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Stakeholder demands and regulatory framework for community energy storage with a focus on Germany

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ABSTRACT

Community energy storage (CES) can provide for a variety of services and offers the possibility of combining individual needs with grid services. Hence, CES has the potential to play an important role in the energy transition, especially for a sustainable urban energy supply. In Germany, however, progress in this field has been slow due to a complex regulatory framework and limited transdisciplinary research.

This paper focuses on an analysis of the regulatory framework in Germany and the demands of the various stakeholders. What opportunities does CES hold for private and public stakeholders? What are the barriers? To answer this, we conducted a literature review on CES, identifying the regulatory and political framework in Germany and Europe. In spring 2018, we conducted structured interviews with 17 professionals from various municipalities, regional authorities, energy suppliers, grid operators, and storage manufacturers.

Both the literature review and our interviews show that in order to achieve greater implementation CES needs to fulfil multiple services to optimize its utility and meet the demands of all stakeholders. Moreover, our research reveals that in Germany one of the biggest obstacles faced by CES, other than a complex regulatory framework, is the lack of a clear legal definition.

1. Introduction

An increasing share of renewable energy in energy production leads to new challenges with respect to distribution and storage. One is the emerging time discrepancy between energy supply and energy demand (e.g. Agora Energiewende, 2014). Precautionary measures are also needed to maintain a stable grid. Self-sufficient urban energy systems can make a positive contribution in this transition (Peter, 2013). One of the technologies capable of supporting self-sufficient urban energy systems and increased flexibility and grid stability is electric battery storage (Barbour et al., 2018; Devine-Wright et al., 2017; Klausen, 2017; Koirala et al., 2018; Müller and Welpe, 2018; Parra et al., 2017b; van Melzen, 2018). Such battery storage systems are becoming more attractive due to falling prices. In Germany, one out of every two new private photovoltaic power plants is currently equipped with a battery storage system (Figgener et al., 2018).

While privately owned battery storage systems are designed to maximize self-consumption (i.e. off-grid provision of power), the grid services that such systems could hypothetically provide are manifold (Devine-Wright et al., 2017; Liu and Wang, 2018; Müller and Welpe, 2018; Parra et al., 2017b, 2017a; van der Stelt et al., 2018). Among other things, the provision of balancing energy, idle power, and the possibility of black starts are some of the services such battery systems can provide (Arghandeh et al., 2014). Compared to individual, privately owned systems, *community energy storage* (CES) might offer even more possibilities for combining individual needs with grid services due to scaling effects (Parra et al., 2017a), including the participation and integration of a larger number of local users (Parra et al., 2017b). For the purposes of this paper, we define CES as battery storage system sited in and serving the power demands of a community within a spatially bounded, organizationally defined area or region. The main purpose of a CES system is to contribute to a self-sufficient energy supply within these boundaries, although interesting and innovative business models may make it possible to combine this goal with other services. To fully exploit the possibilities of CES, appropriate business models and a sympathetic regulatory framework supporting these concepts are needed (Lombardi and Schwabe, 2017; Parra et al., 2017b).

There have recently been a limited number of projects to explore the possibilities of CES (Müller and Welpe, 2018; Parra et al., 2017a), but the concept is still quite new and not widespread. Research, so far, has

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focused on the challenges and opportunities from a technological perspective (beegy GmbH, 2018; synergy, 2018; ZAE Bayern, 2018); however, a holistic evaluation of CES also needs to address the economic, social, and ecological aspects. Since CES involves a number of different stakeholders, including, municipalities, grid operators, battery storage manufacturers, energy providers, and other regulatory authorities, its implementation and the complementary realization of suitable business models and services has multiple facets. What then are the main opportunities and barriers for private and public stakeholders concerning CES? This question, as well as possible services and essential requirements for a successful business model, will be addressed in this paper.

We focus solely on Germany as more general statements are to some degree unreasonable due to the varying policy and regulatory frameworks in place, as these can significantly influence potential opportunities and barriers. Germany was chosen due to the significant number of CES projects already in place and hence the possibility to learn from prior experience. Moreover, in Germany the share of renewable energies in electricity production is close to the European average and fairly diversified with respect to renewable energy sources (European Commission, 2016a). Electricity storage in Germany is especially of interest at a local level as regulations favour self-consumption over feed-in delivery, and such entities by their nature strive for a high degree of self-consumption. Though we focus on Germany, the description of the supranational European framework simplifies the transfer of numerous aspects to other countries.

Our findings are highly relevant for policy makers and businesses; we provide recommendations to policy makers for promoting CES and highlight the current barriers and opportunities identified by the various stakeholders. Additionally, enterprise stakeholders are offered insight into potential business models and services as well as a better understanding of the demands and barriers facing other stakeholders, thus allowing them to shape their business models and services accordingly.

2. Background

2.1. Definition and organizational structure of CES

Although CES is an increasingly common term in the literature, it has no clear-cut definition at the international level (Gaudchau et al., 2016; Weyer, 2015). In most papers CES or comparable terms such as *neighbourhood storage* or *shared battery storage* are used to differentiate it from home storage systems, in the sense that use of the system extends beyond the singular household (cf. Barbour et al., 2018; Kloppenburg et al., 2019; Müller and Welpe, 2018; Parra et al., 2017b). In our definition we chose to follow as closely as possible the definitions provided by the European Union.

The European Commission defines the more generic term *energy storage* as follows: 'Energy storage in the electricity system would be defined as the act of deferring an amount of the energy that was generated to the moment of use, either as final energy or converted into another energy carrier' (European Commission, 2016b). A definition of community and underlying structure can be found in Directive (EU) 2018/2001 on the use of energy from renewable sources. Here, in the context of a definition of renewable energy communities, a community is defined as an entity that is open, voluntary, and effectively controlled by shareholders or members located in proximity. The shareholders or members can be natural persons, small and medium-sized enterprises, or local authorities, including municipalities.

Combining the given interpretations of community and storage, we define CES and the underlying organizational structure as a battery storage system that allows utilization of an amount of electricity to be deferred to the moment determined by natural persons or small and medium-sized enterprises or local authorities located in proximity.

2.2. The role of CES in the future energy system

Battery storage and CES in particular play an important role in a changing energy system, where the number of decentralized renewable energy production units is increasing, smart grids are playing an ever greater role, and more and more prosumers are producing and consuming their own electricity. For the world-wide growing number of prosumers (Inderberg et al., 2018), energy storage can help to substantially increase self-produced energy consumption lead to greater energy autonomy (Moshövel et al., 2015). Nevertheless, Kloppenburg et al. (2019) showed that although energy storage is important for the pro-active and aware prosumer, even with home storage systems prosumers need professional support.

In the Clean Energy Package, adopted by the European Commission in 2019, one of the priorities is boosting 'renewable energy communities' and 'jointly acting renewable self-consumers'. Renewable energy communities have as their main defining purpose the provision of environmental, economic or social benefits. 'Jointly acting renewable self-consumers', on the other hand, refers to a group of prosumers located in the same building or block. The Renewable Energy Directive 2018/2001 states that 'renewable energy communities should be able to share between themselves energy that is produced by their community-owned installations'. This directive will therefore not only boost collective prosuming (Horstink et al., 2020) but also promote commonly used technologies such as CES. This could range from joint self-consumption up to a smart grid (Hansen and Hauge, 2017; Hoicka and MacArthur, 2018; Kloppenburg et al., 2019).

2.3. CES as a socio-technical innovation

In this paper we treat CES as a socio-technical innovation in the energy system in the sense used by Rip and Kemp (1998) – it is a technical innovation but it is also a social innovation, as it acknowledges that the relevant actors are jointly responsible for production, diffusion, and use; one therefore needs to include more groups in the investigation than just engineers (Geels, 2004). Geels (2002) states that suppliers, producers, user groups, societal groups, public authorities, research networks, and financial networks all could play a role in the success of an innovation. In addition, Kivimaa (2014), as well as Verkade and Höffken (2019), underline the important role of intermediaries in the context of energy innovations. In the case of CES, apart from the user groups, which have already been a focus in the literature (e.g. Hoffmann and Mohaupt, 2020; Kalkbrenner, 2019; Kloppenburg et al., 2019; Koirala et al., 2018), energy suppliers, battery manufacturers, and public authorities are of importance and are addressed in this paper. Financial networks are excluded since the energy sector is highly regulated and financing accordingly plays a subordinate role compared to other groups. Drawing on Geels (2002) and Smith et al. (2010), we use a multi-level approach to analyse needed changes for the evolution of CES from niche development to mainstream.

Presently, CES is almost only found in research projects or singular applications (cf. Malhotra et al., 2016), which fits the definition of a niche according to Smith et al. (2010). Kemp et al. (1998) note that niche innovations may not be competitive and tend to take place in a protective space. To investigate this, we use the strategic niche management framework (Kemp et al., 1998). Schot and Geels (2008) identify three main processes for successful strategic niche management: articulation of expectations and visions, building of social networks, and learning processes. Focusing on these processes can help to counteract the techno-economic, cognitive, social, and finance- and investment-related uncertainties (Geels et al., 2018). Smith et al. (2010) go a step further for sustainable niches and state that 'actors (producers and users) undertaking these experiments are relatively more supportive of the social and environmental qualities of niche socio-technical practice, and more forgiving of teething troubles, owing to their differing expectations for future performance as compared to regime members'.

The scalability and mainstreaming of niches is still under discussion. Geels et al. (2018) differentiate between innovations that may scale up through larger projects and innovations that might not so easily scale due to a specific user segment or other limiting factors. CES might fall between these two extremes. While energy communities will certainly increase in their importance and their desire to use their self-produced energy, the diverse field of projects so far (cf. Malhotra et al., 2016), clearly suggests that there is no single solution that fits all. Nevertheless, Geels et al. (2018) propose that scalability should not be the only basis for decision and support mechanisms and possibly not the only path to mainstream. Accessibility of benefits, efficiency, and effectiveness of the innovation should in their opinion also be taken into account. Accordingly, there is a path to mainstream for CES as the results in this paper present. Important aspects for this breakthrough are, according to Geels (2002), infrastructure, technology, market/user practices, sectoral policy, techno-scientific knowledge, industrial networks, and cultural/symbolic meaning. We do not address all of these aspects here, but will contribute to most of them for the case of CES in Germany.

3. Research design and methodology

The opportunities offered by and barriers to CES for private and public stakeholders are in many respects highly dependent on the policy and regulatory framework in place. Hence, for the case of Germany, the national and, where applicable, European policy and regulatory framework will be described. The policy framework emphasizes the topic's relevance and by analysing the obstacles and barriers of the German regulatory framework with respect to the European framework, the results can be translated and transferred to the general European framework and other countries.

In order to gather various viewpoints, structured interviews were carried out in early 2018 with various public and private CES stakeholders. For the interviews we identified five target groups that appear as users, providers, initiators or operators of CES systems and services, or administrators within the legal framework. These groups included municipalities, grid operators, battery storage manufacturers, energy providers, and regional authorities. Due to the complexity of the topic and our desire to collect in-depth knowledge, only professionals with CES experience were chosen, primarily grid operators, manufacturers of storage systems and energy providers that had already implemented CES or CES-related projects or investigated CES feasibility. Similarly, we chose municipalities where storage projects had already been planned or implemented (Müller and Welpe, 2018). In the area of governance, we focused on regional authorities, as we analyzed the national policy and regulatory framework through a literature review. The 17 interviews, average length 50 min, were conducted via telephone, recorded, and subsequently transcribed. All except two were structured.[1] Initially, we contacted 29 potential interviewees via mail (10 municipalities, 5 grid operators, 3 battery storage manufacturers, 5 energy providers, and 6 regional authorities). Experts not responding positively were contacted again via telephone and asked a second time to participate. Although some of our potential experts could not spare the time, we managed to interview a total of 17 respondents, a response rate of 59%.

In developing our interview guidelines, we first selected relevant questions drawn from other interviews and surveys to reach a certain level of comparability (Kerler, 2017; Meier, 2016; Petersen, 2016; Schaeff, 2016; Scheer-Pontenagel, 2017; Windelen, 2016). The other studies, however, usually did not advance beyond basic questions on the topic of energy storage systems, thus confirming the previously identified research gap regarding CES requirements. With this in mind, we chose an explorative approach in our guidelines, which were similarly designed for all actor groups. Following an introductory question concerning the participant's own definition of CES and specification of experience with CES, the interview guidelines included six groups of questions, addressing the following topics:

I. Energy transition and future market development
II. Current situation and comparison to other storage technologies
III. Legal framework
IV. Funding
V. Acceptance and participation[2]
VI. Services and business models

The first two were intended to ascertain the interviewees' level of knowledge, background, and basic ideas about CES and its relevance for the energy system. The next two were intended to capture their attitudes toward the current legal framework and funding situation for CES. Even though our analysis of the current policy and regulatory framework had revealed likely barriers and points for discussion, we formulated open questions regarding opportunities and barriers associated with the legal framework and funding in order to avoid interviewer bias. In the last two groups of questions, we discussed primary relevant topics for the development of storage solutions: questions about the inclusion of citizens, data security, and the respondents' visions of services and business models with respect to CES. For the various stakeholder groups we made slight changes to reflect the actors' specific perspectives; however, we strived for the same depth of information with all stakeholder groups, relying as necessary on further inquiries. The number of questions per the guidelines was between 17 and 21.

In order to analyse the expert interviews, we conducted a content-related, structuring qualitative content analysis (Kuckartz, 2014), for which we developed a set of categories in accordance with the interview guidelines. The six groups of questions mentioned above that served as a basis were in one case further divided into two categories (services and business models) and complemented by three further categories (personal ideas about CES, personal experiences with CES, and data security), as a separate analysis seemed fruitful for these areas. After a first analysis of the interview transcripts, we identified subcategories that made it possible to further structure the interview content. For this paper, we will not go into greater detail regarding all categories but focus instead on the assessment of CES, the legal framework, funding, and ideas for services and business models.

4. Policy and regulatory framework with respect to CES in Germany

4.1. Policy framework

Even though CES-based storage solutions are becoming increasingly attractive to policy makers (Müller and Welpe, 2018; Parra et al., 2017a), the use of CES is not widely established yet and research into growth opportunities in the market is limited. Thus we find few political statements explicitly concerning CES. The political position on this technology has to be extracted from policy statements about storage technologies in general as well as from statements about battery storage technology that are suitable for application in CES.

The German Federal Government described energy storage technologies as vitally important for increasing the share of renewable energy and securing the energy supply as early as the German energy concept of 2010 (BMU BMWi, 2010), thus the need to intensify research and improve the regulatory framework (BMU BMWi, 2010). The coalition agreement between the CDU, CSU, and SPD political parties states

[1] The two interviewees were not available for a structured interview. The conversation concerning the request however included enough information to be eligible for an inclusion in the analysis.

[2] Note that the answers to the fifth group of questions are not analyzed in this paper, as they focus on citizen needs and demands and therefore a different group of stakeholders.

that investments in storage technologies and the integration of heating, mobility, and electricity in combination with storage technologies ought to be encouraged; funding for research, the establishment of a Fraunhofer institute for storage technologies as well as subsidies have also been proposed. Domestic production of batteries once more is also anticipated (Bundesfraktionen der CDU/CSU und der SPD, 2018). But it is not only the political parties comprising the current German government that seem supportive of storage technologies; other parties likewise support advancements in storage technologies (cf. Bündnis 90/Die Grünen, 2017; DIE LINKE, 2017; FDP, 2017).

These statements are underscored by several subsidies and budgets already realized or in place for the promotion of private battery storage systems. The KfW Program 275 (March 2016 to the end of 2018) provided subsidies totalling approx. 30 million euros for private owners who implemented a photovoltaic power plant in combination with a battery storage system. Along with subsidies at the national level, there have also been various subsidies provided by the states (Bezirksregierung Arnsberg, 2018; cf. Figgener et al., 2018; Sächsische Aufbaubank, 2018; Schwab, 2017).

The European Commission classifies energy storage technology as one of the key components for the integration of further renewable energies, as these technologies increase flexibility and hence energy security (European Commission, 2017a). Energy storage technologies, in particular battery storage, can play a major role not only in the energy sector but also with respect to other sectors, especially transportation (European Commission, 2017a; Hannen, 2017). Consequently, the production of battery storage systems is a national, but also a European goal, set by the European Commission (European Commission, 2017b; Hannen, 2017).

The Commission points out the necessity of aligning national regulations and reducing administrative barriers to exploit the full potential of energy storage technologies (European Commission, 2017a). The European Union has proposed support for new business models and innovative storage technologies, establishing funding as part of the Horizon 2020 package (European Commission, 2017a). From a total budget of 80 billion euros for non-nuclear research, Germany used 10.5% of its 90 million euro allotment between 2014 and 2020 to fund projects in the field of battery storage (BMWi, 2017).

Summarizing the German and European policy framework, one can make three main observations. First, policy statements on the German national and the European level stress the great potential storage technologies and particularly battery storage bear for the energy transition. Second, the German government and the European Commission show the intention of advancing research in the field of new storage capacity as well as promoting the production of batteries in Germany and the European Union. Third, subsidies for research and implementation of battery storage systems have already been established.

4.2. Regulatory framework

While the policy framework conveys an optimistic outlook for battery storage and underscores the relevance of the topic, the current regulatory framework has a large impact on shaping developments in the (community) energy storage sector in the near future. In the following description of the regulatory framework, we focus on CES scenarios allowing for multiple-use implementation.

4.2.1. Definition of CES in the regulatory framework

As noted above there is no clear-cut definition of CES at the international level (Gaudchau et al., 2016; Weyer, 2015). In Germany, neither CES nor energy storage are defined in the regulatory framework. The definition of energy storage facilities makes reference only to gas storage (§ 3 EnWG – Energy Industry Act), with no distinction between pump, gas or battery storage (Gaudchau et al., 2016). The EnWG established the three main pillars of the German energy system: production, transportation and consumption, but rather than treating energy storage as a separate pillar it falls under consumption when energy is being charged (cf. § 3 EnWG, § 3 EEG 2017 – Renewable Energy Sources Act) and production when being discharged (cf. § 3 EnWG, § 3 EEG 2017). Thus energy storage is subject to multiple laws and regulations in the German energy sector.

4.2.2. Charges, duties, fees and taxes

A number of charges apply when operating a battery storage system. Given that energy storage falls under both consumption and production, the fees and charges are in some cases doubly applicable. Table 1 summarizes these various fees and their legal basis in German law.

Several exceptions are in place, depending on the operator and type of installation. First, we will elaborate some exceptions that apply to all possible use cases and afterwards focus on the regulatory framework for main-use cases of battery storage.

Storage facilities built after 31 Dec 2008 and put into use between 4 Aug 2011 and 4 Aug 2026 that draw from and feed energy back into the same transmission grid or network are, in accordance with § 118 EnWG, exempted from grid fees, and § 19 StromNEV obligates grid operators to offer individual grid fees when energy is drawn from the same grid it is later returned to. Electricity in the public grid that is traded in the German electricity balancing market is also exempted form grid fees; an exemption from EEG levies is also in part possible. The EEG levy has to be fully paid when feeding out power from an energy storage system, whereas when drawing in power only the difference between incoming and outgoing electricity has to be paid (cf. § 61k EEG 2017). No EEG levy is charged for losses in the energy storage system (cf. § 61k EEG 2017), nor for balancing losses from a grid operator (cf. § 61k EEG 2017). The storage operator must provide for measuring devices and accounting methods to record losses as well as ingoing and outgoing electricity (§ 61k EEG 2017) and delay in the communication of detailed data to the grid operator will lead to a 20% increase in the applicable EEG levy.

A special exception applies to renewable energy. In accordance with § 9 StromStG, electricity from renewable resources stored in an energy storage system is exempted from electricity-specific taxes. The value added tax (VAT), however, is not affected by this exemption if electricity is fed on a regular base into the public grid. Thus, VAT is calculated not on the costs of energy production but on the costs for electricity as if purchased from a basic provider for energy (BMF, 2014; Wild, 2015). In addition, the tax for the investment in energy storage is only refunded if the photovoltaic plant and the energy storage system can be declared as a singular system.

4.2.3. Optimization of self-consumption

When the battery storage system is used to optimize self-consumption, great differences in the regulatory framework arise depending on who is doing the producing, storing and consuming. Four possible constellations can be recognized:

1. Same legal person producing, storing and consuming electricity.
2. Same legal person producing and storing electricity.
3. Same legal person storing and consuming electricity.
4. One legal person only storing electricity.

Table 1
Possible charges according to the German regulatory framework (cf. Conrads et al., 2017).

Regulation	Charges, fees
Energy Industry Act (EnWG)	Grid fees, concession levies
Electricity Network Fee Regulation Ordinance (StromNEV)	Grid fees
Renewable Energy Sources Act (EEG)	EEG levy, VAT
Electricity Tax Law (StromStG)	Electricity tax
Metering Point Operation Act (MsbG)	Charges for metering operation firm

The application of the previously discussed charges and levies differs depending on the particular constellation. Fig. 1 depicts the charges applicable in these various cases, but can only capture in part the complexity of the various scenarios and not every possible exception. For instance, in the rare circumstance in which the operator of a battery storage facility stores electricity only temporarily for an energy supplier, no VAT has to be paid (EWeRK, 2016). Further complex issues and grey areas regarding CES will not be discussed here but can be found elsewhere (cf. Bolay et al., 2017; Conrads et al., 2017).

The table shows that in the case of production, storage and consumption by the same legal person, most exemptions apply. In all cases VAT (19%) must be paid for the electricity fed into and out of the storage system.[3] This is one of the biggest economical burdens, but is most likely to change with the implementation of the Clean Energy Package in Germany.

4.2.4. *Requirements for the balancing energy market*

CES can contribute to optimizing grid operation by providing balancing energy; both positive (grid injection) and negative balancing (grid withdrawal) are possible. Battery storage meets the technical requirements of balancing energy exceptionally well, as problems such as delayed delivery or frequency deviations do not occur (BVES, 2015).

In order to participate as a potential provider in the balancing electricity market, the storage facility has to participate in a prequalification process. This procedure is used to demonstrate fulfilment of the requirements for the provision of balancing power under § 1 EnWG for the provision of energy to the general public. Determination of the necessary technical capabilities and the proper provision of the service must be carried out in accordance with §§ 6 ff. StromNZV; the transmission system operator is responsible for checking the prequalification.

4.2.5. *Possibilities and obstacles with multiple use*

Multiple use offers the potential for increasing the cost effectiveness and hence allowing an economic operation in certain locations (Kalkbrenner, 2019; Müller and Welpe, 2018; Parra et al., 2017a; van Melzen, 2018; Wawer et al., 2018). A battery storage system could primarily be utilized by households for optimizing their self-consumption, but at times when optimization is not possible by the grid operator for increasing the flexibility and stability of the grid (EWeRK, 2016; cf. Müller and Welpe, 2018). In addition to the direct economic benefits of higher revenues, this also offers the opportunity to use a CES system more efficiently (uniform state of charge) and therefore extend its life span.

The main obstacle in Germany is the current lack of legislation concerning multiple usage of CES (cf. Brunekreeft et al., 2017). Previously introduced regulations and relief options only apply if the CES system serves exclusively a single purpose. Moreover, in a multi-use constellation involving the grid operator, the operator – in accordance with the unbundling rules (§7 EnWG) – would not be permitted to operate the energy storage system. And, although sharing investment costs by different stakeholders could increase the profitability of battery storage (Lombardi and Schwabe, 2017), there are no regulations in place that would support such a shared-economy business model.

The European Commission also identified uncertainties in the regulations regarding multi-use concepts as one of the main barriers to CES (European Commission, 2016b). One best-practice use case for a successful promotion of multi-use concepts can be found in California, where the Public Utility Commission of the State of California established a set of rules to specifically promote multi-use CES (Gergen et al., 2018).

[3] The tax law in Germany does allow an exemption here via the small entrepreneur scheme (*Kleinunternehmerregelung*). This is only applicable to CES in very rare cases and for smaller CES systems.

In conclusion, it is clear that a number of improvements to the regulatory framework are needed with respect to CES. There is the overall issue of the complexity of the framework and the lack of a clear definition for (battery) storage, which makes any business case for CES rather risky and unpredictable. Looking at the framework in more detail, there are several other problems, e.g. the economic burden from numerous taxes and levies, the strict requirements for providing balancing energy and the obstacles to multiple use. These conclusions were the basis for the survey among the public and private stakeholders.

5. Public and private stakeholder demands

This section presents results of the interviews with private and public stakeholders. At the beginning of each expert interview, we asked the participant for a characterization or definition of CES. In addition to creating a common understanding, we wanted to identify the most dominant aspects of CES for the various stakeholders. We identified six topics that were relevant when defining CES: a local frame of reference (i.e. a local boundary framing the use or implementation of CES), community use, type of grid connection, electricity supply, storage of energy production, and sector coupling. These aspects were ranked according to the frequency and order in which they were mentioned by the interviewees. The scale was set from zero, meaning no interview partner mentioned the aspect, to five, meaning that the aspect was brought up by all participants.

The most important aspects for municipalities are local and joint usage, in connection with the balancing effect of CES regarding production and consumption, suggesting a strong interest in urban self-sufficiency. The regional authorities take a similar perspective, while showing a slight shift towards the decentralized storage of renewable energies. Grid operators largely regard the type of grid connection and decentral storage as most relevant. The same applies to manufacturers, who also emphasize community use and the decentralized supply. Energy providers share a perspective similar to that of the grid operators, with a clear emphasis on local usage and localization of CES. A more detailed analysis is shown in Fig. 2.

5.1. *Assessments of CES*

The interviewees evaluated the advantages and disadvantages of CES compared to home storage systems and other kinds of storage systems. The stated advantages and disadvantages are collected in Table 2 and Table 3 respectively. The last column indicates whether a specific advantage or disadvantage was mentioned by at least one of the interviewees in the respective stakeholder group.

The majority of interviewees see the advantages of CES primarily in cost reductions due to scaling effects as compared to singular home storage systems. Generally all show uncertainty in the area of ecology, but grid operators, manufacturers and energy providers expect positive effects due to savings in components and materials and the general support of the energy transition. Manufacturers see the technical benefits as an advantage via easy and multiple use. Local support of e-mobility through the CES was mentioned by nine out of 17 experts (53%). In addition, a quarter of the interviewees see an advantage in CES connection and easier maintenance and adaption. Some of the benefits mentioned show the role of CES for the self-sufficiency of urban energy systems, in particular the local reduction of energy imports, stability of the local grid, and the balancing of supply and demand.

Disadvantages arise for all actors due to the difficult legal framework. The grid operators mentioned the topic of storage vs. grid expansion. The best solution for this should be assessed for each case individually. They also remarked that due to long-term usage and the often non-identical user and operator, the financial risks can be relatively high and have to be covered by the investor/operator. They see some disadvantages in CES regarding the energetic and technical usage in comparison to other types of storage. Particularly in cities where

Same legal person… Charge	… producing & storing & consuming: Feed in	… producing & storing & consuming: Feed out	… producing & storing: Feed in	… producing & storing: Feed out	… storing & consuming: Feed in	… storing & consuming: Feed out	… storing: Feed in	… storing: Feed out
Grid fees	No	No	No	Yes	Yes	No	No	No
Concession levies[a]	No	No	No	Yes	Yes	No	Yes	Yes
Electricity taxes	Partly[b]	Partly[b]	Partly[b]	Yes	Yes	Partly[b]	Partly[b]	Partly[b]
EEG levy	No	Partly[e]	Partly[c]	Yes	No	Partly[d]	No	Yes
VAT	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

[a] Same applies for other levies related to grid fees (eg KWK-, Offshore-, AbLaV- and StromNEV-levy)
[b] No exemption of non-renewable plants > 2 MW
[c] Exemption for first 500 charges afterwards full levy
[d] 40% for renewable energy, otherwise 100%
[e] Exemption for PV-plants < 10 kWp and PV-plants/storage units installed before 01.08.2014, otherwise Δ

Fig. 1. Charges and levies depending on the constellation of legal persons producing, storing, and consuming electricity.

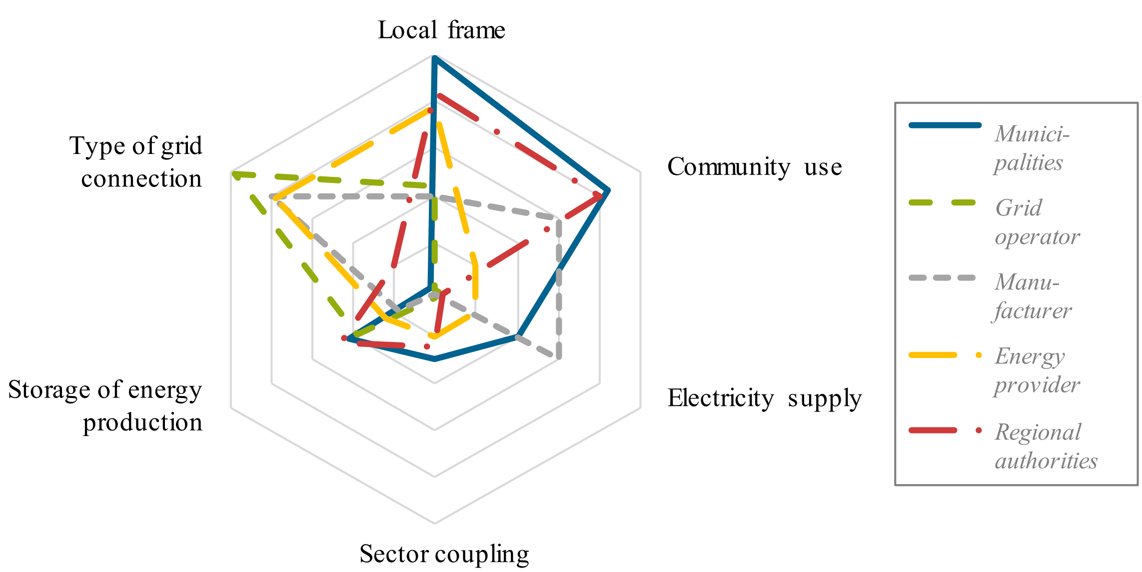

Fig. 2. Relevant aspects for the various actors regarding the concept of CES.

production and consumption are almost equal, some do not see the benefits of CES. It was also noted that all of the uses offered by CES could equally be covered by other technologies, e.g. heat storage, grid expansion, or demand-side management. CES demands, other than a home storage system, the cooperation of a broader range of different actors due to the complexity and scale; at the same time, long-term commitments of customers cannot easily be achieved due to the customer's rights to change suppliers, leading to a large degree of uncertainty for the CES operator.

5.2. Legal framework

In-depth questions about the legal framework brought up a number of issues already described in the first part of this paper (section 4). The complexity of the regulatory framework was mentioned by all actors. Besides the complexity of the regulatory framework, some aspects were subject to special attention and will be elaborated here once more.

Feasibility: A lack of clarity, transparency and even contradictions in the legislation, little informational material, fast and frequent changes and at the same time long-lasting processes are the aspects complicating the implementation of CES according to the actors. In some cases, regulations specifically impede the implementation of CES. For instance, closed distribution grids that facilitate the implementation of CES can only be implemented by industrial and commercial customers. On a more operational level, a reasonable concept for operation and billing has yet to be found. Grid operators, manufacturers and authorities also mentioned the unbundling of grid operations as an obstacle. Due to unbundling, grid operators are only authorized to operate storage to improve grid stability. Hence, even though CES could offer many advantages, the grid operator is not allowed to implement multi-use storage.

Economic Burden and Financial uncertainties: The burden of stored electricity facing double levies and fees (see charges, duties, fees and taxes above) was indicated as the biggest economic barrier. The grid operators primarily mentioned network charges and the VAT on electricity and proposed a redesign to a flat rate. Moreover, missing technological standards lead to high individual costs when implementing CES. Additionally, no existing guarantees in the balancing market for existing CES leads to higher financing costs or greater restrictions when financing new projects. Unclear regulations, standards, and warranty conditions for CES also add to the financial uncertainties. This concerns, for example, communication between technical components (e.g. smart

Table 2
Mentioned advantages of CES.

Topic	Mentioned advantages	Stakeholder group				
Economic benefits	– Cheaper than individual storage (scaling effects)	●	●	●	●	●
	– Decreasing costs for storage		●			
	– Less investment in measuring and control units compared to individual storage			●		
Energetic benefits	– Reduction of energy import in the district	●				
	– Storage of peak energy (peak shaving)		●		●	
	– Balancing of production and consumption		●			
	– Suitable for rural application				●	
Technical benefits	– Relief for the grid in times of excess production	●				●
	– Connection to mobility	●	●	●	●	
	– More flexible usage compared to individual storage			●		
	– Multiple use is possible			●		
	– Smaller inverter power necessary compared to individual storage			●		
	– Local grid stabilization			●		
	– A simpler offer of operating reserve			●		
Efficiency	– Probably more efficient than individual storage	●				●
Manageability	– Outsourcing of necessary technical know-how	●				
	– Easier maintenance and adaption	●	●	●		
	– Better management of fire risk		●	●		
	– Easier connection to other systems and control from outside				●	●
Ecology	– Support of energy transition		●			
	– Concept to discharge bigger storage units			●		
	– Saving of components and material				●	
Feasibility	– Possibilities of participation not only for homeowners			●	●	

Legend: ● *Municipalities,* ● *Grid operator,* ● *Manufacturer,* ● *Energy provider,* ● *Regional authorities*

Table 3
Mentioned disadvantages of CES.

Topic	Mentioned disadvantages	Stakeholder group				
Economy	– Difficult legal framework	●	●	●	●	
	– High investment costs		●			
	– Overall more expensive than an individual storage system			●		
	– A single operator takes all the risk			●		
Energetic benefits	– Bigger shortages and dark doldrums (wind/solar shortfalls) cannot be resolved		●			
	– Little need		●			
	– Storage system makes sense only if clearly more production than consumption (not in the urban context)				●	
	– The individual storage makes more sense for the balance of production and consumption				●	
Technical benefits	– No long-term storage compared to natural gas storage	●				
	– Control and connection are to be perfected		●			
	– Emergency power is more easily supplied by individual storage systems			●		
	– Usage possibilities could also be realized with other technologies					●
Efficiency	– Probably less efficient	●				
	– Efficiency loss in CES				●	
Manageability	– Loss of control for customers	●		●		
	– Higher individual fire impact			●		
	– More demanding technology (e.g. compared to thermal storage)				●	
Ecology	– Uncertainty regarding ecology / energy balance	●	●		●	●
	– Small contribution to the energy transition		●			
Feasibility	– Uncertainty regarding long-term usage		●	●		
	– Problems regarding the installation in a public space		●	●		
	– A lot of technology and control necessary		●			
	– Indispensable need for a project developer			●		

Legend: ● *Municipalities,* ● *Grid operator,* ● *Manufacturer,* ● *Energy provider,* ● *Regional authorities*

meter and storage system) including measurement data due to the lack of interfaces, which are still in development and without standards. For a wider distribution of CES, suitable software and hardware need to be further developed. The so-called Smart Meter Rollout in Germany and the EU means this problem will probably be addressed and resolved in the near future.

Fire prevention: The issue of fire prevention was mentioned several times in different contexts. Appropriate fire risk management requires additional effort and cannot always be handled efficiently. The regulations on permission to operate a CES facility are not always clear and the responsible local authorities may lack the necessary experts.

Besides these recurring concerns, the occasional need for various special permits and unnecessary regulation in tenders for specific types of batteries (e.g. battery compartment requirements) were mentioned as additional burdens.

5.3. Public funding and support

We also discussed with the interviewees the question of financial funding in the form of grants, guarantees, securities, and non-financial support for CES. There are divergent opinions as to whether such funding for CES is necessary. Of the interviewees, seven were against public funding, nine were in favour and one did not give an answer. The most reluctant about public funding were manufacturers, who argued that from their perspective the general profitability of such storage systems is not lacking. It is rather the case that the regulatory framework needs to be adjusted in order to create a level-playing field and suitable market access. The need for support is only seen in relation to project development. In contrast, the interviewees representing the stakeholder group of regional authorities show a general openness towards such funding in order to support the technology's development. However, there exists some uncertainty as to whether the responsibility should lie in the hands of the federal government, the federal state, or local actors such as the public utility companies. Furthermore, there is the consideration that funding for CES should be provided not only to increase self-consumption rates but also, for example, to facilitate sector coupling, show a positive impact on the grid, or to repurpose existing batteries to increase their lifetime use. More important, support should be provided to housing associations and interested citizens in the form of more information about the implementation of CES. The municipalities seemed to be in favour of funding as well; however, the requirements and objectives of funding are not yet clear and their experiences so far are more related to the research context. Nevertheless, there are some ideas of how CES can be supported even without financial funding. The interviewed stakeholders specifically mention public relations via various media and events, distribution of examples, and feasibility studies.

The non-operative actors (municipalities and regional authorities) were asked to identify information deficits, the specific items of information missing in the context of CES, and the modality by which they would like to receive them. As it turns out, well-informed interviewees tended to receive their knowledge through personal contacts. In general, we identified a need for easily accessible information provided by neutral institutions such as ministries or research institutes. Some interviewees also see this as a task for interest groups such as NGOs or lobby organizations. The actors wanted more information about the legal and regulatory framework, use possibilities, as well as best practice examples and business models. The municipal actors pointed at a lack of information for the public; however, some municipal actors noted that not only public information, but also a clear direction for the energy transition and governmental support for storage technologies are also missing.

5.4. Services and business models

As the last element of the interviews, ideas regarding possible CES services and suitable business models were discussed. The interviewees mentioned a number of services that in their view could be realized with CES. Table 4 shows an overview of their suggestions by category.

As potential CES operators and providers of services, the actors primarily mentioned the energy suppliers, in particular, the municipal utilities. In addition, other constellations were conceivable. Municipalities and authorities also considered the possibility of civil energy initiatives or housing associations as storage operators. Grid operators were often referred to as a possible partner for CES projects, but due to unbundling were not considered suitable as operators. Other external service providers or contracting models are also conceivable, but are considered even more difficult due to the fear of greater economic inefficiencies associated with the involvement of a third party.

Addressing possible designs for business models and proposing requirements was difficult for most of the interviewees due to the current difficulties in implementing economically viable CES. The municipal actors pointed out that for a suitable business model, access to the infrastructure and the public space (e.g. for setting up the storage) should be facilitated. In addition, the interviewees viewed an economic participation by the respective neighbourhood residents as desirable. Grid operators expressed concerns that conflicts between business models intended to be grid-friendly *and* customer-friendly might be difficult to reconcile. One example given is that of sunny days with a high level of photovoltaic production, when there is a large probability that both the local user and the grid operator will have surplus electricity they would preferably store in the CES facility. At the same time, most stakeholders pointed out that multiple use is very much desirable for economic viability. From the perspective of the energy supplier, it is particularly important that such business models are economically viable in the long term. In addition, there are some doubts regarding a standardized implementation, since each local district has individual issues that have to be faced when planning a CES project; thus a business model that fits every situation is difficult to achieve.

Table 4
Ideas for CES services.

Ideas for services in the context of …		
…grid	…system	…customer
- Avoiding unnecessary grid expansion - Grid services - Relief of distribution grid - Reactive power compensation - Balancing power - Grid stabilization - Voltage support - Switchable load/reserve/residual load - Reduction of connected load - Reconstruction of power supply	- Energy security - Store excess electricity - Optimization of balancing group - Virtual storage - Peak shaving - Integration of renewable energies	- Increased self-sufficiency - Autarky (for new buildings) - Energy community - Optimization of self-consumption

…sector coupling	**…market**	**… information/ consultation**	**… operation/ maintenance**
- Electro mobility - Power-to-Heat - Integration of charging stations - Carsharing	- Market participation - Trade - Dynamic grid charges - New contract designs	- Energy consulting - Visualization - Power efficiency - Project development	- Operation - Control - Accounting - Maintenance

6. Discussion

This study succeeded in giving a clear overview of the main opportunities and barriers facing private and public stakeholders as intermediaries concerning CES in the particular case of Germany. The description of the current policy and regulatory framework highlighted the importance of this topic and helps in understanding the statements from interviewed experts. The regulatory and policy framework can and will certainly change over time, reducing existing barriers or possibly creating new ones, especially when the Renewable Energy Directive is fully implemented in Germany. Statements from the German government, however, suggest that no major changes are to be expected in the near future (Deutscher Bundestag, 2019). Despite the regulatory uncertainties, however, this paper provides valuable insights into the technological and organizational barriers facing CES and the opportunities it offers, regardless of the regulatory and policy environment. As the investigation is based on a qualitative method with a small sample of 17 interviews, the results cannot be regarded as statistically representative; however, due to the inclusion of at least three interviewees in each identified group, the results of this study address CES opportunities and barriers for all identified relevant public and private stakeholders. Moreover, the interviewees were not questioned in their personal, but rather their professional roles. We therefore presume that it is possible to draw general conclusions in those cases in which we encountered consistent answers across interviews. The results should not be interpreted as stand-alone facts, but they do suggest directions for further research concerning the legal framework, services, and practical experience with CES. In addition, relating the findings to knowledge dealing with strategic niche management allows the results to be applied to other institutional contexts and countries. Overall, we expect that the technical and social issues raised here, in particular, will hold true for other institutional contexts.

The stated advantages and disadvantages do reflect findings in previous studies. The main benefit of CES is seen in the sharing of surplus renewable energy, optimization of battery utilization, and benefits from economies of scale (AlSkaif et al., 2017; Barbour et al., 2018; Müller and

Welpe, 2018; Parra et al., 2017a; van der Stelt et al., 2018; Wawer et al., 2018). In particular, benefits in increasing self-sufficiency for urban energy systems are mentioned in the literature (cf. Bagheri et al., 2019; Koirala et al., 2018; Roberts and Sandberg, 2011; Staller et al., 2016). Moreover, greater cost savings as compared to individual home storage solutions are possible. Less production material is needed and therefore CES makes less use of scarce resources and has a better CO_2 footprint as compared to individual energy storage solutions (van der Stelt et al., 2018). Another advantage, not specifically mentioned by the interviewees but that can be found in the literature, is the possibility to engage a larger number of people in the energy transition who might otherwise not take the initiative (Hicks and Ison, 2018; Liu and Wang, 2018; Parra et al., 2017b). These findings all relate to the concept of niche developments, which often arise to meet technological needs and provide better efficiencies (Geels et al., 2018) in situations where market competition is not yet possible.

The most prominent barrier, as mentioned by the interviewees but also readily found in the literature, is the regulatory framework (Parra et al., 2017b; van Melzen, 2018; Wawer et al., 2018). The complex and sometimes unclear regulations, especially, as well as the added financial burden due to additional fees and taxes that arise with an energy storage site being located in the public grid are all mentioned as major barriers for the mainstreaming of CES (Koirala et al., 2018; Müller and Welpe, 2018; Parra et al., 2017b; Wawer et al., 2018). Nevertheless, financial support was not desired by stakeholders, rather knowledge transfer and administrative support, with both being mentioned as most important for the success of a CES project, thus confirming previous research (Hoppe et al., 2015; Parra et al., 2017b).

As noted in the respective literature, one CES primary use besides optimization of self-consumption is the provision of grid and system services (Arghandeh et al., 2014; Parra et al., 2017a; cf. van Melzen, 2018). Possible services mentioned by the experts, such as peak shaving, prevention of unnecessary grid expansion, cheaper and more flexible grids, load support during outages, and grid stability, are also found frequently in the literature (Arghandeh et al., 2014; Klausen, 2017; Parra et al., 2017a; cf. van Melzen, 2018). At the same time, most stakeholders pointed out that multiple use of the storage is desirable for economic viability, hereby confirming earlier research (Baumann et al., 2019; Kalkbrenner, 2019).

While the actors mentioned a number of services, addressing the barriers referenced above will be critical for implementation of at least some of these. Concrete business models with one or more organizations bearing the responsibility for the supply chain as discussed by Wawer et al. (2018) were not brought up by the interviewees. Many respondents found it difficult to formulate specific requirements. This can be explained, on the one hand, by the uncertainty in the framework and, on the other, by the manifold possibilities with regard to operator models and conceivable combinations of services. Drawing on Schot and Geels (2008), this could have a hindering effect on the mainstreaming of CES as articulation of expectations and visions is one of the three main processes necessary for success.

7. Conclusion and policy implications

The paper provides an overview of the current political and regulatory framework in Germany and compares the current situation of CES with the demands of several stakeholders resulting from 17 structured interviews with experienced experts from municipalities, regional authorities, energy suppliers, grid operators and storage manufacturers. The review of the regulatory framework, the current policy framework in Germany, and the interviews show the high relevance of the topic and the need to improve the regulatory environment for CES.

Although the policy framework suggests an optimistic outlook on battery storage in general by supporting research and underlining the importance of the technology, there are major barriers for CES in Germany. The literature review and the interviews reveal the regulatory framework as being one of the main concerns for CES. Most importantly there is an urgent need for a legal definition of energy storage rather than the current situation in which storage is only addressed a unit of energy consumption or energy production. The consequences are a lack of clarity, unreasonable taxes and levies on CES-stored electricity, and often contradictions that hold stakeholders back from implementing CES. Power production should only be burdened with charges once, regardless of whether it is stored or not. Battery storage and in particular CES are clearly disadvantaged in this respect in most applications as compared to other storage technologies and generation facilities.

Technically conceivable and economically advantageous would be the multiple use of energy storage for a combination of system services, grid services, self-consumption, and possibly other services. This possibility is currently not provided for by law. The lack of an effective policy effort and an unclear legal framework has resulted in a situation where battery storage outside of photovoltaics and electro-mobility is currently used almost exclusively in research projects.

Moreover, for the widespread implementation of CES further standards are needed, not only regarding technical aspects such as communication interfaces or fire prevention, but also in the area of customer protection such as warranty terms. This would lower barriers of entrance in the market and make adaptions to multi-use CES easier. Political officials must also acknowledge that roles and responsibilities might in some cases change with the introduction of CES. As shown in this paper, stakeholders who were formerly only consumers of electricity might become CES operators. Hence, the laws and regulations in the field of energy must be flexible enough to address such changes.

Research is still important for the development of CES with respect to use possibilities. The best case from an ecological viewpoint is still unclear in a general setting – a point mentioned especially by the grid operators. Research projects can help to clarify these aspects by implementing usage monitoring. Presently best-practice examples of CES are more important than financial funding, a point also made by many of the experts. In addition, projects should focus on establishing services and new business models to facilitate the necessary changes to the regulatory framework.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Swantje Gährs: Conceptualization, Methodology, Formal analysis, Investigation, Visualization, Writing - review & editing. **Jan Knoefel:** Methodology, Investigation, Writing - original draft, Writing - review & editing.

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