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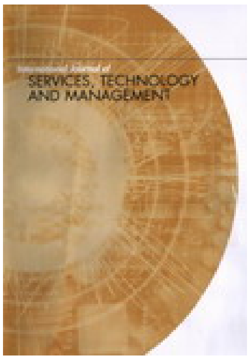

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Design options for smart services in energy communities: a multi-criteria mapping analysis among stakeholders

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Design options for smart services in energy communities: a multi-criteria mapping analysis among stakeholders

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Abstract: The deregulation of energy markets in many countries has stimulated the development of energy communities. Members of these communities generate and trade energy in the general market. In addition to pursuing financial goals, they aim to achieve positive environmental and social effects. Despite the recent surge in such communities, they often lack resources and depend on subsidies to compete with traditional energy providers. New technologies could support these communities with optimising their production and consumption, providing smart services and increasing their competitiveness. By applying the multi-criteria mapping (MCM) method to data collected in focus group discussions and interviews with experts, this study explored the potential of technologies and their prioritisation for the adoption of smart services by energy communities. The study proposes an overall ranking of design options for smart energy services based on four stakeholder perspectives and on opposing views and uncertainties. The results provide insights into the potential of each option for the design of innovative information systems (IS) for energy communities.

Keywords: smart energy communities; SECs; multi-criteria mapping; technology analysis; smart energy services; SESs; service ranking.

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1 Introduction

In most countries, the energy market has been changing as new forms of decentralised energy production have become available to individual households (Kalkbrenner and Roosen, 2016) and new concepts, such as smart energy communities (SECs), have found their way into regulatory systems. SECs are organisations based on the open and voluntary participation of shareholders (e.g., natural persons, micro, small and medium-sized companies, local authorities, etc.) which provide environmental, economic or social benefits to the community through renewable energies (Ceglia et al., 2022; European Union, 2018). From a technical perspective, SECs are considered to be a group of households with different electric loads and technologies integrated into a control system, which manages energy generation and demand in the community (Fazeli et al., 2011). New regulations support the further development of the energy market worldwide (Mulder, 2021; Spence, 2019; Vasily et al., 2019). In Germany, the German Renewable Energy Sources Act (EEG) has had a positive economic impact on the energy industry, increasing investments and employment (Hillebrand et al., 2006) and serving as a model for legislation in other countries (Lehr et al., 2008). It has increased the engagement of the population in local energy systems, as they identify themselves with these systems as community members, comply with social norms and show higher levels of trust and concern about the environment (Fazeli et al., 2011; Kalkbrenner and Roosen, 2016; Massey et al., 2018).

As the development of such communities advances, new technological improvements create the basis for the emergence of smart energy services (SESs) (Marinakis et al., 2020; Kranz et al., 2015; Mathiesen et al., 2015; van Dinther et al., 2021), which use smart grid architectures based on ‘prosumers’ – users that consume and produce energy (Grijalva and Tariq, 2011). Service is considered a perspective on value creation, which is determined by the customer views on the value in use (Edvardsson et al., 2005). Services are considered as smart when they are based on field intelligence, process big data and provide more visibility to businesses (Allmendinger and Lombreglia, 2005). These smart services use interconnected information systems (IS) for data acquisition, algorithms, reports and interfaces for visualisation and configuration (Beverungen et al., 2019; Palensky and Dietrich, 2011).

Some existing studies in the field have focused on the type of renewable energy (Karunathilake et al., 2019), the ecosystems (Vernay and Sebi, 2020) or social innovation aspects (Caramizaru and Uihlein, 2020). Other studies have focused on specific services and processes, such as big data analysis (Zhou et al., 2016), smart metres (Anda and Temmen, 2014), peer-to-peer (P2P) interlinked smart homes (Steinheimer et al., 2012; Zhang et al., 2017) and the smart internet of things (IoT) (Giordano et al., 2020). New SES-based business models, including P2P marketplaces, microgrids or virtual power plants (VPP), are derived from smartly generated energy and have been improved to match demand (Paukstadt and Becker, 2021). These models use smart systems and provide a more holistic approach, instead of concentrating on specific services or smart grids (Lund et al., 2017).

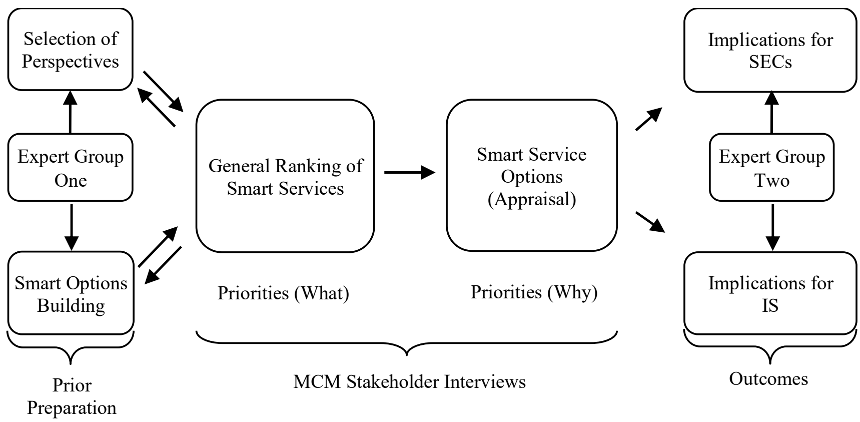
SESs contribute to SECs by ensuring reliability, enhancing market services, minimising the impact on the environment, reducing costs and improving the use of renewable energy (Wang et al., 2015) according to the United Nations’ development goals (Leal Filho et al., 2021). However, since local networks mainly rely on investments by com-munity members in the region, they have limited resources to invest in many technologies (Dóci et al., 2015). Hence, an assessment and analysis of existing solutions, considering the views and opinions of experts and stakeholders in the field, could support SECs in prioritising their investments in technology. The present study enhances an earlier initial analysis on SECs (Viana et al., 2021) with further analyses and data from a second group of experts on the contributions of IS that underpin the adoption of technologies in SECs.

Furthermore, this study considers how the properties of smart services (referred to as smart design options) contribute to SECs from a technical perspective and the influence of these options on SECs in Germany. Due to the long tradition of energy communities (São José et al., 2021) and community members’ willingness to participate in environmentally friendly energy systems (Kalkbrenner and Roosen, 2016) in Germany, the German market holds considerable potential for providing insights into the development of SECs. Hence, this study discusses the potential contribution of smart design options to improving services and processes within German SECs and answers the following research questions:

- What are the options and priorities of the smart services applied in SECs in Germany?
- What challenges and opportunities are derived from these options in SECs and IS solutions?

Figure 1 depicts the research approach and the expected outcomes. First, an expert group defined the options for smart services and four critical perspectives for assessing them. Next, stakeholders were selected to represent these perspectives. The options were assessed (ranking) and discussed (appraisal) during guided interviews. In a second round of discussions, experts assessed the implications related to the development of SES solutions and their impact on SECs. By analysing current options, their uncertainties and potentials, and the relevance and digital readiness of IS solutions, this assessment contributes to the prioritisation of smart services.

Figure 1 Research approach



The subsequent sections are structured as follows. Section 2 explains the methodology and its steps for assessing smart options; Section 3 discusses the results derived from the analysis as well as the contributions for SECs and IS design. Section 4 provides an expert assessment of IS contributions, and Section 5 discusses the main conclusions and provides insights for further research.

2 Research methods

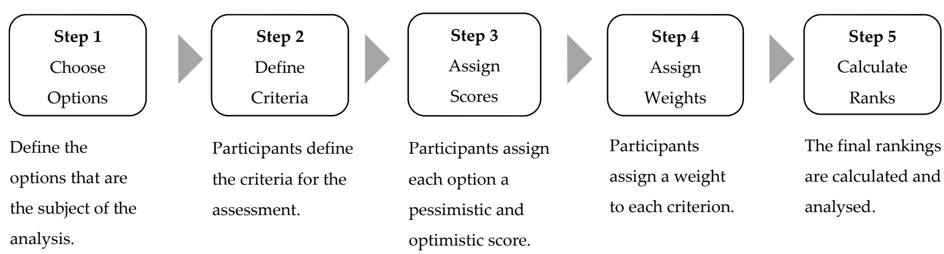
Researchers, industry and policymakers have assessed the risks related to decisions and technologies (Waterstone, 1992) based on risk perception studies (Slovic, 1987). Adopting technologies requires investments, and such assessments define the positive and negative aspects of the evaluated objects, thereby reducing risks. Various methods have been developed to assess and appraise risks (Covello and Merkhofer, 1993; Horvath and Zuckerman, 1993), especially those related to technology (Lefley, 1997; Stirling, 2008). Methods such as RT Delphi (Gordon and Pease, 2006) or cost-effective models (Hubbard, 2014) have been applied to prioritise technologies. However, the multi-criteria mapping (MCM) method provides an extensive view of potential options for assessing the uncertainties of new technological developments (Ely et al., 2014).

MCM provides a structured analysis of the uncertainties in various domains (Hansen, 2010; Shankar et al., 2002; Stirling and Mayer, 2001). The analysis is based on insights and information from stakeholders in a given industry (Carpenter et al., 2003; Donaldson and Preston, 1995; Shankar et al., 2002). Researchers using MCM refer to such stakeholders to allow an analysis that includes different views and perspectives on the same subject, considering the uncertainties (Hansen, 2010; McDowall and Eames, 2007; Shankar et al., 2002).

This study used pre-structured options that were introduced and quantitatively assessed. Pre-structured surveys were employed to study diversity and define the objects of analysis (Jansen, 2010). This descriptive analysis aimed to prioritise the existing options empirically within certain stakeholder groups. Such an analysis is considered to be qualitative if, instead of counting the frequencies of categories, it searches for empirical diversity in the analysed objects, even if the results are expressed in numbers (Jansen, 2010). MCM involves drawing up a numeric assessment to rank the options and visualise uncertainty and also incorporates data from discussions on why some options are considered more relevant.

The analysis in this study followed the steps suggested by Coburn (2016) (see Figure 2). The MCM provided an online platform[1] to guide the interview process and support researchers in setting up the interview environment, allowing the stakeholders to understand the predefined options and follow the research steps. A prior preparation phase, in experts in the field were invited to discuss and determine the options for SECs, was conducted to define these options and the stakeholder groups.

Figure 2 Research steps in MCM



Source: Stirling and Mayer (2000)

2.1 Selection of stakeholders (perspectives) and smart options

First, ten experts on the energy market and IS in Germany constituted expert group 1. They discussed and developed a list of smart design options that affect SECs' performance, as a list of properties for smart services in SECs was not found in the existing literature. Expert group 1 included leaders and representatives from energy and IS-related research institutes, energy communities and software companies. The experts defined smart options based on their expertise, focusing on services that can be improved by using current technologies (see Table 1). They also indicated which stakeholder groups were relevant (see Table 2) in order to combine different perspectives on the topic. They suggested the potential stakeholders; there was no overlap between the experts and the stakeholders. The options below were coded using three-letter acronyms for later visualisation and discussion.

Expert Group 1 selected four perspectives (stakeholder groups) aligned with the current landscape of German SECs, thus identifying the potential German stakeholders to participate in the interview session. The interviews lasted between 60 and 90 minutes; 15 stakeholders contributed to the study.

Table 1 Options and descriptions of smart services

Smart options	*Descriptions and contributions to SECs*
Applications based on measured data (AMD)	Description: user behaviour information and usage anomaly underpin the development of various applications, such as gamification (power saving comparison), individual billing per device, etc.
	Contribution: provision of data visualisation to show consumers their exact power consumption and provide forecasts
Peer-to-peer trade (P2P)	Description: private individuals, small businesses and production companies trade electricity. Consumers, producers and storage facilities form networked communities and trade locally generated electricity with each other
	Contribution: development of trading platforms
Selection of energy mix (SEM)	Description: different systems are combined, and the consumption profile is transparently connected with generation capacities. This improves the location planning of companies as they can plan based on local producers' preferences regarding the energy mix.
	Contribution: consumers select their energy mix systematically
Proof of origin (POO)	Description: electricity is transformed from a commodity to an emotional product by proving when it is produced and where it comes from
	Contribution: information is provided about less burdened networks, improving the local match between supply and demand
Consumption and production optimisation (CPO)	Description: consumption and production can be as close as possible to local communities. IS could support timetable optimisation of flexible producers, consumers and energy storage facilities based on very accurate forecasts and equipment management
	Contribution: timetable optimisation by flexible producers, consumers and energy storage facilities based on accurate forecasts and equipment management
Virtual power plants (VPP)	Description: SECs aggregate their flexibility in order to directly market their surpluses
	Contribution: development of a virtual power plant
New tariffs (NTA)	Description: new flexible tariffs (dynamic fares) are adapted and provided to users (prosumers and flexible consumers)
	Contribution: development of an incentive system to take pressure off the local power grid and balance the community's residual energy load, improving the local match between production and consumption
Investment opportunities (IOP)	Description: people living on low-invested lands and in rented houses/flats could participate financially and generate returns through investments
	Contribution: investments by users are part of the electricity costs. Consumers gradually buy shares of a production plant and participate in the revenue, while SECs invest in production and storage as needed

Table 2 Perspectives: groups of stakeholders

Perspectives/stakeholders	*Participants*
Energy cooperatives	5
Municipal utilities as energy suppliers	5
Energy providers with new disruptive business models	3
Technology/software	2
Total	15

2.2 *Assigning scores and weights based on criteria*

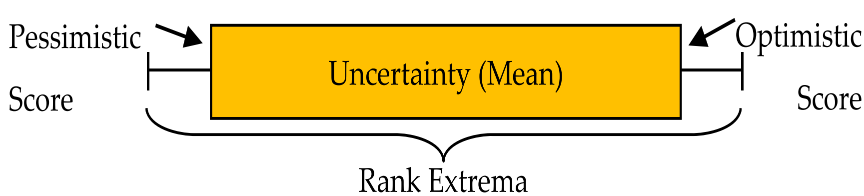
The stakeholders were encouraged to propose up to three criteria during the interviews and assess each option accordingly. This step allowed them to indicate the essential aspects when evaluating the options based on their expertise. The criteria were grouped into five topics:

1. consumers' perspective (costs and acceptance)
2. external factors (feasibility and regulatory requirements)
3. level of innovation
4. economic aspects
5. ecological aspects.

The stakeholders assigned a pessimistic and an optimistic score on a scale ranging from 0 to 100 to each option and weighted each criterion to improve the uncertainty analysis.

Figure 3 shows the chart produced based on the assessment and displays the results. The options may rank high or low, and the difference between the optimistic and pessimistic scores reflects the level of uncertainty. For this purpose, the means of the scores were considered. The highest and lowest scores are shown by the lines on each side of the bar.

Figure 3 Chart analysis (see online version for colours)

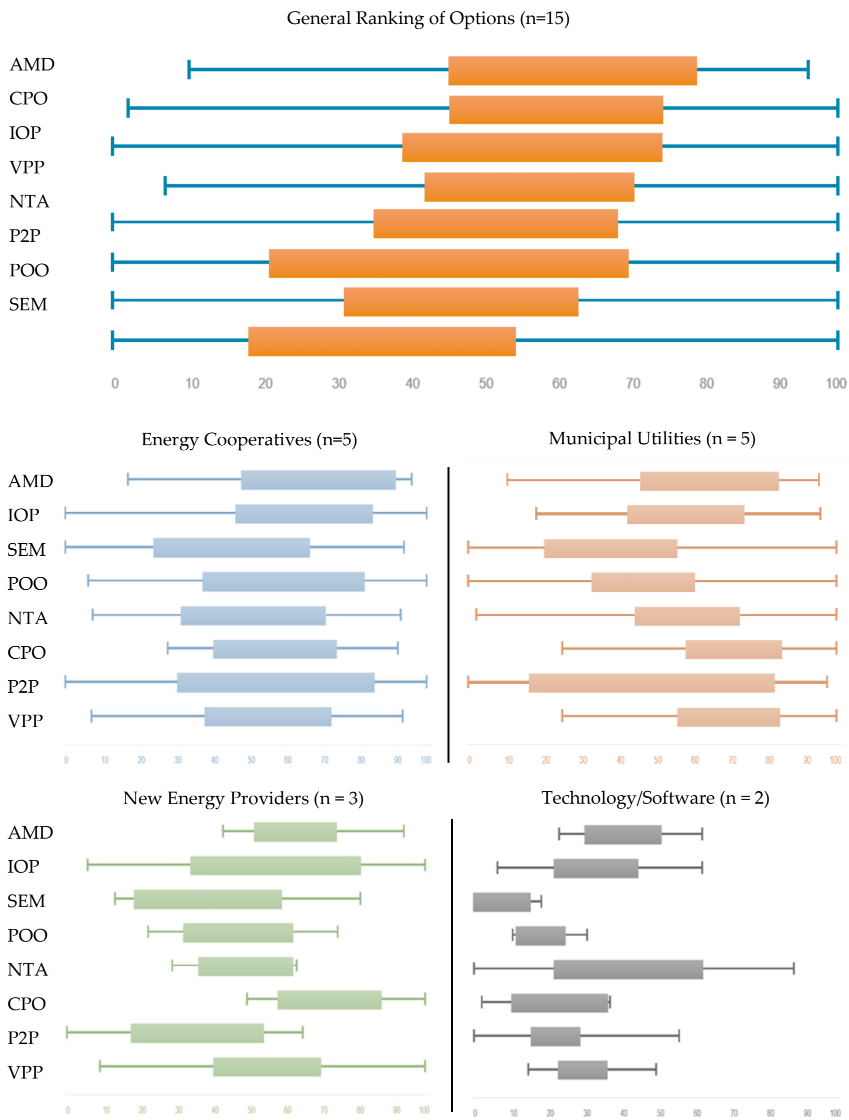


2.3 *Assessing results and implications*

After the analysis provided by the selected stakeholders, a second round was performed with another German expert group, expert group 2, to evaluate the conclusions and implications derived from the results. The group consisted of nine experts with similar backgrounds and expertise as the experts in expert group 1. The assessment of the conclusions by a different group of experts allowed a non-biased analysis of the results based on contributions of the first expert group regarding the options and the assessment by the stakeholder groups.

The experts answered questions regarding the maturity of management systems in the energy market, their support for SECs, the importance of IS contributions to smart options and the digitalisation status of these contributions. The latter was assessed based on the following levels of digital readiness proposed by Anttiroiko et al. (2014): non-digitalised processes, IT deployment for individual process tasks, digitally integrated processes, digitally automated processes and digital self-regulating processes. The analysis supported the validation of the results and provided further insights into the stakeholders' assessment.

Figure 4 Ranking of perspectives: stakeholder groups (see online version for colours)



3 Results of stakeholder analysis

The overview in Figure 4 shows how all options were ranked based on their medium values. The stakeholders ranked the option ‘applications based on measured data’ (AMD) higher, but were more pessimistic regarding the selection of the energy mix (SEM). P2P trading was associated with a higher level of uncertainty, indicating a low level of confidence in the development of such a trading scheme. Despite the indications of this first chart, differences between stakeholder groups emerged when examining their perspectives. Figure 4 depicts the general rankings and differences in stakeholder perspectives. For example, technology-related stakeholders were less optimistic about optimising consumption and production (CPO) than other groups, and municipal utilities were more positive about the VPP option.

Table 3 Optimistic and pessimistic views on the options

Design option	*Opportunities*	*Challenges*
AMD	• Smart metres produce data for predictive consumption models in order to provide the appropriate supply • This option provides indications on consumption for users	• The data transfer between the gateway and terminals is not yet standardised • Different interfaces make access non-discriminatory, and only companies with the same technology can act as providers • Data protection concerns limit the analysis of measured data
IOP	• Participation by community members increases acceptance and accelerates the energy transition	• A new regulation concerning direct transactions in the market has triggered concerns that no return on equity investments will be paid out • SECs must receive support from local stakeholders
SEM	• A relevant option for the future, but the technical feasibility is very difficult in contrast with the benefits	• Most customers find it sufficient to obtain green electricity via certificates • Consumers are emotionally attached to producers and types of energy production
POO	• Strongly related to P2P trading as the origin is clear in such transactions	• Green electricity certificates are rather opaque, and guarantees of origin need to become more accurate • Most customers are sensitive to price and do not understand the issue
NTA	• Uncertainty as to whether incentive systems with variable prices lead to changes in behaviour	• The relocation of power consumption is difficult for many consumers in private and commercial areas • Electricity would continue to be consumed when needed, without short-term price elasticity • A necessary reform of network charges might not take place soon

Table 3 Optimistic and pessimistic views on the options (continued)

Design option	*Opportunities*	*Challenges*
CPO	• Seen as the main reason for starting a com-munity • Balancing generation and consumption at a regional level	• It is necessary to define what needs to be connected and recorded • Privacy issues can hinder implementation • Dependent on application based on measured data (AMD) and smart metres
P2P	• Considers the future of the energy market. However, it requires the regionalisation of trade and marketplaces	• Current market is too complex and not transparent • A community could be achieved by pooling the actors and, therefore, be organised into a common control group without real P2P trading • A community is already working as a control group today, so true innovation would be the emergence of a genuine regional marketplace
VPP	• For a community, the offering of flexibility is interesting • The option is reasonable from a physical point of view and logical for the network	• There is a lack of a clear framework to market it locally • The individual producers or consumers lack expertise

The observed high level of uncertainty was derived from the stakeholders' optimistic and pessimistic scores. In addition to providing a numerical assessment, the stakeholders discussed the reasons for their scores, as shown in Table 3.

The stakeholders reported further opportunities and challenges based on their pessimistic and optimistic scores, which reflect the application of the options. New challenges concern AMD, such as local injection peaks or high withdrawal peaks owing to e-mobility. Nevertheless, smart metres can help predict energy consumption. According to the stakeholders, the benefit of cooperative electricity could be increased through 'add-ons' after the refinement of electricity. Modular product architecture supports the development of interchangeable options (Dahmus et al., 2001). However, the technology-related stakeholders were less optimistic because of the lack of standardisation. In addition, data protection could hinder such an analysis; for example, data-protection concerns have recently emerged regarding the deployment of smart metres (Erkin et al., 2013).

Regarding investment opportunities (IOP), the participation of community members was considered relevant, but investment requires support by local stakeholders, municipal utilities, investment banks, the government and the like. Furthermore, the new energy providers were concerned about the return on investment due to new regulations in the direct market. This concern affected the uncertainty of this option, despite the relevance of citizen participation in financing renewable energy in Germany (Yildiz, 2014).

SEM was ranked low, as stakeholders believed that customers are satisfied with current green electricity certificates. Its technical feasibility is complex, and consumers are sometimes emotionally attached to certain types of electricity. Although energy cooperatives are willing to source their electricity from renewable energy sources, if increasing the share of renewables in the energy mix incurs higher electricity costs, these costs have to be justified. Hence, proof of origin (POO) was ranked differently by the stakeholder groups, as the consumers' level of concern regarding the origin of energy varied. However, when asked to make an active choice between a green and a standard energy provider, energy consumers mostly choose green providers (Hedlin and Sunstein, 2016).

Regarding new tariffs (NTA), the participants differed with regard to changes in their behaviour. Many interviewees claimed that they would continue to consume electricity as needed, thus diminishing the chance of short-term price elasticity. Nevertheless, they stated that CPO is necessary to start an SEC. Efforts should focus on balancing energy generation and consumption as much as possible at a regional level and should also be optimised within the network. The new energy providers argued that installations should be built where consumption is located and, thus, define what should be connected and recorded.

The energy cooperatives reported that their members were motivated by P2P, not only economically but also intrinsically or ideationally. However, the stakeholders from the municipal utility group were uncertain whether the need for such community trading in an existing control group is sufficient, and its implementation can be costly. Therefore, information and communications technologies (ICTs) and control systems are necessary to enable P2P energy trading in the local energy markets.

The participants agreed that a market opportunity is necessary for communities to act as VPP. As renewables become more prevalent, the need for local governance increases. The representatives of municipal utilities were more optimistic about this option. Although the market is not yet ready, they argued that the shift to the end consumer's perspective is shaping the energy transition. From a technological perspective, some studies have developed algorithms that can aggregate the capacities of different energy resources (Pandžić et al., 2013; Pudjianto et al., 2007; Ruiz et al., 2009).

The stakeholders pointed out that energy communities need to integrate processes and disperse data to a high degree. In addition, they have to integrate and coordinate different actors in a cross-organisational environment. Although smart metres are not yet widely used, most options would directly benefit from their availability. Considering the limited resources currently at the disposal of energy communities in Germany, digital service platforms serving several communities are necessary for realising SECs. The stakeholders shared their opinions on technological developments, the behaviour of electricity consumers and the current regulations that support SECs with their strategic planning and provided directions regarding the technical demands for smart services in this industry.

SECs benefit from the development and improvement of smart services integrating recent IS technologies. The determination and assessment of SESs can guide IS designers in prioritising their offerings in the field. In addition, systems should be designed to allow new functionalities to be aggregated into a complete service system (Lund et al., 2017). This requires the integration of IS across different organisations. Furthermore, new systems can assume functionalities typically performed by intermediaries, co-evolving towards decentralised solutions that match buyers and sellers (Alt, 2018) or, in the case of SECs, that match prosumers. Adopting innovative technologies such as blockchain can support cooperative principles in marketplaces (Kollmann et al., 2020) and push forward the transition to decentralised systems.

The views expressed on the options not only support functionalities, such as AMD, P2P and POO, but also SECs with their decisions to adopt smart services, with setting priorities and making investments based on their specific needs and the market reality. The next section presents the implications for research and practice.

4 Expert assessment of potential smart service solutions

Smart service solutions should address the challenges and the potential of technology implementation to optimise SECs. The development and improvement of smart services based on recent IS technologies benefits SECs. As shown in the summary of design options listed in Table 4, the typical characteristics of smart services serve to enhance SECs. Based on data being available from digital devices and the interconnection of IS (see Section 1), proofs of origin and various analyses are possible as well as further usage for purposes of management, personalisation and trading.

In the second round, experts assessed these potential IS contributions with regard to their relevance and readiness in order to provide an answer to the second research question regarding the challenges and opportunities of smart options. Furthermore, the expert group rated the level of maturity of current energy management systems on a scale from 1 to 5, resulting in a mean of 2.9. The results indicate that the current systems are considered to exhibit an intermediate level of maturity with regard to smart IS solutions, such as smart IT support, data management and cloud solutions. Additionally, the experts assessed how well the current energy-related systems support the operation of SECs. They reported that the capacity of the existing systems is not sufficient to support these communities (mean 2.2). The development of new energy systems would allow the incorporation of innovative solutions in order to help SECs manage their energy production and consumption efficiently, while providing smart services.

In their assessment of the options in the MCM interviews, the stakeholders indicated opportunities for SECs to integrate technological solutions into their processes and services. IS can significantly contribute to the implementation of these options. Based on these identified potential contributions, Table 4 shows the assessment from the second round of experts regarding the importance and digital readiness of each contribution (mean on a scale of 1 to 5).

While the experts rated the eight contributions as highly relevant, digital readiness was generally ranked lower. In the MCM analysis, the stakeholders assigned higher ratings to the options of developing applications based on measured data, supporting consumption and production optimisation, identifying IOP and developing VPP. Similarly, the experts rated the contributions related to these options higher. Additionally, P2P trading was rated with the highest level of uncertainty in the MCM analysis. Although the experts reported that the potential of IS to support such trading is highly relevant, they considered the status quo the least digitally ready. In addition to P2P, the experts suggested that certification of energy type and origin as well as provision of incentives and flexible tariffs require further technological developments to make them feasible for SECs.

Table 4 Mean of importance and digital readiness of potential IS contributions to SECs

Related design option	*Potential IS contributions*	*Importance*	*Digital readiness*	*Difference*
IOP	Support in forecasting energy demand, generation and investment costs	4.33	2.67	1.66*
AMD	Provision of relevant analyses based on operational and market data	3.89	2.56	1.33
POO	Support for plant-based certification of energy type and energy origin	3.44	2.22	1.22
SEM	Load management support for grid-serving control of power grids	3.78	2.78	1.00
CPO	Support in reconciling energy generation and consumption for electricity trading	3.89	2.78	1.11
NTA	Provision and management of incentives and flexible tariffs that serve the network	3.78	2.22	1.56*
VPP	Support for building virtual power plants from aggregated SEC generation assets	4.33	3.00	1.33
P2P	Support for peer-to-peer trading through smart contracts	3.67	2.00	1.67*

Note: *Highest differences between relevance and readiness.

5 Conclusions

This study examined how stakeholders assessed the technology-based design options that influence processes within SECs in Germany. Using the MCM method, expert group 1 developed eight options and specified the necessary perspectives on the subject. The stakeholders considered AMD a high priority for SECs as it serves as the foundation for developing further smart options based on the application of smart metres. To answer the first research question, they determined and prioritised the smart services that contribute to future solutions for digital ecosystem platforms in the energy industry. Furthermore, the stakeholders discussed each option from both an optimistic and a pessimistic perspective, answering the second research question regarding the challenges and the opportunities. In addition, they reported that the regulatory challenges, data privacy and the cost-benefit of the available technologies could hinder the application or reduce the relevance of certain options for German SECs.

After the MCM analysis, the IS contributions were assessed by expert group 2 in order to answer the third research question regarding the relevance and readiness of the indicated contributions. The assessment of the contributions by the experts was similar to the assessment by the stakeholders regarding the corresponding options. Generally, the suggested contributions need to be further developed to improve their digital readiness and to increase their relevance. Higher differences between the relevance and readiness of the contributions revealed significant gaps between the development of SESs and future demands in the field, such as in the areas of P2P trading, energy certification, provision of incentives and flexible tariffs. The discussed design options may support SECs in addressing these gaps. Smart communities might substitute, as well as complement, existing systems for energy trading as argued in Alt and Wende (2020). Blockchain-based systems for decentralised communities could address a new market segment for energy exchanges in addition to their existing centralised electronic trading systems (https://doi.org/10.1007/s12525-020-00423-6).

As there are multiple positive aspects of applications based on smart metre data, there is a need for research on the data generated in SECs in order to determine optimisation practices and balance out energy production and consumption. This knowledge-intensive approach supports the development of socially constructed innovations (Battisti, 2012). Furthermore, public policies could support the implementation of technologies in the energy market, influencing how SECs adapt to recent regulatory changes.

Although the results of the MCM provide indications about stakeholders' preferences, we should draw conclusions with caution due to the small number of interviewees and the lack of balance between the stakeholder groups. Moreover, as the stakeholders were related to the SECs, they could be subject to cognitive bias, thus possibly affecting their interpretations of the smart options. In addition, the inclusion of large energy companies in the study could improve the assessment because there is a risk that SECs might represent the interests of their businesses.

Researchers can use these results and methodologies to further investigate the smart service options and identify possible demands for new integrated IS on the energy market. Moreover, further research could use the MCM method to analyse the source of uncertainty for each stakeholder group and to weight their justifications. Finally, as some smart service options are available, market-related information for such options could be explored. Although this study focuses on the current situation of German SECs, it may be assumed that communities in other regions can also benefit from the analysis.

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Notes

1 Multi-criteria mapping – https://www.multicriteriamapping.com/.