The German Example – 20+ Years of Secure Electricity Supply after Liberalisation

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Abstract

Germany relies on the market design of an Energy-Only-Market. Over the past 20+ years, quality of supply improved, and Germany has not seen a single hour of insufficient capacity. At the same time, RES-E increased substantially. Nevertheless, Germany decided to implement a Strategic Reserve as additional 'braces to the belt'.

Index Terms: *Resource Adequacy, Market Design, EOM, CRM, RES-E integration, Security of Supply, Strategic Reserve*

1. Introduction

Around 25 years ago, the European Union passed EU directive 96/92/EC which liberalised electricity generation in Europe. Germany implemented this European directive into national law with a reform of the Energy Law – Energiewirtschaftsgesetz (EnWG) – in 1998.

Since then, Germany relies on the market design of an Energy-Only-Market (EOM) and recently on the so-called EOM 2.0, which is characterized by an EOM accompanied by a strategic reserve. In the meanwhile, Germany has seen numerous capacity additions as well as substantial decommissioning's of older conventional power plants accompanied by a sharp increase of intermittent RES-E penetration by wind and solar. The quality of supply enhanced further during these RES-E additions, shown by the development of the System Average Interruption Duration Index (SAIDI). Additionally, Germany has not seen a single hour of insufficient capacity for more than twenty years, i.e. close to a full investment cycle. Since 2005, only one event of forced load shedding occurred due to a grid fault (so called "Emslandzwischenfall").

Hence, we argue in this article that an EOM can provide power supply reliably over long periods of time, even despite a sharp increase in intermittent RES-E. We believe this is an important contribution to the literature because it is often stated in public debates (at least across Europe), that CRMs are needed to guarantee a certain Resource Adequacy- (RA-) Level (i.e. reliable power supply). And even if conventional systems could reliably provide power, at the very latest additional intermittent RES-E penetration would tip the system. As of today, neither of these concerns materialised in the German example.

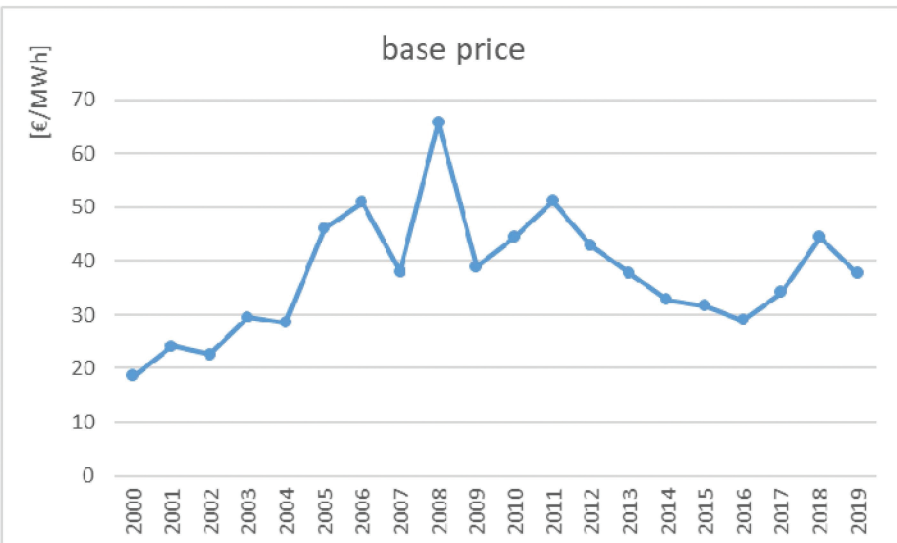
In the following we analyse market design in Germany since liberalisation, discuss theory and empirics of flexibilization in the electricity system and give insights into the empirics of security of supply indices and market induced load-shedding.

2. Past Developments

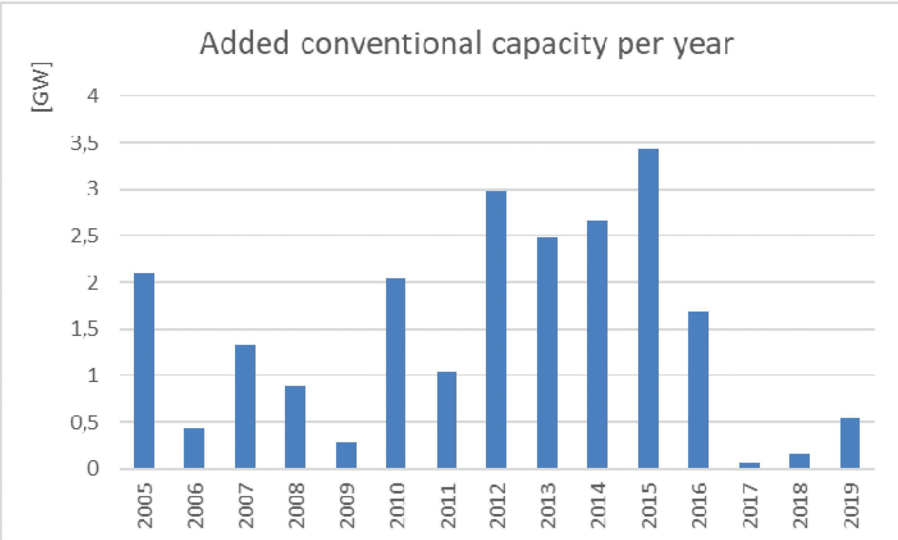
Power plants in Germany earn their revenues on the wholesale market (including intraday and balancing power markets). No long-term capacity payment provides additional revenues.[1] While this has been true for more than 20 years, the market design evolved over time. These changes will be described in the following paragraph if they contributed to the flexibilization of consumption and generation, for which we also discuss theoretical aspects and show some empirical findings.

2.1 Market Design

Since the liberalisation of the European internal electricity market (IEM) Germany relies on an EOM. Starting with a pure energy-only market, the European liberalisation from 1996 was implemented in German law in 1998. When the liberalisation process was completed the German electricity market was characterized by excess capacities.[2] Due to the resulting low electricity wholesale prices, some less efficient conventional power plants became unviable and shut down (or left the market once major overhaul investments would have become necessary). The development of electricity wholesale prices since 2000[3] is given in the following graph.[4]



With capacities leaving the market the wholesale prices consolidated and several new investments took place. Germany has seen numerous capacity additions. In particular, more than 21 Gigawatts (GW) of conventional capacity (i.e. gas, oil, hard coal, lignite, multiple fossil fuels) were added between 2005 and 2019.[5] The



following graph shows the yearly conventional capacity additions.

Despite these numerous investments happening in an energy-only market framework, stakeholders in Germany claimed the necessity for a capacity remuneration mechanism (CRM). The strongest argument of these stakeholders were concerns on security of supply due to insufficient dispatchable resources, when not implementing a CRM.[6] Some referred to the sharp increase in RES-E which depressed electricity wholesale prices, making existing units and new investments unviable. Yet others combined reliability with decarbonisation, essentially trying to use CRMs to replace coal fired with gas fired generation.[7] Driven by this public debate on missing money and thus insufficient resources to guarantee a certain reliability standard, the responsible Federal Ministry of Economics and Energy – BMWi explored and evaluated these arguments in several studies.[8] These studies comprehensively assessed the functioning of the EOM, and compared it to various forms of CRMs. The studies found that an EOM is functioning[9], if a well-designed imbalance pricing and balancing responsibility mechanism is implemented. Furthermore, the studies found that an EOM is less costly than adding any of the assessed CRM forms, while enabling more flexibility in the electricity system (in particular via more price volatility on wholesale markets). This in turn fosters the ability to integrate large shares of intermittent RES-E. Consequently, resource adequacy is achieved by an energy-only market design in an economically efficient manner.

Based on this scientific contribution, the BMWi conducted an intensive and extensive stakeholder interaction process including the release of a *Green Paper*[10] followed by a *White Paper*[11] on *'An Electricity Market for Germany's Energy Transition'*. The process ended with a political compromise, the so called 'Electricity Market 2.0' ('Strommarkt 2.0'), in which the EOM is accompanied by a strategic reserve as additional 'braces to the belt'. The German strategic reserve is an out-of-the-market back-up resource accomplished by a no-way-back-rule to prevent distortions of the wholesale electricity markets. This reserve is called, if the electricity wholesale market does not clear, i.e. if demand exceeds supply given the technical price limits (i.e. 3k €/MWh day-ahead; 10k €/MWh intraday). Then demand not satisfied by the market is provided by the strategic reserve, while BRP's with a negative imbalance have to pay at least twice the price of the technical intraday price-cap for imbalance energy (i.e. 20k €/MWh).[12] The strategic reserve is provided by existing quick starting gas- or oil-fired power plants.

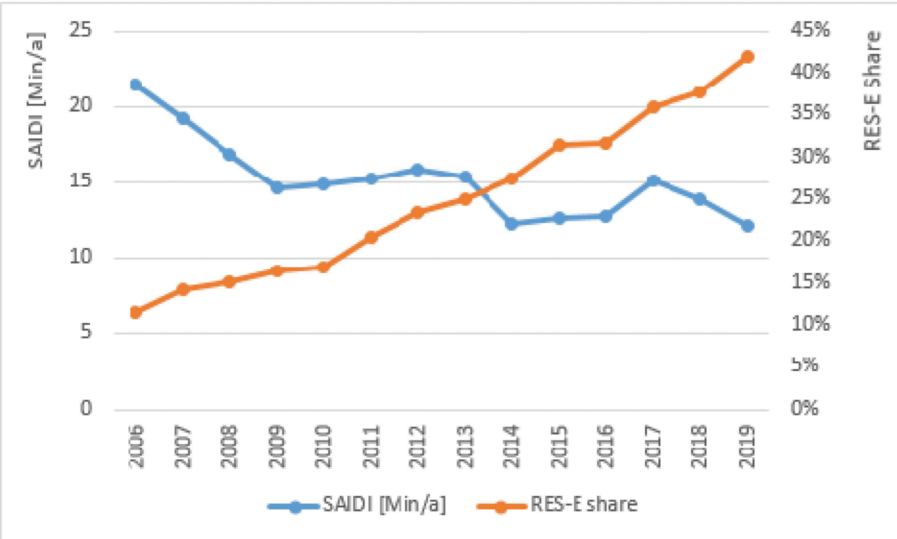
Additionally, Germany implemented a so called 'security standby' (so-called 'Sicherheitsbereitschaft') as an out-of-the-market resource, which is provided by almost three Gigawatts of existing lignite fired power plant capacities. The 'security standby' can secure the power supply in the event of unforeseeable prolonged extreme situations. Both, the strategic reserve as well as the 'security standby' have yet to be called upon.

This is even more remarkable as Germany decided to phase out of nuclear in parallel. By the end of 2020, only 8.1 GW out of 21.5 GW remain in operation. They will also phase-out until the end of the year 2022. On top of this, Germany decided to phase out coal at the latest by the end of the year 2038, starting with capacity reductions of around 8 GW hard coal and 4 GW lignite until the beginning of the year 2023, leaving only 15 GW each in the market. This phase-out processes are accompanied by a further ramp up of generation from wind and PV, which is intermittent and providing very little to secured generation.

Furthermore, barriers to market entry and flexibilization of the electricity markets were removed (e.g. implicit and explicit price caps , minimum capacity requirements were lowered, etc.) and trade products were adjusted to meet requirements of a wind and photovoltaic dominated electricity system (i.e. shorter trading periods were implemented). To improve the responsibility of BRPs, the imbalance pricing mechanism was strengthened. As a consequence, market liquidity in continuous intraday market trading up to physical delivery increased in Germany.

2.2 Evolution of Security of Supply Indices under RES-E development

In Germany, which is one of the frontrunner states in integrating huge amounts of intermittent RES-E in the light of the German Energy Transition, the reliability of supply did not suffer from this RES-E expansion. Contrarily, Germany's SAIDI started at an internationally[13] comparably low value of 22 minutes per year. The following graph shows the evolution of the SAIDI[14] and the RES-E share[15] in Germany.



Despite the increasing share of intermittent RES-E, the German SAIDI did not increase but decrease. The 2019 SAIDI, when the RES-E share was around 42 percent, was only 12 Minutes in Germany. However, the SAIDI measures grid failures and does not include forced load shedding of consumers resulting from insufficient generation resources. Hence, we want to emphasise that forced load shedding in Germany in the past 20 years did not occur due to insufficient generation resources. The only event leading to forced load shedding in Germany in our period of observation resulted from a grid fault (so-called Emslandzwischenfall in November 2006).[16]

2.3 Theory and empirics of the role of flexibility in the EOM

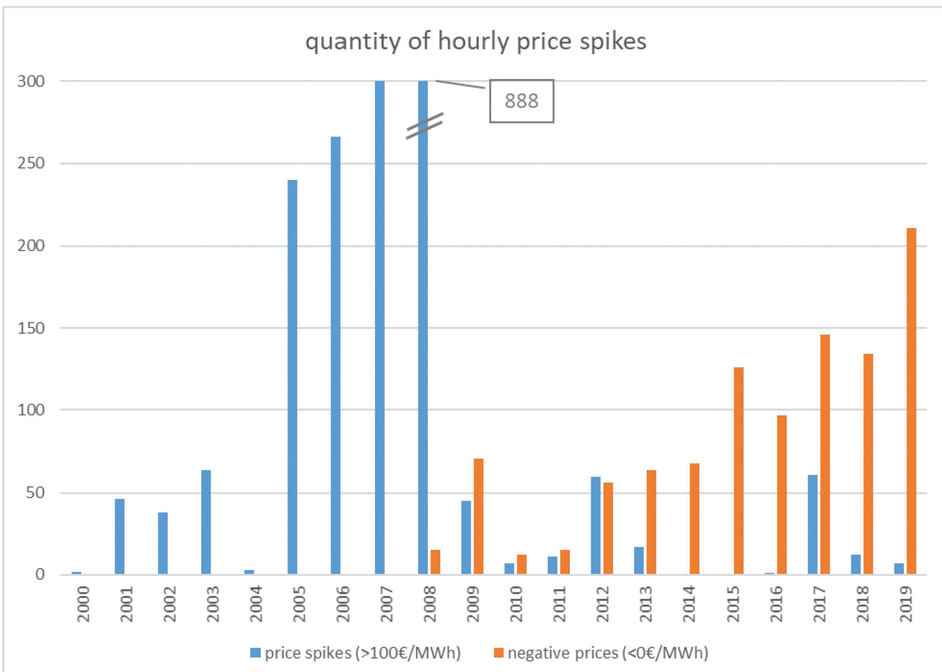
The theoretical background of the EOM is discussed in various literature sources.[17] In its core the EOM relies on the concept of peak load pricing, complemented by a well-designed imbalance pricing mechanism. We can define price peaks as wholesale power prices exceeding the variable costs of the most expensive conventional power plant available, since in this periods all available suppliers are producing and also able to recover a contribution to their fixed costs.[18]

Furthermore, in an EOM such price peaks signal beginning scarcity, which also incentivises more flexibility options both on the supply and on the demand side. Additionally, the commissioning of additional resources can become viable when scarcity occurs more frequently.

Flexibility is not only vital during price peaks but also during very low or even negative price events. The sharp increase in intermittent RES-E feed-in causes such situations. This mechanism enables opportunities for storages and contributes to reduce 'must-run' via a flexibilization of conventional power plants (e.g. coal, nuclear) and CHP-Units to avoid negative contribution margins during those periods.

The following graph shows both the annual number of hours with price peaks and with negative price events in Germany. In the graph, we assume the occurrence of 'price-spikes' whenever the hourly wholesale price is above 100 €/MWh.

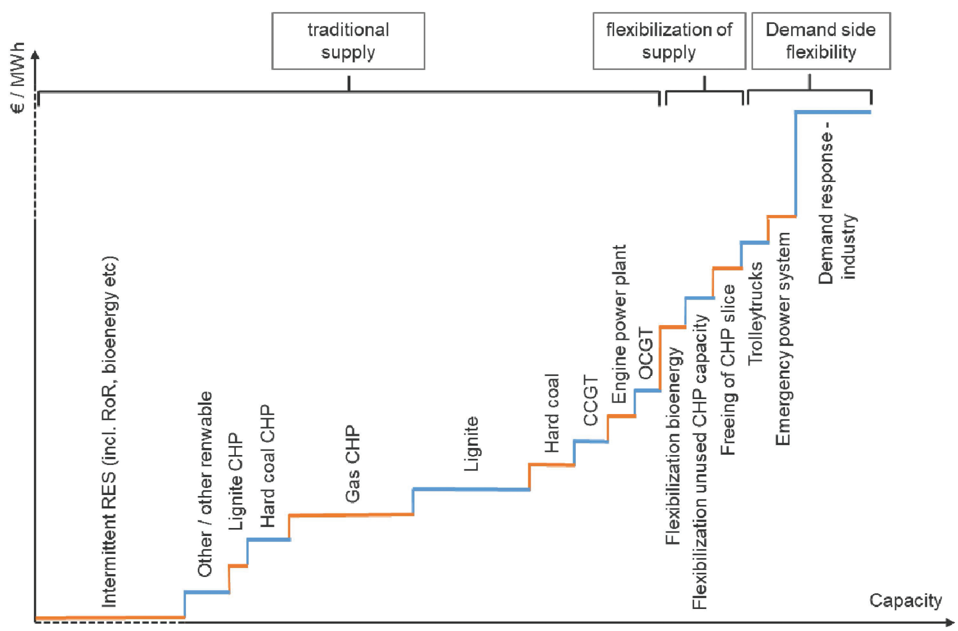
Directly after the liberalization during the year 2000, above mentioned excess capacities prevented the occurrence of price spikes – and also made them unnecessary as no investment signal was needed. Consequently, the electricity wholesale price exceeded 100 € per MWh during two hours only. The occurrence of price spikes in the following years increased until 2008. In this period, the strong econ-



omy was driving the electricity prices. Furthermore, there were concerns that four big generation companies (with more than 80 % market share) may have used their market power and withheld power station capacities.[19] From 2009 on only moderate amounts and heights (i.e. < 230 €/MWh) of price spikes occurred until now, but the occurrence of negative prices increased more or less constantly over the past 10 years. On the one hand peak-load-pricing is contributing to the functioning of the EOM 2.0. On the other hand the occurrence of negative prices contributes to a better / more efficient integration of large amounts of intermittent RES-E feed-in, since it incentivizes reducing must-run via flexibilization of Conventional and CHP units and enables business opportunities for storages.

These empirical results confirm that the market reacts on scarcity with price spikes. However, we do not perform a detailed analysis whether observed spikes where sufficient to cover investment costs in this article. Besides spikes, this also depends on a power plant's utilization, availability, investment costs and revenues on other markets (balancing power, heat for CHP, subsidies for CO_2-allowances or RES-E, …). Furthermore, investors in power plants – as investors in all other markets – face uncertainty at times of investment. In a competitive market, investment may in retrospect prove profitable or futile. Given the amount of excess capacity in the German market, it seems reasonable to assume that some investors were too optimistic with regard to wholesale price expectations.

Regardless of whether all investment was profitable, supply and demand were met every single hour over the past 20 years. The reason for this – despite some subsidized RES-E and CHP capacity additions – is the availability of flexibility options on both – supply and demand side. The following graph illustrates the 'traditional merit order' supplemented by further various forms of flexibilities of supply and demand on electricity markets. The availability of these flexibilities has ensured that market always cleared accompanied by only moderate price spikes according to peak-load pricing theory.



To the right of the 'traditional merit order' (i.e. right of the OCGT) flexibilization of supply may provide further flexibility at moderate costs. And – as one can see, on the consumption side not only industrial DSR is contributing to the further needs of overall flexibility and hence plays a role in scarcity situations with expected price-spikes. Also plenty other demand-side flexibility options, such as the use of (behind the meter) emergency power systems or – in the future – bidirectional electric vehicle charging or overhead bivalent trolley trucks switching to diesel-use, may contribute to peak-load-pricing, when no overcapacities or market entry barriers inhibit the activation of these flexibility potentials.

3. Challenges for the Future

Up to this point, we have shown that security of supply was achieved in the German EOM market framework, both measured by low SAIDI and persistently sufficient generation capacity. This result held despite the sharp increase of intermittent RES-E in Germany. However, while we can learn from the past, the successful history is no guarantee for a successful future. Firstly, we will argue in the following that, from a theoretical perspective, a reliability level of 100% would not even be economically efficient. Secondly, we will emphasise that the German market design in reality is far from a pure EOM, as various regulatory measures interdependent to the wholesale electricity markets exist, which may distort market outcome. And thirdly, measures in other European countries may send potentially distorting market signals towards the German market.

Regarding the first point, it needs to be said that full reliability in terms of adequate resources is not achievable, because at least at very low probability all resources may be subject to forced outages at the same time. Thus regardless of the market design (and thus including EOM as a market design), it is neither rational nor economically efficient for market players to have spare resources for every possible case that could occur – even when the probability for that case is very small. For this reason, German politics implemented the strategic reserve, leading to an even higher reliability standard than the EOM market outcome would provide (and consider efficient), since additional capacities are contracted as an out-of-the-market resource.

Furthermore, policy measures both domestic and abroad may lead to inefficiencies or 'shocks' of the electricity markets. In this sense various German measures tend to distort the pure EOM price signals or to be 'shocks' to the electricity markets. In the former case e.g. CHP-Units or RES-E Units are remunerated outside of the EOM via subsidy schemes, possibly distorting market price signals leading to inefficiencies. While in the latter case political decisions, i.e. to phase-out nuclear and coal power generation at the same time, are possibly challenging / interruptive for the electricity markets. Apart from domestic measures interdependent to the EOM, also surrounding CRMs (e.g. in United Kingdom, France, Italy, Poland and in perspective Belgium) are interdependent to the German EOM and the European IEM as a whole, since the revenue streams of the CRM's may distort signals from the Energy-Only IEM. This could possibly decrease efficiency of the market outcome.

Last but not least, recent 'near-brown-out'-events, e.g. in Germany[20], and a 'brown-out'-event in United Kingdom[21] in 2019, have shown, that even if there is no fundamental issue of insufficient generation resources, technical failures and other imperfections may lead to critical events in terms of the reliability of electricity supply. These two cases show that reliability issues may occur independently from the specific market design (i.e. w/o CRM), with Germany relying on the EOM whereas UK has implemented a market-wide CRM in the year 2014.

4. Conclusions

First, we want to conclude, that the EOM market design in Germany was able to provide a highly reliable electricity supply since market liberalisation in 1996/98, i.e. for more than 20 years. Second, security of supply remained high despite the integration of large shares of RES-E in the system. Third, the German EOM market design fosters innovation-forces of the electricity markets since price-volatility on electricity markets incentivises flexibilization of supply and demand.

Germany's decision to rely on an EOM is also in line with recent EU-legislation in the so-called 'Clean Energy for all Europeans'-Package (CEP). According to the CEP, any form of a CRM must always be regarded as so-called second-best solution, only meant to serve as temporary solutions until existing barriers or false incentives within the EOM are removed.

Footnotes

[1] Renewable energy sources and CHP plants receive additional subsidies.

[2] C.f. e.g. Müsgens (2006).

[3] Data for year 2000 is only available from June, 16th,since then the exchange started operation.

[4] Source of data: https://www.bmwi.de/Redaktion/DE/Binaer/Energiedaten/energiedaten-gesamt-xls.xlsx?__blob=publicationFile&v=85

[5] Source of data: https://www.bundesnetzagentur.de/SharedDocs/Downloads/DE/Sachgebiete/Energie/Unternehmen_Institutionen/Versorgungssicherheit/Erzeugungskapazitaeten/Kraftwerksliste/Kraftwerksliste_2020_1.xlsx?__blob=publicationFile&v=3

[6] C.f. Deutsche Energie-Agentur GmbH (dena) 2008; Kurzanalyse der Kraftwerks- und Netzplanung in Deutschland bis 2020 (mit Ausblick auf 2030). www.vku.de/fileadmin/get/?24103/EMD_Gutachten__Langfassung.pdf; https://www.ewi.uni-koeln.de/cms/wp-content/uploads/2015/12/EWI_Studie_Strommarktdesign_Endbericht_April_2012.pdf

[7] C.f. https://www.oeko.de/uploads/oeko/oekodoc/1586/2012-442-de.pdf

[8] C.f. e.g. r2b energy consulting (2014): https://www.bmwi.de/Redaktion/DE/Publikationen/Studien/funktionsfaehigkeit-eom-und-impact-analyse-kapazitaetsmechanismen.pdf?__blob=publicationFile&v=5 , Frontier Economics / Consentec (2014): https://www.bmwi.de/Redaktion/DE/Publikationen/Studien/folgenabschaetzung-kapazitaetsmechanismen-impact-assessment.pdf?__blob=publicationFile&v=5 .

[9] i.e. Functioning of an EOM in the sense that every consumer is supplied with electricity, as long as their individual willingness to pay is equal or higher than the wholesale electricity price

[10] C.f. https://www.bmwi.de/Redaktion/EN/Publikationen/gruenbuch.html

[11] C.f. https://www.bmwi.de/Redaktion/Migration/DE/Downloads/Publikationen/weissbuch-englisch.pdf?__blob=publicationFile&v=2

[12] This penalty-mechanism additional to the imbalance settlement price mechanism leads to strong incentives for market players to avoid being responsible for calling the strategic reserve due to insufficient resources, lowering the probability of calls of the Strategic Reserve and thus its necessity itself. Thus the design of the strategic reserve provides incentives lowering the probability of calls of the Strategic Reserve and thus its necessity itself.

[13] Compared to e.g. North America, where the mean SAIDI is around 1.5 hours (90 Minutes); c.f. https://www.eia.gov/todayinenergy/detail.php?id=37652#

[14] Source: https://www.bundesnetzagentur.de/DE/Sachgebiete/ElektrizitaetundGas/Unternehmen_Institutionen/Versorgungssicherheit/Versorgungsunterbrechungen/Auswertung_Strom/Versorgungsunterbrech_Strom_node.html

[15] Source: https://www.erneuerbare-energien.de/EE/Redaktion/DE/Downloads/zeitreihen-zur-entwicklung-der-erneuerbaren-energien-in-deutschland-1990-2019-excel.xlsx?__blob=publicationFile&v=23

[16] C.f. https://dserver.bundestag.de/btd/19/099/1909901.pdf

[17] C.f. e.g. Stoft (2002): Power System Economics - Designing Markets for Electricity, Müsgens and Peek (2011), Müsgens (2017), r2b energy consulting (2014), Frontier Economics / Consentec (2014).

[18] As long an EOM is designed as a 'pay as cleared' remuneration mechanism.

[19] C.f. https://www.bundeskartellamt.de/SharedDocs/Meldung/EN/Pressemitteilungen/2011/13_01_2011_SU-Strom.html?nn=3591568 as well as Müsgens (2006)

[20] C.f. https://ga.de/ga-english/news/in-june-the-german-power-grid-was-at-risk-of-a-blackout_aid-44073039

[21] C.f. https://www.ofgem.gov.uk/system/files/docs/2020/01/9_august_2019_power_outage_report.pdf

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