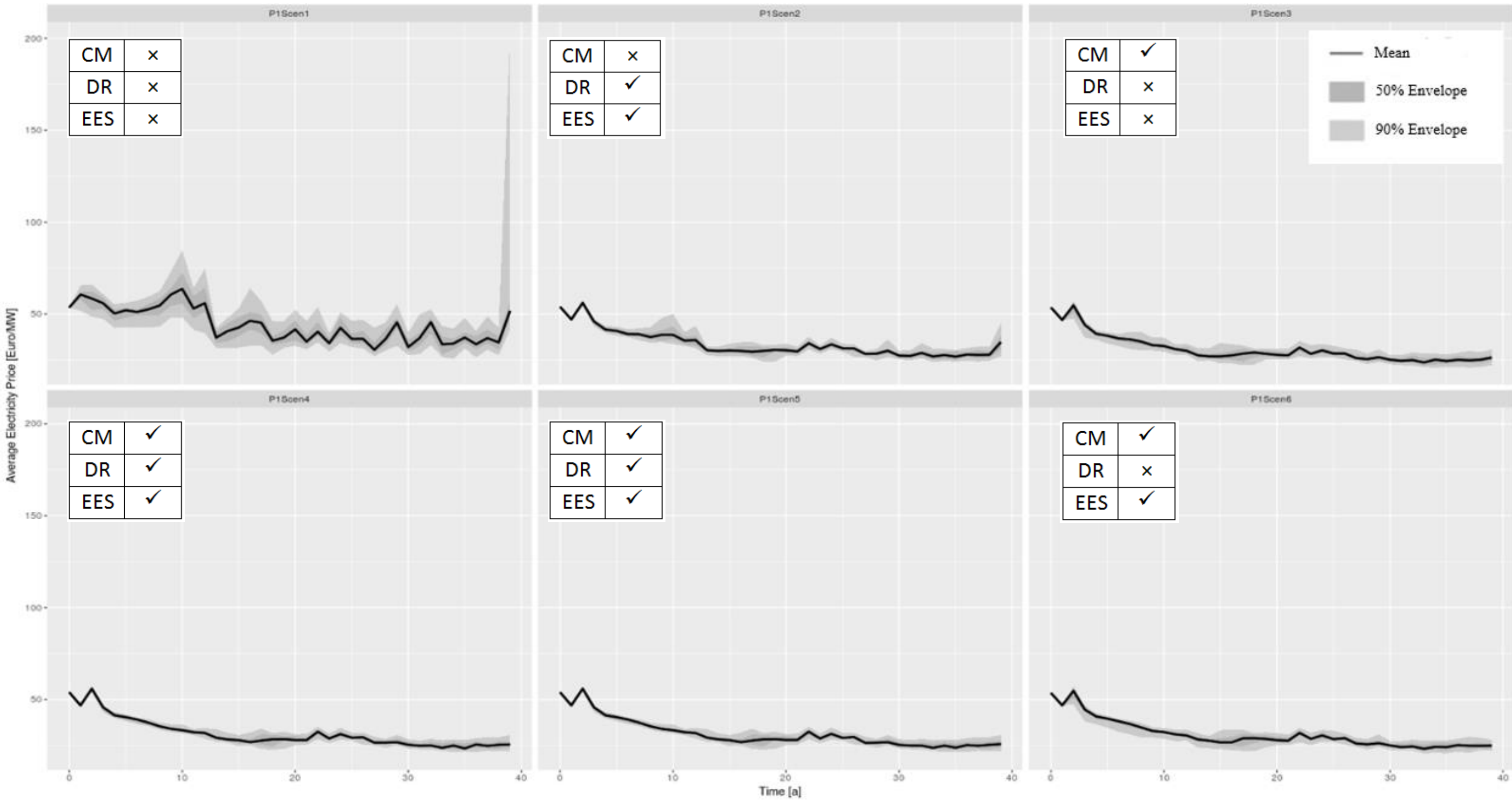
Sr. No.	CM	DR	EES
1.	×	×	×
2.	×	✓	✓
3.	✓	×	×
4.	✓ (Without EES bid)	✓	✓
5.	✓ (With EES bid)	✓	✓
6.	✓ (With EES bid)	×	✓

Annual number of shortage hours



Shortage in number of hours in the electricity spot market per year in experiment 1, 2 & 3 (in that order)

Average of yearly electricity prices



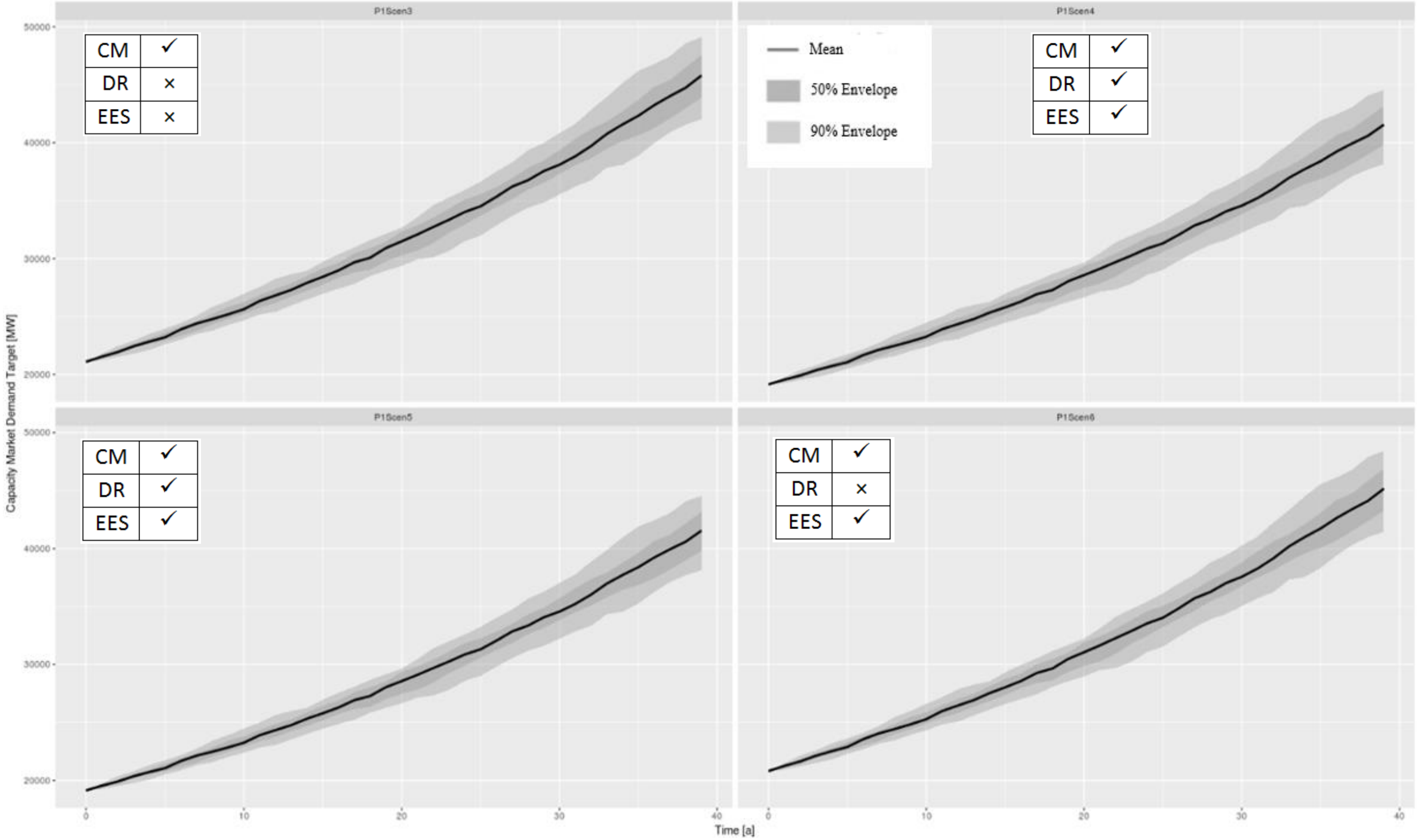
Average of yearly electricity prices in experiment 1, 2, 3, 4, 5 & 6 (in that order)

Discussion

- The increase of (externally funded) RES causes prices to drop in all scenarios.

- DR and EES *can* improve the performance of an energy-only market and remove system adequacy concerns.
    - If there is enough DR and storage
    - In our case: DR is 8% of demand and free
    - Storage: much cheaper than in reality, otherwise no investment!
- Electricity prices do not should include the cost of the capacity market → total cost to consumers > electricity price.

Total capacity obligations



Total capacity obligations for CM as determined by the regulator per year in experiment 3, 4, 5 & 6 (in that order)

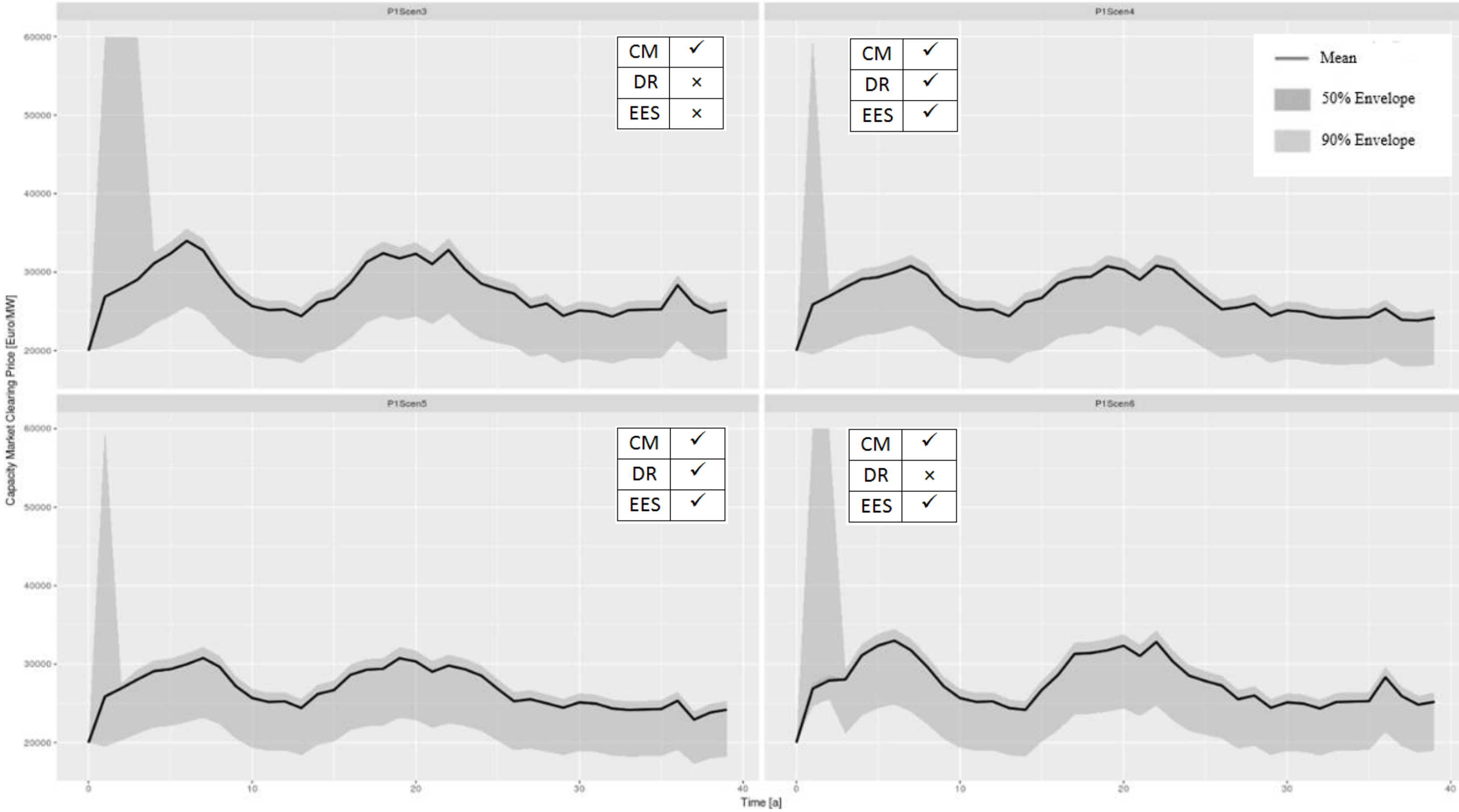
Discussion

- When determining the overall capacity obligations, the regulator takes the peak load and adds the reserve margin of 8% of the peak load to it to calculate the total capacity to be contracted in the CM.

- However, if DR is included, the peak load in the electricity market will be supressed by 8% (the share of elastic load).

- Therefore the total capacity obligations in MW, as set by the regulator, are reduced by 8% in experiment 4 and 5 (which include DR).

CM clearing price



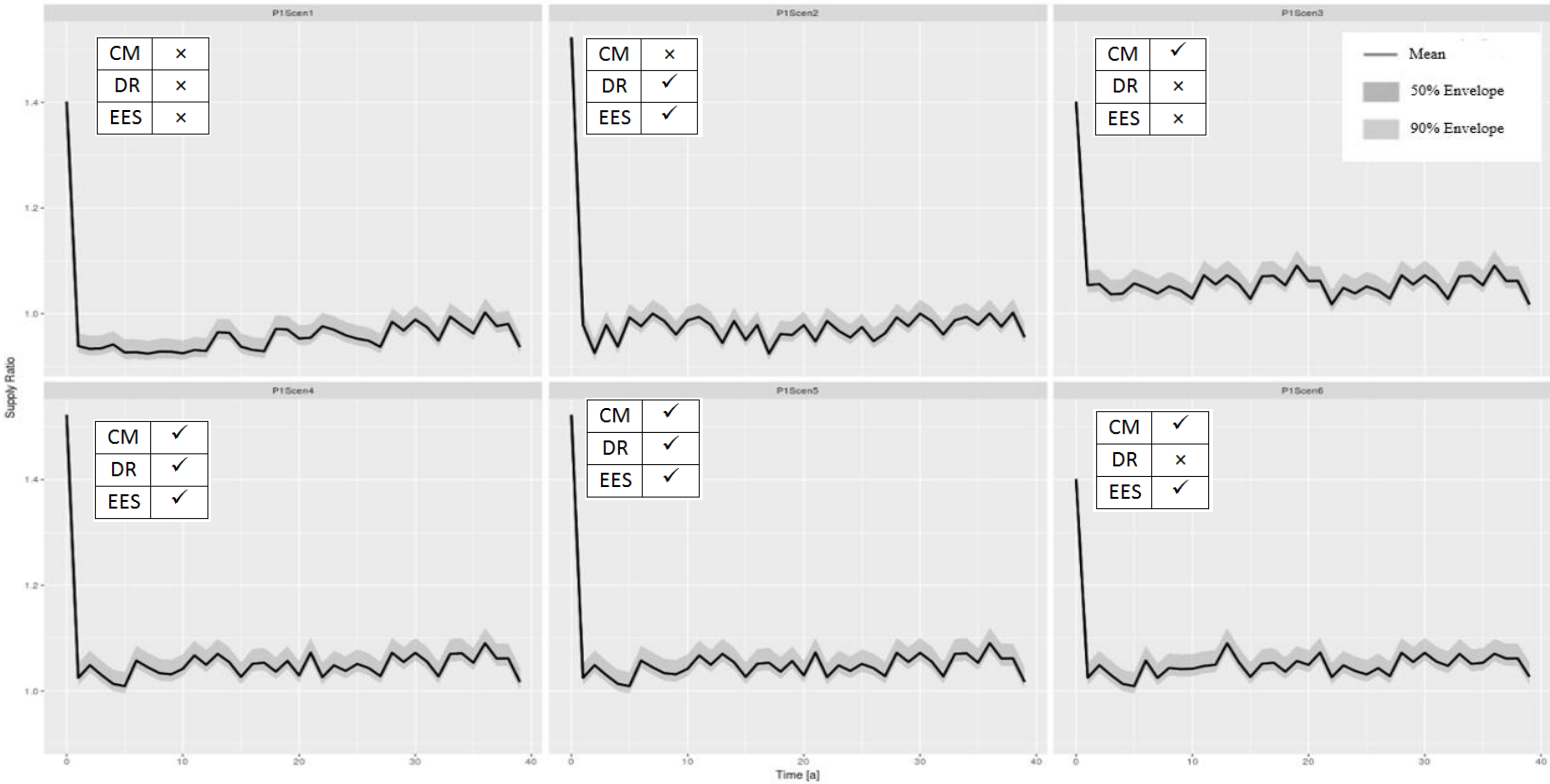
CM clearing price in €/MW per year in experiment 3, 4, 5 & 6 (in that order)

Discussion

- The average CM clearing price for all simulation runs is around 27 k€/MW.
  - In 4 and 5 it is 3.5 – 3.9% lower.

- DR reduce the cost of a CM
  - lower capacity target
  - lower clearing price.

Supply ratio



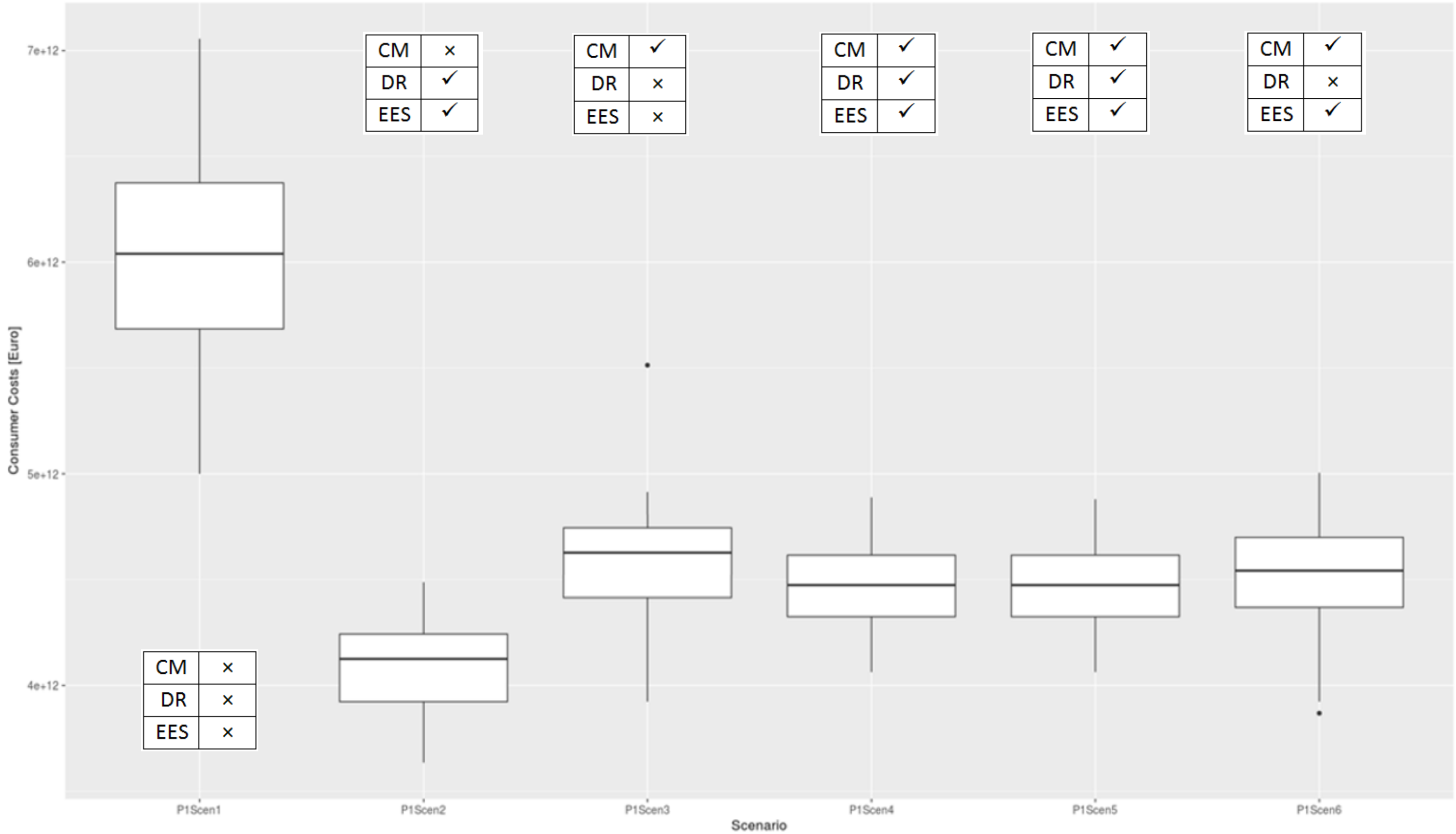
Supply ratio in experiment 1, 2, 3, 4, 5 & 6 (in that order)

Discussion

- The initial dip is due the dismantling of a large share of installed generation capacity in the Netherlands that is not profitable.

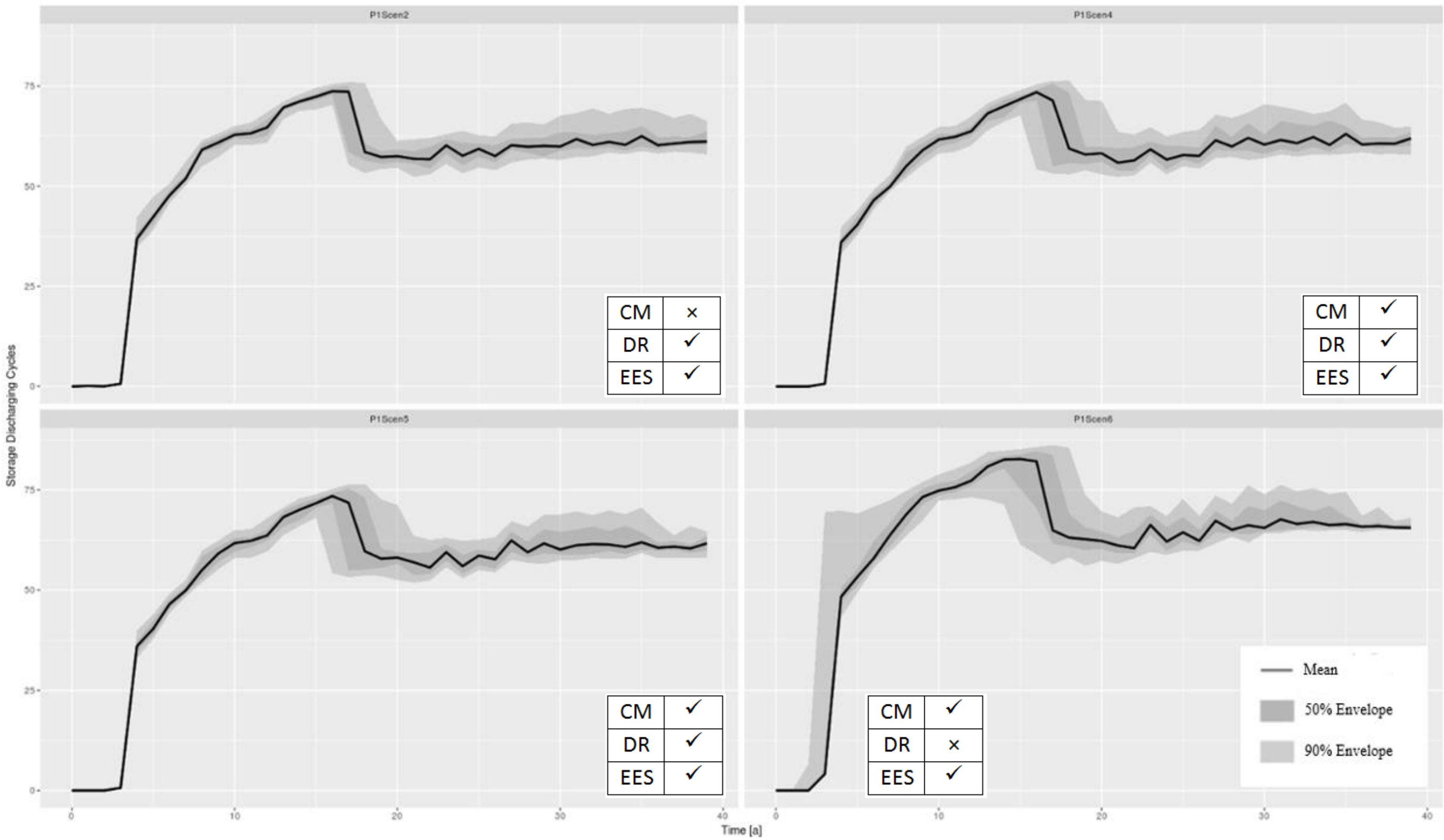
- The average supply ratio in experiment 3, 4, 5 and 6 is approximately indicating 6% excess supply as compared to peak demand which is adequate as to fulfil the requirements of the capacity CM.
  - Apparently, the capacity requirement is too high.
    - But it is in line with real capacity markets.
  - Perhaps our scenarios are not challenging enough?

Total consumer cost



Box plot of the total consumer cost in € in experiment 1, 2, 3, 4, 5 & 6 (in that order)

EES discharging cycles



Total number of EES discharging cycles per year in experiment 2, 4, 5 & 6 (in that order)

Discussion

- The average discharging cycles are calculated by dividing total output of EES per year by maximum energy storage capacity of EES.
- As indicated by the results, the performance of EES is almost similar in experiment 2, 3 and 4.
- The performance of EES is slightly better in experiment 6 as the storage takes advantage of price arbitrage between peak and off peak hours.
- With the increasing share of RES-E in the electricity market, the performance of EES improves.
- The marginal drop in discharging cycle seen in all experiments occurs as the generation capacity under construction becomes online.
- No investment in EES, as it does not recover its cost.

Conclusions

- DR and EES *can* dampen price volatility, but will they?
  - The real potential of DR is still unclear.
  - Storage needs to become much cheaper!
- If DR and EES play a significant role, a CM would need to be adjusted.
  - Lower capacity obligation.
  - They should be allowed to participate in the CM. (But how?)
- Will DR and EES be sufficient to stabilize prices and investment?
  - Considering that year-on-year difference in supply and demand will grow with increasing influence of weather.
- Does the current model adequately reflect investment cycles and possible supply/demand shocks?