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MARKET OPPORTUNITIES AND REGULATORY FRAMEWORK CONDITIONS FOR STATIONARY BATTERY STORAGE SYSTEMS IN GERMANY

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Abstract

In the current and future German power system, characterized by large penetration of intermittent renewable energy sources, the demand and the importance of flexibility options are escalating. Therefore, this contribution provides, based on a literature review and market data analysis, a comprehensive discussion of today's potential application areas for stationary battery storage systems (sBSS) in Germany. The core research focus is based on market opportunities (estimation of application monetary benefits and if possible market sizes) in combination with regulatory framework conditions for each potential sBSS application. Given the background, the analysis identifies twelve use cases for sBSS services with three market opportunity categories: low, medium and high. However, the general outcome shows that especially the policy and regulatory treatment defines the demand and dynamics for mainly all sBSS application areas and hitherto, the multi-application character does not fit into existing regulatory frameworks.

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Keywords: stationary battery storage systems, market opportunity, benefit analysis, regulatory framework, Germany

I. INTRODUCTION

Stationary battery storage system (sBSS) technologies are auspicious and complementary tools to accomplish a system transformation into a low-carbon power sector, based on intermittent renewable energy (RE) sources, like wind and solar. Especially, the bidirectional transformation process of sBSS is a valuable and significant mechanism to decouple energy supply and demand: first, electricity is transformed into a storable form of energy at certain efficiency, and second, with certain losses the stored energy is recovered rapidly into electric energy [1]. Due to that

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fact, sBSS have multiple-application forms along the electricity value chain (supply, transmission, distribution and demand) in a liberalized market setting. According to [2], multi-application technologies are operable in many different ways by diverse actors and thus, have different potential value creation sources. Due to this special technology characteristic, market conditions and policy environments are still vague [3]. Moreover, [4] consternates that until now no clear pattern or preferred application has emerged, which indicates the strong influence of local policy, regulatory and market drivers that differ across energy systems worldwide. Based on these insights, country-specific studies which address legal framework issues are released. Some important market and legal analysis for sBSS applications in the German electricity market are: [5]; [6], [2], [7] and [8]. However, all of the mentioned studies have some drawbacks: some consider only parts of the possible sBSS application areas in the German electricity sector, some do not have specific market opportunity estimations or are missing an in-depth investigation of legal framework conditions. Accordingly, this contribution elaborates plausible sBSS applications and their market opportunities within the German legal framework setting of 2015. In that regard, it is noteworthy that all market opportunity estimations are without any battery specific costs and thus serve as a general revenue indicator.

II. Application Analysis

Due to the unique features and characteristics of sBSS, the potential service are either based on a power or a capacity application and the energy to power ratio range from seconds to hours [9]. Hence, the application areas in the German electricity sector are vast and multidimensional: ranging from power quality to time shift, with numerous stakeholders involved (s. fig. 1). Generally, an application defines the operation mode of sBSS, whereas a market opportunity assessment describes its potential benefit under the current legal framework conditions. There are two forms for a benefit assessment: first, revenues received by the storage owner or operator and second, cost reduction or avoidance by the storage owner or operator [10]. Thus, revenues can be realized in two forms: via existing markets with uniform and standardized product requirements or via bilateral contracts with negotiation potential. Whereas, cost reduction or avoidance is based on individual use cases by the storage owner or operator. In accordance to the mentioned categories, figure 1 illustrates the possible application areas within the German market environment.

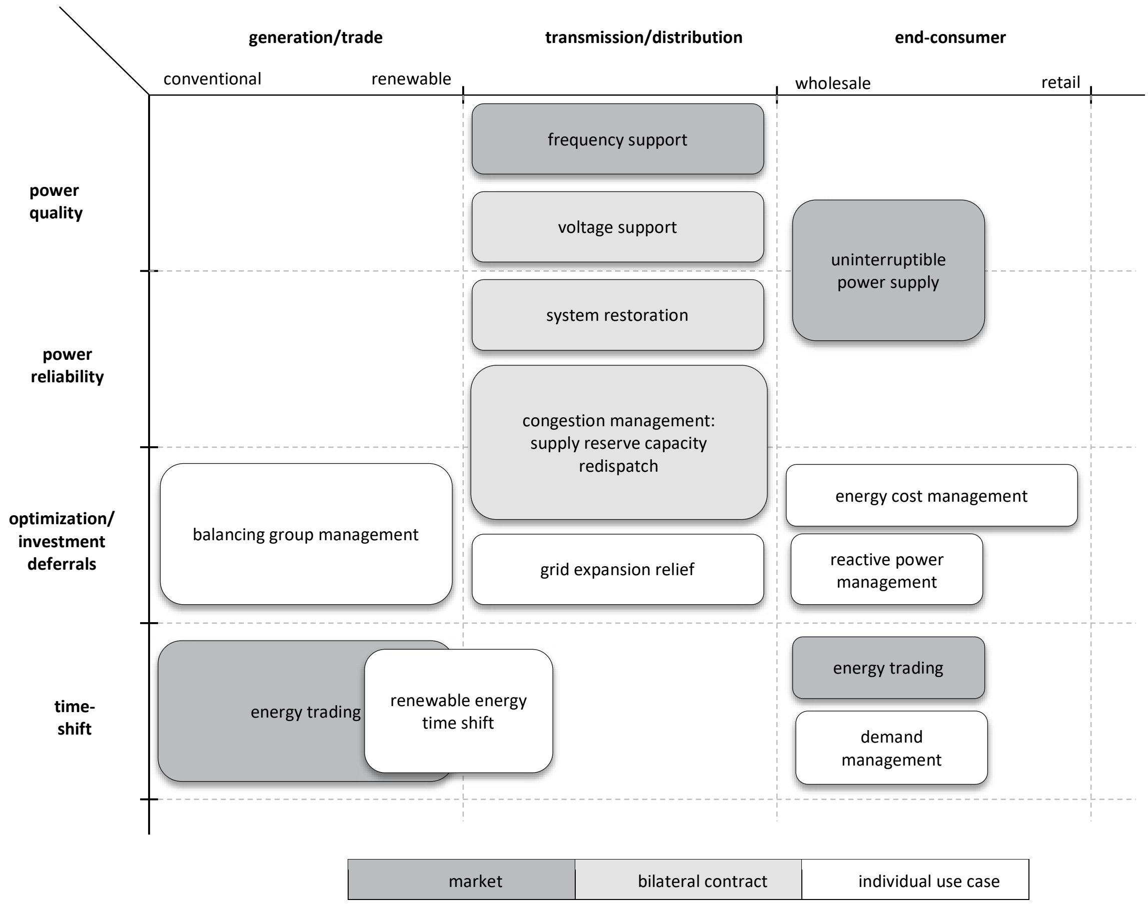

Fig. 1. SBSS value propositions (applications) and value networks (benefits) along the electricity value chain ([11]; [2]).

In accordance to the market setting for each sBSS application, the following sections discuss their operation mode and market opportunities with regard to legal constraints.

A. SBSS applications in markets

Energy trading: The facts that electricity is a homogenous commodity, the short term demand is fairly low price-elastic and the majority of power supply must be consumed at time of feed-in, facilitate intertemporal arbitrage transactions with sBSS. The European liberalization process of the energy sector enables that all stakeholders can participate in electricity trading via power exchange markets. Especially, for sBSS, the short term trading within 1-2 days at EPEX-Spot markets (day-ahead and intraday market) is applicable. At the day-ahead market, with a minimum contract volume of 0.1 MW trading in a daily static auction is possible with 24 hour single and diverse block contracts. Instead, the intraday market is organized as a continuous trading, which starts at 3 pm for the following day and closes 30 minutes before the actual physical delivery. Here, the smallest trades are 15 minutes contracts with a minimum volume of 0.1 MW.

Generally, the attractiveness of the particular market depends on the trading volume, the price spreads and the frequency of price spreads. In both markets, trading volumes are constantly increasing. These volume expansions are mainly influenced by legal framework changes and the evolution of RE. According to the Ordinance on a Nationwide

Equalisation Scheme (AusglMechV) electricity which is remunerated by the Renewable Energy Act (EEG 2014 version – apply for all EEG references in this paper) can only be sold via the day-ahead and intraday market. Without any price limit, the forecasted RE quantities are marketed at the day-ahead market and via intraday trading, the forecast deviations are fetched [12]. On both markets, extreme individual prices occur more frequently - which is an incentive for intertemporal arbitrage trades - but overall the price spreads have dropped – which narrows the revenue opportunities for that benefit area [13]. In particular, lower daily price spreads are highly affected by the noon feed-in maximum of photovoltaics [14].

Frequency support: In order to keep the central European electricity grid stable at 50 Hz, the transmission system operators (TSO) have to balance out feed-in and off-take at any time. To balance the system, TSOs rely on different control reserve forms: primary (PCR), secondary (SCR) and tertiary (TCR) control reserve. Pursuant to the definitions and requirements of the Federal Network Agency from 2011 (BK6-10-097/098/099), the German TSOs procure their needs for different control reserves on one open, transparent and non-discriminatory market (traded via the internet platform www.regelleistung.net). According to section 22 of the Energy Industry Act (EnWG 2015 version – apply for all EnWG references in this paper) the control reserve trading is done in form of a public competitive bidding with the general award method of pay-as-bid and additionally, in case of energy control claims for SCR and TCR, in a merit order procedure. The main differences between the three control reserve forms are the tender time and period, the product time-slice, the award criteria and the remuneration. Next to that, positive and negative SCR and TCR are separately offered, whereas for PCR the power increase and decrease must be ensured by a single offer. However, the PCR bid can be provided with various technical units (pooling).

Main drivers for the lucrativeness of the frequency support application are the market size, the access conditions for the individual control reserves (pre-qualification criteria) and the duration and amount of the respective control energy. According to the rules of the ENTSO-E Operation Handbook, a total PCR of 3,000 MW has to be provided in the continental European synchronously interconnected system [15]. For the dimensioning of SCR and TRC the requirements of the ENTSO-E are not defined as clear as for PCR. In Germany, the TSOs use a static probabilistic design method and update the amount requirements on a quarter-yearly basis [16]. Overall, the demand, especially for SCR and TCR has diminished within the last years. This can be attributed to the merge of former TSO individual markets: the power imbalances of the individual control areas are set off, hence, only the remaining balance must be compensated with control energy [17]. Moreover, since the latest change in pre-qualification conditions 2011 and especially the publication for batteries operating in the PCR segment (“Eckpunkte Freiheitsgrade bei der Erbringung von Primärregelleistung”), the supply side has grown and differentiated, caused by changes in volume and derivate time as well as the possibility of pooling. Previously unused flexibility potential (besides storage systems for example decentralized cogenerations and RES) could enter the market. In 2015, the number of companies supplying SCR and TCR continued to increase, in the PCR segment they remained stable [15]. Overall, there is no clear price trend recognizable for all forms of control reserves. But there is a tendency of declining prices (being of diverse degrees especially for SCR and TCR) [18]. However, the partly considerable fluctuations prove that price development on the markets for control reserves run into a more volatile and less fundamental manner than on energy spot markets [15]. The claim frequency and the amount vary greatly between control reserve forms, because control energy is gradually demanded according to the respective frequency imbalance. The PCR is accessed continuously and permanently according to the frequency fluctuations in the interconnected system. This permanent fluctuation is usually squat and moreover balanced by the entire interconnected European network. Therefore, experts estimates the system capacity demand for PCR as rather low (Younicos AG appraises for 90 % of the operating time a 20 % power load of their storage system) [19]. For SCR the situation is comparable: high and long demands for secondary control energy is rather rare, but the market shows an overall permanent activity. Therefore, offers with a high control energy price tend to be accessed only sporadically and bidders with a moderate or low control energy price are fairly active. However, the situation in the TCR segment is different: according to [7] only 20% of the entire time negative or positive control energy is accessed. Thus, this market is characterized by rather low activity. Consequently, even providers with low control energy prices tend to be inactive the main time.

B. SBSS applications via bilateral contracts

Voltage support: For stable network operation, the voltage level must remain within certain ranges. Since the voltage level depends on the typology of network and the local level of power supply and demand, transmission and distribution system operators rely on an ancillary service called voltage support. The static voltage support can, among others, be achieved by a local offset of reactive power [9]. Principally, a sBSS with an inverter and a corresponding power electronic, can off-set reactive power [20].

The attractiveness of the voltage support application depends on the existence of monetary compensations. On the distribution level, the requirements are part of the FNN-guidelines but there is no monetary compensation [6]. Only at the high and extra high voltage level the respective TSO remunerates this ancillary service. The expenditures for voltage support with inter alia reactive power, account to the fairly little expenditure of ancillary services. According to the Bundesnetzagentur (BNetzA), in recent years the total spending for reactive power amounted in a double-digit million range in Germany. The payment tariffs are individually determined by each TSO.

System restoration: The system restoration process is an integral part of the system responsibility. TSOs, in cooperation distribution system operators (DSO), coordinate the grid re-establishment process. Principally, all sBSS are able to energize transmission and distribution lines, synchronize sub-systems as well as back-up other black start units [7].

As the black start capability is only partial mentioned in the grid code, the requirements for the type and scope are negotiated bilaterally between the system operator and the respective provider. Therefore, compensation is not transparent and benefit estimations are only possible by considering the transparent procurement mechanism of the US-market. Overall, compared to other ancillary services, the significance of black-start capacity as revenue streams is rather low.

Congestion management: Due to the profound transformation of the German electricity supply system, infrastructure changes are not keeping pace with the changing feed-in and off-take infrastructure. Therefore, to ensure system stability, two progressively applied methods are redispatch of generation units for short term congestions and additional supply reserve capacities for longer congestions.

(A) Redispatch: When generation management (redispatch measures) is applied, the responsible network operator intervenes directly in the power plant generation planning process and adjusts feed-in from particular generation or storage facilities [21]. Therefore, redispatch measures always influences at least two power producers: the supplier at the congestion, which has to reduce the energy feed-in, while the supplier who relieves congestion has to increase to the same extent the energy feed-in [22]. SBSS could be directly located at network nodes for transmission congestion relief and could circumvent abrupt load changes from conventional power plants.

For redispatching there is no transparent market. The selection of generators for redispatching is based on their network location, their generation form and their size, which determines either the cost-based (where the adequacy of costs is regulated) or market-based (based individual bids submitted by the generators) redispatch [22]. According to section 13(1a) EnWG, the operators of power plants and storages with a nominal power of minimum 10 MW at all network levels are obliged to participate in cost-based congestion management. In this case, the remuneration and reimbursement is based on the marginal hourly costs at the EPEX-Spot in the previous month [23]. All other generation units can negotiate without restrictions the remuneration and participation for active congestion management [23]. However, if the costs should be covered by the network charges, it must be ensured that the payments are not excessive. Therefore an approximation of redispatch benefits can be derived from the marginal costs of conventional power plants.

(B) Supply reserve capacity: To prevent extreme network and generation bottlenecks as well as to guarantee supply security, when the redispatch potential from all market active power plants available is exhausted, TSOs can rely on additional supply reserve capacities. Since the winter of 2011/12, this is applied practice and has been enshrined by law 2013 in the EnWG. Principally, sBSS can offer this request for additional supply reserve capacity.

Decisive for the deployment of sBSS as supply reserve capacity, are the systemic requirements by the legislature. In the Reserve Power Plant Regulation (ResKV), TSOs are able to contract new power generation units (s. section 8 ResKV). In this case, all facilities which are used as power reserve, are bound to stay outside the energy market - to avoid market and system distortions. Nevertheless, at the end of use, new systems can either operate as a network-serving element for TSOs or can be dismantled and sold (s. section 9(3) ResVk). However, until 2015/16, the BNetzA does not claim any need for new systems as supply reserve capacities [17], which is essential to enter the market.

C. SBSS applications for individual users or operators

Uninterruptible power supply (UPS): Comparable to other industrial countries, large and long power outages (> 3 min) are rare in Germany (12.7 minutes 2015) [24]. However, surveys have shown, that supply disruptions of at least 3 minutes, account to only about 5 % of all by industrial companies reported supply disorders [25]. Consequently, reliant on the respective final power quality needs (e.g. outage time, harmonics), an UPS system can consist solely of a sBSS or in combination with a diesel or gas generator [8]. To estimate a monetary benefit for UPSs, two approaches are viable: first, via the improved service reliability and thus reduces financial losses associated with power outages (used method in this paper) and second, the price paid for UPS systems [10].

Balancing group management: An integral component of the European liberalized electricity market is the balancing group system. Hence, each feed-in and off-take in Germany must belong to a balance group, which is obliged to be balanced out on a quarter-hourly basis [26]. According to the “MaBiS” regulation, each balance group has to inform the respective TSO about their schedule for the previous day, but have the possibility to balance out their schedules until the next day (day-after market). Balancing energy is settled in line with the guidelines of the Electricity Network Access Ordinance (StromNZV), using symmetric imbalance prices for each 15-minute time period, called „regelzonenübergreifender einheitlicher Bilanzausgleichsenergiepreis“ (reBAP) [16]. In principle, the reBAP is determined by dividing the control energy costs arising in a specific quarter of an hour by the balance of the deployed amount of control energy in that same time interval [15].Therefore, a sBSS can optimize the energy balancing cost in both cases (shortage or surplus of balancing group).

Energy cost management: This sBSS application is comparable to energy trading: in both cases, the purpose is intertemporal arbitrage benefits. However, in this incident the focus is not on wholesale prices but on individual end user tariffs. According to section 40(5) EnWG, energy suppliers are obliged to offer load-variable and daytime dependent tariffs. Generally, tariffs primarily depend on the final electricity consumption and are roughly divided into industrial and residential. A lack of clear legislation and the settlement of consumers with demand of < 100,000 kWh/a via standard load profiles, results in the residential sector in load- or daily-time dependent tariffs only. In contrast, tariffs for large-scale consumers are individual negotiated, mainly depending on individual consumption patterns and are usually not public.

Reactive power management: Commonly, generation units as well as network operators are obliged to provide apparent power in accordance to the specific active and reactive power demand of the final user. However, in the industrial segment 50 % of the active energy can be obtained free of charge as reactive energy, which corresponds to a cos ϕ of 0.89 [27]. Again, the prices are subject to individual negotiations. As mentioned in voltage support, sBSS are principally able to provide this service.

Demand management: Until today, no residential tariffs with demand limits or incentives are offered. However, in the industrial segment at least 47 % of all businesses in Southern Germany state to have experiences with peak load shaving [28]. Usually, this is done by the retraction of running processes. Therefore, a laod-shift via sBSS has in addition to economic aspects, production-related benefits. Tariffs for industrial customers with capacity and load metering is subject to supply contracts, depending on the voltage level and the annual demand of maximum voltage. This is usually divided into ≥ 2,500 h/a with a high power price and low energy price and < 2,500 h/a with a low power price and high energy price. The second type is of particular interest for a storage-based demand management and can have very different regional price levels. The financial benefit of a sBSS device which operates as a demand manager depends on the annual period of use. Commonly, cost saving potentials are high, when load peaks have short durations.

Renewable energy self-supply: The decouple of RE generation and electricity consumption, on an hourly or daily range, is an attractive sBSS application. This is especially significant for solar power generation, where there is a daily gap between the maximum feed-in at noon and the maximum off-take in the evening (depending on the season the gap can be between five to six hours in Germany) [29]. In this setting battery units can help to shift renewable electrical energy to higher demand times. This is for small-scale photovoltaic roof-systems as interesting as for commercial producers of large-scale ground-mounted photovoltaic-systems. Nonetheless, for commercial producers the wholesale price of electricity is of concern, whereas electricity procurement costs are most pertinent for small producers and consumers (or prosumers). This application becomes progressively attractive as PV-generation costs and feed-in tariffs have dropped well below electricity purchase prices, whereas purchase prices have increased continuously [5]. However, it is important to note that attractiveness of RE self-supply depend significantly on electricity fee regulations. For instance due to the EEG amendment from 2014, newly installed systems over 10 kW or 10.000 kWh/a have to pay some of the additional electricity charges (e.g. EEG levy) for own consumption.

Grid expansion relief: Major increases in off-take or feed-in make transmission and distribution network upgrade essential. Due to the usual load characteristics, the available transmission capacity limits only the maximal transmittable power, but not the energy [30]. For instance, in Southern Germany photovoltaic systems feed-in less than 100 hours per year with more than 90 % of their installed nominal power [31]. Therefore, energy could be transferred in off-peak or peak periods to a near sBSS and can be charged or discharged when peak load occurs in electrical lines [26]. However, grid expansion is normally more cost-effective. Additionally, the current Incentive Regulation (ARgeV) does not consider more innovative (perhaps more expansive) infrastructure investments [32].

D. Legal charges for sBSS applications

Moreover, the lucrativeness of all sBSS applications depend directly on legal charges for electricity consumption. For instance, in the residential electricity segment, they amount to over 50 % of the final electricity price [33]. These legal charges consist of network charges, the EEG levy, electricity taxes, license fees, the offshore levy according to section 17 EnWG, the cogeneration levy and the levies according to section 19 StromNEV and section 19 AbLaV. Basically, all electrical storage devices are considered as "final consumers" in terms of their electricity uptake from the grid (stored energy). According to section 3 no. 25 EnWG a final consumer is a natural or legal person who purchases energy for their own consumption. This classification is supported by the argument that the conversion process “consumes” energy (efficiency losses) (cf. BGH 2009; BGH 2012). However, for electrical storage systems there are partial (limited to certain storage types or energy consumption patterns) exemptions for network charges, the EE-levy and the electricity tax. Besides the value-added tax, these are the highest fee burdens [33].

Network charges: For storage systems and other atypical consumers, network fees can be reduced according to section 19(2) sentence 1 StromNEV. The network charges can be diminished down to 20 %, if the maximum load deviates materially from the peak load. Moreover, individual network charges can be determined (a reduction down to 10 % is possible) for consumers with a high electricity demand (s. section 19(2) sentence 2 StromNEV).

According to section 118(6) EnWG for new storage devices, further exemptions for network fees excites: all electrical storages which are taken into operation from August 2011 (within the next 15 years) are not obliged to pay any network charges for a period of 20 years for electricity which is stored in the system. A precondition is a fed back in the same network node (s. section 118(6) sentence 3 EnWG).

EEG-levy: In section 60(3) EEG there is an exception for electricity storage. Accordingly, no EEG-levy applies, if the electricity is intermediately stored – meaning that electricity is stored for re-supply. Therefore, it is crucial that a reconversion and re-feed-in takes place.

Instead, if there is no reconversion, the self-sufficiency privilege (German Eigenversorgungsprivileg) according to section 61 EEG may lead to a reduction of the EEG apportionment. 2015, the TSO can demand for own consumption of electricity (over 10,000 kWh/a) an EEG-levy of 30 % (2016: 35 % and from 2017: 45 %). Own use is defined according to section 5 no. 12 EEG as a consumption of electricity by a natural or legal person, who consumes in immediate spatial connection (electricity is not passed through the network) with the own operating power plant itself.

Electricity tax: For electricity tax, there are partially exceptions for electrical storages. For pump storage power plants, there is an exemption according to section 9(1) no. 2 StromStG in connection with section 12(2) no. 2 StromStV. Other storage technologies are not mentioned in the law. However, according to the Federal Government, batteries can be considered to be part of the supply network and thus no electricity tax must be paid [36]. Moreover, if the charged electricity is transferred from a RE generation unit directly to the storage (no public grid is used), electricity taxes can be omitted (s. section 9(1) no. 1 StromStG). Furthermore, the charged electricity can be free of tax, in the case of an internal power supply (up to 2 MW electrical power rating) and direct line to the storage (s. section 9(1) no. 3 StromStG).

Summarizing legal charges for sBSS applications, it can be stated that the cost burden of the individual benefit field depends on the storage type (cf. electricity tax), the commencement of service (cf. network charges), the consumption pattern (cf. EEG-levy and electricity tax) and the grid feedback of electricity (cf. network charge and EEG-levy).

III. Results

In table 1, the estimated and described application market opportunities are listed. It is important to note, that these are just rough approximations and for valid revenue estimations further technology specific simulations are essential.

Table 1. Market opportunities for sBSS applications 2015

application area	market opportunities		
	benefits	market size	notes
day-ahead market	31.6 - 35.1 €/MWh [24]	264 TWh [24]	Phelix-Day-Peak (09-20) and Phelix-Day-Base (00-12)
intraday market		38 TWh [24]	
PCR	21.7 – 23.4 €/MW/h [37]	578 MW [24]	min.= average power price; max.= average marginal power price; potential for SCR and TCR higher because energy price not included
SCRpos	6.0 – 7.5 €/MW/h [37]	2,053 MW [24]	
SCRneg	3.0 – 4.0 €/MW/h [37]	2,027 MW [24]	
TCRpos	0.6 – 1.0 €/MW/h [37]	2,044 MW [24]	
TCRneg	1.8 – 2.7 €/MW/h [37]	2,146 MW [24]	
voltage support	0.60 -8.70 €/Mvarh [38]; [39]; [40]		based on available TSOs-price sheets
system restoration	6.85 €/MW/h [41]	approx. 85 MW [24]	high uncertainty due to approximation based on US-data
redispatch	9.72 -47.54 €/MWh [42]	16,000 GWh [24]	based on marginal cost of conventional power plants (= cost-based redispatch) min.= marginal costs nuclear; max.= marginal costs natural gas
uninterruptible power supply	952 €/MW/h [24]; [43]; [44]	n.s.	Value of Lost Load (VoLL) and System Average Interruption Duration Index (SAIDI)
balancing group management reBAPpos	0.01-75,99 €/MWh [45]	n.s.	max.= average volume-weighted reBAP prices, potential ascending
balancing group management reBAPneg	0.01-42,67 €/MWh [45]	n.s.	
energy cost management (households)	9.00-98.00 €/MWh [46]; [47]; [48]; [49]	n.s.	exemplary cost analysis of the so called “big four” (E.on, RWE, Vattenfall and EnBW), difference between high and low day-tariffs
energy cost management (industry)	3.5 €/MWh [24]	n.s.	based on Spot-market prices: Phelix-Day-Peak and Phelix-Off-Peak
reactive power management	13.00 €/Mvarh [27]	n.s.	estimations by ZVEI
demand management	15.00 €/MWh [50]; [39]; [51]; [52]	n.s.	TSOs power prices on the high voltage level <2,500 h/a
RE self-supply (households)	145 - 189 €/MWh [53]; [33]	n.s.	residential PV-system costs and average electricity costs for households
RE self-supply (industry)	30,3 - 74.30 €/MWh [53]; [33]	n.s.	large-scale PV-system costs and electricity consumption of 100 GWh/a
grid expansion relief	0.10-0.20 €/MWh [54]; [55]; [56]	n.s.	grid expansion costs: costs based on the “Bundesländerszenario”, grid lifespan 40 years and consumption in the distribution network 300 TWh

According to the results, applications with a high market opportunity (with regard to revenue potential, good applicability and favorable legal environment) are energy trading at energy-only-markets, frequency support (especially PCR and SCR), uninterruptible power supply, balancing group management, energy cost management and renewable energy time shift. Applications with a medium market opportunity are redispatch, demand management and reactive power management. A low potential for sBSS have grid expansion relief, voltage support and system restoration. No revenue potential has the supply reserve capacity, due to the current estimations of the BNetzA

IV. DISCUSSION & CONCLUSION

Regarding the sBSS application analysis, the German market offers multiple use cases with different market opportunities. However, current market conditions and policy environments are unclear in regards to the energy services rendered by sBSS. The present electricity market design does not adequately reflect this physical flexibility requirement at the energy only market and energy control market. Additionally, ancillary services determinations and requirements are still favourable to a centralized, fossil fuel based energy supply system. Therefore, a reform in market designs is essential as well as technology neutral regulations for ancillary services. The legal framework is an additional obstacle for the operation of sBSS. The system consideration "energy storage" does not exist: in the EnWG (as well as in other relevant laws) there is no definition of the term "energy storage" as well as the important subcategories "power storage in the power supply system". However, the current legal status of RE system integration mainly focuses on grid expansion, with the resulting effect of diminishing solidarity (more energy self-supply to avoid legal charges). Besides, to achieve widespread sBSS deployment, legal charges such as network charges due to final consumption term for sBSS have to be reconsidered. Furthermore, since sBSS have multiple-application forms along the electricity value chain (supply, transmission, distribution and demand) in a liberalized market setting, they usually do not fit existing regulatory frameworks. To this end, regulations should consider multi-services by sBSS in order to avoid double charges and burdens, which is unfavorable for technology deployment.

REFERENCES

[1] X. He, E. Delarue, W. D'haeseleer, and J.-M. Glachant, "A novel business model for aggregating the values of electricity storage," *Energy Policy*, vol. 39, no. 3, pp. 1575–1585, Mar. 2011.
[2] B. Battke, "Multi-purpose technologies, lock-in and efficiency – Policy implications from the case of stationary electricity storage," ETH Zürich, 2014.
[3] M. Landry and Y. Gagnon, *Energy Storage: Technology Applications and Policy Options*, vol. 79. Elsevier B.V., 2015.
[4] IRENA, "Battery Storage for Renewables : Market Status and Technology Outlook," Bonn, 2015.
[5] P. T. Moseley and J. Garche, *Electrochemical Eenrgy Storage for Renewable Sources and Grid Balancing*. 2015.
[6] M. Sterner, F. Eckert, M. Thema, and F. Bauer, "Der positive Beitrag dezentraler Batteriespeicher für eine stabile Stromversorgung," Berlin, 2015.
[7] H.-P. Beck, B. Engel, L. Hofmann, R. Menges, T. Turek, and H. Weyer, "Eignung von Speichertechnologien zum Erhalt der Systemsicherheit," Goslar, 2013.
[8] G. Fuchs, B. Lunz, M. Leuthold, and U. Sauer, "Technology Overview on Electricity Storage," Aachen, 2012.
[9] M. Sterner and I. Stadler, *Energiespeicher*. Berlin: Springer, 2014.
[10] G. Corey and J. Eyer, "Energy Storage for the Electricity Grid : Benefits and Market Potential Assessment Guide A Study for the DOE Energy Storage Systems Program," New Mexico, 2010.
[11] M. Klausen, M. Resch, and J. Bühler, "Analyis of a Potential Single and Combined Business Model for Stationary Battery Storage Systems," *Energy Procedia*, vol. 99, no. March, pp. 321–331, 2016.
[12] N. Roloff, W. Krewitt, K. Roloff, N. Nils, R. Reeg, and W. Matthias, "Analyse von Rahmenbedingungen für die Integration erneuerbarer Energien in die Strommärkte auf der Basis agentenbasierter Simulation," Stuttgart, 2011.
[13] Dena, "Integration erneuerbarer Energien in die deutsche Stromversorgung im Zeitraum 2015/2020 mit Ausblick 2025," Berlin, 2010.
[14] L. Hirth, "The market value of variable renewables," *Energy Econ.*, vol. 38, pp. 218–236, 2013.
[15] Consentec GmbH, "Description of load-frequency control concept and market for control reserves," p. 43, 2014.
[16] L. Hirth and I. Ziegenhagen, "Balancing power and variable renewables: Three links," *Renew. Sustain. Energy Rev.*, vol. 50, pp. 1035–1051, 2015.
[17] BNetzA, "Monitoringbericht 2014," Bonn, 2014.
[18] L. Hirth, "Balancing power 2015." Neon Energie, Berlin, 2015.
[19] J. Wiemann, "Einsatzmöglichkeiten von Großbatterien im Regelenergiemarkt," HTW-Berlin, 2014.
[20] A. A. Akhil *et al.*, "Electricity storage handbook," New Mexico, 2013.
[21] S. Spiecker, P. Vogel, and C. Weber, "Ökonomische Bewertung von Netzengpässen und Netzinvestitionen," *uwf*, vol. 17, pp. 321–331, 2009.
[22] Frontier Economics and Consentec GmbH, "Relevance of established national bidding areas for European power market integration – an approach to welfare oriented evaluation," 2011.
[23] C. König, *Engpassmanagement in der deutschen und europäischen Elektrizitätsversorgung,*. Nomos, 2013.
[24] BNetzA, "Monitoringbericht 2016," 2016.
[25] C. Bier, "Stellungnahme zum Eckpunktepapier der Bundesnetzagentur zur „ Ausgestaltung des Qualitätselements Netzzuverlässigkeit

Strom im Rahmen der Anreizregulierung"," Essen, 2011.
[26] M. Koller, "Optimiete Bettriebsführung eines 1 MW Batteriespeichers im Verteilnetz," ETH Zürich, 2012.
[27] ZVEI, "Energieeinsparung durch Blindleistungskompensation," 2012.
[28] D. M. Klobasa *et al.*, "Lastmanagement als Beitrag zur Deckung des Spitzenlastbedarfs in Süddeutschland," Berlin, 2013.
[29] F. Genoese, *Modellgestützte Bedarfs- und Wirtschaftlichkeitsanalyse von Energiespeichern zur Integration erneuerbarer Energien in Deutschland*. Karlsruhe: KIT Scientific Publishing 2013, 2013.
[30] S. Aschenbrenner, "Untersuchung verschiedener Geschäftsmodelle für den Einsatz eines Batteriespeichers im Niederspannungsnetz - Theoretische Betrachtungen und Bestimmung von Kenngrößen," Hochschule Regensburg, 2013.
[31] J. Weniger, J. Bergner, T. Tjaden, and V. Quaschning, "Bedeutung von prognosebasierten Betriebsstrategien für die Netzintegration von PV-Speichersystemen," in *29. Symposium Photovoltaische Solarenergie*, 2014.
[32] E. Bruns, M. Futterlieb, D. Ohlhorst, and B. Wenzel, *Netze als Rückgrat der Energiewende*. Berlin: BMU, 2012.
[33] BDEW, "Strompreisanalyse Januar 2016 Die wichtigsten Ergebnisse im Überblick." Berlin, 2016.
[34] BGH, "EnVR 56/08," Karlsruhe, 2009.
[35] BGH, "EnVR 47/11," Karlsruhe, 2012.
[36] C. Pape, N. Gerhardt, P. Härtel, and A. Scholz, "Roadmap Speicher," Berlin, 2014.
[37] e2m, "Marktreport Regelleistung - Januar 2016." 2016.
[38] Amprion, "Netznutzungsvertrag 2013." 2012.
[39] 50 Hertz, "Preisblatt 2014." 2014.
[40] Tennet, "Netznutzungsvertrag 2012." 2012.
[41] C. Pieper and H. Rubel, "Revisiting Energy Storage," Frankfurt am Main, 2011.
[42] D. Böttger and T. Bruckner, "Marktszenarien für eine erfolgreiche und nachhaltige Energiewende 11.," in *Energieversorgungssysteme der Zukunft*, 2014.
[43] G. Erdmann, A. J. Praktiknjo, and A. Hähnel, "Assessing energy supply security: Outage costs in private households," *Energy Policy*, vol. 39, no. 12, pp. 7825–7833, Dec. 2011.
[44] C. Growitsch, R. Malischek, S. Nick, and H. Wetzel, "The Costs of Power Interruptions in Germany - an Assessment in the Light of the Energiewende," Köln, 2013.
[45] 50 Hertz, "Archiv-Bilanzkreisabrechnung," 2017. [Online]. Available: http://www.50hertz.com/de/Maerkte/Archiv/Archiv-Bilanzkreisabrechnung. [Accessed: 12-Dec-2016].
[46] E.ON, "E.ON Grundversorgung Strom (Doppeltarif)," 2014. [Online]. Available: https://www.eon.de/pk/de/strom-und-erdgas/strom/flexibelstrom/eon-grundversorgung-strom/eon-grundversorgung-strom-doppeltarif.html#collapse-tab-2. [Accessed: 30-Sep-2014].
[47] EnBW, "Intelligente Stromzähler," 2014. [Online]. Available: https://www.enbw.com/privatkunden/tarife-und-produkte/strom/stromtarife_84675.html. [Accessed: 29-Sep-2014].
[48] RWE, "RWE EDL21 Meter Strom," 2014. [Online]. Available: https://www.rwe.de/web/cms/de/1160044/privatkunden/strom-vergleich/stromrechner/. [Accessed: 29-Sep-2014].
[49] Vattenfall, "Easy Spar Aktiv," 2014. [Online]. Available: https://www.vattenfall.de/de/berlin-easy-spar-aktiv.htm. [Accessed: 30-Sep-2014].
[50] Amprion, "Entgelte." 2014.
[51] Tennet, "Netzentgelte." 2014.
[52] TransnetBW, "Entgelte Netznutzung." 2014.
[53] C. Kost *et al.*, "Stromgestehungskosten Erneuerbare Energien," 2013.
[54] Dena, "Ausbau- und Innovationsbedarf der Stromverteilnetze in Deutschland bis 2030.," 2012.
[55] S. Roon, M. Sutter, F. Samweber, and K. Wachunger, "Netzausbau in Deutschland," 2014.
[56] U. Leprich, "Netze, Speicher, Lastmanagement," in *BUND-Tagung*, 2014.