The impact of demand response and electrical energy storage on (the need for) a capacity market

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Highlights:

- Analysis of the impact of demand response (elastic demand) on electricity and capacity market.
- Analysis of the impact of electrical energy storage on electricity and capacity markets.
- A hybrid optimization/agent-based model of electricity markets is utilized for this analysis.
- Demand response decreases the overall capacity obligations in the capacity market.
- Energy storage bidding into capacity market pushes peak thermal plants out of the supply mix.

Keywords:

Capacity markets; Demand response; Electrical energy storage; Agent based modelling; Optimization; Security of supply; Electricity market; Resource adequacy

Abstract:

To ensure security of supply and to provide reliable incentives for investment in generation capacity, policy instruments such as capacity markets have been implemented or are being considered in electricity markets worldwide. In this paper, we analyze the change in the need for a capacity market in case demand response and electrical energy storage become widely available, in the presence of a growing portfolio share of intermittent renewable energy sources electricity (RES-E). During this transition, the market is, by definition, not in a long-term equilibrium; the inherit propensity of electricity markets to develop an investment cycle further complicates the investment decision. A capacity mechanism may be needed to compensate controllable power plants for their declining market share as the volume of variable renewable energy sources increases. On the other hand, if storage and demand response develop sufficiently, these flexibility options may reduce the need for a capacity mechanism.

We use EMLAB-Generation, a hybrid electricity market model that uses optimization for short term market operations and is agent based in the long term, to assess the impact of storage and demand response upon the need for a capacity mechanism during the transition period to a low-carbon electricity system. Demand response and electrical energy storage reduce wholesale market price volatility, reducing generation investment price risk. However, infrequent periods in which solar and wind energy are not available for several days or longer continue to pose a challenge to security of supply. As a result, even with high shares of demand response and storage there still is significant investment risk at the end of the supply function, the capacity that is needed to provide during these infrequent shortage periods. If a capacity market is introduced, the question arises of whether and how to remunerate storage. We present a method for calculating the contribution of storage to firm capacity. When storage and demand response are combined with a capacity market, they reduce the capacity market clearing price by pushing out a part of peak thermal generation capacity from the supply curve.

The paper is organised as follows. After the introduction the second section gives a brief overview about the literature review and proposed legislations. The third section describes EMLAB-Generation, the market model that we use along with the capacity market clearing algorithm. In section four we describe the conducted experiments and analyze the results. In the final section, policy implications and conclusions are derived.

Methods

The impact of storage, demand response and a capacity market are modeled in EMLAB-Generation, a hybrid electricity market model that uses optimization for short term market operations while investment is agent-based.[1] A stylized flow chart for a year in the model in given in Appendix A. Agents in the model represent power producing companies that participate in electricity spot and capacity market and make decisions about dismantling and investing in power plants. The power plants can use various technologies for producing power. Agents invest with bounded rationality, i.e. the agents' investment decisions are based on an optimization

[1] http://emlab.tudelft.nl/

algorithm, but the agents do not have perfect information about future market conditions. Therefore the model is suitable for testing the robustness of capacity mechanisms under realistic, less than optimal investment behavior.

Results

First, experiment designs with different combinations of energy efficiency and resource adequacy policy instruments, i.e. demand response, electrical energy storage and capacity market are presented, discussing in detail the inputs to the model and there justification. Table 1 below provides brief detail of the scenario design:

Table 1. Scenarios description. (CM: Capacity Market; DR: Demand response; EES: Electrical energy storage)

Sr. No.	**Scenario Name**	CM	DR	EES
1.	BL	×	×	×
2.	DREES	×	✓	✓
3.	CM	✓	×	×
4.	CMDRnoEES	Without EES bid	✓	✓.
5.	CMDREES	With EES bid	✓	✓

Second, the change in consumer costs and producer costs is evaluated along with the changes due to capacity market in investment in EES capacity, EES cycles per year, supply mix, electricity price, unserved load and total demand shifted per year.

Third, the different para,meters from the capacity market, such as clearing price, clearing volume and impact of EES participation in capacity market are analyzed and discussed.

The contribution of storage to reliable capacity is a function of both its generation capacity and energy storage capacity. In case the storage capacity is limiting, the generation capacity that the storage is allowed to contribute to a capacity market needs to be derated according to its ability to produce continuously during peak hours.

Conclusions

Demand response and electrical energy storage reduce the peak load requirement, which leads to less electricity price volatility in the spot market. However, the issue of supply shortages during less frequent, longer periods with low wind and solar generation is not solved. A capacity market can ensure system adequacy during these periods. Allowing energy storage to participate in the capacity market reduces the cost of the capacity market and improves the business case of storage. Demand response can also be allowed to participate in the capacity market or, in more advanced types of capacity mechanisms, there may be more efficient ways of stimulating it. Participation of demand response in the electricity spot market and the participation of EES in the capacity market reduces the overall capacity obligations in the capacity market. Therefore when a capacity market is complimented with DR and EES, the overall system costs reduce and security of supply is ensured, while creating a business case for controllable thermal power plants.

Appendix A

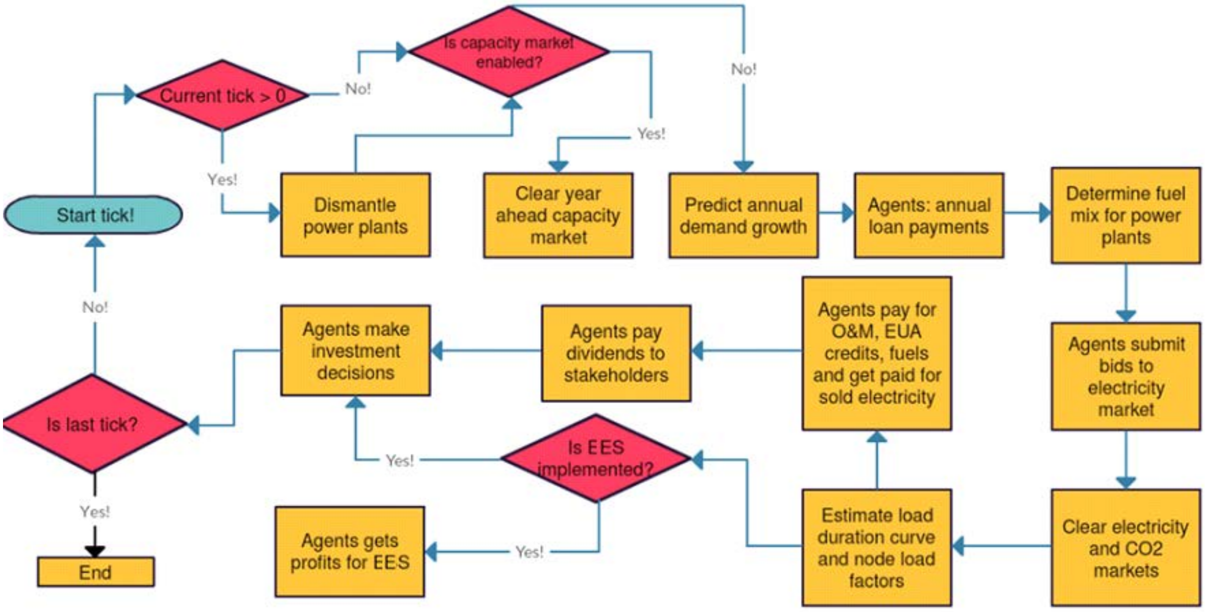

Fig. A.1. Stylized flow chart for a year in the model. EES: Electrical Energy Storage, O&M: Operations and maintenance, CO^2: Carbon dioxide, EUA: EU Emission Allowances

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