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Capacity payment impact on gas-fired generation investments under rising renewable feed-in — A real options analysis

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ABSTRACT

We assess the effect of capacity payments on investments in gas-fired power plants in the presence of different degrees of renewable energy technology (RET) penetration. Low variable cost renewables increasingly make investments in gas-fired generation unprofitable. At the same time, growing feed-in from intermittent RETs amplifies fluctuations in power generation, thus entailing the need for flexible buffer capacity—currently mostly gas-fired power plants. A real options approach is applied to evaluate investment decisions and timing of a single investor in gas-fired power generation. We investigate the necessity and effectiveness of capacity payments. Our model incorporates multiple uncertainties and assesses the effect of capacity payments under different degrees of RET penetration. In a numerical study, we implement stochastic processes for peak-load electricity prices and natural gas prices. We find that capacity payments are an effective measure to promote new gas-fired generation projects. Especially in times of high renewable feed-in, capacity payments are required to incentivize peak-load investments.

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1. Introduction

Gas-fired power generation is becoming increasingly unprofitable and hence undesirable for investors. This applies to existing plants as well as to new projects. According to Bloomberg (2013a), gas-fired power plants were unprofitable most of 2012 in France, the Netherlands, Spain, the Czech Republic, and Germany. In line with these profitability considerations, we find an investment freeze for gas-fired generation projects at several European utilities, as confirmed by interviews with industry partners. The decrease in investment activity and operating profits of gas-fired generation is largely caused by increasing feed-in from renewable energy technologies (RET)[1] as we explain in the following: RETs provide a rising share of power production in several European markets, e.g. Germany 22% and UK 11% of total electricity production in 2012 (AG Energiebilanz, 2013; DECC, 2013). The rise of RETs is expected to continue due to challenging EU CO^2 reduction targets (e.g. the 20–20–20 targets (European Commission, 2009)) and renewable energy support schemes, such as feed-in tariffs, green certificates, or market premiums. These RETs feature negligible variable costs and are always fed into the grid when available. Therefore, at times of RET power production, high-variable-cost generators (namely oil and gas turbines) are pushed out of the market by RET feed-in — known as the merit order effect of renewable energies (Sensfuß et al., 2008).

At the same time, gas-fired generation is increasingly needed to balance uncontrollable fluctuations in power generation — in the absence of cost-efficient large scale storage. These are caused by the fastest growing and most promising RETs (wind power and solar PV (IEA, 2012)), which exhibit high degrees of intermittency since these are entirely weather-dependent. These fluctuations must be balanced by other controllable sources of generation to prevent power outages and guarantee supply. The power production technology with the lowest fixed costs and best ramping properties (i.e. fast ramping times combined with low ramping cost) currently in the market are gas-fired generators (Greenblatt et al., 2007). Additionally, gas-fired generation is the technology with the least greenhouse gas emissions of all fossil-fuel power generation technologies (Worldwatch Institute, 2010).

Combining the two discussed effects, RETs make existing gas-fired generation gradually less profitable while simultaneously entailing the need for more flexible balancing capacity. In the long term, this

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[1] Combined with relatively high natural gas and low coal prices (in Europe).

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combination may lead to underinvestment in flexible generation capacity to balance RET intermittency and thus may put long-term adequacy of supply, one of the major goals of the regulator, at risk (VDE, 2012).[2] According to interviews with several European utilities, there will be no investment in conventional generation capacity without some form of capacity mechanism or regulatory scheme rewarding the reliability provided by conventional generation. Additionally, our interview partners named multiple sources of uncertainty (price-fluctuations of peak-load electricity, fuel and CO_2, as well as future regulation) as reasons why positive investment decisions are currently hardly possible.

To promote adequate investment in flexible generation, several regulatory schemes are currently discussed and already implemented in some markets. The most relevant are capacity markets (e.g. Pennsylvania–Jersey–Maryland–Pool (US) and New England (US)), capacity payments (e.g. Ireland, Portugal, Spain) and strategic reserves (e.g. Poland, Sweden, Finland, and (partly) Germany).

1.1. Capacity market

A capacity market can be defined as a market scheme, in which the regulator defines the total required capacity of the system. The regulator then leaves the pricing per unit of capacity to the market — e.g. through a public auction process (DECC, 2012; Soeder, 2010). Therefore, the regulator can steer the total installed capacity through the definition of the required capacity, but not the price for the provided capacity as it is determined by the market. In some capacity markets, such as the ones of PJM an NYISO, regulators define demand curves for capacity rather than fixed capacity requirements to prevent strategic behavior and the exercise of market power.

1.2. Capacity payment

In a system with capacity payments, either all, or only selected plants[3] receive a fixed or variable compensation for available capacity (Baldick et al., 2005). In such a system, the regulator sets a price paid to the targeted generators. Hence, the regulator can only steer the installed capacity indirectly, by setting the price and leaving it to private operators whether or not to invest.

1.3. Strategic reserves

Strategic reserves are specific power plants, defined as system-relevant and started only in situations of a supply shortage. This backup capacity may be owned directly by the regulator or by private generators receiving a strategic reserve payment. Often these reserves are old and unprofitable plants, which would be closed in the absence of these payments (as seen in Germany, where 2.5 GW of gas- and oil-fired plants have been declared a strategic reserve for the 2012/2013 winter (BMWi, 2013)). Strategic reserves are relatively easy to enact as a policy instrument, as they represent merely a small market intervention as long as only a few selected plants are appointed a strategic reserve. Additionally, the total amount of payments as well as the reserve capacity is deterministic. However, in the long term, more peak-load power plants will come under pressure due to high shares of RETs. Consequently, strategic reserves may not suffice, requiring to introduce capacity markets or payments in order to adequately incentivize flexible conventional generation, as argued by (Bloomberg, 2013b).

We contribute to this discussion by quantifying the effect of capacity payments as an incentive to invest in peak-load power plants in the presence of different degrees of RET penetration. The focus is on capacity payments for three reasons. First, capacity payments are being widely used in markets such as Ireland, Portugal, and Spain for many years. Second, our result for capacity payments can be easily transferred to markets with strategic reserves such as Finland, Germany, and Sweden, because strategic reserve payments are a capacity payment that is paid to a limited number of generators only. Hence, a strategic reserve payment is a special form of a capacity payment. Third, because we want to examine the effect of a certain revenue stream (i.e. the capacity payment) in a market with several uncertainties (i.e. electricity and gas price fluctuations). A capacity payment provides that kind of a certain revenue stream whereas, for example, a capacity market adds another form of uncertainty. This is an area of future research. The paper is, to our knowledge, the first paper to provide a quantification of the influence of capacity payment schemes through a real options approach. We use real options to account for multiple sources of uncertainty, irreversibility of the investment and managerial flexibility. The findings are of value to three groups: First, investors developing valuation methods for future projects, second, regulators discussing future policy decisions regarding adequacy of supply, and third, utilities, grid operators and equipment manufacturers trying to anticipate the impact of potential future regulatory developments.

The paper is structured as follows: In Section 2, we provide a brief overview of the literature regarding electricity supply adequacy and power generation investments, capacity mechanisms, and real options in the power sector. Section 3 describes the real options investment valuation model. In Section 4, we present the results of a numerical case study. Section 5 concludes and provides suggestions for further research.

2. Literature of electricity investments, capacity mechanisms and real options

Adequacy of supply is one of the major concerns in liberalized electricity markets. In order to meet adequacy targets, investment incentives need to be sufficiently high for investors to take the risk of the required investments. These investments in generation capacity are capital-intensive and long-term focused. Several articles have assessed the effects of multiple sources of uncertainty under different risk attitudes: Traber and Kemfert (2011) analyze the incentives to invest in thermal power plants under increased wind feed-in with a computational model. The model shows that incentives to invest in natural gas fired power plants are largely eliminated due to current wind supply. Ehrenmann and Smeers (2011) model generation capacity expansions using a stochastic equilibrium analysis in capacity and energy-only markets. They find that due to multiple uncertainties involved, a capacity market is more likely to lead to adequate supply than an energy-only market. Fan et al. (2012) assess electricity capacity investments under risk aversion using a game theoretic model. They show that multiple sources of uncertainty in the market as well as risk aversion delay investment and reduce profitability.

While there is a consensus on the necessity of sufficiently high incentives, it is a topic of discussion how these should be provided. This begs the question, whether an energy-only market can provide sufficiently high incentives, or an additional regulatory scheme is needed for supply adequacy. Oren (2005) states that generation capacity ensuring long-term supply adequacy can be incentivized through energy-only markets and therefore be treated as a private good. However, he adds that market imperfections like the lack of real-time pricing and the presence of price caps might make mandatory levels of capacity necessary. In contrast, Abbott (2001) argues that adequacy of supply is extremely important to the consumers of electricity and therefore shows characteristics of a public good, since investors themselves are incentivized to invest too little in generation adequacy. Cramton and Stoft (2005) combine the two arguments and propose a capacity market as a mechanism to keep supply adequacy a private good. They argue that with a capacity market, supply adequacy can be traded freely on the market—separately from the electricity. Hence, the capacity market income can supplement revenues of the generator in order to provide

[2] German association of electrical and electronic engineers similar to the IEEE.

[3] For example, in Ireland all generators receive capacity payments for their reliable capacity provided with peak-load capacity receiving a higher amount. Contrastingly, in Spain only new and selected existing plants receive a payment.

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