# HOW DO CAPACITY MARKETS AFFECT DEMAND FLEXIBILITY : WELFARE EFFECTS OF DYNAMIC CAPACITY PRICING IN THE PRESENCE OF HIGH SHARES OF FLUCTUATING RENEWABLE RESOURCES

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## Overview

European electricity market design faces two major and intertwined challenges. First, due to “missing money” concerns reliability may need to be adressed via explicite capacity mechanisms. Secondly, with increasing shares of intermittent renewable generation resources, short term security-of-supply crucially depends on increased power system flexibility. The cost efficient provision of flexibility relies on the competition of various resources such as flexible generation capacity, storage or demand response. This competition may, however, become biased in favour of flexible generation options depending on the particular capacity mechanism design. Against this background, our work is concerned with the regulatory task of implementing resource adequacy at the generation level while sustaining incentives towards demand flexibility. More specifically, we analyze the effect of different ways to pass on capacity costs to consumers on both their market driven incentives to invest in demand response infrastructure and to respond to time variant prices. Further, we compare this effect in a system with low and high shares of fluctuating renewables. Eventually, demand response substitutes for costly supply-sided capacity required to comply with regulatory reliability standards and to accommodate large-scale deployment of fluctuating resources. The welfare implications of this trade-off relationship are subject of this paper under the hypothesis that increasing shares of intermittent resources, *ceteris paribus*, decrease reliability, increase energy price volatility and scarcity price levels. This,in turn, makes it more desirable to uphold all possible demand response incentives, and hence, to pass on scarcity signals in the energy and capacity markets on a time varying basis.

## Methods

To analyze the issue at hand, we use a computational partial equilibrium model of a perfectly competitive electricity market that has been complemented with a forward market for firm capacity (cf. Cramton & Ockenfels, 2012). More specifically, an exogenous reliability target is imposed via a fixed planning reserve margin for dispatchable generation capacity as used in Alcott (2012). Analytically, our analysis builds upon a two-stage investment and operation model alike the approaches used by Borenstein and Holland (2005), Borenstein (2005) as well as Alcott (2012). This setup corresponds to a genuine long-run market equilibrium where all investments in generation, storage and demand response capacity are taken at the initial stage while operation and consumption occur in the second stage. Unlike in many other models, total hourly electricity demand is determined by two types of consumers: a small share which is able to receive and react to prices in real-time and a majority of consumers who cannot, thus, facing a flat electricity price (cf. Borenstein and Holland 2005). The flat and real-time electricity prices (RTP) are determined in the retail sector, where homogenous retailers engage in Bertrand competition when buying electricity from generators and selling it on to end customers. Furthermore, retailers also procure firm capacity from dispatchable generation technologies to comply with exogenous reliability standards, i.e. a capacity reserve margin (Alcott 2012). Retailers then decide upon the pass-through of annual costs for capacity to their customers. These can either be passed on time varyingly, depending on the bindingness of the reserve constraint, or as a constant payment on top of retail electricity prices (ibid.). In contrast to prior approaches we induce three further model extensions: First, we assume large-scale, policy induced deployment of intermittent renewable generation resources. Secondly, we assume a discriminatory capacity market where solely reliability options of dispatchable generation capacity are traded. Finally, we infer endogenous switching from flat rate based to real-time prized consumption, in order to capture the effects of different capacity pricing schemes on the diffusion of demand flexibility. The numerical model is calibrated to the German market and formulated as a non-linear (mixed complementary) optimization problem (MCP) using GAMS.

## Results

Here we present results from comparative statics regarding high or low shares of renewables (wind onshore) as well as high or low shares of real-time priced customers. Running this stylized version of the model gives two main results. First, as can be seen in Figure 1 when implementing a dynamic capacity pricing scheme and increasing the share of price responsive demand from 10% to 50%, the relative reduction in total generation capacity, peaker capacity (CCGT) in particular, is higher in a fluctuating renewables dominated market (High RES) than in a market with only dispatchable generation technologies.

Secondly, this result is also reflected in the total welfare changes for the aforementioned scenarios (see Figure 2). Here, again the relative welfare change for increasing demand responsiveness is relatively higher in a "High RES" market.

**Figure 1**: Change in installed generation capacity [MW] when changing capacity pricing for different shares of variable renewables and real-time priced consumers

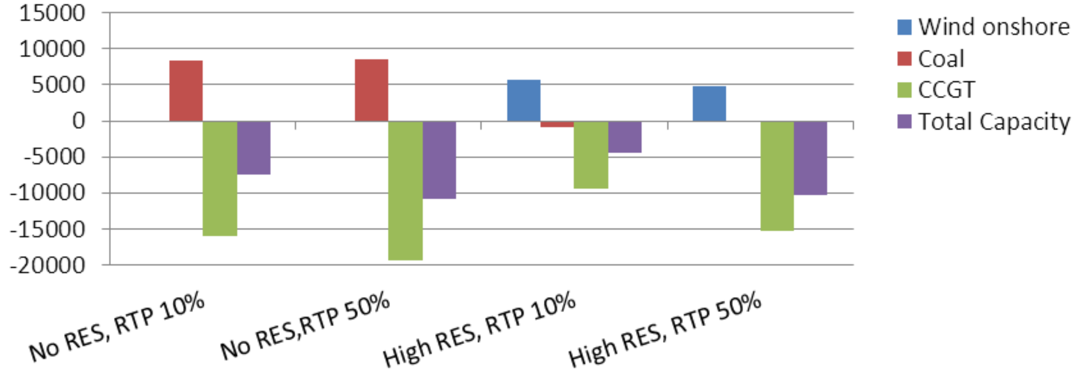
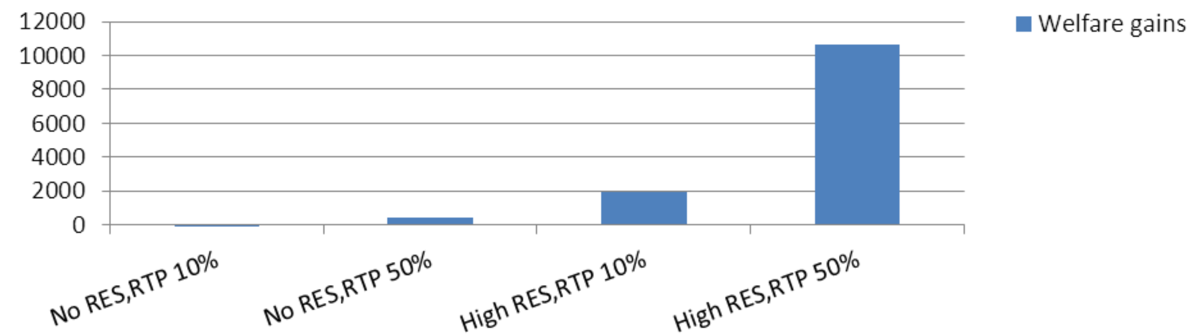



**Figure 2:** Change in total welfare [Mio.€] when changing capacity pricing for different shares of variable renewables and real-time priced consumers




**Conclusions**

Our findings have direct implications for electricity and capacity market design with high shares of fluctuating renewable resources. Passing on capacity costs based on time varying scarcity is more welfare enhancing if renewable shares are high, even if there is only a small share of price responsive consumers (cf. Alcott 2012). A particular implication for the design of forward capacity markets is that end-consumers should still be exposed to sufficiently high prices. This should be considered when determining strike prices for reliability call options, for instance. Further, retailers should be able to pass on the according costs for procured capacity dynamically, i.e. dependent on capacity scarcity, to incentivize demand response in the short and long run. From a mere technological perspective, flexible resources are required to accommodate increased output variability due to intermittency. From an economic perspective, increased demand response from various consumer groups represents one flexibility resource that may become a dynamically efficient alternative to rather costly, conventional supply-sided options such as gas turbines or storage. In future research, we intend to look closer at different, practical ways of dynamic pricing in the context of consumers' risk aversion.

**References**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