1. Introduction

Currently there is an intensive discussion in the EU about the optimal design for electricity markets with high share of renewable energy production. The reason for that are doubts whether the Energy-Only-Market (EOM), which is the current market design in most EU countries, can provide sufficient investment incentives to ensure a long-term security of supply. Due to the increasing feed-in of electricity based on volatile renewable energies, the number of operating hours of conventional power plants is decreasing and thus their revenue situation is becoming worse. However, since the capacity effect of fluctuating renewable energy is relatively low, a significant amount of "back-up" capabilities (in particular conventional power plants such as gas turbines, but also demand side measures) must be installed. But in the "typical" wind year, only a part of the required flexible capacity is used, so that scarcity prices are rare and generating facilities could not earn sufficient revenues to cover their fixed costs. Thus, by increasing the share of renewable electricity production, the missing-money problem will tend to exacerbate and can only be compensated by higher price spikes (near the Value of Lost Load, (VoLL)) in the few hours of pure scarcity in the EOM. However, whether a VoLL - price setting and thus higher price spikes would also be possible in European Countries and what the consequences would be, is difficult to assess at this time. Partially due to low correlation of the prices in retail markets to the ones in wholesale markets, the spikes in wholesale prices will in some cases only contribute to increased costs for the retail market participants.

Overall, this raises the question whether the marginal cost based EOM provides enough incentives for investments in new power plant capacity (both renewable as well as conventional backup) or a new market design including a capacity mechanism should be introduced to guarantee returns on investment while ensuring system adequacy.

2. Literature overview

Doubts about the effectiveness of the EOM in setting of investment incentives can lead to the so-called missing-money problem (Keay, 2013). To fund investments, high peak prices to shortage times are necessary. However, this high peak prices are often suppressed by wholesale market imperfections, in particular by price limits that are politically or technically installed. Furthermore, measures of the system operator to deal with operating reserve shortage, keep wholesale prices under the efficient level, in the small number of hours, when they should be high (Joskow, 2006). Another cause of the missing money problem is the fact, that the majority of the demand cannot see real-time wholesale prices and thus can not react in an adequate way and set the price. Due to the increasing shares of fluctuating renewable energy, the missing-money problem is further exacerbated. Since the full load hours of conventional power plants decreases, the revenues in the operating hours will tend to be higher to cover the fixed costs. Extensive simulations of the US power system (NREL, 2013) indicate a 2 to 5 percent increase in operating costs of fossil fuelled generators, due to the increase of cycling costs. The increase in costs of cycling correlates strongly with the amount of renewable production in the system. From a system perspective the increase in costs is
relatively small when compared with avoided fuel costs, but from the investor perspective, this cost increase further reduces the investment signals.

However, high peak rates and thus higher revenues can be limited by ceiling prices in the electricity market. Thus (Joskow, 2006) recommends the improvement of the performance of the EOM by raising the price cap and hiding it during scarcity hours. Furthermore, he mentions, that increasing forward contracting could help to mitigate market power and to deal better with the uncertainty and volatility of prices and hence to decrease and handle the risk of investments. In addition fluctuating energies have a high need of balancing, but the day-ahead mark is more suitable for fossil power plants, which can forecast their output with confidence. Thus balancing and intraday market contracts should be addressed (Keay, 2013). This would allow a better integration of intermittent renewables into the market. Another necessary measure, which should be executed to improve the functionality of the EOM is the progressive development towards more demand flexibility.

But beside the recommendations to improve the functionality of the EOM, further and more major changes concerning the market design in general are proposed to handle the missing-money problem and to procure an adequate level of generation capacities. In addition, (Key, 2013), state, that even if fluctuating renewables attain “grid parity” and even in scenarios with high carbon prices, the EOM never would provide sufficient investment signals in intermittent renewables, if they are built in quantities which are targeted from the governments. Consequently, the EOM does not provide sufficient investment signals neither for fossil power plants nor for fluctuating renewables and a new market design is needed (Key, 2013). Therefore (Joskow, 2006) mentions that new market segments for the product reliable capacity in form of well-designed capacity markets have the potential to solve the missing money problem. Capacity mechanisms are partially presented as an obvious solution to have the potential to solve the problems and imperfections of the current EOM and missing money problem. However, design and implementation of an efficient and effective capacity mechanism are very complex. Furthermore there exist various options to design capacity mechanisms. Worldwide, strategic reserves, administrative capacity payments, comprehensive capacity markets and capacity options have been implemented (e.g. in Spain, Chile, Norway, the US). Other approaches, which are also currently discussed for the German market, are selective or focused capacity markets and decentralized models where the desired level of security of supply is determined by consumers (EWI (2012), VKU (2013), Matthes et al. (2012)). Several hybrid designs, in which a combination of regulations and competitive markets, are introduced to cope with investment crises. A notable example is Brazilian power market (Pinguelli Rosa, 2013), where the 2001 droughts caused depletion of reservoirs and power rationing. The reforms established long-term contracting of power as the sole form of electricity procurement, in order to reduce the investment risk for new providers. In this long-term contracting environment the contracts for new generation capacity are longer (15 years) than those for existing generation capacity (8 years), and distribution companies are obliged to purchase 100% of their expected power needs. There is also a second trading environment, where the eligible participants are free to enter bilateral contracts and negotiate prices, quantities etc. This “free trading environment” accounts for about a third of the total consumption in the system. From the Brazilian example, a conclusion can be taken that strong focus on the resource adequacy procurement can definitely be in conflict with the need for short and medium term flexibility.

The extent to which the renewable generation displaces the conventional generation differs strongly related to the current state of the power system. For instance, in Eastern Europe in the electricity net exporting countries, the guaranteed dispatch of renewables results in displacement of more conventional power plants than the capacity factor of renewables indicates. This is partially due to overall increase of renewable share in Europe (Majstrović et al. 2012), but the net effect is very similar: the capacity investment is very difficult to break even in the EOM conditions, with no incentives or feed-in contracts.
However, the introduction of a capacity market is a significant intervention in the electricity market, which can unsettle investors and in case of an inadequate parameterization can lead to a distortion of price signals and incentives. In addition, so far, there has not been a structural widespread capacity problem, but rather regional congestion problems and there is no evidence of a fundamental capacity problem in the future (EEX, 2013). One should also consider that the disruptive effect of introducing the capacity market would certainly be different in the countries where the electricity market is still emerging, if compared to countries with strongly developed market infrastructure.

Consequently, (EEX, 2013) recommends considering the introduction of a capacity market as measure of last resort and in a first step taping the full potential of the EOM. This includes, besides the above mentioned measures as scarcity pricing and increasing demand flexibility, the complete integration of renewable energies into the electricity market as well as grid expansion at European level. Sufficient transmission capacity would link the different countries closer together and diversify the overall European capacity mix (EEX, 2013).

3. Activities and Outputs Main results and interpretations (from the modelling if applicable)

To provide decision makers with new insights into the question, whether the EOM provides sufficient investment signals for a decarbonisation of the electricity mix the agent-based simulation model PowerACE is applied.

The model exemplarily displays all the power plants in the German electricity market. Essential input parameters are the development of electricity demand, prices of carbon dioxide and fuels, imports and exports of electricity and the expansion of renewable energies. Investments occur in the model on the basis of calculation of profitability of the simulated power plant utilization of predetermined conventional technology options. Decision basis of the investment planning agents are the hourly prices of the spot and forward market simulated in the model and any additional revenues from capacity mechanisms.

An important model extension is the implementation of capacity mechanisms. Different market designs could be analyzed under various parameter settings regarding the investment behavior of the agents, the development of generation capacity, electricity prices, carbon dioxide emissions and costs. Furthermore it is possible to examine whether it comes to an undersupply of demand in several scenarios or under certain parameterizations.

Another model extension is the implementation of demand flexibility. For the moment, the flexibility is limited to the integration of sheddable load, but will be extended to shiftable load as well. Thus, on the one hand demand response can prevent market failure in the EOM by setting the price in scarcity hours and on the other hand demand resources can take part in capacity markets earning additional revenues.

The database for the simulation consists of input parameters from various sources, for example, the power plant list of the Federal Network Agency and the Energy Roadmap 2050 of the European Commission. The demand for electricity in Germany is in this simulation characterized by an increase of approximately 547 TWh in 2010 to approximately 667 TWh in 2050. This development could be explained by assuming a strong increase of electric mobility.

The analyzed period covers the years 2010 to 2050. The expansion path of renewable energy is in all simulations the objectives of the federal government to reach a share of 80% of electricity supply by 2050.

Simulation results for the EOM and for an energy market design with a centralized capacity market based on capacity options are briefly summarized and compared in the following.
installed power plant capacities in the German EOM (Figure 1) and in case of an introduction of a centralized capacity market (Figure 2). The investment activity in the EOM is strongly influenced by cycles, which can be explained by a high level of prices on the wholesale market during scarcity periods. In the simulation with a centralized capacity market, however, the investments are carried out earlier and more evenly. The level of security of supply is thus significantly higher in the case of a capacity market than in the EOM. Besides, nearly 12 GW additional natural gas capacities are built, if a capacity market is introduced. This comes along with the need of restructuring the power sector to more low carbon technologies.

The evaluation of an energy market design with a decentralized capacity market based on capacity certificates still deserves further study. Nevertheless, our preliminary analysis and results indicates, that the investment activity is on the one hand strongly influenced by made assumptions about the risk appetite of the single market players and on the other hand by the regulatory given penalty for a shortfall of capacity certificates.

The higher investment activity raises also the question of whether capacity markets tend to cause a build-up of excess capacity or in the EOM situations occur in which the demand cannot be met. Agent-based simulation models allow the examination of a shortfall in demand. In the model, this situation is solved with the help of a reference provider. In case, the situation occurs in a simulation, that demand exceeds supply, the reference agent jumps to a reference gas power plant. This is offered at very high prices and high volume on the market. A sign of a shortfall in demand in the model is thus the occurrence of the high bid price of the reference power plant. In the simulation with capacity market, due to its objective and adequate parameter setting, shortage of demand can be prevented. However, in the EOM this situation occurs, even by accounting for demand response in terms of sheddable load.

Altogether, the modelling results for the EOM could serve as an indication of future investment activities in an EOM whose potential isn’t yet fully achieved. Besides load shedding potential, which is implemented in the model, there exist other measures as mentioned in chapter 3 for improving the efficiency of the EOM. This includes the implementation and analysis of shifting load potential as well as the future potential and economic feasibility of electricity storage technologies or virtual power plants. Thus before introducing new market segments like capacity markets, the impacts of these measures on prices and on the investment behavior should be analyzed profoundly as well.

4. Policy recommendations

Changes in the electricity market design can unsettle investors and bring additional risk premiums and transaction costs. For the short term, in particular to handle occurring regional congestions, the introduction of a strategic serve could be sufficient to guarantee security of supply. In the long term, the advantages and disadvantages of such changes as the introduction of a new market designs should be analysed in detail.

Instead of performing major changes in the electricity market design, for the short term, it is therefore initially recommended to improve the functioning of the EOM by raising price caps, so that prices near the VoLL are possible. In addition, measures that lead to a more flexible demand and that advance electricity storage technologies should be made as well as intraday and balancing markets should be intensified and reinforced. These measures would allow a better integration of renewable energies and individual demand segments. Furthermore European cross border trade should be enhanced by European grid extension. This would strengthen the European Electricity market and diversify the overall capacity mix.

In the long term (2025 and beyond), however, capacity markets could be introduced to handle the missing-money problem, which is getting worse with increasing share of renewable energies. Thereby it is important that renewable energy technologies also take part in capacity markets according to their capacity credit. Furthermore, it is likely, that the
EOM will never provide sufficient investment signals in intermittent renewable sources, even if they attain “grid parity” and even in scenarios with high carbon prices. Capacity markets do not only have the potential to guarantee security of supply, but also to set sufficient investment signals which are necessary for low carbon technologies and therefore a decarbonisation of the electricity mix.

5. Conclusions

Previously, it was shown that the EOM under certain conditions may not provide sufficient conventional power plant capacity in the long term, in order to guarantee the necessary system security, even by accounting for load shedding potential. The opportunities to improve the EOM should be examined and checked, since they can cause minor distortions of the market as the introduction of other market segments. In contrast, a wide variety of flexible options can be equally incited in pure EOM being a market design relatively simple and transparent. A comprehensive redesign of the market design therefore seems only useful if it turns out that the current market design does not work in the long term with the necessary and reasonable adjustments.

The modelling activity, which has been made and presented in this assessment, mainly consists of the implementation, configuration and analysis of the mechanism of capacity options but also of a decentralized capacity market. It has been shown that capacity markets are capable to meet the requirements to ensure security of supply for high levels of renewable energy generation. Differences to the EOM in terms of development of conventional generating capacity could be observed both in quantity and in quality as with capacity investment in gas generation capacity is increased. Thus it could be stated, that capacity markets have the potential to provide investment signals that are necessary for a decarbonisation of the electricity mix. Nevertheless the major challenge for a good functioning and well-designed capacity mechanisms is an adequate parameterization.

6. Background document, references

Recently own publications:


And in this case also a suggested solution (not convinced though):

Note that the EU project Market4RES (led by Sintef Energy Research) is also analysing the topic

Further background documents:

- EEX, (7.2.2013): EEX response to the public consultation of the European Commission (DG Energy) on generation adequacy, capacity mechanisms and the internal market in electricity
- The NREL study "Western Wind and Solar Integration Study - Phase 2", 2013: http://www.nrel.gov/electricity/transmission/western_wind.html
7. **Appendix**

- Figure 1: Investment behavior in the EOM, exemplary for the German electricity market

![Installed conservative capacity in the EOM](image1)

- Figure 2: Investment behavior with central capacity market, exemplary for the German electricity market

![Installed conservative capacity with capacity market](image2)