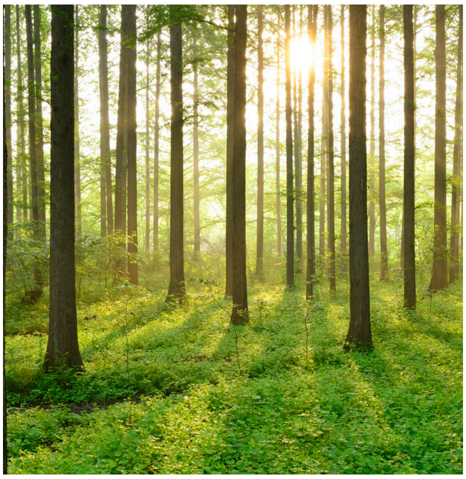
POLITICAL ECONOMY OF SAFE-GUARDING SECURITY OF SUPPLY WITH HIGH SHARES OF RENEWABLES

REPORT 2017:441



EFORIS

ELMARKNADENS FUNKTION
OCH ROLL I SAMHÄLLET

Energiforsk

Political Economy of Safe-guarding Security of Supply with High Shares of Renewables

Review of Existing Research and Lessons from Germany

ERIK GAWEL, PAUL LEHMANN, ALEXANDRA PURKUS, PATRIK SÖDERHOLM AND SEBASTIAN STRUNZ

ISBN 978-91-7673-441-4 | © ENERGIFORSK October 2017

Energiforsk AB | Phone: 08-677 25 30 | E-mail: kontakt@energiforsk.se | www.energiforsk.se

Foreword

EFORIS is a research program on electricity market design. The goal is to develop a better understanding of the electricity market and its role in society.

This study has been conducted by Erik Gawel, Paul Lehmann, Alexandra Purkus, Patrik Söderholm and Sebastian Strunz. These authors are affiliated with the Helmholtz-Centre for Environmental Research – UFZ, Leipzig, Germany, and Luleå University of Technology (LTU), Luleå, Sweden, respectively.

The completion of the report has benefited from prior research carried out in the context of the Helmholtz Alliance Energy-Trans, as well as from useful comments on an earlier draft from Mats Nilsson, Klaus Hammes, Jan Strömbergsson, Henrik Forsgren, Per Lundström, and Lars Josefsson. Research assistance from Frank Hirschi and Lukas Jany is also gratefully acknowledged. Any remaining errors, however, reside solely with the authors.

Sammanfattning

Den ökade andelen vindkraft och solel på de europeiska elmarknaderna har inneburit att en oro för det nordiska elsystemets leveranssäkerhet vuxit fram. Syftet med denna rapport är att syntetisera den ekonomiska forskning som analyserar karaktären på de leveranssäkerhetsproblem som kan uppstå på elmarknader. Extra uppmärksamhet ägnas åt erfarenheterna från Tyskland, samt åt att identifiera centrala lärdomar för utformningen av det svenska (och nordiska) regelverket.

Mer specifikt diskuteras först hur leveranssäkerhet kan definieras, samt varför s.k. energy-only marknader, dvs. marknader där kapacitet inte prissätts, inte alltid kan förväntas leverera en effektiv nivå på leveranssäkerheten. En rad olika policy- och marknadsmisslyckanden uppmärksammas. Sedan identifieras och utvärderas en rad möjliga reformer av elmarknadens organisation och regelverk som kan bidra till att hantera sådana misslyckanden. Dessa reformer är av tre olika slag: åtgärder som stärker energy-only marknaden (t.ex. borttagandet av pristak, förstärkning av balansmarknaden via kortare handelsperioder, etc.); införandet av olika former av kapacitetsmekanismer (t.ex. riktade, marknadsövergripande, etc.) och strategiska effektreserver; samt reformer av de energipolitiska styrmedlen (t.ex. premiering av flexibel förnybar kraft, ökad efterfrågeflexibilitet, nätverksreglering, etc.).

Till skillnad från tidigare elmarknadsstudier har även den politiska debatten om leveranssäkerhet analyserats; fokus ligger på den tyska politiska processen och i vilken utsträckning centrala resultat från tidigare forskning getts utrymme i denna process. Detta politisk-ekonomiska perspektiv ökar förståelsen för drivkrafterna bakom reella politiska beslut, i Tysklands fall en förstärkning av den existerande energy-only marknaden samt införandet av en effektreserv.

I rapporten identifieras ett antal generiska lärdomar från de tyska erfarenheterna: (a) alla aktörer inom elsystemet kan på olika sätt bidra till ökad leveranssäkerhet; (b) underinvesteringar i leveranssäkerhet orsakas normalt sett av en kombination av olika faktorer, och dessa bör därför i första hand hanteras genom en portfölj av olika kontext-specifika åtgärder i stället för via en generell kapacitetsmekanism; (c) omställningen av energisystemet behöver inte nödvändigtvis komma i konflikt med mål kopplade till leveranssäkerhet; (d) de åtgärder som implementeras för att säkerställa leveranssäkerheten bör så långt som möjligt integreras med andra länder, samt ta hänsyn till eventuella risker för institutionell inlåsning; och (e) den politiska beslutsprocessen behöver baseras på trovärdiga långsiktiga åtaganden samt transparent samverkan med berörda aktörer.

När det gäller lärdomar för utformningen av det svenska regelverket är våra slutsatser i linje med tidigare studier som har argumenterat för en vänta-se-och-utvärdera strategi. Vi betonar dock betydelsen av att i nuläget inte göra politiska utfästelser gällande introduktionen av framtida kvantitativa mått och/eller mer utvecklade kapacitetsmekanismer. Sådana mått av leveranssäkerhet är svåra att definiera samt utvärdera, och det finns en risk att för långtgående åtgärder innebär ett överdrivet fokus på leveranssäkerhet med åtföljande höga kostnader. I stället förordas ett antal mer marginella reformer av existerande marknadsdesign, t.ex. en höjning av högsta tillåtna priser, kortare handelsperioder etc.

Summary

The increasing shares of wind power and solar PV in the European electricity markets have raised concerns about security of supply being jeopardized. The objective of this report is to synthesize the economic research on the nature and extent of intermittency problems in electricity markets, and not least discuss how to deal with these in the electricity market design. Particular attention is devoted to German experiences, and on identifying key lessons for Swedish market design.

Specifically, we first discuss how security of supply can be defined, and why real-world so-called energy-only markets, i.e., markets without any pricing of capacity *per se*, may not provide an efficient level of security of supply. The latter includes a broad set of various market and policy failures. Furthermore, the report identifies and evaluates different regulatory options for addressing security of supply issues in the electricity system. These include three categories of options: measures to strengthen the energy-only market (e.g., removing price caps, strengthening the balancing market, etc.); the introduction of various forms of capacity mechanisms (i.e., focused, comprehensive, and decentralized capacity markets and strategic reserves); and various energy policy reforms (e.g., flexible renewable energy feed-in, improving demand-side management, adjusting network regulation, etc.).

Unlike many previous economic studies, we also analyze the drivers of the policy debate on security of supply in Germany, and not least the extent to which the knowledge gained through previous research has penetrated this debate. This political economy perspective permits better understanding of the rationale behind the actual outcomes of the policy processes, i.e., in Germany's case a strengthening of the energy-only market and the installation of a strategic reserve.

A number of generic lessons from the German policy debate are highlighted: (a) all actors in the electricity supply system can in various ways contribute to security of supply; (b) underinvestment in security of supply most often have multiple causes, and should preferably be addressed through a portfolio of context-specific measures rather than through the use of single capacity mechanisms; (c) the energy transition taking place in, e.g., Germany, does not fundamentally question security of supply; (d) the measures implemented to safeguard security of supply should include an international perspective as well as consider the risks of potential institutional lock-in; and (e) the policy decision-making process needs to build on credible long-term commitments and transparent consultations with stakeholders.

In terms of lessons for the Swedish market design, our conclusions are in line with earlier studies arguing for a wait, see and evaluate strategy. We contend, though, that policy should abstain from making early, future commitments regarding the introduction of quantitative measures and more extended capacity mechanisms. Quantitative measures of security of supply are far from straightforward to define, monitor and evaluate; there is a risk that such measures become too constraining and leads to an exaggerated focus on security-of-supply. A portfolio of measures that strengthen the existing Swedish market design (e.g., removing price caps, reduced trading intervals etc.) should help address the causes of security of supply concerns in a more targeted and cost-effective manner.

List of content

1 Introduction

1.1 BACKGROUND AND MOTIVATION

Renewable energy supply in the electricity sector (RES-E) is often intermittent and dependent on external factors such as wind speeds and solar radiation. The increasing shares of wind power and solar photovoltaics (PV) in the European electricity markets have therefore raised concerns that a secure supply of electricity may be jeopardized. In periods with relatively high levels of electricity generated from intermittent energy sources, wind power and solar PV generation will with their low variable generation costs out-compete the conventional power plants (e.g., Nicolosi, 2010). On the other hand, during periods of low wind power and solar PV generation, flexible back-up capacity has to be held available. Overall, this reduces the predictability of electricity supply and increases the cost of power generation. For instance, wind conditions often fluctuate from hour to hour, and exact wind speeds cannot be predicted with high accuracy over daily periods. Previous studies indicate that in Germany the day-ahead forecast error can amount to more than 20 percent of average wind generation (e.g., Newbery, 2010).

At the regulatory level this can be dealt with – and is dealt with – in a number of ways. *First*, system integration of RES-E may be addressed by designing the RES policy framework correspondingly. For instance, for stability reasons the network operators may be permitted to deviate from priority access for renewable electricity. Additionally, technical minimum requirements may be demanded from power generators, e.g., some countries requiring RES-E generation to fulfill minimum standards regarding controllability. Moreover, system integration costs can also be better imposed on RES-E investors if RES-E remuneration reflects market prices, as under a premium tariff (in contrast to a fixed tariff). However, in practice the institutional framework may often fail to internalize these costs properly. For instance, Germany has only embarked on a sliding transition from feed-in tariffs to premium tariffs.

Second, regulatory measures to safeguard security of supply may also address the infrastructures that are complementary to RES-E power plants, e.g., reserve capacity, networks and storage as well as electricity demand management. This may involve a variety of single policy measures but also the fundamentals of electric power market design. Existing spot, future and balance markets typically fail to send proper investment signals due to the design and timing of the contracts traded, the absence of locational price signals, regulatory uncertainty and/or market power (e.g., Löschel et al., 2013a, Hirth et al., 2015). Consequently, power market reforms need to be considered critically, including not least, different types of capacity mechanisms offering additional payments for providing generation capacity (Cramton et al., 2013; Bergman, 2016).

The importance of intermittent generation in the European electricity markets requires a thorough understanding of the extent and the nature of security of supply problems, and how they can be addressed by the regulator. During recent years, a research literature has emerged that addresses these issues in various country contexts. It is therefore useful to synthesize the main generic lessons from this research, and not least the extent to which empirical and policy-related lessons from specific countries (e.g., Germany) can be transferred to other countries (e.g., Sweden).

Moreover, since regulations often have to rely on second-best solutions involving difficult trade-offs,[1] the political debate and the ensuing policy process will tend to be dominated by a diverse number of regulatory proposals from interest groups, political parties etc. These proposals in turn require further scrutiny, and it becomes essential to contrast such proposals with what one can learn from existing peer-reviewed research. Undertaking such a comparison should help to increase the transparency of regulatory decision-making.

1.2 AN ECONOMIC APPROACH TO ELECTRICITY SECURITY OF SUPPLY

Since not all electric power technologies provide electricity with the same temporal and spatial characteristics, standard methods for assessing the costs of these technologies (e.g., the so-called levelized cost approach) are misleading (Joskow, 2011). Instead it is necessary to evaluate technologies on a system level. As Hirth (2013a) notes, there exist two strands of literature analyzing the system impacts of intermittent power sources. The first strand is an engineering-based approach that aims at quantifying integration costs (e.g., Holttinen et al., 2011), while the second strand aims at estimating the marginal value of intermittent power (e.g., Borenstein, 2008; Hirth, 2013a). This report departs primarily from the marginal value approach.[2]

The marginal value of, for instance, wind power is not only affected by the timing of generation, but also by its location, taking into account the uncertainty under which the wind power is generated. Existing research has addressed how the intermittency problem may affect the electricity market. In general, previous work reports decreasing values of RES-E with increased penetration, but there may be important differences across various countries and regions. For instance, Forsund and Hjalmarsson (2011) and Matevosyan et al. (2007) study the interaction between wind power expansion and hydropower in the Nordic electricity market. Other studies consider the situation where wind and hydropower are geographically separated, and where therefore transmission constraints play a significant role (Green and Vasilakos, 2012; Mauritzen, 2013). The work by, for instance, Lion Hirth has instead addressed the balancing power problem in Germany, a market where hydropower does not play the same role as in the Nordic case (e.g., Hirth, 2013a; Hirth and Ziegenhagen, 2015).

[1] For instance, from a security of supply perspective premium tariffs for supporting RES-E technologies are often preferred over fixed tariffs, e.g., they set incentives for a higher demand orientation of RES-E generation where possible. Still, compared to fixed tariffs, premium tariffs may increase transaction costs and reduce investment certainty, thus potentially making it more difficult to attain given RES-E targets.

[2] The analysis does not, however, address the eventual costs imposed on other power generation options following increased generation of, for instance, wind power. Specifically, since wind power generation is naturally volatile this requires other power sources to start up and shut down in accordance with weather conditions, thus increasing the probability of failures in, say, coal-fired power plants (e.g., Fogelberg and Lazarczyk, 2015).

Previous research has increasingly addressed the regulatory options available to promote security of supply in electricity markets, including different types of capacity mechanisms (Bergman, 2016). This includes evaluations of the recent reforms of RES-E support schemes in Germany (Gawel and Lehmann, 2014), particularly the gradual transition towards a premium scheme (Gawel et al., 2013, Gawel and Purkus, 2013, Purkus et al., 2015), as well as proposals to develop grid regulation (Korte and Gawel, 2015, 2016). Analyses of how existing policies and regulatory designs affect the cost of security of supply and balancing power exist also for the Nordic electricity market (e.g., Mauritzen, 2015).

In light of the increased attention that is currently being devoted to these issues in policy-making circles, it is useful to synthesize this research and identify the key lessons and policy implications, as well as discuss to what extent such lessons can be transferred across countries. The most important contribution of the present report lies in its scrutiny of the different types of regulatory options. In doing so, it is also necessary to take into account that the policy debate in all countries will often be affected not only by the output from rigorous research efforts, but also by proposals and analyses stemming from different private and public organizations.

1.3 OBJECTIVES AND SCOPE

The overall objective of this report is to synthesize the economic research on the nature and extent of intermittency problems in electricity markets, and not least discuss important implications for how to deal with them in the electricity market design. In reviewing existing research the report highlights a number of generic questions (see below). Empirically, though, we primarily focus on the German situation and any potential lessons for the Swedish case, while at the same time taking into account important differences in the two countries' electricity systems (e.g., the higher relevance and availability of hydropower in Sweden compared to Germany, the presence of four rather than one transmission system operator in Germany etc.). Specifically, the project work will be divided into three main tasks:

- Synthesize the existing research on the economics of intermittency in the electricity market, focusing on how the electric power system has been affected by increasing shares of RES-E generation and how this can be – and should be – dealt with in the regulation of the market.
- Analyze the drivers of the policy debate on intermittency in Germany, and not the least the extent to which the knowledge gained through previous research has been able to penetrate this debate (e.g., as evidenced in reports from interest organizations, recent policy proposals etc.). The potential consequences of failing to address important issues and trade-offs will be analyzed as well.
- Identify and discuss important lessons for the Swedish debate on how to address security of supply and intermittency concerns, e.g., through regulatory reforms, in the Nordic electricity market.

Both the research synthesis and the analysis of the German debate and the lessons from this will be centered on a number of key questions: (a) what is a suitable definition of security of supply, e.g., when considering the need for a systemic approach where RES-E generation and balancing power interact and where the former also can provide balancing services (at least in the presence of properly designed policies) (e.g., Hirth and Ziegenhagen, 2015); (b) what are the potential reasons for security of supply problems, taking into account that in addition to RES-E deployment there may be additional market and regulatory failures; (c) is there evidence that high shares of volatile RES-E generate security of supply issues; and (d) how can security of supply be addressed in policy-making, emphasizing the need to also look beyond single policy instruments (e.g., capacity payments), and therefore also considering policy mixes and a strengthening of the existing regulatory structure.

Germany is an interesting case, not only due to the rapid expansion of volatile RES-E in the country, but also because of data availability, the cooperation between system operators, the presence of market design reforms, and a vivid political debate on how to regulate the power system. In Sweden the German experiences have attracted a lot of attention, and this project can shed additional light on what can be learnt – and not learnt – from the German case and the policy debate. This should be valuable information for officials working with the electricity market and not the least for political decision-makers. The research synthesis should also be useful for academic researchers planning future research efforts in this field.

1.4 OUTLINE OF THE REPORT

In Section 2 we discuss security of supply in the context of electricity systems, i.e., how it can be defined and why so-called energy only markets may not be able to provide an efficient level of security of supply. Different types of relevant policy failures are also identified and discussed. Section 3 identifies, discusses and evaluates a broad range of policy options for addressing security of supply issues associated with high shares of renewables in the electricity system. It devotes particular attention to the German case and experiences. In Section 4 the report analyzes the drivers of the policy debate on regulatory options in Germany, and attempts to understand the extent to which the knowledge gained through previous research has been able to penetrate this debate, e.g., as evidenced in reports from interest organizations, recent policy proposals etc. Finally, Section 5 summarizes the main findings from the research synthesis and the analysis of the German experiences. Moreover, it pin-points and discusses a number of important lessons for the Swedish debate on how to address any security of supply concerns through regulatory reforms in the Nordic electricity market.

2 The Economics of Security of Supply and Intermittency in the Electricity Market

2.1 DEFINING SECURITY-OF-SUPPLY IN THE ELECTRICITY SYSTEM

2.1.1 Dimensions of Security of Supply

On a very general level, there is security of electricity supply if supply matches the demand for electricity at all times. In the following, we will review some more specific definitions, and reflect upon different aspects of security of supply (for a more extensive discussion, see Reeg et al. 2015). For instance, from a more technical point of view, which focuses on electricity generation, transmission system and distribution network, security of supply may be defined as the permanent and uninterrupted coverage of a given electricity demand (cf. Stoft 2002; NERC 2007). The drawback of such a technically focused definition is that it restricts our view to generation and transmission: any other options that may help to ensure that supply meets demand, such as flexibility options on the demand side, are beyond the scope of this definition. It is therefore useful to take a broader perspective, integrating all possible actors and measures that may contribute to safe-guarding security of supply. Consequently, we more generally define it as the guaranteed and continuous balancing of supply and demand (cf. Gottstein and Skillings 2012; Beckers and Hofrichter 2014).

In order to obtain a structured concept of security of supply, a differentiation into two main aspects is useful: *adequacy of generation capacity* versus *network security* (e.g., Oren 2003; NERC 2007; Finon and Pignon 2008).

- *Adequacy of generation capacity:* Adequacy relates to the ability of the system to cover the maximum expected peak load through secured production (ENTSO-E 2013). Usually, national frameworks are the reference point for this definition (Maurer et al. 2012; Nicolosi 2012; Neuhoff et al. 2016). That is, two side conditions have to be taken into account: typically the risks related to both (a) imports of primary energy sources required to operate the respective domestic generation capacities as well as (b) imports of electricity ("secondary energy security"), are to be minimized by safe-guarding adequate domestic capacities.
- *Network security:* Security represents the electricity system's ability to deal with disturbances in the short term (Oren 2003). In particular, the maintenance of the necessary network frequency is to be ensured in real time in the event of abrupt changes in power output and reception by adjustments in the operation of the infrastructure units (Gottstein and Skillings 2012).

Table 1 provides an overview of the different dimensions of security of supply. The two concepts may be distinguished with respect to the time dimension, whose importance is emphasized by Cramton and Ockenfels (2012, p. 115): "Reliability of electricity supply is a particularly tricky issue in electricity markets in part because the short-term is very short and the long-term is very long." Now adequacy of generation capacity is clearly a long-term issue. It has been argued, therefore, that adequacy is the most crucial security-of-supply issue: "But if there is not enough generating capacity in the *long-term*, it will not be possible to serve all load and achieve security and firmness in the short-term. In this way, adequate generation is the most fundamental reliability issue," (Cramton and Ockenfels 2012, p. 115). In other words, the adequacy of generation capacity is a necessary, but not sufficient, prerequisite for network security:[3] While it is correct that supply cannot be secured in the short-term if generation capacities do not suffice in peak hours, adequacy alone cannot guarantee that the provision of network services is resilient. In the short term, inadequacy of generation capacities may still be given. Hence, network security is a short term issue because it implies ''the ability of the electric system to withstand sudden disturbances'', in particular during peak hours (Finon and Pignon 2008, p. 143).

Table 1: The Different Aspects of Security of Supply in the Electricity System

	Adequacy of generation capacities	**Network security**
Explanation	Generation capacities needed to meet aggregate demand at all times	Resilience of the network in terms of voltage, frequency and stability conditions
Time dimension	Long term	Short term
Economic characteristic	Public good (given existing institutional setting)	Public good/Common-pool resource

Furthermore, *adequacy of generation capacity* and *network security* can be compared with respect to their economic characteristics on the private/public good dimension (a *private good* is excludable and rival in consumption while a *public good* is non-excludable and non-rival). Traditionally, it has been argued that security of supply has strong public good characteristics, this due to "the positive social externality associated with construction of capacity or reduction in peak load," (Jaffe and Felder 1996: 52; Abbot 2001). Moreover, "economic theory tells us that the existence of this "capacity externality" suggests capacity and peak-shaving demand-side technologies will, in equilibrium, be underprovided by a competitive market," (Jaffe and Felder 1996, p. 54). Yet, this assessment does not clearly distinguish between adequacy and security because it mixes long-term issues (construction of generation capacities) and short-term issues (demand reduction in peak hours). So it is again useful to consider the role of each concept separately.

First, adequacy "can potentially be treated as a *private good.* … [It] amounts to no more than insurance against shortages, which in a competitive environment with no barriers to entry translate into temporary price hikes. Such insurance can, at least in principle be treated as a private good by allowing customers to choose the level of protection they desire," (Oren 2003, p. 3). Generally, the technological requirements to transform adequacy from a public into a private good already exist – i.e., metering, monitoring and switching could make adequacy of generation capacities an excludable good. Still, the political and institutional environments do not (yet) provide the necessary regulatory framework to take advantage of these technologies (Kiesling 2009). Hence, there exists an incentive for consumers to

[3] However, strictly speaking, the two aforementioned conditions of adequacy (primary energy security and secondary security) need not necessarily be ensured in order to ensure grid stability.

understate their willingness to pay for security of supply. This makes adequacy a public good in the environment of current electricity markets, where consumers have no incentive to reveal their 'true' valuation: "if customers are not blacked out for paying too little, they will not pay for reliability, regardless of whether they have priority-rationing contracts," (Cramton and Ockenfels 2012, p. 116).

Second, network security "is a system-wide phenomenon with inherent externality and free ridership problems," (Oren 2003, p. 3). At the same time, however, one may also argue that security is not a pure public good. Up to a point, network security is non-rival in that the number of electricity consumers is irrelevant. Still, the network may be congestible if there are capacity constraints, so that if a certain number of consumers access the grid, the probability of service interruption increases. In this case, it thus seems more accurate to refer to a common pool resource (e.g., public swimming pools, highways), which are rival in consumption but still are characterized by non-excludability (Müsgens and Peek 2011).

Finally, it is useful to comment on the relationship between adequacy and security. In part, adequacy of generation capacity and network security are substitutes. For instance, flexibility measures introduced to optimize grid security in the short term (e.g., smart-meter roll-out), may positively impact the adequacy of generation capacity by reducing peak load. Yet, at the same time, both aspects need to complement each other: ceteris paribus, an increase in generation capacities also entails the need for an extension of the transmission capacity. In the medium term, with increasing feed-in from renewables calling for a range of flexibility measures, this might benefit both adequacy and network security. In the long term, this may render security of supply excludable, thereby transforming and privatizing what is, for now, a public good. The crucial question reads: if the market does not clear, will consumers be switched off according to their willingness to pay for reliability? An affirmative answer to this question, of course, would require a broad societal consensus for such a transformation. Potentially negative social side-effects would have to be addressed via adaptations of social and distributional policy.

More generally, security of supply comprises a range of aspects and it becomes more complex with increasing market shares for renewable energy sources. Against this background, the regulatory framework of the electricity system is supposed to *not only* ensure sufficient investments in generation and transmission infrastructure (and efficient management of a given infrastructure) *but also* to acknowledge the potential and the restrictions of all kinds of flexibility options.

2.1.2 The Relationship between Security of Supply and other Energy Policy Objectives

The above discussion demonstrates that measures to safeguard security of supply must anticipate possible interactions with other energy policy objectives. These objectives may relate to economic efficiency, distributional effects, environmental compatibility and/or political enforceability.

Concerning *economic efficiency*, the following specific sub-dimensions have to be considered:

- *Static efficiency*. The measures for ensuring security of supply are to be selected in such a way that overall costs are minimized. Against this background, investments in the various infrastructure units must not only take into account adequacy and reliability matters, but also the respective cost structure. The institutional framework must be designed in such a way that all systemic options with the potential for cost-effective provision of security of supply can be activated.
- *Dynamic efficiency*. The measures taken should incentivize the development and deployment of new technologies that can contribute to security of supply.
- *Transaction cost efficiency.* The magnitudes of search and information costs, bargaining costs, and any monitoring and enforcement costs borne by both regulators as well as by regulated actors should be considered by choosing measure to safeguard security of supply (McCann 2013).
- *Adaptive efficiency*. Regulatory interventions and related infrastructure decisions create technical, institutional and financial path dependencies. In the presence of uncertainty and information deficits, it is therefore crucial that the regulation is designed to adapt to unforeseen changes in the underlying conditions (North 1990). Consequently, regulations must allow and promote innovation, learning processes and knowledge diffusion. Against this background, decentralized decision-making processes as well as a high diversity of technologies, institutions and actors are desirable.

The *distributional effects* of security of supply measures are to be acknowledged. On the one hand, affordability for private electricity consumers needs to be assured. On the other hand, energy-intensive industries have to compete internationally. In the German context of RES-E subsidies, due to the comparatively high degree of organization of industrial interests, industry consumers successfully dodged the largest part of the financing burden at the expense of private electricity consumers (Gawel and Klassert 2013).

The *environmental effectiveness* of security of supply measures needs to be ensured. For instance, if flexible back-up generation capacities are fossil-based, long-term emission reduction goals might be compromised. The transformation of electricity systems towards renewable energy sources also brings along an increase in land use and associated challenges of acceptability. In both Germany and Sweden, wind farms and transmission lines have yielded NIMBY-like protests. Consequently, the regulatory framework of the electricity system should also comprise an explicit spatial component to address these acceptability issues.

Finally, *political feasibility* depends on the prevailing interest constellation among concerned stakeholders (i.e., voters, politicians, interest groups, bureaucracy). The above examples demonstrate that energy and environmental policy should be understood as the result of political bargaining where the well-organized groups often will succeed at the expense of less-organized stakeholders (Becker 1983; Kirchgässner and Schneider 2003). Hence, an important criterion when comparing policy options is also the extent of political opposition different measures can be expected to face.

From the above it should be clear that the different objectives yield diverse trade-offs that may be solved differently, following diverse national preferences, e.g., as regards the technology portfolio, as well as interest constellations. For instance, Germany has achieved a rapid increase in renewable energy shares and a parallel reduction in nuclear shares at the cost of higher electricity retail prices than the US or the UK (cf. Pollitt and Anaya 2016, p. 84).

2.2 MARKET AND POLICY FAILURES AS POTENTIAL REASONS FOR SECURITY OF SUPPLY PROBLEMS

Most existing electricity markets are so-called Energy Only Markets (EOMs) in the sense that capacity adequacy is expected to be secured as a result of the economic incentives faced by the market actors and without any pricing of capacity *per se*. In principle, price signals in the EOM, with its segments intraday, day-ahead, futures markets, provide incentives for investments in generation capacities and storage systems as well as adjustments in energy demand. Additionally, the balancing market provides remuneration for short-term network stabilization.

However, there may be several reasons why energy-only and balancing markets may not always be able to ensure adequacy of generation capacities and network security. In the remainder, we first discuss general market and policy failures which may impair the ability of both the EOM and the balancing market to ensure security of supply (see also Reeg et al. (2015) for a more extensive discussion). Subsequently, we shed light on the impact of specific policy measures that have been implemented to promote the transition of the electricity sector (support schemes for renewable energy sources, the EU Emissions Trading Scheme and a phase-out of nuclear electricity generation).

2.2.1 General Market and Policy Failures in the Energy Only Market

Below we identify and discuss four different deficiencies in the EOM that may lead to an inefficient provision of security of supply. The ambition here is primarily to identify potential market and policy failures, and not to assess their empirical relevance in a given context.

Thesis I: The Energy-Only Market may not be able to guarantee sufficient investments and the desired level of security of supply in every instance

In an ideal EOM setting, bids are made based on marginal costs in non-peak load times, and the market clearing price equals the marginal cost of the most expensive plants that must be called upon to meet demand. Plants, but also demand-side response measures with marginal costs below those of the "marginal plant", achieve positive marginal returns. This contributes towards covering fixed costs. Moreover, in peak load times, scarcity rents can be achieved, because individual peak-load plants are essential for covering demand - as a result, they can set prices that allow for a recovery of their variable as well as fixed costs. In principle, these mechanisms should allow for full cost recovery of all plants that are required to provide the desired level of security of supply, resulting in adequate investment incentives (Frontier Economics 2014, p. 49f.). This applies not only to generation capacities, but also to demand response measures and storage systems. The desired level of security of supply, meanwhile, is expressed through the maximum willingness to pay of consumers (or "value of lost load") (Joskow and Tirole 2007).

Particularly during peak load periods, consumers have incentives to shed or shift loads to times with lower prices. Similarly, various storage systems can make use of peak/off-peak price spreads by storing electricity when prices are low and supplying it when prices are high.

Nonetheless, there are several reasons why this ideal setting may not come to pass. For one, scarcity prices might be higher than what is socially optimal if peak load suppliers can exert market power (cf. Bergler et al. 2016). Even in the absence of market power, scarcity prices might be higher than what is considered socially acceptable. To reflect these concerns but also technical constraints in spot market trading, price ceilings are often applied in electricity markets (Neuhoff et al 2016, p. 253; Sijm 2014, p. 47f.). For example, in the EPEX spot intraday auctions, price fluctuations are limited to a range between -3000 to 3000€ per MWh for technical reasons.[4] Existing Nord Pool rules imply that day-ahead prices are capped at 3000€ per MWh, while balance market prices are capped at 5000€ per MWh.[5]

However, price ceilings can be lower than the value of lost loads, and therefore too low to cover peak load costs ("missing-money problem") (Spees et al. 2013). If this is the case, price ceilings might reduce investment incentives to a degree where adequacy of generation capacity is no longer ensured (Neuhoff et al 2016, p. 253; Sijm 2014, p. 47f). An increasingly flexible demand side, however, can alleviate the missing-money problem (Neuhoff et al. 2016, p. 253; Finon and Pignon 2008, p. 145ff.). Moreover, market power exertion or other deviations from marginal cost-based bidding in spot markets may lead to spot-market prices, which are higher than in the theoretically ideal setting, therefore facilitating cost recovery (Neuhoff et al. 2016, p. 253).

Furthermore, high price volatility and induced high investment risks can be a source of lower-than-optimal investments. One reason for price volatility is the lack of price elasticity on the demand side (Cramton et al. 2013): even with an increasing interest in demand-side response measures, many electricity consumers do not align consumption decisions with real-time price signals, primarily because they face time-invariant electricity tariffs. Furthermore, the stochastic nature of variable renewable electricity generation contributes to price volatility. These ups and downs in prices imply risks for forecasting and the calculation of cash flows. Hedging against these risks is costly or may not even be possible. For example, stochastic weather periods with uncommon wind and sun occurrences can have a large impact on the number of peak load hours and the achievement of full cost recovery. Demand-side response measures and storage systems can reduce price volatility, but this ability decreases for longer periods with unexpected weather patterns. These risks translate into barriers to invest.

Sunk costs give rise to additional entry barriers, given information disadvantages and risk considerations on the part of potential new suppliers (cf. Pindyck 2009).

[4] For different products (i.e. day-ahead auction, intraday auction, intraday continuous) different limits apply (see EPEX Spot 2016).

[5] Indeed, Bergman et al. (2017) point out that although empirical estimates of the value of lost load are subject to uncertainty, they tend to be well above 3000€ per MWh. In addition, this cap level is generally considerably lower than in many other countries, such as Australia where the corresponding cap is about 9000€ per MWh.

Cost characteristics and thus the price setting behaviour of actors in the market following a new entry can only be assessed in advance to a limited extent; this can cause reluctance to make the necessary investments to enter the market, especially in the case of risk aversion (e.g., Lehmann and Söderholm 2016). This problem is exacerbated if incumbents can make use of market power to erect barriers to entry, by strategically bidding below the marginal costs of competitors.

The above-mentioned reasons for underinvestment may be exacerbated by policy-induced regulatory uncertainty. The sudden introduction of environmental regulations, an imposed decommissioning of power stations or the politically promoted expansion of renewable energies are examples of politically induced risks which alter the profitability of investments (see also the more extensive discussion in Section 2.2.2). The longer the planning period required for new plants, the greater the necessity for reliable, long-term price signals – in their absence, investors may be unwilling to undertake investments.

From an adequacy perspective, indicators in Germany imply that at least in the short- to mid-term, sufficient capacities are available to cover expected peak demand (50Hertz et al. 2013; AEE 2013; Bundesnetzagentur and Bundeskartellamt 2013: 32f.). Due to the nuclear phase-out, a negative balance may occur in specific regions (i.e. Southern Germany) after 2020 at the earliest (Borggrefe et al. 2014). Also, overcapacities exist in other EU Member States as well, from which Germany could import electricity. The long-term transition towards an electricity system based largely on renewables, however, gives rise to the question under what conditions the EOM will prove structurally able to provide investment signals for variable renewable energy sources with marginal costs close to zero (Winkler and Altmann 2012; Auer and Haas 2016; IEA RETD TCP 2016; Henriot and Glachant 2013). With an increasing feed-in of variable renewable energy sources, the merit order effect (see section 2.3) becomes more pronounced, leading to reductions in wholesale prices. As wind and solar power plants, respectively, tend to have a high degree of simultaneity in their feed-in, the market value of wind and solar power decreases more strongly than the average market value of electricity generation (Hirth 2013a, b).

Thesis II: The Energy Only Market does not always provide investment signals in time

The revenues expected over the lifetime of a power plant (30 years and more) are highly uncertain due to price volatility in electricity markets. This investment uncertainty is aggravated by the fact that a significant amount of capital needs to be invested before the operation of the plant is actually permitted, e.g., for the exploration of installation sites and preparation of permitting forms. Under ideal conditions, future and forward markets or options would provide sufficient opportunities to hedge price and quantity risks of future electricity production according to investors' risk preferences. If that was the case, future capacity needs would be depicted in timely investment signals.

In reality, however, the liquidity of long-term markets is too low, and prices hard to predict. In particular, markets relevant to large power plants, which would need to reach 10-15 years into the future, do not exist (EEX 2016). The reason for this lies in the large uncertainty associated with future developments, which is difficult to assess. Consequently, the market does not send direct long-term price signals for planning and constructing power plants. The perspective for extending long-term future and forward contracts, meanwhile, has not been assessed optimistically (Cramton and Ockenfels 2012).

Another long-term risk that affects the income perspectives for power plants is the potential occurrence of "pork cycles", according to the cobweb model; high prices trigger simultaneous capacity investments, but by the time the new plants come online, the market may be saturated, leading to difficulties in cost recovery (Gaidosch 2008). This might prove particularly problematic for flexibility options with long planning periods (e.g., pump storage plants, large storage river plants, large-scale adjustments in industrial loads). If, in the meantime, flexibility options with shorter planning periods enter the markets, the profit margins achievable by making use of peak/off-peak spreads might be significantly lowered.

Thesis III: The Energy Only Market does not always provide a generation structure which is sufficiently flexible

While the first two theses primarily refer to the adequacy of generation capacities, the flexibility of the generation structure also affects network security. In an ideal EOM setting, it can be assumed that price signals lead to a sufficiently flexible generation structure in the market. In times of supply shortages, scarcities cause price increases in spot and balancing markets. These increases will stimulate investments in generation capacities that are flexible enough to respond even to short-term fluctuations (e.g., Grossi et al. 2014). Investments in demand-response measures or storage systems are likewise incentivised.

In addition to offering compensation for marginal generation (or load reduction) costs and reflecting the private value of a secure electricity supply, balancing markets also express the social value of preventing network instability, i.e., blackouts. The ability of responses to maintain short-term network security, by adjusting quickly not only to fluctuations in demand but also supply, is therefore crucial – this leads to somewhat different requirements on the generation structure than peak-load pricing with its focus on ensuring the adequacy of capacity in times of peak demand.

A potentially insufficient flexibility of the generation structure is not so much a market failure in itself, as that it can result from other market or policy failures discussed above. Of particular relevance are the large uncertainties, which result from the combination of long project realisation times, price volatility in spot and balancing markets and regulatory uncertainty. These may lead to increasing capital and liquidity costs and potential decreases in the willingness to invest. In addition, strategic behaviour of market participants can lead to relevant distortions of market signals.

This leads to the controversial question whether market failures are significant enough to prevent timely investments in flexible generation and storage capacities as well as a flexibilisation of electricity demand, given the continuing increase in variable renewable energy sources (Häseler 2014). Peak/off-peak spreads in the EPEX spot market have been decreasing in the past years, as have average wholesale price levels (Auer and Haas 2016; EPEX SPOT 2013). Likewise, price and quantity signals in balancing markets do not yet indicate a growing demand for flexibility in Germany (Hirth and Ziegenhagen 2015). Both developments can at least partly be explained by the existence of excess capacities, which result from the expansion of wind power and solar PV and continued operation of conventional power plants. In principle, lower wholesale prices which endanger the refinancing of conventional power plants should eventually lead to a reduction of temporary excess capacities. The interesting question, then, is whether sufficient flexibility incentives will emerge as part of this market adjustment process, or whether the market failures discussed above necessitate policy interventions on behalf of flexibility provision. In Germany, the federal grid agency's prohibition of shutting down specific power plants and the use of the grid reserve may indicate doubts in the market's ability to provide enough flexibility (e.g., Bundesnetzagentur and Bundeskartellamt 2013: p. 41f; Bundesnetzagentur 2013). However, these measures can rather be understood as reflections of network bottlenecks than insufficient generation capacities (Borggrefe et al. 2014).

Meanwhile, in balancing markets, the design of market rules determines whether and to what degree "unconventional" market actors, such as operators of variable wind turbines, demand-response measures or aggregators of electric vehicle responses, can participate in the provision of balancing services (e.g., IEA RETD TCP 2016, p. 44ff; Vandezande et al. 2010; Eid et al. 2016; Hirth and Ziegenhagen 2015). Barriers are posed, for example, by rules pertaining to large minimum bid sizes, symmetry requirements for products (i.e., if both positive and negative reserve needs to be offered), long tender periods or costly registration processes (e.g., Hirth and Ziegenhagen 2015). In order to set incentives for investments in "unconventional" flexibility options and improved network security contributions of, inter alia, variable renewable energy sources (through negative balancing power provision) and demand side response measures, adjusting balancing market rules to allow participation of these actors and fair competitive conditions is an important precondition.

Thesis IV: The Energy Only Market does not guarantee sufficient network investments

Network investments play an important role in maintaining network security – by transporting electricity between generation and load locations, networks achieve a local balancing of supply and demand. Given the natural monopoly character of networks, regulation is required to prevent the exertion of market power and set incentives for socially optimal investments (typically through direct investment regulation and/or price regulation). However, the EOM market and policy failures discussed above (e.g., price ceilings, volatility of prices, regulatory uncertainty, long lead times, strategic behaviour) influence network investments – once these failures are taken into account, the optimal level of network investments may differ from a first-best optimum in the absence of market failures.

Furthermore, the introduction of a regionally differentiated EOM with regional price and scarcity signals, such as in Sweden and Norway, can lead to a closer integration of network and capacity investment decisions, because investment incentives can be linked to price differences between regions with or without grid bottlenecks (Löschel et al 2013a, b; Henriot and Glachant 2013: 60ff.).

2.2.2 Impacts of Policies Promoting an Energy Transition

Renewable energy policies

In the short term, the promotion of renewable electricity generation increases the amount of installed capacity in the electricity system. This results in overcapacities which, from an adequacy perspective, can be assessed as positive, even though the intermittent power only provide secure capacity to a limited degree. In the long term, however, there can be a negative impact on the adequacy of generation capacity. If electricity demand remains constant, the load factors for conventional generators decrease, while the so-called *merit order effect* leads to lower wholesale electricity prices. As a result, revenues and profits for conventional plants decrease (Sijm 2014, p. 39f.), and this can worsen the "missing money" problem discussed in section 2.2.1 (Sensfuß et al. 2008; Traber and Kemfert 2011). Additionally, the volatility of variable renewable generation feed-in and uncertainty about the future development of policy support increase investment risks for market actors.

In the mid to long term, conventional plant operators are likely to react by shutting down plants, thereby lowering the amount of secure capacity in the system. Moreover, the location of new renewable electricity capacities may not coincide with demand centers, and regional bottlenecks in the transmission network may further reduce the amount of secure capacity available (e.g., Schroeder et al. 2013). However, this negative impact can be mitigated by network extensions. Moreover, the combination of storage systems, demand response measures, dispatchable renewable power and options for increasing the reliability of variable energy sources (e.g., weak-wind turbines) provides avenues for compensating for the decrease in secure conventional capacity (see Lund et al. (2015) for a review of various options).

At the same time, decreasing wholesale prices and an increase in curtailment (due to network bottlenecks or negative electricity prices) also affect the profitability of investments in renewable energy plants (Sijm 2014, p. 39f.). Also, depending on its design, renewable energy policy can have impacts on investment incentives for flexibility options. While generally, the demand for flexibility is expected to increase, the expansion of photovoltaic plants causes mid-day price peaks to erode. This contributes to a decrease in peak/off-peak spreads, which are important for the profitability of investments in storage systems and other flexibility options. Meanwhile, if the policy support to renewable energy is financed by a surcharge on electricity prices, the resulting increase in consumer prices can lead to energy-saving efforts and a decrease in electricity consumption, all depending on the own-price elasticity of electricity demand.

In terms of network security, the expansion of variable renewable power implies a new role for dispatchable generation capacities – rather than adjusting to fluctuations in demand, they now have to cover residual load (i.e., the load not covered by variable renewable electricity and "must-run" generators) (Gottstein and Skillings 2012; Reeg 2014). This requires plants that can handle steep residual load gradients (Winkler et al. 2013; Nitsch et al. 2012). Among conventional power plants, gas power plants are particularly well suited for fast response adjustment; however, their profitability is negatively affected by the erosion in price peaks.

Furthermore, network security can be negatively affected when the location of plants is not aligned with existing network infrastructure, and the feed-in of renewable power leads to network congestion (Nicolosi 2010). However, network security can be maintained if renewable power plants can be remotely curtailed.

The European Emissions Trading System

Emissions pricing through the European Emissions Trading System (EU ETS) has a positive impact on wholesale electricity prices (Linares et al. 2006; Lise et al. 2010; Sijm et al. 2006). If the emission allowances are allocated for free, this increases incentives for investments in fossil fuel plants, with free allocation effectively acting as an investment subsidy. However, the EU ETS has also increased the electricity generation costs of fossil fuel plants. In the current third trading period, electricity generators have to source emission allowances from the market – as a result, it stands to reason that by now, the profitability of conventional plants is negatively impacted, reducing incentives for their operation and investments in new plants. Still, low emission allowance prices dampen this effect (Hoffmann 2007). Low allowance prices may be related to interactions with support schemes for renewable energies. But the possible sources of declining allowance prices are numerous and tedious to disentangle (e.g., Hintermann et al. 2016). In any case, if future carbon prices were to increase – e.g., following the establishment of a market stability reserve in 2018 or further potential reform efforts – the incentives for investing in emissions-intensive secure capacity would decrease.

If carbon prices were sufficiently high, meanwhile, there would be incentives to shift investments from emission-intensive coal power plants to comparatively low-carbon gas power plants. In terms of network security, this would be positive, as the latter tends to be more flexible. Besides the low allowance prices, the free allocation of allowances in the first two trading periods has prevented this effect from occurring, this favoured coal power plants over gas power plants (Pahle et al. 2011). Full auctioning of emission allowances is therefore a positive development also from a network security point of view.

Nuclear phase-out

In the short term, the nuclear phase-out in Germany decreases the amount of secure capacity available. However, it also shifts the merit-order curve to the left, increasing wholesale electricity prices (Knopf et al. 2014). In the mid and long term, this leads to investments in new generation capacities to compensate for nuclear capacities exiting the market. Moreover, higher wholesale prices may also increase the flexibility on the demand side, thus reducing adequacy-related security of supply problems. On the other hand, regional grid congestions may be worsened, because with nuclear power plants, significant generation capacities that are close to load centres in the south of Germany are taken off the grid. Similar problems would emerge in the Nordic market in the case of a Swedish nuclear phase-out.

By shifting the merit order curve to the left, the nuclear phase-out may also improve the profitability of gas power plants, given their role as marginal peak-load plants. By incentivising the operation and build-up of flexible capacity, this may positively contribute to network security. However, in the longer term this effect depends on what technologies are used to replace nuclear power plants. In Sweden, for instance, there is little scope for an expansion of gas power.

2.3 THE IMPACT OF HIGH SHARES OF VOLATILE RENEWABLE POWER GENERATION ON ELECTRICITY MARKETS: SOME EMPIRICAL LESSONS

From an economic point of view two problems related to the penetration of solar PV and wind power need to be addressed. First, wind power and solar PV have very low variable costs of generation, and for this reason they will outcompete he traditional power plants. Second, with a more intense penetration of these energy sources total power generation becomes less predictable in the short (and very short) term. In essence, this means that electricity may become more volatile over time, and the variations in, say, wind-plant output impose an external cost on the electricity system, i.e., the cost of maintaining idle capacity and spinning reserves in other types of power plants. However, a high share of intermittent power will lead to average price levels that are too low to induce enough investment in such capacity. Much of the economic empirical research on the challenges of volatile renewable electricity generation has focused on the size of these external costs, as well as on the impact of intermittent power penetration on electricity prices and price volatility in the market (Söderholm 2013).

A few economic studies outline optimization models of the electricity system to address important trade-offs associated with the increasing generation of wind power. Previous studies (e.g., Benitez et al. 2008) indicate, for instance, that the cost of backup capacity could represent a significant share (e.g., 15-25%) of the investment costs of a wind farm. These costs are typically lower if hydraulic storage is available; the flexibility of hydropower plants implies that they can adjust their storage and discharges so that energy can be provided to the system more or less instantaneously (similar to a peak-load plant).[6] As noted below, the German and Nordic electricity markets differ a lot with respect to the share of hydropower in the system (see also Forsund and Hjalmarsson 2011).

The economic costs associated with the integration of intermittent power in the power system can be divided into three categories: (a) balancing costs; (b) grid-related costs; and (c) profile costs (e.g., Hirth et al. 2015). The empirical evidence suggests that each of these cost categories may vary significantly across different RES-E technologies. For instance, the balancing costs, i.e., the marginal costs of dealing with any deviations from day-ahead generation schedules due to forecast errors, tend to be lower for solar PV than for wind power due to fewer such errors (Hirth 2013a). The profile costs, i.e., the marginal costs of output adjustment due to the timing of RES-E generation, will however often be higher for solar PV than for wind power because solar radiation is concentrated in few hours, and they also tend to be higher for onshore compared to offshore wind power (Hirth et al. 2015). Tafarte et al. (2014) also find that overall profile costs tend to be lower with equal shares of solar PV and wind power. Finally, the grid-related costs will be lower for RES-E plants that are located closer to load centers.

[6] A traditional hydropower plant can in turn be enhanced by pumped hydro storage, although the cost of this may not necessarily be lower than the increases in the value of wind power generation.

The impacts of intermittent power on electricity prices and price volatility have been addressed in a number of empirical studies. Some argue that increased use of renewable energy will decrease the volatility in electricity prices caused by fossil fuels (Couture and Gagnon 2010; Doherty et al. 2006). However, this argument is generally not supported by data covering, for instance, the German and the Nordic electricity markets. Mauritzen (2011) studied the impact of wind power on price volatility in Denmark, and concluded that while higher wind power generation had negative impacts on intraday price volatility, volatility in the longer run (measured in average daily prices) increased.[7] In an empirical study of German electricity price volatility, Ketterer (2014) relied on day-ahead price data from the European Energy Exchange EEX, which were analyzed using a GARCH model. The author found that while the average price of electricity decreased, the price volatility increased following a larger penetration of wind power.[8]

In a comparative study between the electricity markets of Denmark and Germany, Rintamäki et al. (2017) concluded that wind power and other zero-marginal cost technologies cause German intraday price volatility to increase, while it decreases in Denmark. The authors pinpoint the access to flexible generation capacity and differing wind power generation patterns as the main contributing reasons behind these differences. Specifically, in Germany wind power generation occurs more frequently at off-peak hours, while Denmark has better access to the hydropower reservoirs in the other Nordic countries. Finally, Pereira and Rodriguez (2015) employed the ARX-EGARCH (exponential, autoregressive GARCH) model using day-ahead price data from the Portuguese wholesale electricity market. They also found that wind penetration has reduced electricity prices but has led to increased price volatility. These effects were more frequently occurring during day-time peak hours compared to night-time hours when demand was lower and power could be supplied through base-load generation.

The empirical findings suggesting that the market price of electricity decreases as the generation of intermittent power increases, imply that the incentives to invest in other (base-load) electric power sources will be weaker (see also Traber and Kemfert 2011). In fact, in hours of high wind power and solar PV generation these energy sources can "cannibalize" themselves as the market value (in terms of EUR per MWh) declines. Previous empirical work has indicated that this decline can be substantial, e.g., at a 30 % market share each MWh of wind power can be worth around 40 % less than at a lower market share (Mills and Wiser 2012; Hirth 2013a).

The price effects following from higher penetration of, for instance, wind power has been shown to have relevance for the exercise of market power (Forsund and Hjalmarsson 2011). The fact that real-time wind availability tends to be negatively correlated with electricity prices implies a greater risk of market power (thus in turn exacerbating the price effect). The exercise of market power is generally

---

[7] In a related study Mauritzen (2013) investigated the impact of increased wind power generation (in Denmark) on the pattern of short-term trade in the Nordic electricity market. He shows that such an effect can be found; with increased wind power generation export also increases and the generation of Norwegian hydropower is reduced.

[8] Similar results have also been reported based on U.S. data. See, for instance, Woo et al. (2011).

increasing in the demand for conventional power generation, and electricity prices will be high when wind power output is the lowest (and vice versa).

The present report primarily discusses the question of whether existing electricity market designs provide efficient incentives for security of supply. Previous studies addressing these issues have so far mainly focused on qualitative evidence. Some previous work has, for instance, highlighted the trade-offs involved when wind power replaces conventional power. Specifically, since the cost of such replacement will vary by location, efficient nodal pricing could permit hydropower to balance wind power intermittency in a decentralized manner. Nevertheless, such balancing combined with nodal pricing may not be liquid enough to be efficient, something which would call for central dispatch such as in the U.S. so-called PJM market established in 1998 (e.g., Newbery et al. 2010). Moreover, system integration costs are imposed on RES-E investors only if the RES-E remuneration reflects market prices, as a under a premium (rather than a fixed) tariff (Mauritzen 2015; Hirth et al. 2015).

However, previous studies confirm our findings in the present report, namely that the prevailing market designs often fail to internalize system integration costs properly. For this reason it is useful to scrutinize the policy options available for addressing security of supply concerns in a cost-effective manner. This issue is discussed in the next chapter.

3 Policy Options for Addressing Security of Supply Problems Associated with High Shares of Renewables: The Case of Germany

3.1 OVERVIEW

In the following, we discuss four categories of policy interventions that can be implemented to deal with security of supply problems that arise from high shares of intermittent renewable electricity (cf. Reeg et al. 2015). Parts of the discussion are general, but we devote particular attention to the German case.

3.1.1 Measures for Strengthening the Energy Only Market

Several measures have been put forward in the German debate to strengthen the EOM and to overcome the failures discussed in Section 2.2. Such policy measures have to address the problem that the intermittent renewables, i.e., wind power and solar PV, tend to – once they generate electricity – outcompete conventional power plants. For these plants revenues fall unless this is compensated through higher prices. This applies to all types of conventional power plants, not only those intended to serve peak demand. An additional problem is that high shares of intermittent renewables imply that the level of total power generation becomes less predictable in the short (and very short) term.

Abstaining from price caps

Price caps run the risk of preventing the scarcity rents necessary to recover the costs of investments into power stations (e.g., Cramton and Ockenfels 2012; Joskow 2006). A credible announcement of policy makers to abstain from politically set price caps – or raise existing price caps to a sufficiently high level – may therefore be necessary to prevent under-investment into power stations resulting from actual or expected price controls. Obviously, this would also imply the possibility of wholesale power prices that are excessively high due to strategic behaviour of power generators in situations of scarcity in the market (Joskow 2006).

Strengthening balancing group management

The obligation of German balancing group managers to balance feed-in and off-take every 15 minutes theoretically creates an incentive to remunerate guaranteed and flexible capacities. Yet, in practice, this obligation oftentimes is not met (BMWi 2014). This points towards a lack of corresponding sanctions. Consequently, the national agency for network regulation in Germany (Bundesnetzagentur, BNetzA) should supervise the management of balancing groups more thoroughly and set stronger incentives for actual balancing (Heim and Schober 2014). This would imply a higher remuneration for guaranteed and flexible capacities in the EOM (e.g., Connect Energy Economics 2014). Consequently, the incentives of balancing group managers to seek – and of producers to supply – secured and flexible capacities would increase with rising share of volatile renewables.

Strengthening balancing markets

To adjust the balancing power market to the requirements of a system with high shares of volatile renewables, it has been proposed to hold the auctions more frequently, to shorten the duration of the contracts (to one hour) and to implement marginal pricing (instead of pay-as-bid) (Hirth and Ziegenhagen 2015). Such refinements may be additionally supported by facilitating cross-border agreements (IEA RETD TCP 2016, p. 106). Beyond these approaches, reserve and balancing power management can be improved in general, e.g., by sizing reserve requirements dynamically and making procurement more responsive to market signals (Hirth and Ziegenhagen 2015).

Completing the electricity market liberalisation

Issues of strategic behaviour of electricity generators in situations of scarcity (in the absence of price caps, see also above) can be mitigated by strengthening the competition among electricity producers. This is the explicit objective of the electricity market liberalisation initiated in Europe and Germany in 1998. In this context, the complete unbundling of network operation is of particular importance to allow free access to networks and a non-discriminatory competition among power producers. In this context the deregulation of the Nordic electricity market has been more complete in spite of differences in reforms across countries; the market has been opened for competition on generation and retailing, and there is an explicit requirement that transmission and distribution networks should be open for third-parties at non-discriminatory prices (e.g., Bergman et al. 2017).

Differentiating electricity prices spatially

Even if the total guaranteed capacity installed within a country allows for meeting peak load, congestion in networks could call for re-dispatch measures, thus distorting incentives of the EOM, and even create scarcity of capacities at a regional scale (Neuhoff et al. 2013; Elberg et al. 2012; Löschel et al. 2013b). Network congestion may be aggravated by the unbundling of electricity generation and transmission, which results in generation and network infrastructures being planned independently (if network charges are not borne (partially) by power generators).

Spatially differentiated electricity prices – implemented through market splitting or nodal pricing – may be a regulatory response to these challenges (Henriot and Glachant 2013, p. 30; IEA RETD TCP 2016; Kunz 2013; Löschel et al. 2013a, b). Spatially differentiated electricity prices induce power generators to consider (and thereby mitigate) network congestion when taking location decisions for their power plants. Four regional price areas were introduced in Sweden in 2012, and spatially differentiated prices existed before then in Norway.

Accelerating permitting procedures

Capacity constraints may also emerge if investors respond "too late" to price signals, i.e., capacity extensions may be incentivised in general but not at the right point in time. This "missing-time" issue may have multiple causes. An important reason has been lengthy permitting procedures both for power stations and networks. Measures accelerating the permission of such infrastructures may therefore be an important element of the policy mix. In Germany such measures include the law on energy line extension (Energieleitungsausbaugesetz - EnLAG) or the law of the acceleration of grid extension (Netzausbaubeschleunigungsgesetz – NABEG).

3.1.2 The Introduction of Capacity Mechanisms

While the above measures for strengthening the EOM will increase the likelihood that the reliability of the electricity system will be maintained, such an outcome is not certain and/or may not be politically acceptable (e.g., due to low acceptance for price spikes). A further step to address security of supply is to introduce so-called capacity mechanisms. Such mechanisms can be used to safeguard a target level of security supply in the form of payment for available MWs (i.e., storage, production capacity, flexible demand etc.).

Capacity mechanisms can be designed in different ways. The German debate on capacity mechanisms has encompassed four approaches: (a) a comprehensive capacity market; (b) a focused capacity market; (c) a decentralized capacity market; and (d) a strategic reserve. All four options are briefly introduced in the following.[9] In 2015, the German government eventually decided to introduce a strategic reserve (officially labelled "capacity reserve") (Neuhoff et al. 2016, p. 254). In Sweden a temporary strategic reserve has been in place, and the plan is to keep this until (at least) 2025.

Comprehensive capacity market

The concept of a comprehensive capacity market with security of supply contracts was published on behalf of the Federal Ministry of Economics and Energy (BMWi) by the Institute for Energy Economics of the University of Cologne (EWI) in March 2012 (Elberg et al 2012). In the case of a comprehensive capacity market, a central coordinator – presumably the regulatory authority – prescribes the necessary total capacity to be assessed with a five to seven-year lead-time. A tender procedure is used to auction the necessary generation capacity needed for ensuring security of supply. Incumbent suppliers, new plants as well as demand side management capacities can participate. The EWI proposed the "Descending Clock Auction" where the auction starts with a high start-up price and the bidders have to decide how much capacity they offer at this price. In the following steps the price will be reduced and the suppliers will be able to offer capacities again, until the targeted quantity is reached and thus provided via security of supply contracts.

Focused capacity market

The concept of a focused capacity market was published 2012 by the ÖkoInstitut, the LBD Beratungsgesellschaft and Raue LLP on behalf of WWF Germany (see Matthes et al. 2012). In this model, a central coordinator prescribes generation capacities for new plants and also decides on continuing the operation of plants that are at risk of being shut down. The capacity is reliably provided on the contracted scale. Furthermore, as in the comprehensive capacity market, end

[9] Bergman (2016) provides a more in-depth discussion of different types of capacity mechanisms.

customers with controllable loads can also participate in the market. The major difference to a comprehensive capacity market consists in the option to define pre-qualification criteria for participating generators. These criteria may refer to technological standards (operating times and the ability to utilize the power stations' capacities), environmental (emission intensity) and spatial requirements (e.g., distance to load centers).

Decentralized capacity market

The decentralized capacity mechanism, implemented through a so-called capacity certificates market, was developed by enervis and BET on behalf of the Association of Municipal Enterprises (VKU) in their statement on an integrated energy market design (Ecke et al. 2013). In this case, not a central authority, but the consumers (i.e., electricity distributors or suppliers) of security of supply order a guaranteed capacity for bottleneck situations. Respectively, they ration the capacity uptake of consumers that can be disconnected. Insofar as capacity measuring and individual remote switch-off capability are given, consumers can accordingly define their preferred security of supply level within the scope of their purchasing power. Then, power stations, disconnectable loads and storage units provide the capacity in a technology neutral manner to the contracted extent. In this way, security of supply is essentially transformed from a public into a private good. The corresponding price is set through decentralized market transactions.

Strategic reserve

In Germany the idea of establishing a strategic reserve was first put into the debate by the Federal Association of the Energy and Water Industries (BDEW) as a short- to medium-term solution. In May 2013, together with the Federal Association for Renewable Energy (BEE) and various scientists and consultants, the concept was further refined (BMU et al. 2013). In this case, capacities outside the market are kept as a reserve, which can be used in case of a scarcity situation in the EOM (see Maurer 2013; r2b 2012). The model proposed by Consentec on behalf of the BDEW contains explicit capacity payments for the provision of back-up generation capacities (and, where appropriate, demand-side responses). In this proposal, capacity payments – made by the regulator or the transmission system operator (TSO) – shall solely be used in situations of scarcity (imbalance between supply and demand at the EOM) (Maurer 2013, p. 28). The amount of capacity payments is determined by means of an auction. As a nucleus for the strategic reserve, the currently implemented network reserve could be further developed (see BMU et al 2013; BMWi 2014).

3.1.3 Adjustment of Energy Transition Instruments

It is also important to consider the option of adjusting the design of existing policy instruments aimed at promoting the transition to a carbon-free energy system. Below we briefly discuss two such options.

Promoting flexible RES feed-in

Flexible RES feed-in is understood as a precondition to reduce the residual load provided by non-RES generation capacities. In particular, flexible electric power generation from biomass may play an important role, and may be triggered, e.g., by strengthening the premium paid for flexibility provision under the German support scheme (Reeg et al. 2013). For electricity generation from volatile wind power and solar PV – which can primarily be controlled by shutting the plants down – flexibility needs can be addressed through plant design. In particular, the installation of plants with feed-in patterns complementary to those of the plants already in place may be promoted (e.g., photovoltaic modules mounted with east or west direction, weak wind turbines). This will increase the capacity factor of RES plants installed and reduce the need for back-up capacity.

Incentives may be set by further differentiating RES support schemes or by making RES support more market-based (integration of capacity premiums into direct marketing) (Andor et al. 2012; Ecke et al. 2013). Moreover, the integration of RES generation into the provision of system services (provision of balancing power and reactive power, maintenance of frequency stability) may help to reduce non-RES capacities required for these services at the moment (must-run capacities) (Leprich et al. 2012; Jansen 2014; Reeg 2014). This integration may be facilitated by adjusting balancing power markets to accommodate RES generation (BMWi 2014; Jansen 2014, see also Section 3.1.1) as well as by providing extra remunerations for the provision of these services.

Strengthening the European Emissions Trading Scheme

Tightening the emissions cap under the EU ETS would (ceteris paribus) increase allowance prices and eventually also wholesale electricity prices. At the same time, it would also increase the generation costs of non-RES generation but to different extents: the operation of flexible, low-emission gas turbines would become more profitable, which eventually could also affect the corresponding infrastructure investments. Thus, strengthening the EU ETS could also implicitly set incentives to transitioning the electricity sector to more flexible generation technologies which can back up volatile RES feed-in.

3.1.4 Additional Policy Options for Safeguarding Security of Supply

While the policy options discussed so far primarily have addressed the role of electric power generation and the actors involved therein, other actors in the electricity system may also contribute to safe-guarding security of supply.

Improving demand-side management

Adjusting electricity demand to volatile RES feed-in may also help to reduce the need of additional back-up capacities to meet residual load (Elberg et al. 2012; Nicolosi 2012). In particular, loads could be shifted from moments of low feed-in to moments of high feed-in. Moreover, a general reduction in demand (e.g., through energy efficiency improvements) would reduce back-up capacity needs, not least when the RES feed-in is low.

An important option to improve demand-side management is dynamic electricity pricing for final customers. Consequently, in such a setting customers would have stronger incentives to shift the load to moments with high RES feed-in and correspondingly low electricity prices. In addition, an electricity demand that is more responsive to prices could also mitigate issues of market power in the electricity market and thereby strengthen the EOM (Maurer et al. 2012, see also Section 3.1.1). A general reduction of electricity demand could be promoted by energy-efficiency programs, or electricity taxes that increase electricity prices.

Adjusting network regulation

As pointed out above, network congestion may be another source of regional capacity constraints (Neuhoff et al. 2013; Elberg et al. 2012). As an alternative or complement to regionally differentiated electricity market prices (see Section 3.1.1), this issue may also be addressed by network management. Two approaches are possible. First, network extensions may reduce congestion and allow for a spatially wider balancing of supply and demand, taking advantage of regional differences in peak loads and RES in-feed (e.g., due to meteorological differences). This would increase guaranteed RES capacity and reduce the need for non-RES back-up capacities (Elberg et al. 2012).

Network extensions could also be promoted through adjustments in the incentive regulation for network operators, i.e., designing network charges to stronger incentivize network extensions (e.g., Korte and Gawel 2015; Agricola et al. 2012; Brunekreeft and Meyer 2011b; Elsenbast 2011). More generally, the permitting procedures for network extensions could be accelerated (see also Section 3.1.1). Second, network congestion can also be addressed by congestion management. Regionally differentiated network charges can be designed to reflect differences in congestion at least partly (Löschel et al. 2013a). This would lead to corresponding electricity price increases in areas with excess demand and decreases in areas with excess supply. In the long run, this could affect the location decisions of (industrial) consumers and thereby mitigate issues of network congestion. If the network charge is also (partly) levied on electricity generators, these will be incentivized to adjust their location decisions correspondingly (Hiroux and Saguan 2010; van der Welle and de Joode 2011; Löschel et al. 2013a).

Extending storage

Obviously, electricity storage holds a large potential to reduce the need for back-up capacities. It temporarily balances differences between moments of excess supply and excess demand (e.g., Leprich et al. 2012). Its dual character of being able to consume and feed in electricity also holds the potential to support the functioning of the EOM. First, flexible storage systems may increase the elasticity of electricity demand. Second, storage operators compete with regular electricity generators in moments of scarcity, and may thereby mitigate issues of market power. The use and extension of storage systems may be promoted through subsidies to research and development as well as deployment to encourage learning-by-doing processes. For example, storage systems could be exempt from network charges (Drake et al. 2013). Moreover, the access of storage systems to balancing markets could be facilitated.

Europeanizing the management of security of supply

This approach builds on the notion that security of supply is not only safeguarded by domestic capacities but also by foreign ones. Given the already existing transborder transmission capacities, domestic capacity demand could already be reduced (e.g., Maurer et al. 2012; Böckers et al. 2012). Correspondingly, capacity mechanisms should, if implemented, be coordinated across Europe (Finon 2014; Neuhoff et al. 2016). However, there are concerns about the ongoing process in the EU. Capacity mechanisms are implemented in many Member States, but the designs of these tend to differ (Bergman et al. 2017). For instance, while Germany and Sweden so far have opted for a strategic reserve, Ireland, Spain, Portugal, Italy and Greece have all introduced capacity payments. In a worst case scenario such a development can disturb cross-border trade, making the total production and/or use of electricity inefficient, and in turn even lead to re-nationalization of electricity markets in the EU.[10] Still, if regional capacity mechanisms are introduced, with limited opportunities for national governments to implement price regulations or restricted access, there does not need to be a conflict between continued use of capacity mechanisms in the EU and a further integration of the electricity markets of the Member States (Bergman, 2016).

Still, if achieved, a European perspective on safeguarding security of supply could also strengthen initiatives to extend interconnectors in Europe. Similar to network extensions within a country, this would facilitate the spatial balancing of supply and demand as well as of volatile RES feed-in. Moreover, a general empowerment of the European internal market, also beyond network extensions, may improve competition and mitigate issues of market power (and thus make potential price caps obsolete, see Section 3.1.1).

The market integration process in the EU is particularly evident in northern Europe. The Nordic electricity market is now connected to the electricity markets of the Baltic States, Poland and to some extent Germany (the so-called Elspot area). Still, Bergman et al. (2017) note that this integration of national electricity markets is hardly visible in the reported energy statistics (e.g., from the Swedish Energy Agency), potentially making it more difficult to introduce and not least follow-up different measures to safeguard security of supply.

3.2 EVALUATION

The objective of this sub-section is to evaluate the policy options using the criteria introduced in Section 2.1.2. In this respect, it is not the idea to discuss the impacts of every single option in detail. Rather this section will compare the performance of a broad policy mix in general to that of single-policy approaches, such as capacity mechanisms. The fundamental question that is addressed thus is: Can security of supply be provided sustainably by single-policy approaches – or only by a policy mix?

[10] The observation that capacity mechanisms can have distorting impacts on electricity generation and trade can be illustrated by the introduction of capacity payments in Russia in 2011. This made exports of electricity to Finland less economically interesting, and exports fell considerably. As a result, the total costs of supplying electricity in Russia and Finland increased (Bergman, 2016). See also Tangerås (2017) for an analysis of the link between renewable electricity expansion and market integration.

3.2.1 Security of Supply

Basically all of the policy options presented above may contribute to safeguarding security of supply in the electricity market. Regarding adequacy, the strongest and most immediate incentives to maintain or add capacities are probably created by capacity mechanisms. These create new revenue streams for power plant operators and thus directly incentivize new investments. Nevertheless, for most capacity mechanisms (except for the strategic reserve) the eventual incentives to provide capacities crucially hinges on the lead time of the corresponding auctions as well as the duration of payments. Adequacy concerns related to import dependence can primarily be addressed by focused capacity markets and strategic reserves as these allow for additional pre-qualification criteria. These latter approaches are also preferable in terms of network security as they allow targeting capacity payments to those flexibility options that are best suited to balance volatile RES feed-in (e.g., gas turbines, storage). Comprehensive and decentralized capacity markets may fail to do so. In fact, they may generate additional payments for existing but inflexible (coal) power plants (Tietjen 2012).

Alternative policy approaches – strengthening the EOM, adjustments of energy transition instruments and other policy options – may by themselves be less effective than capacity mechanisms. Thus, they can be either considered as complements to capacity mechanisms, or need to be combined in a policy mix to replace capacity mechanism. On the one hand, Cramton and Ockenfels (2012) argue that demand-side management alone can hardly replace the role of capacity mechanisms. On the other hand, Elberg et al. (2012) point out that the activation of a large potential of demand-side management may at least in theory empower the EOM to provide sufficient incentives for capacity investments. It should also be noted that the introduction of capacity mechanisms could in fact undermine the emergence of market-based contracts, i.e., between producers and retailers and/or between wind and solar power producers and conventional producers.

Eventually, the decisive questions are: (a) how quickly can single policy options deliver contributions to security of supply, and (b) how can they be combined in a meaningful way. Measures to strengthen the EOM and adjust the energy transition instruments (i.e., RES support schemes, EU ETS) will be able to make short-term contributions. In contrast, options to accelerate network and storage extensions and permitting procedures and to trigger demand side management are likely to generate benefits rather in the long run.

When combining multiple policy approaches in a policy mix, it is necessary to consider whether the various options are really complements, or rather substitutes, particularly in the course of time. For example, regionally differentiated electricity prices and network charges could become obsolete with ongoing network extensions. In addition, incentives to introduce flexible RES feed-in or storage operation may simultaneously reduce incentives to run non-RES power plants more flexibly (Nicolosi 2010; Energy Brainpool 2014; Reeg 2014). In the end, the performance of the policy mix thus crucially depends on the choice and the design of policy instruments. This concern notwithstanding, the German Ministry of Economic Affairs and Energy expects that the combination of these measures activates a diversity of capacity potentials, which by far exceeds demand, such that security of supply can be provided at all times and makes additional capacity mechanisms obsolete (BMWi 2014, p. 18).

3.2.2 Static and Dynamic Efficiency

Compared to the textbook view of a capacity mechanism (e.g., the comprehensive capacity market), a policy mix may impair static efficiency at first sight because it hampers the equalization of marginal costs of safeguarding security of supply. Yet, this argument only holds if issues of security of supply can only be attributed to a single market failure. Our discussion in Section 2.2 has demonstrated that multiple market and policy failures may explain insufficient adequacy of investments and network security. Following the classical Tinbergen rule, these multiple failures can only be addressed efficiently by a policy mix (Tinbergen 1952). In this respect, many of the policy approaches outlined in Section 3.1 have the strength to address a market or policy failure more directly than a capacity mechanism.

In terms of broader economic policies, many of the policy approaches beyond capacity mechanisms have the appeal of contributing not only to safeguarding security of supply but also to other policy objectives. Strengthening the EU ETS will not only promote the use of flexible gas turbines but also address the externalities from greenhouse gas emissions more effectively. Supporting demand-side management may also help to reduce electricity consumption overall. Studies on behalf of the Federal Ministry of Economic Affairs and Energy demonstrate that the social costs of using a capacity mechanism to safeguard security of supply would be higher than the costs associated with developing other policy approaches and strengthening the EOM (Frontier Economics and Formaet 2014; r2b 2014).

Analogously, dynamic efficiency will be best provided if government interventions address market and policy failures as directly as possible. For example, different adjustments to the incentive regulation of networks are more likely to trigger innovation than capacity mechanisms, which hardly reward technological progress related to the installation and operation of networks.

3.2.3 Transaction Cost Efficiency

The magnitude of transaction costs is determined by the complexity of the regulatory environment. In this respect, a policy mix may bring about higher transaction costs for the regulator and the regulated firms than a single policy strategy based on, say, a capacity mechanism. The transaction costs of the policy mix can be reduced, however, by the fact that many of the policy options discussed are already implemented and would simply need to be adjusted. Moreover, some of the policy approaches may also be employed to address policy objectives beyond security of supply. Strengthening the EU ETS is one example, which also helps to address the climate change challenge. Thus, the specific transaction costs, which would be attributable to safeguarding security of supply, may be small in many instances.

And in fact, the transaction costs involved in introducing capacity mechanisms may be significant. This typically involves the introduction of new organizations, e.g., a regulatory body managing the strategic reserve, and new institutions, such as a new market segment in the case of comprehensive, focused and decentralized capacity markets (Beckers and Hoffrichter 2014). Typically, such newly introduced institutions need to be adjusted several times in the initial phase, and this creates additional costs for market actors (Beckers et al. 2012; Süßenbacher et al. 2011).

3.2.4 Adaptive Efficiency

The economic market is typically assumed to be the institutional arrangement exhibiting the highest degree of adaptive efficiency (North 1990). In this respect, government policies should correct the market mechanism but do not make it obsolete. Against this background, particularly those policy options described in Section 3.1 to strengthen the energy-only market should be preferred. Moreover, the policy mix should – where possible – rest on existing policy instruments, rather than lead to creating new organizations and institutions with corresponding inertia and path dependencies. This is clearly one downside of policy approaches relying primarily on capacity mechanisms. The additional revenue streams create constituencies, which are likely to resist future adjustments of the instrument or even its abolition (if future knowledge suggests doing so). Among the various capacity mechanisms, capacity markets (comprehensive, focused or decentralized) in contrast to a strategic reserve bring about the largest payments and degree of intervention. Thus, capacity markets may be particularly prone to expensive and irreversible regulatory errors (Neuhoff et al. 2016).

Theoretically, improvements in terms of security of supply can be attained under a policy mix by numerous relatively small and gradual adjustments to policy instruments, while capacity mechanisms typically would require a more severe intervention. Assuming that gradual adjustments are more politically feasible than radical adjustments, a policy mix could improve adaptive efficiency. Yet, the validity of this conclusion depends on the eventual distributional impacts and the corresponding political hurdles associated with changes in the policy mix. These are however difficult to assess (see also Sections 3.2.5 and 3.2.7).

A policy mix approach may also imply that more actors and interests are affected by regulatory changes than under a single-policy approach resting on a capacity mechanism only. Moreover, instruments may reinforce each other within a policy mix, making adjustments more tedious. It is thus eventually unclear whether an ongoing, learning adjustment of the regulatory framework to safeguard security of supply can be best provided under a policy mix or under a single-policy strategy based on capacity payments.

3.2.5 Distributional Effects

Intuition and evidence regarding the distributional impacts of different measures to safeguard security of supply are quite ambiguous. In the following the focus will be on impacts on final electricity customers.

The impact of capacity mechanisms on electricity prices paid by retail customers is twofold: On the one hand, all approaches involve additional payments to power plant operators, which need to be funded by a surcharge on the retail electricity price. On the other hand, capacity markets (but not the strategic reserve) may lead to declining wholesale power prices as they subsidize electricity generation. An assessment presented by Frontier Economics and Consentec (2014) shows that, on aggregate, both effects may lead to a net burden (strategic reserve, comprehensive capacity market) or net relief (focused capacity market) for final customers.

Indeed, a comprehensive assessment of the distributional effects must not only refer to pecuniary effects but also to the distribution of benefits in terms of security of supply. Given the public good character of security of supply, these benefits are likely to be shared equally by all electricity customers. Retail prices will fluctuate less in the presence of a capacity mechanism, at least for consumers with variable rate contracts. At the same time, though, the incentives for flexibility-enhancing measures (e.g., smart metering) will be reduced, at least if the consumers (e.g., larger companies) can be active themselves in the capacity mechanism.

Similarly to capacity mechanisms, other instruments in the policy mix may also lead to net burdens or relief for customers. For example, providing extra support for system-friendly RES generation (e.g., by higher tariffs for generation close to load centers or east-west-mounted photovoltaic modules) likely increases RES support costs and corresponding surcharges on the retail electricity price. At the same time, however, such measures will help increase the market value of RES generation (i.e. higher wholesale prices). Thus, higher support costs will not be fully reflected in the surcharge (which is usually computed as support costs net of wholesale power prices).

Moreover, the merit-order effect of RES generation contributes to decreasing the wholesale prices. These effects eventually imply that the aggregate effect on retail power prices is unclear *ex ante*. Further examples are regionally differentiated wholesale electricity price and network charges. These may result in increases in retail prices in some areas and decreases in other areas. Price increases could be mitigated by the fact that incentives for relocation of investments and generation may reduce the need for re-dispatch and corresponding costs. On a conceptual level, it is thus difficult to determine *ex ante* what actors would be affected to what extent under a broad policy mix compared to single-policy approaches, such as capacity mechanisms.

3.2.6 Environmental Effectiveness

Many of the policy options that were discussed in Section 3.1 can make positive contributions to attain objectives of environmental protection. Strengthening the EU ETS will simultaneously generate benefits in terms of mitigating climate change. Moreover, any measure safeguarding security of supply in the presence of high feed-in levels from volatile renewables will help improve the political legitimacy of RES objectives. Also, measures to promote demand-side management and reductions in electricity consumption may facilitate the attainment of ambitious RES targets (which are typically expressed as a share of total electricity consumption). In this respect, negative impacts may result from the introduction of market-based approaches to RES support (e.g., market premiums or tenders). These may increase investment risks and additional transaction costs, which may slow down RES investments (Gawel et al. 2013).

In the short run, the capacity mechanisms would be neutral in terms of global greenhouse gas emissions: In the case of electricity generation these are capped EU-wide by the EU ETS and changes in the structure of the national power plant stock would only result in emissions being shifted between sectors and countries. Yet, the attainment of national climate targets may be affected if capacity mechanisms alter the carbon emissions from electricity generation (Frontier Economics and Consentec 2014). Whether this effect is positive or negative depends crucially on the design of the capacity mechanism. A comprehensive capacity mechanism may theoretically also lead to more investments into cheap but emission-intensive coal power plants. In contrast, more targeted approaches, like focused capacity markets and strategic reserves, may implement environmental pre-qualification criteria for capacity payments. Similar concerns may also be raised with respect to the long-run, structural effects of capacity mechanisms. Depending on how these are designed, extra capacity payments may also perpetuate the existing electricity system relying on incumbent, non-RES technologies, and impair the transition to a fully RES-based electricity system.

However, compared to a broad policy mix, a single-policy approach based on a capacity mechanism may lead to less detrimental effects in terms of land use. Capacity mechanisms would most likely promote rather centralized options to safeguard security of supply, such as power plants, large storage systems and demand-side management by large industry customers. In contrast, a broad policy mix would potentially activate a broader set of options, which are often characterized by higher land use, e.g., network extensions or a spatially more even distribution of RES plants (closer to load centers). Such impacts will be aggravated if spatial and land-use planning approaches attach a higher priority to safeguarding security of supply than to environmental and nature conservation, e.g., by laws meaning to accelerate network extensions.

3.2.7 Political Feasibility

Whether a broad policy mix and/or a single policy approach are politically feasible depends primarily on how either option affects the rents of the different societal actors. On a general level, electricity generators can be assumed to have a vested interest in receiving extra payments generated by capacity mechanisms. Certainly, the eventual preferences as to the design of the capacity mechanism depend on the generation portfolio of the generator. Operators of gas turbines that only run at peak load in Germany – oftentimes the municipal utilities – can be expected to support focused and decentralized approaches as these would put them at a comparative advantage compared to large producers generating electricity primarily from coal and nuclear. The latter in turn would probably benefit most under a comprehensive capacity market without any pre-qualification criteria (Hermann and Ecke 2012). Certainly, they may also be supportive of targeted capacity mechanisms if they are able to influence the design of the eligibility criteria to their advantage (what eventually happened in Germany when the strategic reserve was designed to include coal-fired power plants as well, see Lehmann et al. 2016).

Industrial and residential electricity customers have an interest in low electricity prices and may therefore reject costly policy options such as a capacity mechanism. Yet, as pointed out in Section 3.2.5, the distributional impacts will vary with the design of the capacity mechanism or policy mix, and so will the preferences regarding how to safeguard security of supply. At the same time, customers will have a strong preference for (full) security of supply. If public debates signal that only capacity mechanisms can safeguard security of supply reliably, corresponding costs may receive less priority when decisions on the regulatory framework are made.

When choosing between capacity mechanisms and a broader policy mix, policy-makers may tend to trade off the interests of supporters of capacity mechanisms and opponents. Overall, it may be expected that the interests of supporters receive a higher priority for two reasons. First, the supporters (electricity generators) may be better organized and equipped than the opponents (particularly residential electricity customers). Second, politicians may react very sensitively to a potential threat of black outs and subsequently alleged failure of the energy transition. Consequently, they may be tempted to reduce such risks to zero at any possible cost and opt for capacity mechanisms – or at least keep their options open to implementing this approach at some point in the future. However, such announcements may actually initiate a self-enforcing process: In the expectation of future capacity payments, electricity generators may strategically withhold necessary investments (or even shut down existing power plants) to increase (or generate) capacity shortages which eventually make the introduction of capacity mechanisms inevitable.

4 The Political Economy of the German Policy Debate

In this chapter, we turn to the political economy of the security of supply debate in Germany. The political economy perspective aims at explaining the actual outcomes of the political process – as opposed to conceiving hypothetical optimal policy solutions. Buchanan (1984) summarized this analytical point of view neatly as “politics without romance”. The main assumption behind the political economy perspective is that outcomes are determined by the self-interest of all actors involved in the processes of political debate, decision-making and implementation. This guiding principle also leads the analysis of the following subsections: in section 4.1 we introduce the main actors of the security of supply debate in Germany and their positions. In section 4.2 we outline the results of the political process so far. In section 4.3 we connect these two strands by relating the political outcomes to the self-interest of the involved actors.

4.1 ACTORS IN THE POLICY DEBATE AND THEIR INTERESTS

Politics, even if the official legislative process in representative democracies takes place in the parliament, involves a number of (partly informal) arenas. For instance, stakeholders may figure as main drivers of agenda setting, and the media may provide instant feedback from the general public on ongoing decision making processes. The German security-of-supply debate is an interesting example in this respect. First, as will be outlined in detail, stakeholder involvement was and continues to be very strong. Second, by contrast, general public involvement was rather low as compared to other aspects of energy policy that have attracted considerably more coverage in general media outlets and public discussions (e.g., the debate on rising electricity prices). Thus, in the security-of-supply case an intense and expert-debate unfolded, with participation from the administration, industry interest groups, NGOs and their respective scientific advisers.

Based on its discussion paper “An Electricity Market for Germany's Energy Transition (Green Paper)” (BMWi 2014) which was published in October 2014, the German Federal Ministry for Economic Affairs and Energy invited comments from stakeholders which would be taken into consideration for drafting the final strategic “white paper” on the future of the German electricity market (BMWi 2015a). 597 of a total of 696 statements submitted as part of this consultation process are available via the BWMi’s website (BMWi 2015b), alongside an overview of consultation results (BMWi 2015c). These documents provide a useful basis for analysing the actors in the German policy debate and their interests, because they make actors’ positions regarding policy options transparent. Based on BMWi (2015c), we first identify what policy proposals find broad support, and what issues are contentious. As a particularly controversial issue emerges the question of whether a strengthened EOM, possibly in combination with a strategic reserve, will be sufficient to provide security of supply in the future or whether it needs to be supplemented with a more comprehensive capacity mechanism, i.e. a comprehensive, focused or decentralised capacity market.

In sections 4.1.2-4.1.4 we examine more closely how different actor groups position themselves with regard to this question, and what key reasons are given for their positions. For this, we focus on consultation contributions by organizations (212 statements), rather than private individuals (484 statements, see BMWi 2015c, p. 17). Actor groups are divided into (i) interest groups, encompassing "established" energy industry associations and companies; "challenger" energy industry associations and companies; transmission system operators (TSOs); unions; industry and commerce associations and companies as energy consumers, as well as private consumer associations; environmental non-government organizations; (ii) federal state ministries and other government agencies; and (iii) research and consultancy organizations and advisory boards. Selectively, the analysis of consultation statements is complemented by positions of actors who have shaped the political debate on capacity mechanisms in Germany, but have not participated in the consultation (such as the Federal Ministry for Economic Affairs and Energy itself and a number of research organizations).

4.1.1 Points of Agreement and Contention

According to BMWI (2015c), there is a broad consensus among actors that measures for strengthening the energy only market should be implemented as "no regret measures", independent of whether a capacity mechanism will be put into place or not. This means that actors predominantly view capacity mechanisms not as an alternative to a policy mix, but as a measure that should or should not be implemented on top of a combination of measures for strengthening the EOM, adjustments of energy transition instruments, and further policy options for safeguarding security of supply (see 3.1.1).

Many statements contain proposals about how individual measures beyond capacity mechanisms should be designed (BMWi 2015c). Several questions stand out as somewhat contentious – examples are whether exemptions in state-induced electricity price components and grid charges should be reduced or extended to promote flexibility measures; to what extent RES should be curtailed to reduce grid expansion needs; or whether Germany should adopt unilateral climate policy measures besides pursuing a strengthening of the EU-ETS (e.g., a national minimum carbon price or emission reduction requirements for power plants).

Among the policy options outlined in Section 3.1.1, differentiating electricity prices spatially stands out as an option which is predominantly rejected. According to BMWi (2015c), the majority of consultation participants argue for maintaining a uniform price zone for Germany, as a precondition for cost-effective electricity supply, and to avoid increasing regional differences in locational conditions for industries as well as decreases in market transparency and liquidity. Actor groups arguing against spatially differentiated electricity prices are, in particular, the TSOs, federal states, energy industry associations (representing both established energy industry actors and challengers), chemical and manufacturing industry associations, unions, energy production and trading companies, the federal grid agency (Bundesnetzagentur) and the European Energy Exchange (EEX). Several of these stress that grid expansion is a necessary precondition to maintain a uniform price zone.

Among capacity mechanisms, introducing a strategic reserve (or "capacity reserve") to safeguard security of supply finds broad support across actor categories, both among proponents of a strengthened "EOM 2.0" and those arguing in favour of introducing capacity markets, who view it as a transitory instrument (BMWi 2015c, p. 14). Only a minority of actors argue that a strategic reserve is not necessary at this stage; these include Austrian and Swiss government agencies (the latter together with the Swiss TSO and Swiss established energy industry associations), one federal state (Brandenburg), the EEX, a lignite mining company and three industry associations. Moreover, opinions diverge on the relation between the strategic reserve and the existing grid reserve, and the conditions for participating in the strategic reserve (BMWi 2015c, p. 15f.).

However, much more contentious proves the point of whether or not a capacity market should be introduced and if so, what model should be adopted (see 3.1.2). 142 of 212 organizations participating in the consultation defined a position on this issue (BMWi 2015c, p. 17f.). Overall, 81 organizations argue for an EOM 2.0, potentially in combination with a strategic reserve but without a capacity market. A further 17 state that a capacity market should be introduced in addition to other measures only if this eventually proves to be necessary at a later date. 25 argue for implementing a capacity market in a more timely fashion, and 8 of these support the introduction of a strategic reserve in addition (at least as a transitory measure). For 19 organizations the position for or against capacity markets is found to be unclear. Among the proponents of capacity markets, main arguments are that the EOM would set insufficient incentives for capacity investments; that capacity markets would not necessarily lead to high additional costs (particularly, once effects of uncertainty and market power abuse on the EOM are taken into account); and that capacity markets could support flexibilisation (cf. BMWi 2015c, p. 20). On the other hand, major arguments voiced against capacity markets are that a strengthened EOM 2.0 could guarantee security of supply in the future; that a capacity market would be a major, risky and potentially costly intervention in the electricity market; and that capacity markets would make the transformation of the energy system more difficult (cf. BMWi 2015c, p. 21).

4.1.2 Interest Groups' Positions on Capacity Mechanisms

Among interest groups, a clear division is visible in who supports the introduction of a capacity market and who opposes it. Main supporters among interest groups are actors which represent the energy industry, particularly the established energy industry, and unions. On the other hand, statements by renewable energy industry and other "challenger" energy industry representatives favour a strengthened EOM without capacity markets, same as energy consumer interest groups. Nonetheless, a strategic reserve is frequently supported. Among environmental interest groups, opinions are divided.

Actor groups in favor of capacity markets

Energy industry associations who support capacity markets include the Association of Municipal Enterprises (VKU), one more German and one European municipal energy utility association, one power plant operator association, one energy trader association, and the Federal Association of the Energy and Water

Industries (BDEW) which states that it represents 90% of electricity sales in Germany (BDEW 2017). These associations unequivocally favour the concept of a decentralised capacity market, which was originally developed on behalf of the Association of Municipal Enterprises (VKU) (see 3.1.2). As central arguments for a capacity market, both the BDEW (2014) and VKU (2015) state that the social acceptance of extreme price peaks is questionable, but these would be needed to refinance investments via the EOM. Also, given the lead time of investments, the VKU criticises that price peaks would not signal investment needs early enough. Moreover, both associations warn against overestimating the cost-effective flexibilisation potential of the demand side. Until the capacity market is in place, BDEW and VKU call for a strategic reserve to safeguard security of supply.

The introduction of a capacity market is further supported by several municipal and supra-regional **energy producing companies**; if a preference is voiced, a decentralised capacity market is the model of choice. For instance, as two of the "big four" players in the German electricity market[11], RWE (2015) and E.ON (2015) both doubt the political credibility of permitting price peaks, which would lead to unstable and insecure framework conditions for planning new investments. Also, RWE emphasises that signals from a strengthened balancing market would not be timely enough to incentivise investments; whereas E.ON highlights that the EOM 2.0's success depends on whether enough consumers are willing to reduce demand in time of price peaks, which is found to be too uncertain. Both support a decentralised capacity market, with a strategic reserve as a transitory instrument until it is established.

The capacity market is also supported by three individual unions, the German Trade Union Confederation (DGB) and one staff organisation. Among those who express a preference for a specific concept, the decentralised capacity market is preferred; moreover, all four **union associations** also support a strategic reserve. Critique of the EOM's capability to safeguard security of supply also centres on the role of high price peaks. DGB (2015) views the political commitment towards permitting high price peaks as not credible, which imposes high risks on future investments and may also make high risk premiums necessary. IG Metall (2015) emphasises that high price peaks will trigger "boom and bust" cycles in the investment goods industry, while a capacity market will lead to more stable investments with positive effects for employment. DGB and IG Metall stress that the capacity market should be technology-open, and not preclude participation of modern, flexible coal power plants (DGB 2015).

Among **environmental interest groups**, a focused capacity market is supported by the WWF, based on a mandated study by Öko-Institut and others (see 3.1.2, Matthes et al. 2012). The proposed focus is on incentivizing flexible and low carbon production capacities and demand side flexibility, to promote structural change towards a RES-based and eventually carbon neutral electricity system (WWF 2015). The statement points out that the current lack of price signals for investments in flexible capacities is particularly problematic. It shares the unions' and energy

[11] EnBW, E.ON, RWE and Vattenfall, who together account for 62% of the conventional electricity generation capacity directly connected to German and Austrian electricity grids (Monopolkommission 2015).

industry associations' assessment that refinancing investments via price peaks with uncertain social acceptance is too risky, emphasizing potential welfare losses associated with risk premiums and market power abuse. Also, to increase demand side flexibility, larger incentives are thought to be necessary than what would be available through the EOM.

A decentralized capacity market is also supported by a **citizen initiative** against a planned long distance transmission line.

Actor groups in favor of an EOM 2.0 without capacity markets

Among **energy industry associations**, nine renewable energy industry, citizen energy and other "challenger" energy industry associations clearly do favor a strengthened EOM without capacity markets, although a strategic reserve is also frequently supported. The German Renewable Energy Federation (BEE), for instance, emphasizes that overcapacities in Germany and Europe are significant, and that the call for capacity markets is triggered not by imminent security of supply problems but the decreasing profitability of conventional power plants (BEE 2015). Accordingly, capacity markets would slow down the necessary structural change of the electricity system and further reduce flexibility incentives. Moreover, they would not solve regional security of supply problems which are traced back to insufficient grid expansion. The EOM 2.0, on the other hand, is expected to possess a high potential for innovative solutions.

Proponents of the EOM 2.0 further include three **energy industry associations representing actors outside of Germany**. For example, NORDENERGI (2015), a collaboration of Nordic associations of electricity producers, suppliers and distributors, views the EOM 2.0 as a sensible starting point for reforms, this since provides more scope for developing demand side flexibility and trade via interconnectors than a capacity market. Moreover, the latter is judged to discriminate against intermittent RES. A strategic reserve, on the other hand, could indicate whether a capacity market might be needed in the future.

Among individual **energy producing companies,** several "challenger" companies from the renewables industry and energy services industry support the EOM 2.0 without a capacity market. Interestingly, this position is shared by several "established" energy companies, including members of associations in favour of capacity markets. For example, both EnBW (2015) and EWE (2015) view the capacity market as a measure of last resort which should only be introduced if and when security of supply monitoring showed that a strengthened EOM 2.0 in combination with a strategic reserve cannot provide security of supply at reasonable costs. A credible political acceptance of price peaks is seen as a precondition for a functioning EOM with flexibility incentives. If the introduction of a capacity market proved necessary eventually, the decentralized model is preferred.

On the side of **energy consumer organizations**, twelve industry and commerce associations and the Federation of German Consumer Organizations (vzbv) support the EOM 2.0, often in combination with a strategic reserve. Four industry associations view capacity markets as a measure of last resort, to be introduced only once it is clear that EOM 2.0 and strategic reserve fail in providing security of supply. The same position is held by a coal mining industry association, another focusses on the EOM 2.0. For instance, both BDI (2015) and DIHK (2015) see capacity markets as last resort measures, but warn that they are more susceptible to political interventions than the EOM, e.g., on behalf of other aims than security of supply, resulting in higher policy uncertainty. Moreover, lower compatibility with the EU internal market is viewed as a problem. DIHK (2015) also stresses that by reducing price fluctuations and price peaks, capacity markets would reduce the EOM's functionality, reduce incentives for making electricity generation and consumption more flexible, and make the market integration of RES more difficult. Furthermore, both DIHK and vzbz (2015) emphasize the likelihood of significant additional costs for electricity consumers as arguments against capacity markets. Similarly, several individual **industry companies** support the EOM 2.0 without a capacity market, but argue predominantly for a strategic reserve.

Three **environmental interest groups** position themselves against the introduction of capacity markets, supporting a strategic reserve instead. All three state that given current overcapacities, the focus should be on taking CO_2-intensive and inflexible coal power plants out of the market (BUND 2015, Greenpeace 2015, NABU 2015). A capacity market, on the other hand, might set wrong incentives on behalf of conventional power plants, thereby counteracting the energy transition, and result in high costs due to its regulatory complexity.

In a joint statement, the German **transmission system operators** support introducing a strategic reserve as a transitory instrument to deal with temporary grid shortages; in general, they emphasize the role of grid expansion for safeguarding security of supply (50Hertz, Amprion, TenneT and TransnetBW 2015). Utilisation of grid reserve and strategic reserve should be used as an indicator to assess whether a capacity market is needed in the long term. Also, the Norwegian TSO registers support for strengthening the EOM and optimising electricity flows across interconnectors (Statnett 2015). Moreover, if a capacity market was introduced, it should allow cross-border participation.

As a relevant individual actor, the **EEX** states that a new market design would not be necessary and that introducing capacity markets would be risky and complex (EEX 2015). Instead, the EOM is viewed as capable of developing new solutions to solve energy transition challenges, e.g., new products for marketing flexibility. A market adjustment process with a reduction of overcapacities is considered necessary.

Positions on the design of a strategic reserve

As to the design of the strategic reserve, a widespread point of disagreement is whether it should be open to all technologies or only to specific ones. Several environmental interest groups stress that the strategic reserve should not generate income streams for emission-intensive power plants (BUND 2015; NABU 2015; WWF 2015); however, Greenpeace (2015) and the BEE (2015) as a renewable energy industry association argue that the reserve should be used to take emission-intensive plants out of the market (in case of Greenpeace, only if a proposed "coal phase-out law" fails to be realized). On the other hand, two energy industry associations (BDEW 2014; VKU 2015) and one industry association (BDI 2015) argue that climate change mitigation issues and capacity provision issues should be treated by different instruments. A technology neutral design of a strategic reserve is also supported on the energy consumer side by several industry associations, a European association of local energy distributors, one union, and Austrian and Swiss energy industry associations (the latter together with the Swiss TSO and government agencies). Moreover, Swiss and Austrian energy industry associations and government agencies and the German industry association (BDI) explicitly argue in favour of allowing cross-border participation in the strategic reserve (cf. BMWi 2015c).

4.1.3 Federal State Ministries' and other Government Agencies' Positions on Capacity Mechanisms

From fifteen **federal states** who position themselves on the question of capacity markets, eleven support an EOM 2.0 without a capacity market (Berlin, Brandenburg, Hamburg, Hessen, Mecklenburg-Vorpommern, Niedersachsen, Nordrhein-Westfalen, Rheinland-Pfalz, Sachsen, Sachsen-Anhalt, Schleswig-Holstein, see BMWi 2015c). Nine of these find that it should be combined with a strategic reserve if necessary. For example, Niedersachsen (2015) and Sachsen (2015) view a reduction of overcapacities as a precondition to allow the EOM 2.0 to function, whereas capacity markets would be likely to conserve conventional overcapacities and reduce flexibility incentives. Nordrhein-Westfalen (2015) adds that it would be particularly problematic if a capacity market subsidized new capacities in southern Germany, counteracting grid expansion plans.

With Baden-Württemberg and Bayern, only two states unequivocally support the introduction of a capacity market. Both favour the focused capacity market model; Baden-Württemberg (2015) sees its role in supporting investments in flexibility options such as new plants, storage and demand side flexibilisation, whereas Bayern (2015) foresees a focus on highly efficient, flexible and low pollution plants. Bayern also stresses the necessity of a strategic reserve as a transitory instrument. Both states view the EOM's price signals as an insufficient basis for long-term planning decisions and the reliance on extreme price peaks as susceptible to market power abuse. Bayern also highlights the necessity of timely investment signals for replacing the states' nuclear power plants. In motivating its preference for a focused capacity market, Baden-Württemberg warns against the privatisation of security of supply that a decentralised capacity market would bring.

Meanwhile, Thüringen and Saarland take an intermediate position, supporting the introduction of a capacity market at a later stage if it is shown that a strengthened EOM 2.0 and a strategic reserve are insufficient for guaranteeing security of supply. As to the question of whether the strategic reserve should be technology neutral, Niedersachsen (2015) argues that lignite plants should be put into the strategic reserve to reduce overcapacities and CO_2 emissions; Nordrhein-Westfalen (2015) likewise states that the use of the reserve for CO_2 reduction purposes should be further examined.

As a government agency, the **Bundesnetzagentur** (2015) voices general support for the development of a capacity mechanism while security of supply conditions are still good; for the transition period, a technology-neutral strategic reserve is supported. The statement contains no concrete preference for a capacity market model; however, it emphasizes that if a decision on behalf of an EOM 2.0 is made, it should be made clear that capacity markets will not be introduced in the future because that expectation would cause the EOM 2.0 to fail.

Two German government agencies which argue for an EOM 2.0 without capacity markets are the **German Environment Agency** (UBA) and the **Federal Cartel Office** (BKartA). The former emphasizes that optimizing the EOM and combining it with a reserve allows for a reversibility of policy decisions, which is necessary to avoid unnecessary costs and allow learning from errors (UBA 2015). The latter views profitability problems of existing plants and the postponement of new investments as normal market reactions given current overcapacities (BKartA 2015). Among other problems (e.g., additional costs), the introduction of a capacity market is rejected for competition policy reasons. It is seen as a significant intervention in the market competition mechanism with many risks, such as high susceptibility to market power abuse, which is moreover found to be very difficult to control on capacity markets. A strategic reserve finds the BKartA's support, if viewed as necessary politically.

Also, several **non-German government agencies** support the EOM 2.0 without capacity markets, including a combined statement of three Swiss government organizations together with the Swiss TSO and two established energy industry associations (Bundesamt für Energie et al. 2015), the Ministry of Industry and Trade of the Czech Republic (Czech Republic 2015), the Danish Ministry of Climate, Energy and Building (Denmark 2015) and the Austrian energy regulatory agency (e-control 2015). All of them stress the need for greater regional and European cooperation on energy market design and security of supply issues, remarking that adverse impacts of the capacity market would also affect neighboring countries (e.g., in the case of Denmark, by enacting downward pressure on EOM market prices and decreasing its functionality). The Swiss and Austrian statements also express a skeptic view on the need for a strategic reserve, but state that if it was implemented it should enable cross-border participation of capacities.

Relevant government actors which did not take part in the consultation but had an important role in shaping the debate are the **Federal Government** (Bundes-regierung) and the **federal ministries of economics and the environment**. In its grand coalition treaty in 2013, the Bundesregierung agreed to implement a capacity mechanism in the medium term, without specifying a model (CDU, CSU and SPD 2013). The Federal Ministry of Economic Affairs and Energy (BMWi) initially mandated EWI (Elberg et al. 2012) for a proposal of a comprehensive capacity market (see 3.1.1.2). At a later stage, following the re-election of the government and the shift of energy responsibilities from the environmental to the economics ministry, the BMWi mandated a study by Frontier Economics (2014) which indicated that a capacity market would be costly and not necessary. The set-up of the green paper (BMWi 2014) included a pre-decision that some kind of capacity mechanism (i.e. a strategic reserve) would be needed. The environmental ministry (BMUB, formerly BMU) promoted a strategic reserve in the debate (BMU et al. 2013).

4.1.4 Research and Consultancy Organizations' and Advisory Boards' Positions on Capacity Mechanisms

In total, only sixteen research and consultancy organizations participated in the green book consultation, and even fewer took a position on the capacity market issue. However, more positions were published as part of the scientific debate.

As part of the consultation, the Öko-Institut submitted its proposal for a focused capacity market which was developed for WWF (Matthes et al. 2012). Outside of the consultation, the EWI developed a proposal for a comprehensive capacity market as a mandated study for the BMWi (Elberg et al. 2012).

With the exception of the Öko-Institut, research, consultancy and advisory board **organizations participating in the consultation** support the EOM 2.0 without a capacity market. The research project Energetische Biomassenutzung (2015) highlights that by capping price peaks, capacity markets would reduce necessary incentives for the flexibilisation of electricity generation and demand. Lehmann et al. (2015) find that so far, the necessity of capacity markets is not clear, yet they would be non-reversible and imply a high potential for steering errors. Rather, a policy mix that includes a strengthening of existing instruments to address the underlying causes of security of supply problems is assessed to be more cost-effective, possibly in combination with a (reversible) strategic reserve as a "risk buffer".

The expert council on the environment (SRU 2015) advances a similar position, viewing the introduction of a capacity market as an irreversible intervention whose necessity is as yet unclear. The advisory board warns that design errors might block the energy transformation and result in high costs, while a strategic reserve would allow for time for learning. In combination with a high CO_2 price in a reformed EU ETS, emission-intensive plants should be driven into the strategic reserve by market processes. Green Budget Germany (FÖS 2015) similarly finds that central and decentralised capacity markets would result in unnecessary costs and delay the environmental transformation of the electricity system. The organization states that a focused capacity market would have a higher compatibility with this transformation, but as its success depends strongly on design decisions, it might necessitate many interventions in the market and high regulatory risks. Meanwhile, a strategic reserve could be used as a socially compatible way to take emission-intensive plants out of the market, although further emission reduction measures should be examined.

For improving the functionality of the EOM, the Institute for Advanced Sustainability Studies (2015) suggests using a command and control instrument to reduce overcapacities and CO_2 emissions, by taking emission-intensive and inflexible plants out of the market. This is expected to improve the profitability of remaining peak and mid-load plants. Capacity markets, meanwhile, are discouraged as an irreversible intervention, while the strategic reserve is seen as a reversible alternative which allows for learning. The Regulatory Assistance Project (RAP 2015) also views a capacity market as unnecessary, but emphasizes that if it is pursued, it should be coordinated in a EU or regional context and include quality (particularly flexibility) criteria. In general, it is stated that the question of how to reduce overcapacities of inflexible CO_2-emission-intensive plants should have priority over discussing investments in new capacities.

As for research and advisory **organizations outside of the consultation**, many economists do not consider a capacity market as an option now but potentially in the long run if the EOM turns out to fail. The Monopolkommission (2015) promotes the consequent use of competitive instruments for the energy transition; however, if the EOM failed, a comprehensive capacity market should be created. The proposal to implement a strategic reserve is criticized; according to the commission, it should only be used as a temporary instrument. The Düsseldorf Institute for Competition Economics (Böckers et al. 2012) finds that there is no necessity for a capacity market at the moment; it is viewed as an option only in the long run and only if implemented at the European level. Cramton and Ockenfels (2012) suggest a design for a capacity market but admit that this is not helpful to address the issues at hand in Germany. Instead, they find that highest priority should be given to building a stable and reliable political and market framework. The Technical University Berlin (Beckers and Hoffrichter 2014) conclude that in the long run, a complete switch from power to capacity market may be reasonable, to accommodate RES with marginal costs close to zero. The German Institute for Economic Research (Neuhoff et al. 2013) find that Germany does not need a capacity market, a strategic reserve being sufficient.

4.2 RESULTS OF THE GERMAN DEBATE ON INTERMITTENCY AND SECURITY OF SUPPLY: POLICY OUTCOMES TO DATE

4.2.1 Overview of the Process Leading to Policy Decisions on Instruments to Safeguard Security of Supply:

The issue of security of supply within the RES-dominated electricity system of the future constitutes a typical "expert dilemma" (Nennen and Garbe 1996): a range of scientific studies addresses the topic but there exists no general consensus as regards the best solution. Rather, expert opinions point in different directions, often openly contradicting each other. In the present case, the expert discourse was not primarily carried out in traditional academic outlets and forums (i.e. scientific journals and conferences). Instead, the different actors, within both industry, NGOs and bureaucracy, commissioned research studies to back up their case: for instance, the Federal Association for Renewable Energies (BEE; Schütz and Klusmann 2011), the Federal Association of New Energy Providers (bne; BET 2011) and the Federal Association of Energy and Water Industries (BDEW; Nicolosi 2012) each assigned research institutes to evaluate the challenges of safeguarding security of supply in the RES age. The discourse was not restricted to purely national players, as the case of the WWF shows, who commissioned the Eco-Institute to devise a specific proposal for an RES-friendly market design (Matthes et al. 2012).

The different proposals (as extensively outlined in Section 4.1) were publicly discussed in a number of export forums. As a prominent 'debate moderator' in this context emerged the "Agora Energiewende", a think tank founded by the Mercator foundation. For instance, Agora Energiewende organized discussion panels and assembled overview reports comparing different design proposals for capacity markets (Agora Energiewende 2013). Official political players also encouraged and initiated the dialogue: in 2011 the Federal Ministry of Economic Affairs and Energy (BMWi) launched the so-called "power plant forum" (Kraftwerksforum), where industry stakeholders and representatives from government agencies (e.g., the Federal Net Regulation agency, BNetzA) and ministries participated. The BMWi-commissioned study by Elberg et al. (2012), arguing for a comprehensive capacity market (see 3.1.1.2 above), figured as the starting point for these discussions but was later complemented by other studies to evaluate all available political options. Although the security of supply debate was primarily led on the national level, regional actors also weighed in. For instance, the ministry of environment, climate and energy in the South-West state of Baden-Württemberg assigned a study that argued for focused capacity markets (LBD 2011).

The discussions within the "power plant forum" led the BMWi to adopt the proposal for comprehensive capacity markets. Chronologically, a December 2012 meeting of the forum discussed different design options for capacity markets; in May 2013, the BMWi published a clearing-study that compared comprehensive and focused capacity markets (Growitsch/Matthes/Ziesing 2013); in November 2013, the BMWi (more precisely, its scientific advisory board), recommended that a comprehensive capacity market should be introduced because a strategic reserve was deemed insufficient (BMWi 2013).

The strategic reserve, in turn, represented the preferred option of the "expert dialogue on the strategic reserve", which combined the Federal Association of Renewables, the Federal Association of Energy and Water Industries and the Ministry of the Environment, as well as scientific experts from research institutes (Fraunhofer ISI), universities (RWTH Aachen) and consulting firms (r2b energy consulting). Finally, the discussion forum "platform renewable energies", jointly initiated by the BMWi and the Ministry of Environment, addressed the challenges and options of market design in the future.

Thus, at the time of the last federal election in autumn 2013 the main parameters of the debate were set. The question *"does Germany need a capacity mechanism to safeguard security of supply?"* had essentially been replaced by the question *"which kind of capacity mechanism does Germany need?".* Two options emerged as main contenders: on the one hand, the strategic reserve, promoted by the Ministry of the Environment, on the other hand, comprehensive capacity markets, supported by the BMWi. The 2013 election led to a renewal of the 'grand coalition' between the conservative Christian Democrats and Social Democrats. In their coalition agreement, they stated rather vaguely that "in the medium term, a capacity mechanism shall be developed", leaving explicit design issues open. The 2013 coalition agreement also saw a shift of responsibilities in that the organization of the energy transition, traditionally within the competency of the Ministry of the Environment, now fell under the responsibility of the thus strengthened BMWi (formerly headed by Sigmar Gabriel, vice-chancellor and former leader of the Social Democrats). This shift also implied that traditional inter-ministry conflicts were transformed into an intra-ministry conflict to be solved within the BMWi. Furthermore, in order to streamline discussions and avoid redundancies at least on the federal level, the "power plant forum" and the "platform renewable energies" were merged into a new "platform electricity market". The administrative merging of competencies and discussion forums, therefore, consolidated the debate.

This consolidation process was fostered by an explicit step-wise decision making procedure to be initiated with a "greenbook", which was to be revised after a stakeholder consultation period, eventually leading to a "whitebook". After another consultation period, specific legislative proposals were to be drafted. As a first step, therefore, the "greenbook" on the future of the electricity market was published in November 2014: it systematically listed expert opinions and compared the pros and cons of different proposals (BMWi 2014). Interestingly, the greenbook already displayed a preference for the strategic reserve, even though BMWi-commissioned studies again criticized the strategic reserve (Frontier Economics and Formaet 2014; r2b et al. 2014). Second, the consultation process on the "greenbook" ended in March 2015 with exactly 696 petitions/comments voiced (see BMWi 2015b). It was followed by a comprehensive review of these comments (597 of which can be publicly accessed, see BMWi 2015c). As a result, third, the "whitebook" entitled "electricity market of the future" was published in July 2015. Fourth, another consultation period until August 2015 yielded 258 comments on the "whitebook". The next, fifth, step followed in September 2015 when a draft for the revision of the electricity market law was officially brought forward. Thus, the legislative phase had been entered. In July 2016, the "law on the development of the electricity market" was adopted in parliament. The law stipulates that a strategic reserve shall be introduced by way of a specific regulation (the latter has been drafted simultaneously and has also been open to public consultation, leading to only 25 specific comments).

In fact, the 2016 electricity market law contains two related but distinguishable policy instruments to safeguard security of supply, the so-called "capacity reserve" (in effect, a strategic reserve as outlined above) and the "security stand-by" – while the former is a more general instrument (in principle open to include demand-side management), the latter is specifically designed to cover old lignite power plants. In the following, we will look at both instruments in more detail and show how the additional lignite-specific instrument came about through climate policy issues that had been discussed in parallel to the electricity market discussion.

4.2.2 The Capacity Reserve and the Security Stand-by

Capacity reserve

The 2016 electricity market law (§13e EnWG) aims to complement the "energy only market 2.0" with a technology-neutral "safety net" – the main idea being that a capacity reserve is being built up that does not interfere with the electricity market. Rather, reserve capacities should only be used in rare circumstances so as to prevent supply-side-induced shortages. TSOs have to wait until all market operations have been conducted and will call for the activation of reserve capacities as some kind of "system services of last resort" in case that the market cannot be cleared. Hence, TSOs are not allowed to sell electricity from the reserve capacities on the market (electricity generated in the respective installations must not be sold on the market – neither in full nor in part); rather, the TSOs will be remunerated by rolling costs over to the network charges paid by all electricity consumers. Furthermore, the capacities held in reserve are to be strictly separated from the wholesale market in that capacities must not return on the wholesale electricity market after their participation in the capacity reserve ends.

Overall, the reserve capacity will amount to 2 GW for the first two-year period from 2018 to 2020. The remuneration for the capacities will be determined via an auction based on uniform pricing. The first auction will be held on September 1, 2017, covering the period from 10/2018 until 09/2020 on. Based on the experiences from this first period, adaptions for the second period after 2020 may apply, for instance as regards the amount of capacities to be tendered. In principle, the scheme is said to be technology-neutral, but technical requirements regarding ramp-up times (< 12 hours) and voltage (100 kilovolt) will make it difficult if not impossible for older coal power plants but also biomass plants to participate.

Security stand-by

Besides the reserve capacity, the 2016 electricity market law (§13g EnWG) also introduces a so-called „security stand-by“ *(Sicherheitsbereitschaft)*, which effectively means compensation payments for old lignite coal power plants: the law stipulates a stepwise process of taking eight lignite plants out of the market while keeping them in some kind of additional capacity reserve for four years. Why did the legislator add another technology-specific instrument on top of the capacity reserve? To answer this question, one needs to consider the climate policy discussion in Germany. The official legitimation for the "security stand-by" is based on the risk that Germany is not on track to meet its emission reduction targets for 2020 (-40% as compared to 1990). Model calculations suggest that Germany will fall short of this target by about 22 million tons of CO_2. Retiring the eight lignite plants specified in the law should officially contribute another 12 million tons of CO_2 towards the emission reduction target (the remaining 10 million tons to be achieved in other areas).

It should be emphasized that the "security stand-by" has not been a prominent proposal within the German climate policy discussion from the beginning. Rather, it constituted a last-minute proposal put forward by the union that also represents coal mining facilities. The security stand-by replaced the so-called "climate levy", a proposal conceived by the Eco-institute (the study had been commissioned by the BMWi). This climate levy aimed at modifying the merit-order in Germany to the benefit of low GHG-emission plants; the scheme envisaged "emission allowances" for all power plants. These emission allowances would decrease with the age of a plant (from 20 years on, no limit for emissions from plants up to 20 years old); if a plant emits more than the number of allowances, additional ETS permits would have to be handed in. This scheme would have led to a carbon price of around 18-20 € in Germany in 2020. ETS-permits would have been drawn from circulation so as to prevent emission relocation in Europe. However, this plan was scrapped – on short notice – in favor of the "security stand-by". The latter, of course, does not consider the functioning of the ETS as no ETS permits are taken out of circulation. So any reductions in emissions in Germany through the "security stand-by" are to be compensated by increased emissions elsewhere.

Overall, the security stand-by implies an additional reserve capacity of 2.7 GW. The first lignite plant has been put in reserve in October 2016, two more will follow in 2017, three in 2018, the final two in 2019. After four years within the reserve, each plant must be permanently retired. The scheme for runs for seven years and incurs costs of about 230 million € per year. Given that the flexibility potential of old lignite plants is limited, it does not seem overly unfair to interpret the "security stand-by" as a „golden handshake" to appease unions and plant operators that represent structurally weak regions in Germany. At the very least, compensation payments for old lignite power plants run counter the intentions of a technology-neutral, flexibility-centered capacity reserve as laid down in the "white book" for developing the electricity market (Höffler 2015).

In sum, the purportedly technology-neutral and flexibility-oriented instrument of a capacity reserve is foiled by a generous 'pension scheme' for old lignite plants: viewing bot schemes together, more than 50% of the capacity that is being hold "in reserve" comes from lignite plants. The decision to scrap the "climate protection levy", but to grant compensation payments for lignite coal power plants is questionable both with regard to the climate goals and with regard to the aim of complementing RES capacities with flexible back-up capacities to safeguard security of supply (Gawel and Strunz 2015).

Nevertheless, in May 2016 the EU Commission has confirmed that the "security stand-by", which will hand out a total of 1.6 bn €, meets the requirements of EU law as laid out in the state aid guidelines. The Commission expects that the effects on the electricity market will be limited and that potential distortions would be "largely offset by the environmental benefits".[12] Interestingly, however, the Commission, starting with April 2017, investigates whether the "capacity reserve" is in line with the state aid guidelines.[13] In particular, it questions i) the momentary need for the measure, ii) the reversibility of the measure in the medium and long term, iii) its openness to demand-side flexibility and the non-eligibility of foreign bidders as well as iv) Germany's overall commitment to electricity market reforms. Given the various issues discussed above (e.g., overcapacities, institutional path dependencies), the Commission's concerns seem well-founded. Nevertheless, against the background that the "security stand-by" has been approved (as well as capacity mechanisms in other EU member states, such as France), one might suspect that the capacity reserve will eventually be approved as well.

4.2.3 Reform of the German Renewable Energy Support Scheme

In parallel to the further development of the electricity design, the 2012, 2014 and 2017 reforms of the Renewable Energy Sources Law (EEG) have tried to strengthen the alignment of RES production and investment decisions with electricity market signals (e.g., by making direct marketing of RES electricity obligatory for all but small scale plants, and changing from fixed feed-in tariffs to a sliding feed-in premium) (e.g., Purkus et al. 2015). In the debate surrounding the 2017 reform, which saw the introduction of a competitive bidding scheme for selected RES technologies, major concerns were the cost-effectiveness of future RES expansion,

[12] http://europa.eu/rapid/press-release_IP-16-1911_en.htm.

[13] http://europa.eu/rapid/press-release_IP-17-903_en.htm.

as well as the question of how to improve alignment between RES expansion, grid expansion and the wider system transition (cf. BMWi 2016). With the consideration of "grid bottleneck areas" in the calculation of tendered quantities (RES capacities to be supported), security of supply concerns now directly impact upon the further expansion of renewables: within such "grid bottleneck areas", the support of new renewable capacities is conditional on the expansion of grid capacities (the aim is to avoid grid congestion resulting from strong wind feed-in).

Furthermore, and rather similar to the development of the capacity reserve discussion described above, the development of the RES support also demonstrates the importance of vested interests and institutional context: a completely technology-neutral RES support scheme is not feasible from a political economy point of view.[14] Not only do the representatives of different industries such as PV or wind lobby for technology-differentiated instruments, but also does Germany's federal political system induce a regional competition to attract RES support (see also Gawel and Purkus 2016): for instance, Bavaria lobbied for extended support for biomass while Northern German states focus on support for wind energy. Analogously, it is not surprising a representative of an Eastern German state where open pit coal mining is traditionally strong, vigorously denounced the "climate levy" but defended lignite as a cost-effective source of energy that cannot be swiftly substituted by renewable energy sources when nuclear power is phased-out simultaneously (Möllring 2015).

4.3 POLITICO-ECONOMIC EXPLANATIONS FOR POLICY OUTCOMES

To understand the public debate on safeguarding security of supply with high shares of volatile renewables as well as the eventual political decisions, it is usually helpful to look at the political economy of policy-making. Basically, this implies the application of economic theory to political processes.[15] This political economy perspective is very helpful in explaining the actual results of political processes. That is, it enables us to analyse why and in what ways political outcomes deviate from hypothetically derived ideal solutions to a given policy problem.

Within this report, we concentrate on the specific motivations of relevant actors in the German debate. In other words, we will not provide an extended review of the scientific literature on political economy but focus on the main implications for the German context. In a nutshell, the politico-economic perspective aims to explain preferences for specific policy choices by the individual interests of the political actors involved. Relevant political actors include politicians, bureaucrats, interest groups, voters, media and science. All of these actors try to further their interests within the political arena where the role of politicians may be described best as "transfer brokers" that aim at balancing the different stakeholders' interests – all the while following their own interest of maximizing the likelihood of electoral success and general public support (McCormick and Tollison 1981).

[14] That said, there are also economic rationales for maintaining some technology differentiation in RES support design (Gawel et al. 2017).

[15] See Mueller (2003) for an introduction to the political economy or "Public Choice" perspective.

This politico-economic view may explain the important divide in the political debate in Germany which referred to the fundamental question of whether a strengthened EOM supplemented only by a strategic reserve would be sufficient to safeguard security of supply – or whether additional capacity markets would be needed.

4.3.1 A Heterogeneous Set of Individual Interests: Interest Groups, Voters, Bureaucrats and Scientists

The claim for and against additional capacity market, but also differences in the particular design of these payments, can be explained first with the usual rent-seeking behaviour of different *interest groups*. The rent seeking hypothesis states that interest groups will try to increase their private profits through influencing politics and the design of social rules (see Krueger 1974). While this hypothesis addresses all policy fields, it also has been shown to be particularly relevant within the area of environmental policy (e.g., Kirchgässner and Schneider 2003; Kollmann and Schneider 2010) as well as climate policy (e.g., Helm 2010). Furthermore, the resulting design of energy policies and the regulation of electricity markets may well be explained by the presumptions of political economy theory on self-interests of actors and the distribution of power among them (e.g., Erdogdu 2014, Gawel et al. 2014). The transition to a sustainable energy system, therefore, is also subject to the same constraints of stakeholder lobbying and political log-rolling (e.g., Arent et al. 2017, Strunz et al. 2016).

Thus, against the background of the fundamental rent-seeking hypothesis, it did not come as a surprise that most non-renewable electricity producers in Germany favoured the introduction of capacity mechanisms, particularly a decentralized capacity market, which would create an additional income stream for all types of electricity generation (BDEW 2014; VKU 2015; see Section 4.1.2). Consequently, these incumbent electricity producers also had an interest in creating the threat that even a strengthened EOM would not provide sufficient investment incentives. They attributed this primarily to the politico-economic concern that the necessary high electricity price peaks in times of scarcity may not be sustained politically. With a similar reasoning, many German unions supported the introduction of capacity payments (DGB 2015, IG Metall 2015). Their interest to secure jobs in the energy sector as well as upstream industries (e.g., lignite mining etc.) may have contributed to this decision.

In turn, interest groups rejecting the introduction of fully fledged capacity markets could expect higher rents in a setting with a strengthened EOM. The renewable energy industry would have lost its comparative advantage (established by separate support schemes) by the implementation of broad-band capacity payments also for non-renewables. In turn, the strategic reserve allowed targeting payments to low-carbon technologies only. Consumer protection agencies, industry and household electricity consumers (i.e., voters), rejected additional capacity markets because of the expected electricity price increases (see Section 4.1.2). The consumers' basic interest in secure electricity supply could be satisfied by the strategic reserve as well. Moreover, a strengthened EOM with stronger incentives for demand-side management would also create new business opportunities for industry customers. Two other important opponents of capacity markets could also expect higher rents in a strengthened EOM: German TSOs (because the concept of a strengthened EOM involved significant investments into networks) and the power exchange EEX (because the concept of a strengthened EOM increased the importance of spot, day-ahead, future and balancing markets). Finally, electricity producers, TSOs and government agencies beyond Germany tended to reject a German capacity market because of potential negative impacts on their domestic EOM and, consequently, the profitability of domestic plants. At the same time, they tried to call for opportunities for domestic plants to participate in German strategic reserve or capacity market, should it be implemented.

Environmentalist interest groups preferred those policy choices which allowed a direct regulation of the electricity mix to promote the attainment of environmental objectives and to satisfy their green constituencies. Consequently, they clearly favoured a strategic reserve (either to withdraw dirty power plants from the market or to generate additional revenue streams for selected low-carbon technologies) or a focussed capacity market for flexible, low emission plants.

Bureaucracy theory (Niskanen 1971) regards also administrations as a sphere of self-interested actors. This may explain the position of the German regulatory agency BNetzA, which supported the introduction of capacity markets. These would have been managed by BNetzA and would have increased its regulatory scope, power and budget significantly.

Interestingly, in general scientists took an ambiguous role in the public debate. Commissioned by specific interest groups, some policy-oriented think tanks developed concrete proposals for the implementation of capacity payments (see Section 4.1.4). However, overall, academic economists tended to be rather sceptical whether capacity payments would actually be necessary at the moment to safeguard reliable electricity supply in Germany. They typically recommended to focus on strengthening the EOM and implement capacity payments only if this measure proves to be ineffective in the future.

4.3.2 The Eventual Policy Choice: Risk-averse Politicians Trading off Individual Interests

Consequently, a very diverse set of opinions and suggestions, based on different interests, were directed to policy makers. In general, the chances for interest groups from the energy sector to succeed with pleas for additional capacity payments (irrespectively of their actual design) were exceedingly beneficial. Following the theory of collective action (Olson 1965, 1982; Coleman 1966; Vanberg 1982), it becomes more difficult to organize interests, the more general and broad those interests are. If, in turn, just a small number of political actors share a common interest, its realization is strongly dependent on the contribution of every member of the group. Thereby, small, homogeneous groups can be organized much easier and therefore gain relatively more influence on the political process (consider, for instance, the leverage of industry interest groups as compared to the beneficiaries of environmental protection, Kirchgässner and Schneider 2003). This applies traditionally to the energy industry.

In the debate on capacity payments, the structurally high influence of interest groups was yet significantly higher because the question of how to safeguard security of supply involved a high potential for threatening and blackmailing policy-makers. To secure political support, policy-makers would do their utmost to prevent blackouts and to demonstrate action regarding the question of security of supply. The – even just indirect – threat of insecure electricity supply would have come at high political costs. Besides the blackouts itself, the faith in the ability of policy-makers to manage the German energy transition successfully would have been deeply unsettled in general. Consequently, risks in terms of security of supply needed to be strictly controlled from the point of view of vote-maximizing, risk-averse politicians (Gawel and Korte 2014). They were more afraid of the political risk of a blackout than of unpopular electricity price increases following the introduction of additional capacity payments. It was thus not surprising that relevant questions regarding the cost-effectiveness of capacity markets (and their potential impacts on electricity prices) were largely neglected politically.

In Germany, it remained rather unclear whether under-investments and capacity shortages were actually to be expected. The corresponding information was distributed asymmetrically between power plant operators and policy-makers. Hence, power plant operators interested in capacity payments could exploit their informational advantage. They sent signals to policy-makers which emphasized the trustworthiness of future under-investment and capacity shortages. These signals included publicly announced plans for shut-downs, ostentatiously practised investment restraints as well as complaints about losses of economic performance. It is impossible for politicians to assess from the outside to what extent this is just strategic behaviour.

These politico-economic considerations may help to explain why especially the Southern German States of Bavaria and Baden-Württemberg strongly advocated the introduction of capacity markets. These states host the major German load centres and responded particularly sensitive to security of supply risks.

Eventually, the Federal Ministry of Economic Affairs and Energy (BMWi), which had the lead for organizing the reform of the power market, took a Salomonic solution to satisfy the competing political interests simultaneously (Lehmann et al. 2016). It adopted a variety of (no-regret) measures to strengthen the EOM. These measures aimed at increasing the trust in the capacity of the EOM to deliver a sufficient level of security of supply. At the same time, it installed the strategic reserve as a safeguard. Thus, it abstained from implementing a fully-fledged capacity market at the moment – and thus satisfied those actors arguing that the market will do. The strategic reserve addressed the security of supply concerns posed by other actors. Moreover, the "security stand-by", the add-on to the strategic reserve had particular political appeal. By withdrawing old, emission-intensive coal-fired power plants from the market the security stand-by helped to pacify the parallel political debate on how to attain Germany's greenhouse gas reduction targets effectively. Thus, the strategic reserve, in combination with the security stand-by, killed two birds (political concerns related to security of supply and climate change) with one stone.

Certainly, the double strategy of strengthening the EOM and complementing it with the strategic reserve to safeguard security of supply opens up for a political dilemma (Bundesnetzagentur 2015, Gawel and Korte 2014; Lehmann et al. 2015, Lehmann et al. 2016). Any political strategy aimed at ensuring security of supply without broad-band capacity markets can only work if policy-makers can give credible assurances that such capacity mechanism will not be introduced in the foreseeable future. Otherwise a self-fulfilling prophecy threatens: in expectation of possible future capacity payments companies might see themselves incentivised to strategically hold off on investments and, with the announcement of power plant shut-downs, create a political threat. Ultimately, even just the political prospect of a future possibility of a capacity mechanism would in the end make it politically inevitable due to this strategic withholding of investment. By installing the strategic reserve, policy-makers may thus undermine the trust in the EOM – which would be necessary to incentivize sufficient levels of capacity investments. Also, the policy-makers cannot credibly exclude additional regulatory amendments, e.g., if new information on actual under-investment and capacity shortages becomes available. In addition, the security stand-by constituted a rather obvious political concession to specific stakeholders from the lignite industry, which might raise expectations for similar concessions to other sectors. It thus remains unclear whether policy-makers will withstand the political pressures to implement more comprehensive capacity payments in the future.

5 Concluding Discussion and Implications for Sweden

5.1 LESSONS FROM THE GERMAN POLICY DEBATE: SECURITY OF SUPPLY PROBLEMS REQUIRE SYSTEMIC PERSPECTIVES AND SOLUTIONS

The literature as well as the public debate on security of supply symbolizes the complexity and manifold uncertainties associated with energy transitions in Germany and Europe. Particularly under these circumstances, from a scientific perspective, it is important at this point not to make far-reaching and profound decisions such as introducing novel, permanent regulatory instruments in the absence of clear evidence. It would appear to make more sense to have a security of supply policy that stands on many legs. A portfolio of measures can help to tackle the diverse causes of possible capacity constraints in a more targeted and cost-effective manner. Specifically, based on the analysis presented in this report, eleven generic lessons from the German policy debate are useful to stress:

1. **Building fossil-fuelled power plants is not the only option available to provide security of supply.** In principle, all actors in the electricity supply system - operators of non-renewable and renewable energy installations, grids and storage systems as well as energy consumers - can contribute to security of supply as well. When discussing measures for safeguarding security of supply contributions by all these actors need to be taken into account properly.

2. **Flexibility of capacities matters.** Security of supply does not only refer to an adequate amount of generation capacities. Additionally, sufficiently flexible capacities (generation, storage, demand-side management) must be available in order to be able to respond to short-term, unexpected disruptions in the system so that grid stability can be guaranteed, ideally at all times.

3. **Potential problems of security of supply typically have multiple causes.** Under-investment and capacity shortages may be due to a diverse set of market and policy failures (e.g., price caps, inflexible demand, market power, regulatory uncertainty). Policy-makers seeking solutions to these problems of security of supply therefore need a thorough understanding of these causes. A policy response that only addresses selected causes (such as the missing-money problem) is certainly inadequate to safeguard security of supply.

4. **Energy transitions do not fundamentally question security of supply.** Without a doubt, particularly the increasing share of (intermittent) renewable energy sources in electricity generation as a whole creates new challenges for ensuring security of supply. However, market participants will respond to this dynamic change of the energy system properly if the designs of electricity markets and the broader regulatory framework allow them to do so. Certainly, an energy transition should not be scapegoated for potential supply constraints. Even in the absence of an energy transition, the diverse market and policy failures (e.g., short-term profit maximization under uncertainty and/or low demand responses) may cause issues of supply.

5. **Challenges to security of supply (and adequate responses) are highly context-specific and uncertain.** In Germany, concerns regarding security of supply have emerged in a very puzzling environment. On the one hand, electricity generation exhibits significant overcapacities. On the other, the phase-out of nuclear power generation and the publicly supported the deployment of primarily intermittent renewable generation do affect market signals and investment incentives. It is thus unclear *ex ante* whether actual or threatened closures of power plants are economically sensible responses to over-capacities – or rather pointing towards a specific challenge arising in the context of an energy transition. Moreover, the technological and regulatory frameworks are evolving very dynamically which makes it difficult to anticipate whether and how quickly markets and market actors will adapt to changing circumstances. These specific circumstances need to be taken into account when transferring lessons from one national context to another.

6. **Security of supply risks should not be minimized at all costs.** A reasonable discussion of measures aimed at ensuring security of supply must consider all societally relevant criteria (including also cost-effectiveness, social and environmental compatibility) and objectives (greenhouse gas reduction targets, RES deployment targets). Unquestionably, a certain level of security of supply should be guaranteed at the lowest possible cost. In addition, distributional impacts need to be considered carefully. Finally, measures need to be compatible with the national goals for climate protection and renewable energy deployment a country has committed to.

7. **Security of supply needs to be provided by an intelligent portfolio of measures instead of single capacity payments for fossil-fired power plants.** A portfolio of measures helps to tackle the diverse causes of possible capacity constraints in a more targeted and cost-effective manner. Thus, the political debate should not be narrowed down to a single policy instrument like an additional capacity payment. In fact, if implemented in isolation, broad-band capacity payments do not necessarily activate precisely those options that are cost-effective and flexible enough to balance supply and demand – such as flexible power plants, storage systems or demand side management. Certainly, the design of a policy mix to safeguard security of supply needs to consider possible interactions between the different policy measures carefully.

8. **The assessment of national measures to safeguard security of supply needs to include a European perspective.** Given that markets are internationally interwoven, assessments of future challenges to security of supply and corresponding policy responses need to account for interdependencies with electricity supply and demand abroad. This perspective may reduce (e.g., if electricity can be imported) as well as increase (e.g., if other countries adopt capacity payments) the need to take national action. Certainly, a stronger European coordination of measures to safeguard security of supply is politically challenging since countries have different preferences in terms of security of supply and have therefore tended to maintain decision-making responsibilities at the national level (Strunz et al. 2015).

9. **Measures to safeguard security of supply should consider the cost of potential institutional lock-ins.** For example, implementing a completely new capacity market with broad-band payments for all capacities will create an important path dependency: Once established it can only be adjusted to changing circumstances, or even fundamentally revised, with difficulty. After all, it is to be expected that the future recipients of payments will have a vested interest in maintaining the payments and that they will assert their interest politically. Such a lock-in effect will be less pronounced with less invasive policy strategies, such as, for example, a strategic reserve. The option to learn and improve policies over time is particularly valuable if policy benefits (in terms of safeguarding security of supply) and costs (e.g., power price increases) are still largely uncertain.

10. **The possible political decision to abstain from additional capacity payments requires credible long-term commitment.** A political strategy aimed at ensuring security of supply without capacity payments can only work if policy makers can give credible assurances that a capacity mechanism will not be introduced in the foreseeable future. Otherwise a self-fulfilling prophecy threatens: in expectation of possible future capacity payments, companies might see themselves incentivized to strategically withhold investments and, with the announcement of power plant shutdowns, create a political threat. Full commitment is certainly challenging given the uncertainty of future investments and capacity shortages. However, policy-makers need to be aware that even just the political prospect of a future possibility of a capacity mechanism could in the end make it politically inevitable.

11. **Consultation processes are useful to prepare the political decision.** Given the complexity and uncertainty involved, it is important that the political process is designed to be as transparent and participatory as possible so that the perspectives of all the relevant actors - including those of electricity suppliers, grid and storage system operators and, not least, energy consumers can be given due consideration. This will help to: (a) incorporate additional information; (b) make the interests of different groups as well as their impact on the actual outcome of policy making more transparent; and (c) may eventually increase the efficiency and acceptance of the decision-making process – as the Green and White Paper process of the German Ministry of Economic Affairs and Energy has demonstrated.

It is the task of policy makers to evaluate the established uncertainties with regard to ensuring the supply of electricity and to make decisions on this basis. Therefore, it would be politically legitimate if, following careful and transparent consideration, political decision makers were to conclude that additional capacity-building measures are essential to safeguard against possible supply constraints. Transparency might imply specifying an explicit security of supply target. Germany has not yet – as a number of other EU member states already have – issued a quantifiable reliability target; such a target could be indicated in terms of "loss of load expectation" (LOLE sets out the number of hours per year during which some customer disconnection is expected) or "expected energy not served" (EENS sets out the expected amount of MWh not served during a given period).

Germany does routinely carry out assessments of generation capacity adequacy based on these and other measures (see EU Commission 2016: 71ff.), so one could argue that issuing an explicit target constitutes the next logical step. The EU Commission’s investigation of Germany’s capacity reserve scheme will possibly build up pressure in this respect.

In any case, given the current knowledge gaps, it would be crucial that the mechanism be selected in such a way that less rigid structures emerge in the future which – with better evidence of the performance capacity of conventional electricity markets and a clear understanding of the advantages and disadvantages of various measures – would not be difficult to adjust. Therefore, if a decision in favor of capacity payments is taken at a political level, then efforts should be made to ensure a strategic, centrally administered capacity reserve (strategic reserve) as a short- and medium-term risk buffer. This approach could provide the required flexible capacities in a targeted manner. What is more, it could be reversed at any time.

5.2 LESSONS FOR THE CHALLENGES FACING SWEDISH MARKET DESIGN: STRENGTHEN THE ENERGY-ONLY-MARKET AND ADOPT A “WAIT, SEE AND EVALUATE” APPROACH TO CAPACITY MECHANISMS

As different countries’ electricity markets have distinct features, one should be very careful in drawing too far-fetched – and not least very detailed – implications for Swedish regulatory design based on the German experiences. The organization and the design of the Swedish and German market differ in several ways (see examples below), as do the generation mixes. Most notably in the latter case, from a security of supply perspective Sweden (and the Nordic power system as a whole) benefits a lot from having ample access to hydropower. In Sweden hydropower accounts for about 40 percent of total power generation (in the year 2016), while the corresponding share in Germany is just above 3 percent. Hydropower is highly flexible in terms of balancing short-term variations in intermittent generation and compensating shortfalls of such generation during several days (Bergman et al. 2017). For this reason the challenges associated with the expansion of intermittent power generations are overall less pressing in the Nordic market compared to the German one. Moreover, the liberalization of the electricity market has generally been more far-reaching in the Nordic case.

Keeping the above differences and caveats in mind, the remainder of this section discusses some general lessons for how to address the security of supply of the future electricity supply system in Sweden. In achieving this, we relate to and comment on the findings and suggestions outlined by the so-called EFORIS panel project, which has aimed at analyzing the question of whether there is a need for a Swedish electricity market reform in light of the expected increases in wind and solar power (Bergman et al. 2017). This report considered both measures that can be implemented to improve the EOM, as well as the option to introduce a capacity mechanism (instead of the existing strategic reserve).

A first lesson is that in the choice between these two general options, our analysis supports the conclusion that a portfolio of measures that strengthen the EOM can help to address the causes of security of supply concerns in a more targeted and cost-effective manner compared to capacity mechanisms. Thus, the strengthening of existing structures should likely have priority. Compared to the German market design, the Swedish market has many characteristics that are compatible with safe-guarding security of supply. These include not only a high share of hydropower, but also, for instance, regionally differentiated wholesale prices and an integrated Nordic (and beyond) EOM that permits international trade in electricity.

Nevertheless, there is also scope for a further strengthening of the Swedish market design. In Sweden there are regulated caps on the price of electricity, and these have occasionally not been at sufficiently high levels (e.g., Tangerås 2015). First, according to existing Nordpool rules, both the day-ahead prices and the prices in the balance market are capped at levels that by all likelihood are considerably lower than the values an average consumer assigns an unsupplied MWh of energy (the so-called value of lost load, VOLL).[16]

In addition, when a market-clearing price cannot be established in the day-ahead market (through the regular bids), the Swedish Transmission System Operator, Svenska Kraftnät, is mandated to activate the strategic reserve and procure access to production capacity. In the recent past the price of electricity provided by the reserve is set just above (Euro 0.1) the highest bid (e.g., equaling the variable cost of peak load plants). This means in turn that it has not reflected the so-called scarcity rent, i.e., the difference between the market price and the variable cost in the marginal plant needed to clear the market. Such a *de facto* cap on the price of electricity will lead to underinvestment in peak load capacity, this since the lower (capped) price is not high enough to cover the fixed costs of capacity increases. In addition, it will also reduce the incentives for energy efficiency measures and energy storage.

In other words, while the Swedish strategic reserve has provided extra capacity, this also weakens the incentives for market-based provision of security of supply of various forms (see also Bergman et al. 2017). In this way the strategic reserve has in a way contributed to creating the problems that it is intended to resolve. However, in 2017 the Swedish TSO Svenska Kraftnät decided to introduce a higher price cap, i.e., Euro 3000 per MWh, thus providing higher revenues for peak load capacity during periods of scarcity pricing. This change will be effectuated during the winter 2017/18, and it will also facilitate further harmonization with the Finnish electricity system in which a corresponding (higher) price cap was introduced in late 2016.

The above assertions are well in line with the first recommendations made by the so-called EFORIS panel project, namely that several minor changes of the design of the Swedish electricity market are needed in a first step. The Panel suggests that the caps on market prices are raised, trading intervals are reduced, the balance requirements are referred to shorter (than hourly) periods, the gate closure is set closer to the time of delivery etc. (Bergman et al. 2017). In other words, the Panel contends, there is little evidence, at least to date, that the overall model for pricing

[16] It is difficult to define a single value for VOLL because it will be dependent on many conditions, such as the activities effected by the curtailment and therefore, for instance, the time of day, the number of interruptions, and their duration.

electricity in the Nordic area will not work also in the future. Still, amendments of the EOM are likely to be required to better address security of supply concerns.

While we agree with these conclusions, our report also suggests that in evaluating measures to address security of supply concerns an even broader mix of (both new and existing) instruments and regulations needs to be evaluated and considered. In other words, there are numerous ways to strengthen the existing market design, such as improving the transparency and timeliness of permitting procedures for new capacity, allowing for demand-side management, different ways of designing the electricity certificate scheme with respect to flexible RES-feed-in, network regulation as well as removing any (e.g., regulative and tax-related) obstacles to improving flexibility in the system (e.g., battery storage).

Technological change in, for instance, smart metering and demand side solutions such as battery storage etc., is developing quite rapidly, thus suggesting that the (option) value of waiting for new information should be high. However, it should be recognized that some of the new technical solutions may not be well aligned with existing legislation and institutions. For instance, the Swedish Energy Markets Inspectorate has noted that a more integrated electricity system implies greater difficulties in making clear legal distinctions between generation, distribution and use. For instance, the way in which battery storages will be regulated depends on whether it is considered to be a generation source or if it is part of the network. In this case the legislation does not, it is argued, provide enough clarity. The design of energy taxes may also hamper the diffusion of new solutions delivering security of supply services. If such regulatory considerations are not clarified – and inefficient obstacles removed – there is a risk that the supply of system services becomes too limited.

In the longer-run, the EFORIS panel project suggests that, if deemed necessary, the current strategic reserve could be replaced by en extended capacity mechanism (i.e., preferably a Nordic one). This report therefore proposes that a quantitative measure of supply security is defined and monitored and that a trigger value at which an extended capacity mechanism is needed is determined (Bergman et al. 2017).

Here our assessment is also slightly different. Capacity mechanisms have clear drawbacks, and the proposed measure essentially implies the introduction of such a mechanism (even if it is only the introduction of a quantitative measure). Again, before such measures are proposed it would be necessary to look at a broader portfolio of measures that can be introduced out of which most involve revisions of existing regulations and policies, and then evaluate these in the context of the sometimes conflicting objectives of renewable energy penetration, security of supply, competitiveness etc. Moreover, quantitative measures of security of supply are far from straightforward to define, monitor and evaluate;[17] there is a risk that such a measure becomes too constraining and implies an exaggerated focus on

[17] For instance, the distributional effects of capacity mechanisms are also difficult to assert, but they may give rise to a substantial redistribution of income from consumers to producers. From a Swedish perspective this issue needs particular attention given the importance of energy-intensive industries for the country's economy.

security-of-supply (e.g., Bergman 2016). Another risk is associated with inefficient investments and international trade in electricity if different countries employ different means of addressing security of supply concerns. These mechanisms may also undermine adjustments in the form of voluntary capacity contracts between producers and retailers and between producers of intermittent electricity and conventional producers.

Moreover, and equally important, the political economy of introducing (and even proposing) capacity mechanisms should be considered at greater depth. First, once implemented capacity mechanisms may be difficult to adapt, or revise, to address changing framework conditions. Second, in the expectation of future capacity payments, electricity generators may strategically withhold necessary investments (or even shut down existing power plants) to increase (or generate) capacity shortages, something which may make the introduction of capacity mechanisms inevitable. Thus, making early announcements of future capacity payments may generate a self-reinforcing process.

Thus, the above tends to speak for a wait, see and evaluate strategy (as suggested also by Bergman 2016), and thus refrain from making early, future commitments regarding the introduction of trigger values, quantitative measures and more extended capacity mechanisms. Such an approach is also motivated by the fact that currently there is, unlike the situation in Germany, no urgent need for reserve capacity in the Swedish electricity system. This is much due to the high share of hydropower in the Nordic system. Still, if several nuclear plants are phased out the picture may change quickly. The future profitability of wind power and solar PV is also uncertain, e.g., in the presence of high wind power generation under periods of low electricity prices. Several issues need to be addressed and evaluated in full, and in the next section we highlight some important avenues for future research with special references to the Swedish (and Nordic) market.

5.3 AVENUES FOR FUTURE RESEARCH AND EVALUATION STUDIES

This report has addressed the challenges involved in adapting electricity market design to a situation with high proportion of intermittent power, and where the main conceptual contribution of the report has concerned identifying the potential causes of security of supply problems as well as discussing how different policy responses – and combinations of policy measures – can be implemented to address these problems. It should be evident however that additional empirical research is needed for a better understanding of the significance of various market and policy failures. Such research ought to target a broad range of potential failures, i.e., price caps, inflexible demand, market power, regulatory hurdles and uncertainty etc.

Similarly, future research on the market design options available for addressing the security of supply problems associated with high shares of renewables should not be narrowed down to single policy instruments such as additional capacity payments, but rather address a combination of measures and their interaction. For instance, the various support schemes for renewable electricity have primarily been analyzed from the perspective of their ability to promote the adoption of new technology, but increased attention could also be devoted to, for instance, the option of strengthening the premium paid for flexibility provision. This does not, of course, exclude additional research on capacity mechanisms, and with special emphasis on how such a mechanism could be efficiently implemented in the (Nordic) market and the consequence of this (e.g., distributional impacts).

In the specific context of Swedish electricity market design there is also a need to better understand the future prospects for introducing high shares of wind power and solar PV in the Nordic electricity market.[18] This development will determine the future demand for different types of options for safe-guarding security of supply. However, the future profitability of these options is also highly uncertain; it will depend not only on the aggregate penetration of intermittent power but also on the competitiveness between different types of options, i.e., flexible generation versus demand flexibility. For instance, to what extent can battery storages be expected to undermine the competitiveness of balancing capacity of hydropower in Norway and Sweden? Moreover, the future role of consumer demand flexibility also needs to be scrutinized.

The experiences from the German energy transition have also highlighted the role of political economy issues in the empirical context of security of supply. These issues also deserve further scrutiny, e.g., by analyzing in more depth the potential presence of firm-regulatory information asymmetries in the electricity market and their role in shaping policy outcomes. In the light of politicians' reluctance to lose the citizens' faith in their ability to manage the electricity system, the arguments questioning the cost-effectiveness of capacity mechanisms could be neglected in the policy process.

[18] Bergman (2016) notes that future economic analyses would benefit greatly from the development of an electricity market model in which future short-term variations in Nordic wind power and solar PV generation could be represented and analyzed.

6 References

50Hertz, Amprion, Tennet, and TransnetBW (2013). Bericht der deutschen Übertragungsnetzbetreiber zur Leistungsbilanz 2013 nach EnWG § 12 Abs. 4 und 5, o. O, 2013.

50Hertz, Amprion, Tennet, and TransnetBW (2015). Gemeinsame Stellungnahme der Übertragungsnetzbetreiber zum Grünbuch Ein Strommarkt für die Energiewende, o. O, 2013.

Abbot, M. (2001). Is the Security of Electricity Supply a Public Good? The Electricity Journal, August/September, 31-33.

AEE (2013). Studienvergleich AEE: Bedarf an Steuerbaren Kapazitäten im Stromsystem. Agentur für Erneuerbare Energien, Berlin.

Agora Energiewende (2012). Brauchen wir einen kapazitätsmarkt? Berlin. Online: https://www.agora-energiewende.de/fileadmin/Projekte/2012/Kapazitaetsmarkt-oder-strategische-Reserve/Agora_Impulse_Kapazitaetsmarkt-Veranstaltung_24082012_web.pdf (accessed 12.04.2017).

Agricola, A.-C., B. Höflich, P. Richard et al. (2012). Ausbau- und Innovationsbedarf der Stromverteilnetze in Deutschland bis 2030 (dena-Verteilnetzstudie). Deutsche Energi-Agentur, Berlin.

Andor, M., K. Flinkerbusch, and A. Voß (2012). Quantities vs. Capacities: Minimizing the Social Cost of Renewable Energy Promotion. Centrum für Angewandte Wirtschaftsforschung, Münster.

Arent, D., C. Arndt, M. Miller, F. Tarp, and O. Zinaman (Eds.) (2017). The Political Economy of Clean Energy Transitions. Oxford University Press, Oxford.

Auer, H. & Haas, R. (2016). On integrating large shares of variable renewables into the electricity system. Energy 115, Part 3, 1592-1601.

Baden-Württemberg (2015). Stellungnahme des Ministeriums für Umwelt, Klima und Energiewirtschaft des Landes Baden-Württemberg zum Grünbuch des Bundesministeriums für Wirtschaft und Energie. Ministerium für Umwelt, Klima und Energiewirtschaft Baden-Württemberg, Stuttgart.

Bayern (2015). Stellungnahme zum Grünbuch „Ein Strommarkt für die Energiewende". Bayerisches Staatsministerium für Wirtschaft und Medien, Energie und Technologie, München.

BDEW (2014). Stellungnahme zum Diskussionspapier des Bundesministeriums für Wirtschaft und Energie (Grünbuch). Ein Strommarkt für die Energiewende. Bundesverband der Energie- und Wasserwirtschaft, Berlin.

BDEW (2017). Der Verband. Bundesverband der Energie- und Wasserwirtschaft, Berlin. Online: https://www.bdew.de/internet.nsf/id/3234B9552AA5EA77C12578-33003BF17F (accessed 10.04.2017).

BDI (2015). Ergänzungsanmerkungen Grünbuch Strommarkt. Bundesverband der Deutschen Industrie, Berlin.

Becker, G. S. (1983). A Theory of Competition among Pressure Groups for Political Influence. The Quarterly Journal of Economics, 98(3), 371-400.

Beckers, T., and A. Hoffrichter (2014). Grundsätzliche und aktuelle Fragen des institutionellen Stromsektordesigns – Eine institutionenökonomische Analyse zur Bereitstellung und Refinanzierung von Erzeugungsanlagen mit Fokus auf FEE. Arbeitspapier, TU Berlin, Fachgebiet Wirtschafts- und Infrastrukturpolitik (WIP).

Beckers, T., A. Hoffrichter and C. von Hirschhausen (2012). Internationale Erfahrungen mit Kapazitätsinstrumenten und Schlussfolgerungen für die deutsche Diskussion. Technische Universität Berlin, Berlin.

BEE (2015). BEE-Stellungnahme zum Diskussionspapier des Bundesministeriums für Wirtschaft und Energie (Grünbuch). Ein Strommarkt für die Energiewende. Bundesverband Erneuerbare Energien e.V. (BEE), Berlin.

Benitez, L. E., P. C. Benitez, and G. C. van Kooten (2008). The Economics of Wind Power with Energy Storage. Energy Economics, 65, 1973-1989.

Bergler, J., S. Heim and K. Hüschelrath (2016). Strategic Capacity Withholding Through Failures in the German-Austrian Electricity Market. Discussion Paper No. 16-009, Centre for European Economic Research (ZEW), Mannheim.

Bergman, L. (2016). Mot en integrerad europeisk marknad för el? En studie om kapacitetsmekanismer. Report 2016:263, Energiforsk, Stockholm.

Bergman, L., M. Nilsson, E. S. Amundsen, N. Damsgaard, H. Feuk, N-H. von den Fehr, A. Guldbrand, L. Joelsson, P. Lundström, and T. Unger (2017). Time for a Second Electricity Market Reform? Conclusions of the EFORIS Panel Project, Report 2017:402, Energiforsk, Stockholm.

BET (2011). Kapazitätsmarkt – Rahmenbedingungen, Notwendigkeit und Eck-punkte einer Ausgestaltung. Büro für Energiewirtschaft und technische Planung (BET), Aachen.

BKartA (2015). Stellungnahme des Bundeskartellamtes zum Diskussionspapier des Bundesministeriums für Wirtschaft und Energie (Grünbuch) „Ein Strommarkt für die Energiewende“. Bundeskartellamt, Bonn.

BMU, BDEW, BEE, Ecofys, Hochschule Regensburg, r2b Energy Consulting, Institut für Elektrische Anlagen und Energiewirtschaft (IAEW) der Rhein-Westfälischen Technischen Hochschule (RWTH) Aachen, Fraunhofer Gesellschaft (FhG) Institut für Innovationsforschung und Systemanalyse (ISI), Consentec (2013). Märkte stärken, Versorgung sichern. Konzept für die Umsetzung einer Strategischen Reserve in Deutschland. Ergebnisbericht des Fachdialogs „Strategische Reserve“. Online: https://www.bdew.de/internet.nsf/res/-E69B9CA8FB2C03C7C1257BEF002F1447/$file/Anlage_5_130503_FachdialogStrategischeReserve_Ergebnisbericht_final.pdf (accessed 30.11. 2016).

BMWi (2013). Langfristige Steuerung der Versorgungssicherheit im Stromsektor. Gutachten des Wissenschaftlichen Beirats beim Bundesministerium für Wirtschaft und Energie, Online: http://www.bmwi.de/BMWi/Redaktion/PDF/Publikationen/-Studien/wissenschaftlicher-beirat-langfristige-steuerung-derversorgungssicherheit-im-stromsektor,property=pdf,bereich=bmwi2012,sprache=de,rwb=true.pdf.

BMWi (2014). An Electricity Market for Germany's Energy Transition (Green Paper). Discussion Paper of the Federal Ministry for Economic Affairs and Energy, Berlin.

BMWi (2015a). An Electricity Market for Germany’s Energy Transition. White Paper by the Federal Ministry for Economic Affairs and Energy, Berlin.

BMWi (2015b). Stellungnahmen zum Grünbuch "Ein Strommarkt für die Energiewende“. Online: http://www.bmwi.de/Navigation/DE/Service/Stellungnahmen/Gruenbuch/stellungnahmen-gruenbuch.html (Accessed 29.03.2017).

BMWi (2015c). Detaillierte Auswertung der Konsultation. Ergebnisse der Konsultation des Grünbuchs: Ein Strommarkt für die Energiewende (Konsultationsdokument), Berlin

BMWi (2016). EEG-Novelle 2016. Fortgeschriebenes Eckpunktepapier zum Vorschlag des BMWi für das neue EEG, Berlin.

Böckers, V., L. Giessing, J. Haucap, U. Heimeshoff and J. Rösch (2012). Braucht Deutschland einen Kapazitätsmarkt für Kraftwerke? Eine Analyse des deutschen Marktes für Stromerzeugung. Ordnungspolitische Perspektiven Nr. 24, Düsseldorfer Institut für Wettbewerbsökonomie, Düsseldorf.

Borenstein, S. (2008). The Market Value and Cost of Solar Photovoltaic Electricity Production, CSEM Working Paper 176, University of California Energy Institute, Berkley.

Borggrefe, F. et al. (2014). Kurzstudie zur Kapazitätsentwicklung in Süddeutschland bis 2025 unter Berücksichtigung der Situation in Deutschland und den europäischen Nachbarstaaten. Kurzstudie des Deutsches Zentrum für Luft und Raumfahrt (DLR) und Institut für Energiewirtschaft und rationelle Energieanwendung (IER) der Universität Stuttgart im Auftrag des Landesministeriums für Umwelt und Energiewirtschaft Baden-Württemberg (UMBW), Stuttgart.

Brunekreeft, G., and R. Meyer (2011). Netzinvestitionen im Strommarkt: Anreiz- oder Hemmniswirkungen der deutschen Anreizregulierung? Energiewirtschaftliche Tagesfragen, 61(1/2), 2-5.

Buchanan, J. M. (1965). An economic theory of clubs. Economica, 32(125), 1-14.

Buchanan, J. M. (1984). Politics without Romance: A Sketch of Positive Public Choice Theory and its Normative Implications. In J. M. Buchanan, and R. Tollison (Eds.), The Theory of Public Choice II. Michigan University Press, Ann Arbor, pp. 11-22.

BUND (2015). Stellungnahme des BUND zum Grünbuch „Ein Strommarkt für die Energiewende“ des Bundesministeriums für Wirtschaft und Energie. Bund für Umwelt und Naturschutz Deutschland, Berlin.

Bundesamt für Energie (BFE), Eidgenossische Elektrizitätskommission (ElCom), swisselectric, Swissgrid, and Verband Schweizerischer Elektrizitätsunternehmen (VSE) (2015). Stellungnahme zum Diskussionspapier „Ein Strommarkt für die Energiewende“ des Bundesministeriums für Wirtschaft und Energie (Grünbuch), Bern.

Bundesnetzagentur (2013). Bericht zum Zustand der leitungsgebundenen Energieversorgung im Winter 2012/13, Bonn.

Bundesnetzagentur (2015). Stellungnahme zum Diskussionspapier des Bundesministeriums für Wirtschaft und Energie: „Ein Strommarkt für die Energiewende“ (sog. Grünbuch), Bonn.

Bundesnetzagentur & Bundeskartellamt (2013). Monitoringbericht 2013, Bonn.

CDU/CSU/SPD (2013). Deutschland Zukunft gestalten. Koalitionsvertrag zwischen CDU, CSU und SPD 18. Online: https://www.bundesregierung.de/Content/DE-/_Anlagen/2013/2013-12-17-koalitionsvertrag.pdf?__blob=publicationFile (accessed 10.04.2017).

Coleman, J. S. (1966). Individual Interests and Collective Action. Papers on Non-Market Decision-Making, 1, 49-62.

Connect Energy Economics (2014). Leitstudie Strommarkt Arbeitspaket Optimierung des Strommarktdesigns im Auftrag des Bundesministeriums für Wirtschaft und Energie, Berlin.

Couture, T., and Y. Gagnon (2010). An Analysis of Feed-in Tariff Remuneration Models: Implications for Renewable Energy Investment. Energy Policy, 38(2), 955-965.

Cramton, P., and A. Ockenfels (2012). Economics and Design of Capacity Markets for the Power Sector. Zeitschrift für Energiewirtschaft, 36, 113-134.

Cramton, P., A. Ockenfels, and S. Stoft (2013). Capacity Market Fundamentals. Economics of Energy & Environmental Policy, 2(2), 27-46.

Czech Republic (2015). The Czech Republic´s Comments on the Discussion Paper of the Federal Ministry for Economic Affairs and Energy (Green Paper). Ministry of Industry and Trade of the Czech Republic, Prague.

Denmark (2015). Comments from Denmark on the Green Paper ‘An Electricity Market for Germany’s Energy Transition’. Danish Ministry of Climate, Energy and Building, Copenhagen.

DGB (2015). Stellungnahme des Deutschen Gewerkschaftsbundes zum Grünbuch „Ein Strommarkt für die Energiewende“ des Bundesministeriums für Wirtschaft und Energie (BMWi). Deutscher Gewerkschaftsbund, Berlin.

DIHK (2015). Stellungnahme zum Diskussionspapier des Bundesministeriums für Wirtschaft und Energie (Grünbuch) „Strommarkt für die Energiewende“ vom 31. Oktober 2014. Deutscher Industrie – und Handelskammertag, Berlin.

Doherty, R., H. Outhred and M. O'Malley (2006). Establishing the Role that Wind Generation May Have in Guture Generation Portfolios. IEEE Transactions on Power Systems, 21(3), 1415-1422.

Drake, F.-D., C. Gatzen, E. Hauptmeier, F. Schulte, and M. Zähringer (2013). Sind Speicher wirklich der fehlende Baustein zur Energiewende? Energiewirtschaftliche Tagesfragen, 63(8), 34-38.

E.ON (2015). E.ON Position: „Ein Strommarkt für die Energiewende“. Diskussionspapier des Bundesministeriums für Wirtschaft und Energie (Grünbuch). E.ON SE, Düsseldorf.

Ecke, J., N. Herrmann, U. Hilmes, R. Kremp, U. Macharey, A. Nilde, H. Wolter, and W. Zander (2013). Ein zukunftsfähiges Energiemarktdesign für Deutschland. Studie im Auftrag des Verbands Kommunaler Unternehmen (VKU), Berlin.

e-control (2015). Betreffend: Grünbuch “Ein Strommarkt für die Energiewende”, Stellungnahme der Energie-Control Austria. Energie-Control Austria für die Regulierung der Elektrizitäts- und Erdgaswirtschaft, Wien.

EEX (2015). Stellungnahme der European Energy Exchange AG. Grünbuch: Ein Strommarkt für die Energiewende. European Energy Exchange AG, Leipzig.

EEX (2016). Futures Market Data. Online: https://www.eex.com/en/market-data/power/futures (accessed 14.12.2016).

Eid, C., P. Codani, Y. Perez, J. Reneses, and R. Hakvoort (2016). Managing Electric Flexibility from Distributed Energy Resources: A Review of Incentives for Market Design. Renewable and Sustainable Energy Reviews, 64, 237-247.

Elberg, C., C. Growitsch, F. Höffler, and J. Richter. (2012). Untersuchungen zu einem zukunftsfähigen Strommarktdesign. Studie im Auftrag des BMWi, durchgeführt vom Energiewirtschaftliches Institut an der Universität Köln, Köln.

Elsenbast, W. (2011). Investitionsanreize bei der Regulierung der Energieinfrastruktur. Wirtschaftsdienst, 91(11), 784-791.

EnBW (2015). Stellungnahme der EnBW Energie Baden – Württemberg AG zum Diskussionspapier des Bundesministeriums für Wirtschaft und Energie Ein Strommarkt für die Energiewende (Grünbuch). Energie Baden - Württemberg AG, Karlsruhe.

Energetische Biomassenutzung (2015). Stellungnahme zum Grünbuch “Ein Strommarkt für die Energiewende“ des Bundesministeriums für Wirtschaft und Energie. Perspektiven der Biomasseverstromung aus Sicht des Förderprogramms „Energetische Biomassenutzung“, o. O.

Energy Brainpool (2014). Zukünftige Auswirkungen der Sechs-Stunden-Regelung gemäß §24 EEG 2014. Kurzstudie im Auftrag des Bundesverbandes Windenergie (BWE), Berlin.

ENTSO-E (2013). Scenario Outlook and Adequacy Forecast 2013-2030. European Network of Transmission System Operators for Electricity (ENTSO-E), Brussels.

EPEX Spot (2013). Power for Today. Power for Tomorrow. Impact of Renewables on Market Prices. Online: http://static.epexspot.com/document/25343/EPEX%20-SPOT%27s%20presentation info (accessed 19.12.2016).

EPEX Spot (2016). Products. Online: https://www.epexspot.com/en/product-info (accessed 14.12.2016).

Erdogdu, E. (2014). The Political Economy of Electricity Market Liberalization: A Cross-country Approach. The Energy Journal, 35(3), 91-128.

EU Commission (2016). Commission staff working document accompanying the document "Final Report of the Sector Inquiry on Capacity Mechanisms". SWD(2016) 385 final, Brussels.

EWE (2015). „Ein Strommarkt für die Energiewende". Grünbuch des Bundesministeriums für Wirtschaft und Energie vom 31.10.2014. EWE AG, Oldenburg.

Finon, D., and V. Pignon (2008). Electricity and Long-term Capacity Adequacy: The Quest for Regulatory Mechanism Compatible with Electricity Market. Utilities Policy, 16(3), 143-158.

Finon, D. (2014). Capacity Mechanisms and Cross-Border Participation: The EU Wide Approach in Question. CEEM Working Paper 2014-8, Dauphine University Paris, Paris.

Fogelberg, S., and E. Lazarczyk (2015). Wind Power Volatility and the Impact on Failure Rates in the Nordic Electricity Market. IFN Working Paper No. 1065, Research Institute of Industrial Economics, Stockholm.

Forsund, F., and L. Hjalmarsson (2011). Renewable Energy Expansion and the Value of Balance Regulation Power. In P-O. Johansson, and B. Kriström (Eds.), Modern Cost-benefit Analysis of Hydropower Conflicts, Edward Elgar, Cheltenham, 97-126.

FÖS (2015). Strommarktdesign: Thesen zu unterschiedlichen Reformoptionen. Forum Ökologisch-Soziale Marktwirtschaft, Berlin.

Frontier Economics (2014). Strommarkt in Deutschland – Gewährleistet das derzeitige Marktdesign Versorgungssicherheit? Frontier Economics, London.

Frontier Economics and Consentec (2014). Folgenabschätzung Kapazitätsmechanismen (Impact Assessment). Gutachten im Auftrag des Bundesministeriums für Wirtschaft und Energie (BMWi), London, Aachen.

Frontier Economics and Formaet (2014). Strommarkt in Deutschland – Gewährleistet das derzeitige Marktdesign Versorgungssicherheit? Bericht für das Bundesministerium für Wirtschaft und Energie, London, Aachen.

Gaidosch, L. (2008). Zyklen bei Kraftwerksinvestitionen in liberalisierten Märkten - Ein Modell des deutschen Stromerzeugungsmarktes. Dissertation, Technical University Berlin, Fakultät für Wirtschaft und Management, Berlin.

Gawel, E., and P. Lehmann (2014). Die Förderung der erneuerbaren Energien nach der EEG-Reform 2014. Wirtschaftsdienst, 94 (9), 652-658.

Gawel, E., and C. Klassert (2013). Probleme der besonderen Ausgleichsregelung im EEG. Zeitschrift für Umweltrecht, 24(9), 467-480.

Gawel, E., and K. Korte (2014). Das Grünbuch Strommarktdesign: Subventionen für konventionelle Kraftwerke ante portas? WISO direkt, Dezember 2014, Berlin.

Gawel, E., and A. Purkus (2013). Promoting the Market and System Integration of Renewable Energies through Premium Schemes – A Case Study of the German Market Premium. Energy Policy, 61, 599-609.

Gawel, E., and A. Purkus (2016). EEG 2017 – Mehr Markt bei der Erneuerbare-Energien-Förderung? Wirtschaftsdienst, 96(12), 910–915

Gawel, E., and S. Strunz (2015). Ist ein nationaler Klimabeitrag für die Kohlekraft sinnvoll – und wenn ja, welcher? Ifo-Schnelldienst, 68(14), 8-11.

Gawel, E., S. Strunz, and P. Lehmann (2014). A Public Choice View on the Climate and Energy Policy Mix in the EU – How do Emissions Trading Scheme and Support for Renewable Energies Interact? Energy Policy, 64, 175-182.

Gawel, E., P. Lehmann, A. Purkus, P. Söderholm, and K. Witte (2017). Rationales for Technology-specific RES Support and their Relevance for German Policy. Energy Policy, 102, 16-26.

Gawel, E., A. Purkus, K. Korte, and P. Lehmann (2013). Förderung der Markt- und Systemintegration erneuerbarer Energien - Perspektiven einer instrumentellen Weiterentwicklung. Vierteljahreshefte für Wirtschaftsforschung, 82(3), 123-136.

Gottstein, M., and S. Skillings (2012),. Beyond Capacity Markets – Delivering Capability Resources to Europe's Decarbonised Power System. IEEE, Florence.

Green, R., and N. Vasilakos (2012). Storing Wind for a Rainy Day: What Kind of Electricity Does Denmark Export? The Energy Journal, 33(3), 1-22.

Greenpeace (2015). Greenpeace-Stellungnahme zum Grünbuch „Ein Strommarkt für die Energiewende". Greenpeace, Hamburg.

Grossi, L., S. Heim, and M. Waterson (2014). A Vision of the European Energy Future? The Impact of the German Response to the Fukushima Earthquake. ZEW Discussion Paper No. 14-051, Centre for European Economic Research, Mannheim.

Growitsch, C., F. C. Matthes, and H-J. Ziesing (2013). Clearing-Studie Kapazitätsmärkte. Online: http://www.bmwi.de/BMWi/Redaktion/PDF/C-D/studie-clearing-studiekapazitaetsmaerkte,property=pdf,bereich=bmwi2012,sprache=de,rwb=true.pdf (accessed 17.05.2014).

Häseler, S. (2014). Procuring Flexibility to Support Germany's Renewables: Policy Options. Zeitschrift für Energiewirtschaft, 38(3), 151-162.

Helm, D. (2010). Government Failure, Rent-seeking, and Capture: The Design of Climate Change Policy. Oxford Review of Economic Policy, 26(2), 182-196.

Heim, S., and D. Schober (2014). Strategic Behavior of Energy Suppliers in Balancing Markets under Increased Renewable Supply. European Conference of the International Association for Energy Economics, 28-30th of October 2014, Rome.

Henriot, A., and J. M. Glachant (2013). Melting-pots and Salad Bowls: The Current Debate on Electricity Market Design for Integration of Intermittent RES. Utilities Policy, 27, 57-64.

Hermann, N., and J. Ecke (2012). Gewinner und Verlierer eines Kapazitätsmarktes – Verteilungswirkungen eines neuen Strommarktdesigns. Energiewirtschaftliche Tagesfragen, 62(1/2), 28-33.

Hintermann, B., S. Peterson, and W. Rickels (2016). Price and Market Behavior in Phase II of the EU ETS: A Review of the Literature. Review of Environmental Economics and Policy, 10(1), 108-128.

Hiroux, C., and M. Saguan (2010). Large-scale Wind Power in European Electricity Markets: Time for Revisiting Support Schemes and Market Designs? Energy Policy, 38(7), 3135-3145.

Hirth, L. (2013a). The Economics of Wind and Solar Variability, Doctoral Dissertation, Technical University Berlin.

Hirth, L. (2013b). The Market Value of Variable Renewables: The Effect of Solar Wind Power Variability on their Relative Price. Energy Economics, 38, 218-236.

Hirth, L., and I. Ziegenhagen (2015). Balancing Power and Variable Renewables: Three Links. Renewable and Sustainable Energy Reviews, 50, 1035-1051.

Hirth, L., F. Ueckerdt, and O. Edenhofer (2015). Integration Costs Revisited – An Economic Framework of Wind and Solar Variability. Renewable Energy, 74, 925-939.

Höffler, F. (2015). Zur Analyse des CO_2-Minderungsbeitrag des Stromsektors. Ifo-Schnelldienst, 68(14), 22-25.

Hoffmann, V. (2007). EU ETS and Investment Decisions: The Case of the German Electricity Industry. European Management Journal, 25(6), 464-474.

Holttinen, H., P. Meibom, A. Orths, B. Lange, M. O'Malley, J. O. Tande, A. Estanqueiro, E. Gomez, L. Söder, G. Strbac, J. C. Smith, and F. van Hulle (2011). Impacts of Large Amounts of Wind Power on Design and Operation of Power Systems, Results of IEA Collaboration. Wind Energy, 14(2), 179–192.

IASS (2015). Kommentar zum Grünbuch „Ein Strommarkt für die Energiewende". Institute for Advanced Sustainability Studies, Potsdam.

IEA RETD TCP (2016). Electricity Market Design and RE Deployment (RES-E-MARKETS) [Fabien Roques, Dmitri Perekhodtsev (FTI-CL Energy), Lion Hirth (Neon)], IEA Renewable Energy Technology Deployment Technology Collaboration Programme (IEA RETD TCP), Utrecht.

IG Metall (2015). Stellungnahme der IG Metall zum Grünbuch „Ein Strommarkt für die Energiewende". IG Metall, Frankfurt am Main.

Jaffe, A. B., and F. A. Felder (1996). Should Electricity Markets Have a Capacity Requirement? If So, How Should It Be Priced? The Electricity Journal, 9(10), 52-60.

Jansen, M. (2014). Optimierung der Marktbedingungen für die Regelleistungs-erbringung durch Erneuerbare Energien. Studie des FhG Institut für Windenergie und Energiesystemtechnik (IWES) Online: http://www.bee-ev.de/fileadmin/-Publikationen/Studien/20140407_BEE_OptimierungderMarktbedingungenfrRegelleistungserbringungfuerErneuerbareEnergien.pdf (accessed 2016/11/30).

Joskow, P., and J. Tirole (2007). Reliability and Competitive Electricity Markets. RAND Journal of Economics, 38(1), 60-84.

Joskow, P. (2006). Competitive Electricity Markets and Investment in New Generating Capacity. In D. Helm (Ed.) The New Energy Paradigm. Oxford University Press, Oxford.

Joskow, P. (2011). Comparing the Costs of intermittent and Dispatchable Electricity Generation Technologies. American Economic Review: Papers and Proceedings, 100(3), 238-241.

Ketterer, J. C. (2014). The Impact of Wind Power Generation on the Electricity Price in Germany. Energy Economics, 44, 270-280.

Kiesling, L. (2009). Deregulation, Innovation and Market Liberalization. Electricity Regulation in a Continually Evolving Environment. Routledge/Taylor and Francis, London and New York.

Kirchgässner, G., and F. Schneider (2003). On the Political Economy of Environmental Policy. Public Choice, 115, 369-396.

Knopf, B., M. Pahle, H. Kondziella, F. Joas, O. Edenhofer, and T. Bruckner (2014). Germany's Nuclear Phase-out: Sensitivities and Impacts on Electricity Prices and CO2 Emissions. Economics of Energy & Environmental Policy, 3(1), 89-105.

Kollmann, A., and F. Schneider (2010). Why does Environmental Policy in Representative Democracies Tend to be Inadequate? A Preliminary Public Choice Analysis. Sustainability, 2, 3710-3734.

Korte, K., and E. Gawel (2015). Stromnetzinvestitionen und Anreizregulierung – Problemfelder und Lösungsansätze. Wirtschaftsdienst, 95(2), 127-134.

Korte, K., and E. Gawel (2016). Regional Differenzierte Netzentgelte als Auslauf-modell? Energiewirtschaftliche Tagesfragen, 66(1/2), 61-65.

Krueger, A. O. (1974). The Political Economy of the Rent-Seeking Society. American Economic Review, 64(3), 291-303.

Kunz, F. (2013). Improving Congestion Management: How to Facilitate the Integration of Renewable Generation in Germany. Energy Journal 34(4), 55-78.

LBD (2011). Energiewirtschaftliche Erfordernisse zur Ausgestaltung des Marktdesigns für einen Kapazitätsmarkt Strom. Online: http://www.baden-wuerttemberg.de/fileadmin/redaktion/dateien/Altdaten/202/120120_Gutachten_Kapazitaetsmarkt_Strom_Bericht.pdf.

Lehmann, P., and P. Söderholm (2016). Can Technology-specific Deployment Policies be Cost-effective? The Case of Renewable Energy Support Schemes. Discussion Paper No. 1/2016, Helmholtz Centre for Environmental Research (UFZ), Leipzig. Also forthcoming in Environmental & Resource Economics.

Lehmann, P., R. Brandt, E. Gawel, S. Heim, K.- Korte, A. Löschel, P. Massier, M. Reeg, D. Schober, and S. Wassermann (2015). Capacity Payments to Secure Electricity Supply? On the Future of Germany's Power Market Design. Energy, Sustainability and Society, 5(15), 1-7.

Lehmann, P., E. Gawel, K. Korte, M- Reeg, and D. Schober (2016). Sichere Stromversorgung bei hohen Anteilen volatiler Erneuerbarer: Was kann ein Strommarkt 2.0 leisten? Wirtschaftsdienst, 96(5), 344-350.

Leprich, U., E. Hauser, K. Grashof, L. Grote, M. Luxenburger, M. Sabatier, and A. Zipp (2012). Kompassstudie Marktdesign. Leitideen für ein Design eines Stromsystems mit hohem Anteil fluktuierender Erneuerbarer Energien., BEE-Plattform Systemtransformation, Ponte Press, Bochum.

Linares, P., F. J. Santos, M. Ventosa, and L. Lapiedra (2006). Impacts of the European Emissions Trading Scheme Directive and Permit Assignment Methods on the Spanish Electricity Sector. Energy Journal, 27(1), 79-98.

Lise, W., J. Sijm, and B. F. Hobbs (2010). The Impact of the EU ETS on Prices, Profits and Emissions in the Power Sector: Simulation Results with the COMPETES EU20 Model. Environmental & Resource Economics, 47, 23–44.

Löschel, A., F. Flues, F. Pothen, and P. Massier (2013a). Der deutsche Strommarkt im Umbruch: Zur Notwendigkeit einer Marktordnung aus einem Guss. Wirtschaftsdienst, 93(10), 778-784.

Löschel, A., F. Flues, F. Pothen, and P. Massier (2013b). Den Strommarkt an die Wirklichkeit anpassen – Skizze einer neuen Marktordnung. Energiewirtschaftliche Tagesfragen, 63(10), 22-25.

Lund, P. D., J. Lindgren, J. Mikkola, and J. Salpakari (2015). Review of Energy System Flexibility Measures to Enable High Levels of Variable Renewable Electricity. Renewable and Sustainable Energy Reviews, 45, 785-807.

Matevosyan, J., M. Olsson, and L. Söder (2007). Short Term Hydro Power Planning Coordinated with Wind Power in Areas with Congestion Problems. Wind Energy Journal, 10(3), 1-11.

Matthes, F. C., B. Schlemmermeier, C. Diermann, H. Hermann, and C. von Hammerstein (2012). Focused Capacity Markets. A New Market Design for the Transition to a New Energy System. A Study for the WWF Germany Environmental Foundation. Online: http://www.wwf.de/fileadmin/fm-wwf/Publikationen-PDF/2013_01_28_focused_capacity_market_ENG.pdf (accessed 2016/11/30).

Maurer, C. (2013). Versorgungssicherheit effizient gestalten: Zur Diskussion um Kapazitätsmechanismen in Deutschland. In Agora Energiewende (Ed.), Kapazitätsmarkt oder strategische Reserve: Was ist der nächste Schritt? Eine Übersicht über die in der Diskussion befindlichen Modelle zur Gewährleistung der Versorgungssicherheit in Deutschland, Berlin, pp. 27-35.

Maurer, C., B. Tersteegen, and J. Jasper (2012). Kapazitätsmechanismen in Deutschland und Europa: Wann gibt es wirklich einen Bedarf? Energiewirtschaftliche Tagesfragen, 62(3), 32-37.

Mauritzen, J. (2011). What Happens When it's Windy in Denmark? An Empirical Analysis of Wind Power on Price Volatility in the Nordic Electricity Market. Working Paper No. 889, Research Institute of Industrial Economics, Stockholm.

Mauritzen, J. (2013). Dead Battery? Wind Power, the Spot Market, and Hydro Power Interaction in the Nordic Electricity Market. Energy Journal, 34(1), 103-121.

Mauritzen, J. (2015). Now or Later? Trading Wind Power Closer to Real-time: How Poorly Designed Subsidies can Lead to Higher Balancing Costs. Energy Journal, 36(4), 149-164.

McCann, L. (2013). Transaction Costs and Environmental Policy Design. Ecological Economics, 88, 253-262.

McCormick, R. E., and R. D. Tollison (1981). Politicians, Legislation and the Economy: An Inquiry into the Interest-group Theory of Government. Martinus-Nijhoff, Boston.

Mills, A., and R. Wiser (2012). Changes in the Economic Value of Variable Generation at High Penetration Levels: A Pilot Case Study of California. LBNL-5445E, Ernest Orlando Lawrence Berkeley National Laboratory, California.

Möllring, H. (2015). Der sogenannte Klimabeitrag – kein Beitrag zum Klima, aber zur Wettbewerbsverzerrung. Ifo-Schnelldienst, 68(14), 15-18.

Monopolkommission (2015). Energie 2015: Ein wettbewerbliches Marktdesign für die Energiewende. Sondergutachten 71, Berlin.

Mueller, D. C (2003). Public Choice III. Third edition. Cambridge University Press, Cambridge.

Müsgens, F., and M. Peek (2011). Sind Kapazitätsmärkte in Deutschland erforderlich? – Eine kritische Analyse vor dem Hintergrund der Ökonomischen Theorie. Zeitschrift für Neues Energierecht, 6, 576-583.

NABU (2015). NABU-Stellungnahme zum Grünbuch. Naturschutzbund Deutschland, Berlin.

Nennen, H.-U., and D. Garbe (1996). Das Expertendilemma. Zur Rolle Wissenschaftlicher Gutachter in der öffentlichen Meinungsbildung. Springer, Berlin.

NERC (2007). Definition of "Adequate Level of Reliability". North American Electric Reliability Corporation (NERC), Princeton, New Jersey.

Neuhoff, K., J. Diekmann, F. Kunz, S. Rüster, W. P. Schill, and S. Schwenen (2016). A Coordinated Strategic Reserve to Safeguard the European Energy Transition. Utilities Policy, 41, 252-263.

Neuhoff, K., J. Diekmann, C. Kemfert, W.-P. Schill, S. Schwenen, T. Traber, and C. von Hirschhausen (2013). Energiewende und Versorgungssicherheit: Deutschland braucht keinen Kapazitätsmarkt. DIW Wochenbericht, 48, 5-15.

Newbery, D. (2010). Special Issue: Market Design for a Large Share of Wind Power. Energy Policy, 38(7), 3131-3256.

Nicolosi, M. (2010). Wind Power Integration and Power System Flexibility – An Empirical Analysis of Extreme Events in Germany under the New Negative Price Regime. Energy Policy, 38(11), 7257-7268.

Nicolosi, M. (2012). Necessity of and Design Options for a Capacity Mechanism for Germany. Interim report produced for the Federal Environment Agency (UBA), translated from German, Ecofys.

Niedersachsen (2015). Stellungnahme zum Grünbuch „Ein Strommarkt für die Energiewende“. Niedersächsisches Ministerium für Umwelt, Energie und Klimaschutz, Hannover.

Niskanen, W. A. (1971). Bureaucracy and Representative Government, Aldine Transaction, Atherton.

Nitsch, J., T. Pregger, T. Naegler, D. Heide, D. Luca de Tena, F. Trieb, Y. Scholz, K. Nienhaus, N. Gerhardt, M. Sterner, T. Trost, A. von Oehsen, R. Schwimm, C. Pape, H. Hahn, and M. Wickert (2012). Langfristszenarien und Strategien für den Ausbau der erneuerbaren Energien in Deutschland bei Berücksichtigung der Entwicklung in Europa und global. Deutsches Zentrum für Luft- und Raumfahrt (DLR), Fraunhofer Institut für Windenergie und Energiesystemtechnik (IWES), Ingenieurbüro für neue Energien (IFNE), Forschungsbericht für das Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, Stuttgart, Kassel, and Berlin.

Nordenergi (2015). Nordenergi Response to: An Electricity Market for Germany's Energy Transition – Discussion Paper of the Federal Ministry for Economic Affairs and Energy. Nordenergi, Helsinki.

Nordrhein-Westfalen (2015). Stellungnahme der Landesregierung Nordrhein-Westfalen zum Diskussionspapier des Bundesministerium für Wirtschaft und Energie (Grünbuch) „Ein Strommarkt für die Energiewende“. Landesregierung Nordrhein-Westfalen, Düsseldorf.

North, D. C. (1990). Institutions, Institutional Change and Economic Performance. Cambridge University Press, Cambridge.

Olson, M. (1965). The Logic of Collective Action. Harvard University Press, Cambridge.

Olson, M. (1982). The Rise and Decline of Nations: Public Goods and the Theory of Groups. Harvard University Press, Cambridge.

Oren, S. (2003). Ensuring Generation Adequacy in Competitive Electricity Markets. University of California Energy Institute - Energy Policy & Economics, University of California, Berkley, California.

Pahle, M., L. Fan, W.-P. Schill (2011). How Emission Certificate Allocations Distort Fossil Investments: The German Example. Energy Policy, 39(4), 1975-1987.

Pereira, J. P., and P. M. Rodrigues (2015). The Impact of Wind Generation on the Mean and Volatility of Electricity Prices in Portugal. In European Energy Market (EEM), 12th International Conference, IEEE.

Pindyck, R. S. (2009). Sunk Costs and Risk-Based Barriers to Entry. NBER Working Papers 14755, The National Bureau of Economic Research, Cambridge. Online: http://www.nber.org/papers/w14755.pdf (accessed 2016/11/30).

Pollitt, M., & and K. Anaya (2016). Can Current Electricity Markets Cope with High Shares of Renewables Comparison? The Energy Journal, 37, 69-88.

Purkus, A., E. Gawel, M. Deissenroth, K. Nienhaus, and S. Wassermann (2015). Market Integration of Renewable Energies through Direct Marketing – Lessons Learned from the German Market Premium Scheme. Energy, Sustainability and Society, 5(1), 12.

r2b (2012). Ziele und Ausgestaltung einer Strategischen Reserve – Eckpunkte-papier. Online: http://www.r2b-energy.com/pdf/Eckpunkte-Strategische-Reserve-r2b.pdf (accessed 2016/11/30).

r2b, Connect Energy Economics, Fraunhofer ISI, and Consentec (2014). Endbericht Leitstudie Strommarkt, Arbeitspaket Funktionsfähigkeit EOM & Impact-Analyse Kapazitätsmechanismen. Studie im Auftrag des Bundesministeriums für Wirtschaft und Energie, Köln.

RAP (2015). Ein Strommarkt für die Energiewende. Diskussionspapier des Bundesministeriums für Wirtschaft und Energie (Grünbuch). Stellungnahme des Regulatory Assistance Projects. The Regulatory Assistance Project, Berlin.

Reeg, M. (2014). Entwurf eines ganzheitlichen Strommarktdesigns für hohe Anteile erneuerbarer Energien – Flexibilität statt reiner Kapazität. DLR Diskussionspapier 14/01. Online: http://www.dlr.de/tt/de/Portaldata/41/Resources/dokumente/institut/system/discussion_papers/STB_Diskussionspapier_012014_Entwurf_eines_ganzheitlichen_Strommarktdesigns_fuer_hohe_Anteile_erneuerbarer_Energien.pdf (accessed 2016/11/30).

Reeg, M., R. Brandt, E. Gawel, S. Heim, K. Korte, P. Lehmann, P. Massier, D. Schober, and S. Wassermann (2015). Kapazitätsmechanismen als Rettungsschirm der Energiewende? Zur Versorgungssicherheit bei hohen Anteilen fluktuierender erneuerbarer Energien im Stromsystem. Discussion Paper 01/15, Helmholtz Centre for Environmental Research – UFZ, Leipzig.

Reeg, M., K. Nienhaus, N. Roloff, U. Pfenning, M. Deissenroth, S. Wassermann, W. Hauser, W. Weimer-Jehle, W., U. Klann, and T. Kast (2013): AMIRIS – Weiterentwicklung eines agentenbasierten Simulationsmodells zur Untersuchung des Akteursverhaltens bei der Marktintegration von Strom aus erneuerbaren Energien unter verschiedenen Fördermechanismen. Forschungsbericht für das Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, Stuttgart, Saarbrücken, Vilshofen.

Rintamäki, T., A. S. Siddiqui, and A. Salo (2017). Does Renewable Energy Generation Decrease the Volatility of Electricity Prices? An Analysis of Denmark and Germany. Energy Economics, 62, 270-282.

RWE (2015). Ein Strommarkt für die Energiewende. Beitrag von RWE zur Konsultation des Grünbuches. RWE AG, Essen.

Sachsen (2015). Grünbuch - Ein Strommarkt für die Energiewende. Konsultationsverfahren. Sächsisches Staatsministerium für Wirtschaft, Arbeit und Verkehr, Dresden.

Schroeder, A., P-Y. Oei, A. Sander, L. Hankel, and L. C. Laurisch (2013). The Integration of Renewable Energies into the German Transmission Grid—A Scenario Comparison. Energy Policy, 61, 140-150.

Schütz, D., and B. Klusmann (Eds.) (2011). Die Zukunft des Strommarktes. Anregungen für den Weg zu 100 Prozent Erneuerbare Energien. Ponte Press GmbH, Bochum.

Sensfuß, F., M. Ragwitz, and M. Genoese (2008): The Merit-order Effect: A Detailed Analysis of the Price Effect of Renewable Electricity Generation on Spot Market Prices in Germany. Energy Policy, 36, 3086-3094.

Sijm, J. P. M. (2014). Cost and Revenue Related Impacts of Integrating Electricity from Variable Renewable Energy into the Power System. A Review of Recent Literature. ECN Policy Studies, Petten, The Netherlands.

Sijm, J., K. Neuhoff, and Y. Chen (2006). CO2 Cost Pass-through and Windfall Profits in the Power Sector. Climate Policy, 6(1), 49-72.

Söderholm, P. (2013). The Economics of Wind Power: An Introduction, In J. F. Shogren (Ed.), Encyclopedia of Resource, Energy, and Environmental Economics, Elsevier Science Ltd., 195-199.

Spees, K., S. A. Newell, and J. Pfeifenberger (2013). Capacity Markets – Lessons Learned from the First Decade. Economics of Energy & Environmental Policy, 2(2), 1-26.

SRU (2015). Stellungnahme zur Konsultation des Bundesministeriums für Wirtschaft und Energie zum Grünbuch „Strommarkt für die Energiewende". Sachverständigenrat für Umweltfragen, Berlin.

Statnett (2015). Response to the discusion paper „An electricity market for Germany's Energy Transition". Statnett SF, Oslo.

Stoft, S. (2002). Power System Economics – Designing Markets for Electricity. IEEE Press & Wiley-Interscience, Hoboken, New Jersey.

Strunz, S., E. Gawel, and P. Lehmann (2015). Towards a General „Europeanization“ of EU Member States' Energy Policies? Economics of Energy & Environmental Policy, 4(2), 143-159.

Strunz, S., E. Gawel, and P. Lehmann (2016). The Political Economy of Renewable Energy Policies in Germany and the EU. Utilities Policy, 42, 33-41.

Süßenbacher, W., M. Schwaiger, and H. Stigler (2011): Kapazitätsmärkte und -mechanismen im internationalen Kontext. 7. Internationale Energiewirtschaftstagung an der TU Wien (IEWT), 16-18 February 2011, Wien.

Tafarte, P., S. Das, M. Eichhorn, and D. Thrän (2014). Small Adaptations, Big Impacts: Options for an Optimized Mix of Variable Renewable Energy Sources. Energy, 72, 80-92.

Tangerås, T. (2015). Det här kan marknaden klara! Försörjningstryggheten i det nordiska elsystemet. Presentation for the Swedish Energy Commission, 4 November, Stockholm.

Tangerås, T. (2017). Equilibrium Supply Security in a Multinational Electricity Market with Renewable Production. Working Paper No. 1162, Research Institute of Industrial Economics, Stockholm.

Tietjen, O. (2012). Kapazitätsmärkte – Hintergründe und Varianten mit Fokus auf einen emissionsarmen deutschen Strommarkt. Germanwatch. Berlin.

Tinbergen, J. (1952). On the Theory of Economic Policy. North-Holland, Amsterdam.

Traber, T., and C. Kemfert (2011). Gone with the Wind? - Electricity Market Prices and Incentives to Invest in Thermal Power Plants under Increasing Wind Energy Supply. Energy Economics, 33(2), 249-256.

UBA (2015). Stellungnahme des Umweltbundesamtes zur Konsultation des Grünbuchs „Ein Strommarkt für die Energiewende“ des Bundesministeriums für Wirtschaft und Energie. Umweltbundesamt, Dessau-Roßlau.

Van der Welle, A. J. and J. de Joode (2011). Regulatory Road Maps for the Integration of Intermittent Electricity Generation: Methodology Development and the Case of The Netherlands. Energy Policy, 39(10), 5829-5839.

Vanberg, V. (1982). Markt und Organisation. Individualistische Sozialtheorie und das Problem korporativen Handelns, Tübingen.

Vandezande, L., L. Meeus, R. Belmans, M. Saguan, and J-M. Glachant (2010). Well-functioning Balancing Markets: A Prerequisite for Wind Power Integration. Energy Policy, 38(7), 3146-3154.

VKU (2015). Stellungnahme zum Grünbuch des Bundesministeriums für Wirtschaft und Energie „Ein Strommarkt für die Energiewende“. Verband kommunaler Unternehmen, Berlin.

vzbz (2015). Die Energiewende braucht keinen Kapazitätsmarkt: Stellungnahme des Verbraucherzentrale Bundesverbandes zum Diskussionspapier „Ein Strommarkt für die Energiewende“ (Grünbuch) des Bundesministeriums für Wirtschaft und Energie. Verbraucherzentrale Bundesverband (vzbz), Berlin.

Winkler, J., and M. Altmann (2012). Market Designs for a Completely Renewable Power Sector. Zeitschrift für Energiewirtschaft, 36(2), 77-92.

Winkler, J., D. Keles, L. Renz, F. Sensfuß, and W. Fichtner (2013): Perspektiven zur aktuellen Kapazitätsmarktdiskussion in Deutschland. Zeitschrift für Energiewirtschaft, 37, 233-248.

Woo, C. K., I. Horowitz, J. Moore, and A. Pacheco (2011). The Impact of Wind Generation on the Electricity Spot-market Price Level and Variance: The Texas Experience. Energy Policy, 39(7), 3939-3944.

WWF (2015). Stellungnahme zum Diskussionspapier des BMWi (Grünbuch) „Ein Strommarkt für die Energiewende“. WWF Deutschland, Berlin.

POLITICAL ECONOMY OF SAFE-GUARDING SECURITY OF SUPPLY WITH HIGH SHARES OF RENEWABLES

The increasing shares of wind power and solar PV in the European electricity markets have raised concerns about security of supply being jeopardized. In this report, we discuss how security of supply can be defined and why real-world so-called energy-only markets may not be able to provide an efficient level of security of supply. The report identifies and evaluates a wide set of regulatory options for addressing security of supply issues in the electricity system. Particular attention is devoted to the German experiences. We also discuss important lessons for Swedish electricity market design.

A number of generic lessons from the German policy debate are highlighted: (a) all actors in the electricity supply system can in various ways contribute to security of supply; (b) underinvestment in security of supply most often have multiple causes, and should preferably be addressed through a portfolio of context-specific measures rather than through single capacity mechanisms; (c) the energy transition taking place in, e.g., Germany does not fundamentally question security of supply; (d) the measures implemented to safeguard security of supply should include an international perspective as well as consider the cost of potential institutional lock-in; and (e) the policy decision-making process needs to rely on credible long-term commitments and transparent consultation processes.

In terms of specific lessons for Swedish market design, our conclusions are partly in line with earlier studies arguing for a wait, see and evaluate strategy and focus on strengthening the so-called energy-only market. We contend that policy makers should abstain from making early, future commitments regarding the introduction of quantitative measures as well as more extended capacity mechanisms.

Energiforsk is the Swedish Energy Research Centre – an industrially owned body dedicated to meeting the common energy challenges faced by industries, authorities and society. Our vision is to be hub of Swedish energy research and our mission is to make the world of energy smarter!

Energiforsk