Energy Community Preferences of Solar Prosumers and Electricity Consumers in the Digital Energy Ecosystem

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Introduction

In the strategies for energy transition and smart grids, energy consumers will become energy citizens who actively manage their energy demand and supply together with other digital energy ecosystem actors (Goulden, Bedwell, Rennick-Egglestone, Rodden, & Spence, 2014), and participate in energy markets selling and buying micro-generated energy and demand flexibility (Schick & Gad, 2015). The European Commission estimates that by 2050, almost half of EU households may be producing renewable energy (European Union, 2019; Kampman, Blommerde, & Afman, 2016). The energy community is widely considered one of the most important emerging organizational and business models in the energy transition. Estimates suggest that by 2030, energy communities could own some 17% of installed wind capacity and 21% of solar in Europe (Caramizaru & Uihlein, 2020). The dual transition of digitalization and energy fosters the emergence of new kinds of actor and role in the digital energy ecosystem. The evolving digital infrastructure and the role of energy citizens (CE Delft, 2016; Matschoss, Repo, & Timonen, 2019) advance innovations that are emerging in the energy ecosystem, and open up opportunities to local and virtual communities to share, pool and trade energy and energy-related knowledge (Hyysalo, 2021). A more decentralized energy system, where consumers play an active role, may be more democratic and participative, offering citizens opportunities to make their own decisions on what type of energy they want to use, and make energy an ecological resource subject to collective decision-making (Lennon, et al., 2019). The new EU rules actively promote this with provisions on self-consumption of energy, and local and renewable energy communities. (European Union, 2019). Energy prosumers and consumers are key actors in the digital energy ecosystem, potentially through energy communities. A virtual digital energy ecosystem provides more means for energy system management, and widens the potential of traditionally local, financial and ideology based energy communities (Meelen, Truffer, & Schwanen, 2019; van der Schoor & Scholtens, 2015). A virtual energy community may, for example, provide flexibility services for a distribution system operator (DSO) or a large renewable energy (RE) power plant (Huuki, et al., 2020).On the other hand, the diversity and complexity of the growing number of distributed RE resources, and the changing roles of energy ecosystem actors, pose challenges to managing the energy system.

In the ongoing energy transition, citizens, who have long been relatively passive consumers of energy, are increasingly producing energy, and thus becoming prosumers. The term “prosumer” refers to the simultaneous behavior of producing and consuming (Toffler, 1980). In the energy community context, prosumers produce energy, for example using solar panels, that is primarily for their own use, but may also trade, share and pool energy through digital applications such as energy communities (Brown, Hall, & Davis, 2020; Gržanić, Capuder, Zhang, & Huang, 2022; Kotilainen, Sommarberg, Järventausta, & Aalto, 2016). The growing number of energy prosumers and interest in clean and local energy are advancing opportunities for

energy co-operatives, P2P energy markets, and virtual power plants, meaning that consumers increasingly produce and share or trade energy, and energy production is dispersed and merged into energy consumers' everyday activities (Olkkonen, Korjonen-Kuusipuro, & Grönberg, 2017). Also, energy consumers without their own source of energy production have more opportunities to participate in energy markets through digital technologies and services, such as energy communities. Energy consumers may have a major role to play in contributing and creating new solutions and knowledge in digital energy ecosystems (Hyysalo, 2021). Recent developments in the digital energy ecosystem have led to a growth in the number of energy communities, in many different forms and with varying degrees of success (Espe, Potdar, & Chang, 2018). The active participation of prosumers and energy consumers has become a critical issue in the future development of energy communities (Espe, Potdar, & Chang, 2018; Kotilainen, Sommarberg, Järventausta, & Aalto, 2016; Vernay & Sebi, 2020). However, end-user preferences have to date been largely ignored by other digital energy ecosystem actors. Here, those preferences are reflected against the framework of the digital energy ecosystem, providing a useful conceptual structure to understand solar prosumers and energy consumers as end-users of the energy community in a complex socio-technical energy system.

A digital ecosystem is defined as a distributed socio-technical system formed through the integration of technologies and networks, system users, and social and knowledge sharing, with functions such as adaptability, self-organization, and sustainability (Bakhtadze, Pavlov, Pyatetsky, & Suleykin, 2019; Nachira, Dini, & Nicolai, 2007). The digital energy ecosystem is based on smart grid technologies, decentralized RE production, and a network of actors, business models, and processes (Kotilainen, Sommarberg, Järventausta, & Aalto, 2016; Tsujimoto, Kajikawa, Tomita, & Matsumoto, 2018). New and incumbent actors interact in the ecosystem network. They include, for example, distribution system operators (DSOs), prosumers, energy consumers, aggregators, local communities, and energy technology manufactures (e.g., home energy management systems and solar panels). It is recognized that users and user communities affect the creation of a sustainable ecosystem, and the other actors in the ecosystem (Hienerth, Lettl, & Keinz, 2014; Khavul & Bruton, 2013), and determine the success of new actors in the digital energy ecosystem, such as digital service providers, telecom operators, and data management companies (Kotilainen, Sommarberg, Järventausta, & Aalto, 2016). Manifold social, economic, political, psychological, and other factors affect the implementation of interactions in the digital energy ecosystem network (Dong, Hussain, & Chang, 2007), and this study focuses on those factors from the end-users' perspective.
Energy communities have received much attention in recent years as a means to empower energy consumers and engage them with the energy transition (Brummer, 2018; Caramizaru & Uihlein, 2020). An energy community is "a configuration of technologies, services and infrastructures, regulations, and actors (e.g., producers, suppliers, policy-makers and users) that fulfills a societal function" (Schot, 2016), such as balancing energy demand and supply. According to the European Union Clean Energy Package "[c]itizens can join in energy communities pooling their energy, and benefit from incentives for renewable energy production" (European Union, 2019). An energy community may take many forms, from virtual and distributed to local renewables, with varying degrees of collective capacity (Bauwens, Gotchev, & Holstenkamp, 2016; Soeiro & Ferreira Dias, 2020). It may, for example, be a local grassroots initiative for producing and sharing energy within a local community or housing company, or an entirely virtual, distributed group of actors pooling and/or sharing their energy for energy markets (Hyysalo, 2021).

Energy transition requires increased awareness of the end-user's role in the energy system (Lennon, et al., 2019). Hence, research on energy transition has in recent years expanded from technology and economic research to social science and the humanities, with the focus on energy users and their changing role (Ingeborgrud, et al., 2020). In this chapter, we present end-users' preferences on how to improve the energy community end-user experience (UX). Here, UX is widely understood to include also the users' emotions, beliefs, preferences, and perceptions that are present prior to the use of or participation in the energy community (e.g., Chen & Duh, 2009; Tuomela, Iivari, & Svento, 2021). In energy strategy planning,

and for the design of efficient and useful energy services, applications and initiatives, it is essential to understand end-user preferences, concerns and motivations. Furthermore, solar prosumers, and electricity consumers without energy micro-production, have different roles in the energy community, thus their preferences may differ and result in different requirements for the energy community. Here, the terms users, consumers and members of the energy community are used interchangeably, ultimately describing individuals as prosumers, energy consumers, users of digital energy community services and solutions, and as participants in the energy community. Despite the interest in energy communities, very little is known about end-users' preferences, and how solar prosumers' preferences differ from those of electricity consumers (Morstyn, Farrell, Darby, & McCulloch, 2018). Policy makers, energy technology designers, and energy market stakeholders need to better understand end-users' preferences regarding the energy community, in order to create solutions and services that meet users' expectations and needs, and design effective strategies to promote energy communities. In this chapter, we analyze and discuss the solar prosumers and energy consumers' interest and preferences regarding the energy community. Methodologically, we propose the adoption an ecosystem framework. We argue that adopting a digital energy ecosystem perspective is especially suited to the analysis of energy communities, given that they must coordinate and integrate their actions with other ecosystem actors, if they are to accelerate transformation of the energy sector (Bauwens, Gotchev, & Holstenkamp, 2016; Vernay & Sebi, 2020). This chapter answers the following research questions: R1) What preferences do electricity users have concerning energy communities? and, R2) How do the preferences of solar prosumers and electricity consumers differ regarding energy communities? We utilize survey data collected from Finnish energy prosumers and electricity consumers. Here, the term electricity consumer describes people not engaged in their own energy micro-production, thus excluding solar prosumers who both produce and consume.

The chapter is structured as follows. The first section provides a brief overview of the literature on energy community users' preferences and experiences. In the research design section, we present the applied method and research setting. The third section analyses the survey results. Finally, the discussion reflects our findings with other studies in the field, and presents suggestions for further research.

Related research

Energy community, to which manifold characteristics and functions are attributed, is a relatively new entity in the energy sector. Energy (sustainable/low-carbon/clean-energy) communities vary in structure, size and composition, responsible stakeholder(s), purpose, and features. Members of the energy community can be households, prosumers (i.e., individuals who consume and produce energy), businesses, and institutions. Depending on their characteristics, energy communities have diverse consequences and impacts on people, places, and energy the sector (Soeiro & Ferreira Dias, 2020a). The common factor is the goal to decarbonize the energy system and increase the use of renewable energy (Summeren, Wieczorek, Bombaerts, & Verbong, 2020).

Multiple conceptualizations have been presented on energy community activities. In the EU, the Renewable Energy Directive (European Union, 2018) defines 'energy community' as a legal entity that "is based on voluntary and open participation and is effectively controlled by members or shareholders that are natural persons, local authorities, including municipalities, or small enterprises; has for its primary purpose to provide environmental, economic or social community benefits to its members or shareholders or to the local areas where it operates rather than to generate financial profits; and may engage in generation, including from renewable sources, distribution, supply, consumption, aggregation, energy storage, energy efficiency services or charging services for electric vehicles or provide other energy services to its members or shareholders." (Roberts, Frieden, & d'Herbemont, 2019). Two types of energy community are further defined: 'Renewable energy community' and 'Citizen energy community' (Roberts, Frieden, & d'Herbemont, 2019). Citizen energy communities (CEC) "may engage [people or organizations] in

generation, including from renewable sources, distribution, supply, consumption, aggregation, energy storage, energy efficiency services or charging services for electric vehicles or provide other energy services to its members or shareholders" (Roberts, Frieden, & d'Herbemont, 2019). Renewable energy community (REC) is a special instance of CEC, referring to an entity where members are located in the proximity of renewable energy projects controlled or owned by the community (Hunkin & Krell, 2018). REC may produce, consume, store and sell renewable energy, to share within the community and access all suitable markets (Roberts, Frieden, & d'Herbemont, 2019). Small and geographically local community energy initiatives produce or invest in the production of renewable energy primarily to cover their own energy needs (Doci, Vasileiadou, & Petersen, 2015), with an emphasis on the social and shared identity aspect of the energy community, and provide the local community a form of co-operation and collaboration to reduce their energy carbon footprint (Heiskanen, Johnson, Robinson, Vadovics, & Saastamoinen, 2010). Other conceptualizations of energy community activities include 'Prosumer community group', referring to a community of prosumers generating and sharing energy (Espe, Potdar, & Chang, 2018; Rathnayaka, Potdar, Dillon, Hussain, & Chang, 2014), and 'local energy initiative' (LEI) (Ghorbani, Nascimento, & Filatova, 2020).

Energy communities require and inspire new business models and technology applications in energy markets (Reis, Goncalves, Lopes, & Henggeler Antunes, 2021). The energy community may be a (local) RE production and sharing network, or a two- or multi-sided platform that matches two or more user groups (Abdelkafi, Raasch, & Roth, 2019; Eisenmann, Parker, & Van Alstyne, 2006; Hagiu, 2013). The platform may offer user groups diverse pricing and value proposals, but it is important to have a sufficiently high volume of users to attract those from other groups (Hagiu, 2013; Huuki & Svento, 2021; Kallio, Heiskanen, Apajalahti, & Marschoss, 2020). One of the first energy community applications was peer-to peer (P2P) energy selling and buying in a blockchain-enabled microgrid (Brooklyn Microgrid, 2021; Mengelkamp, et al., 2018), but more applications, such as local RE communities and Virtual Power Plants (VPP), are being implemented as the concept of an energy community evolves (Mourik, Breukers, Summeren, & Wieczorek, 2019; Summeren, Wieczorek, Bombaerts, & Verbong, 2020). P2P energy trade transactions are made via distributed ledger, such as blockchain, instead of bilateral agreements between utilities and consumers/prosumers (Kounelis, et al., 2017; Nidhin Mahesh, Sai Shibu, & Balamurugan, 2019; Wu, Wu, Cimen, Vasquez, & Guerrero, 2022). In the meantime, Internet of Things (IoT) enables detailed accounts of energy flows (Ferreira & Martins, 2018) and energy ecosystems (Yin, Wang, Yang, Guo, & Zhang, 2021). An energy community may comprise a local microgrid, connected to or isolated from the main grid (Fahad Zia, Elbouchikhi, & Benbouzid, 2018; Hirsch, Parag, & Guerrero, 2018). Microgrids can provide flexibility and other services to the grid, improving stability and resilience (Fahad Zia, Elbouchikhi, & Benbouzid, 2018; Harrison, 2021). Most microgrids have to date been installed for industrial or remote use, and only 13% for community use (in 2015) (Emerging Microgrid Business Models, 2016; Vanadzina, Mendes, Honkapuro, Pinomaa, & Melkas, 2019). Regulations and laws for electricity markets vary by country, and may either deter or enable the evolution of energy community business models. In Europe, for example Austria, Spain, France, Germany, and Belgium have introduced legal frameworks that allow collective self-consumption (CSC), whereas in many other European countries sharing and pooling energy through CSC is heavily regulated and restricted (Frieden, Tuerk, Roberts, d'Herbemont, & Gubina, 2019).

There are several driving forces for energy communities. For example, a need for demand-side flexibility and management (Lund, Lindgren, Mikkola, & Salpakari, 2015; Paterakis, Erdinç, & Catalão, 2017); consumers' willingness to produce and use energy from renewable sources (Heiskanen & Matschoss, 2017; Mundaca & Samahita, 2020); the development of P2P markets for distributed energy facilitated by digitalization (IEA, 2017; Morstyn, Farrell, Darby, & McCulloch, 2018; Zhang, Wu, Zhou, Cheng, & Long, 2018); new possibilities for end-users to participate in energy markets (Kotilainen, Sommarberg, Järventausta, & Aalto, 2016; Teotia & Bhakar, 2016); new and improved technologies for decentralized

energy production, management and sharing (IEA, 2020; Zhou, 2016); and, the availability of detailed information on energy production, use and markets, due to smart meters, smart grids and IoT (Baidya, Potdar, Ray, & Nandi, 2021; Kotilainen, Sommarberg, Järventausta, & Aalto, 2016). Furthermore, energy communities may be a means to lower the barriers to active agency in energy markets, engaging and empowering people as energy citizens (European Commission, 2015; Heiskanen, Johnson, Robinson, Vadovics, & Saastamoinen, 2010; Ingeborgrud, et al., 2020; Young & Middlemiss, 2012).
Previous studies have identified that energy communities provide energy citizens with the capacity to work together, to transform their energy infrastructure at the local level (Raven, Heiskanen, Lovio, Hodson, & Brohmann, 2008), and foster individual and household energy behavior change (Heiskanen, Johnson, Robinson, Vadovics, & Saastamoinen, 2010). Energy community participation may also reduce feelings of helplessness and disempowerment in changing energy consumption conventions (Tukker, et al., 2008), give people confidence in enacting change, and spread knowledge that others are participating. Hence, together with other community members, energy communities are collectively making a significant difference (Heiskanen, Johnson, Robinson, Vadovics, & Saastamoinen, 2010; Soeiro & Ferreira Dias, 2020a). In their case study in the Netherlands, Van der Schoor & Scholtens (2015) identified the development of a shared vision, the level of activities, and the type of organization as important factors of the strength of the local energy initiatives. Also, according to a study on emerging energy community business models in Finland, participating in energy communities can be a way to build your identity, to represent yourself as environmentally conscious and supporting local and micro-generated renewable energy (Kallio, Heiskanen, Apajalahti, & Marschoss, 2020). Studies on energy users' preferences regarding energy communities, and motivations or barriers to participate in one, are more scant.

Soeiro and Ferreira Dias (2020a) found in a survey of community energy participants in Europe that the environmental impacts are much more important to them than the financial. According to Doci & Vasileiadou (2014), motivations to invest in renewables at community level are both economic and environmental (normative), but also hedonic, such as the presence of other people, having fun, and integrating in a strong community. This social dimension seems to be an important condition for the realization of local energy projects (Kounelis, et al., 2017), though social conflicts are identified as a potential barrier (Soeiro & Ferreira Dias, 2020a). The survey by Kalkbrenner and Roosen (2016), on motives and willingness to participate in community energy amongst German energy users, revealed that the attitude towards community energy is positive, yet the willingness to volunteer is greater than the willingness to invest money. People emphasize the importance of social rather than just environmentally motivated aspects (Kalkbrenner & Roosen, 2016). Also, a survey among 599 citizens in the Netherlands indicated that environmental concerns, renewables acceptance, energy independence, community trust, community resistance, education, energy-related education, and awareness of local energy initiatives were the most important factors in determining the citizens' willingness to participate in community energy systems (Koirala, et al., 2018). In a literature review on community energy initiatives in Germany, the UK and USA, Brummer (2018) identified several societal benefits conferred by community energy (e.g. economic benefits, knowledge and acceptance, and climate protection and sustainability), as well as regulatory barriers in these countries impeding the formation and resilience of community energy initiatives. However, Brummer did not study motives and preferences concerning the energy community from the participants' perspective. Participation in energy co-operatives may increase acceptance of local renewable projects (Brummer, 2018; Soeiro & Ferreira Dias, 2020a). Yet, conflicts of interest within co-operatives, and conflicts pertaining to values underlying a cooperative's strategy, are more pronounced than in more formal and hierarchical organizations (Yildiz, et al., 2015). Both the ownership of a renewable energy system, and living in a rural rather than urban community, increase the likelihood of participation in community energy (Kalkbrenner & Roosen, 2016).

Besides citizens, also business and public stakeholder objectives in joining an energy community are heterogenous and possibly conflicting (Heuninckx, te Boveldt, Macharis, & Coosemans, 2022). In a participatory study on a Flemish energy community, financial incentives were potential members' main motives for participation, but the decision to join is often influenced also by a variable combination of social, economic, technical, and environmental motivations. For example, local governments mainly want an energy community to yield social and environmental advantages, whereas the local DSO seeks value added to its main grid, and expects the energy community can help avoid major grid investments (Heuninckx, te Boveldt, Macharis, & Coosemans, 2022).

A case study on RE prosumer communities found that energy resources were usually owned by energy cooperatives, municipalities and communities, most of which interacted with the grid by supplying excess energy from the community to the power grid (Adu-Kankam & Camarinha-Matos, 2019). Also, collaboration was an integral component of their mode of operations. Furthermore, co-ownership of renewable energy production affects people's willingness to demand flexibility (Roth, Lowitzsch, Yildiz, & Hashani, 2018), and probably increases awareness on demand flexibility. However, energy communities are mushrooming, often without a coherent operational model(s), and consequently the user experience and user roles vary greatly (e.g., Gorroño-Albizu, Sperling, & Djørup, 2019). For example, the Farm Power energy community was not considered especially easy-to-use for the consumer, and there have been challenges in attracting customers (Kallio, Heiskanen, Apajalahti, & Marschoss, 2020). Also, more services, such as demand-side management, were expected to be part of the community's services in the future, as now only small producers are selling electricity to buyers (Kallio, Heiskanen, Apajalahti, & Marschoss, 2020). Pumphrey, Walker, Andoni, & Robu (2020) interviewed domestic consumers, business consumers, domestic prosumers and business prosumers for their preferences on the peer-to-peer energy trading in the UK. The interviews identified ease of payment as a key theme for electricity trading, but the authors noted there may be tensions with sustainability and greater awareness of energy-related environmental impacts. Consumers identified a lack of engagement with the process of receiving energy, and cost, but prosumers identified positive associations with power, and personal and business image.

Methods and materials

Our survey is a part of the value-based research on energy communities, aiming to identify stakeholder values and implement them in the digital energy ecosystem. Two key energy community stakeholders were identified and involved in the survey: solar prosumers and electricity consumers, as potential initiators of and participants in the energy community. A large national DSO provided a list of 1361 contacts for the survey. However, the DSO did not influence the survey contents or analysis of the results in any way, nor did the company finance the research. The survey was targeted to 1361 households resident in a detached or semi-detached house, and 33% of these households were solar panel owners. The survey questionnaire was tested on three test users before sending to the surveyees. The survey was conducted in January-February 2020. The invitation to answer the online survey was sent via email, the response rate was 45% (n = 617), and 41% of the respondents were solar panel owners.

The survey gathered versatile information on energy communities, including general interest to participate in an energy community, motives for and barriers to participation, preferred spatial scale, size and operator, and desired services and features that the energy community might offer. We utilized the previous literature on energy communities in planning the survey questions (Brummer, 2018; Doci & Vasileiadou, 2014; Soeiro & Ferreira Dias, 2020a). We assumed in the survey that the concept "energy community" would be new to many respondents, and therefore defined it at the beginning of the question set concerning energy community as follows: "In the energy community, members share the benefits of electricity generation and procurement with each other. The energy community consists of households and possibly small local energy producers and municipal actors. Typically, surplus electricity generated by home

photovoltaic (PV) systems can be distributed and procured through the energy community. The community will increase the choice of members to participate in the electricity market and will influence the way electricity is used and the environmental impact of energy consumption. The energy community allows participation in joint procurement (for example, solar power plants or electricity storage facilities)." We are aware of the ambiguous nature of the term, and while we wanted the survey respondents to get an idea of the possibilities of the energy community, we looked to avoid overly guiding their views and perceptions.

Energy community preferences by solar prosumers and electricity consumers

Energy consumers and prosumers were asked about their interest in participating in an energy community, the motives for and barriers to being an energy community member, their preferences on size, locality, and the nature of the responsible organization, and preferred features of the energy community. The energy community preferences of the solar prosumers and electricity consumers were analyzed side by side.

Interest and motives to participate in the energy community

The overall response to the question on interest in participating in an energy community was rather positive, as can be seen in Figure 1. Most respondents were either interested or slightly interested in participating in an energy community. Hesitancy may have been due to the novelty and lack of examples of energy communities. Those who expressed themselves very interested in participating in an energy community amounted to 13% of all respondents, but 16% were not at all interested. Solar prosumers were slightly more interested in participating compared with electricity consumers.

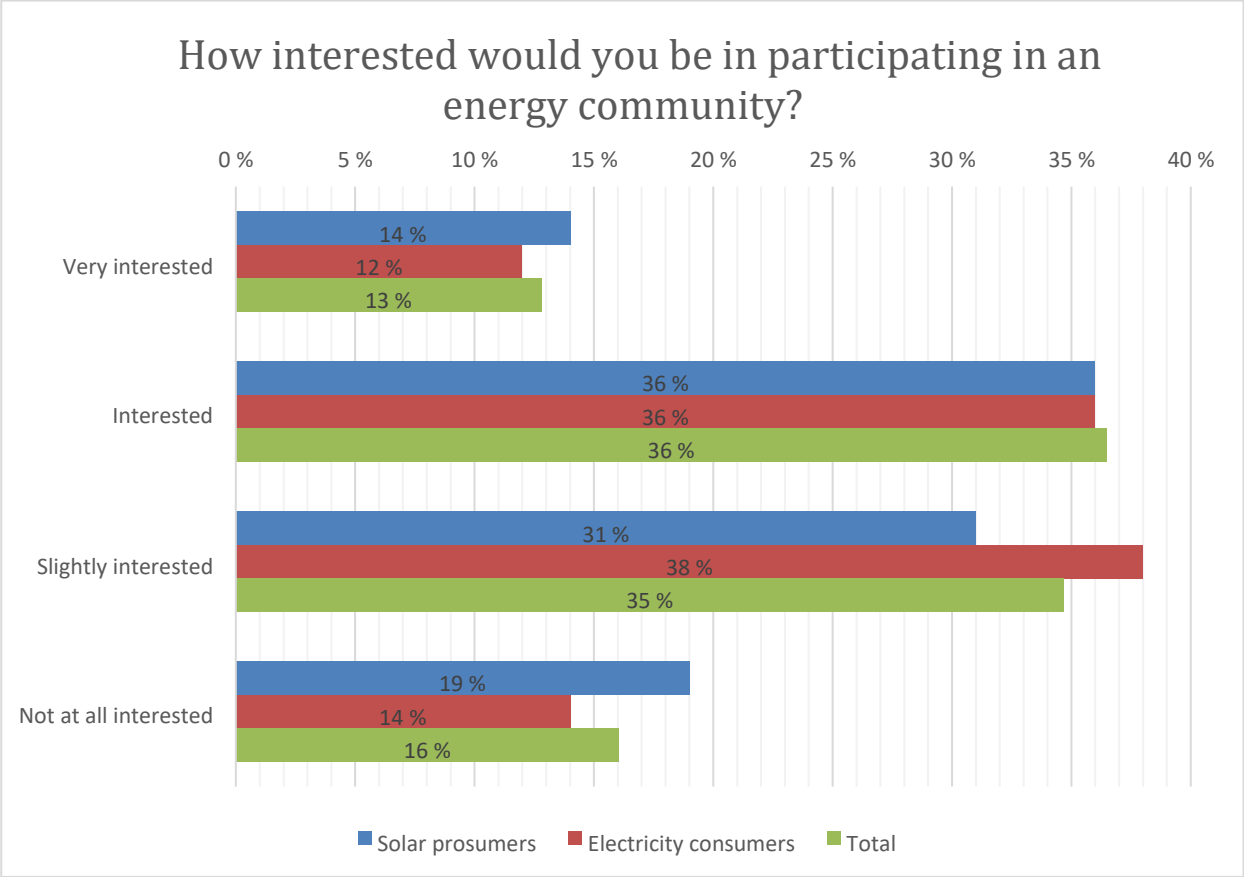

Figure 1. Interest in participating in an energy community.

Figure 2 shows that two-thirds of the respondents were interested in participating in an energy community first and foremost for economic gain, followed by environmental friendliness. One-third sought

independence from the big energy companies, whereas just over half reported they would like to use micro-generated electricity, and a quarter to participate out of curiosity and experimentation. Energy security and social community aspects in production and consumption were considered relatively important but not necessary factors, which also applied to information on energy consumption, and participation in electricity markets together with others. Prosumers were more eager to try out new ways to produce and share energy, and with other prosumers and consumers to participate in and influence energy markets. Energy users without their own production sought economic gains more often than did solar prosumers. Taken as a whole, intrinsic motivations that relate to the enjoyment of participation and energy management are less important than the extrinsic, such as cost savings and personal benefits.

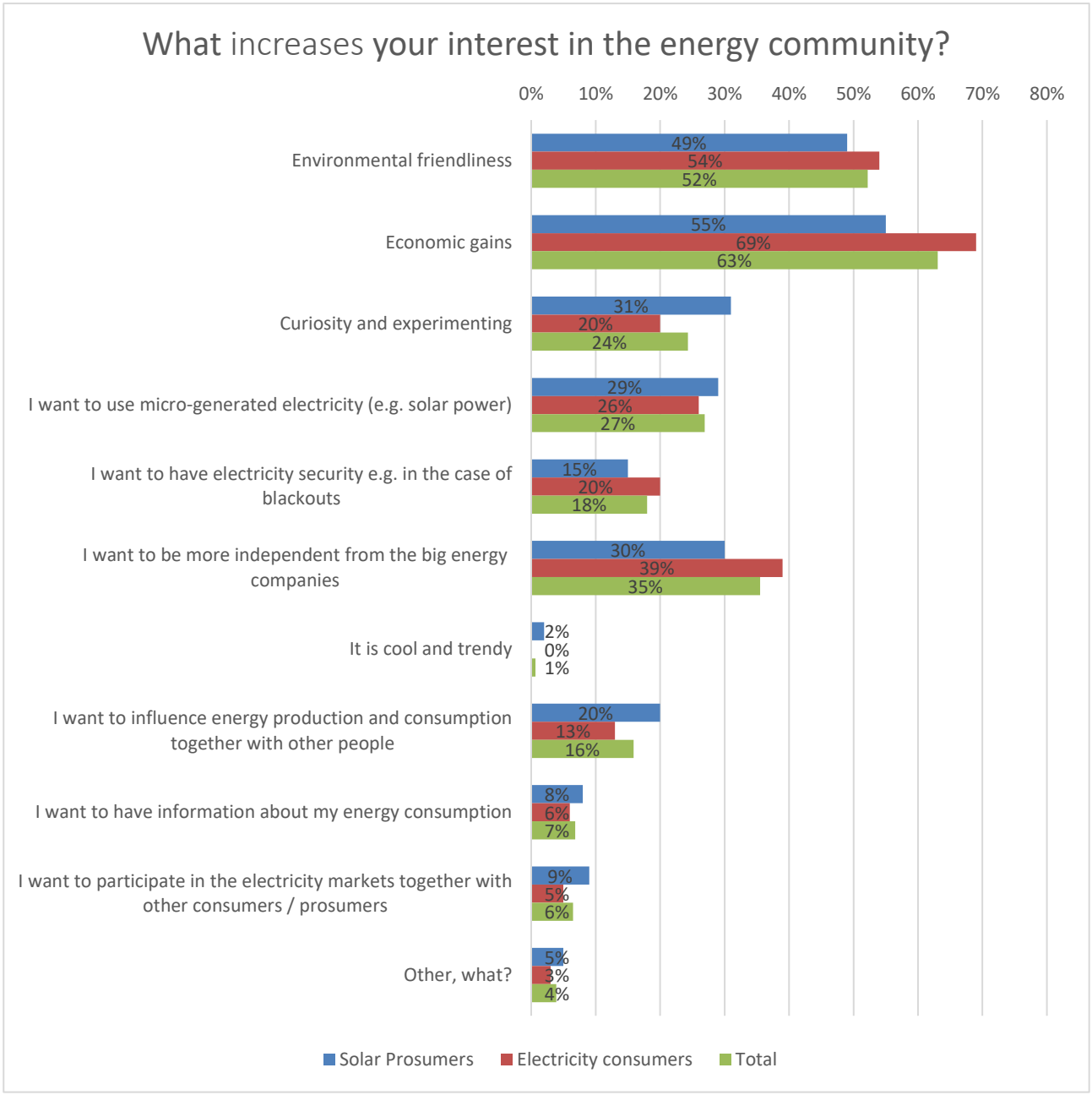

Figure 2. Factors that increase interest in an energy community (up to 3 options per respondent).

Presumed technical challenges, doubts over whether electricity would cost less in an energy community, and reluctance to go to any trouble regarding electricity consumption were considered hindrances to

participation in an energy community by around a third respondents in each case (see Figure 3). Also, one in six respondents did not believe participation would benefit them or distrusted energy companies. One in eight had no interest whatsoever in energy communities. Yet, few doubted the environmental benefits of the energy community or the significance of solar power as a mode of production. Also, relatively few respondents expressed a reluctance to buy electricity directly from other households, were indifferent to how electricity is produced, or not interested in energy and electricity.

The "Other, what?" question concerning factors that reduce interest in the energy community was answered by 65 respondents. Most cited doubts concerning economic issues such as price (9), initial investments (4), and an insufficiently positive cost-benefit ratio as barriers to participate in an energy community. Problematic community dynamics (3) and a lack of knowledge concerning energy communities (5) decreased interest for some respondents, as well as the high age of the respondent (2) and legal and regulatory barriers (2).

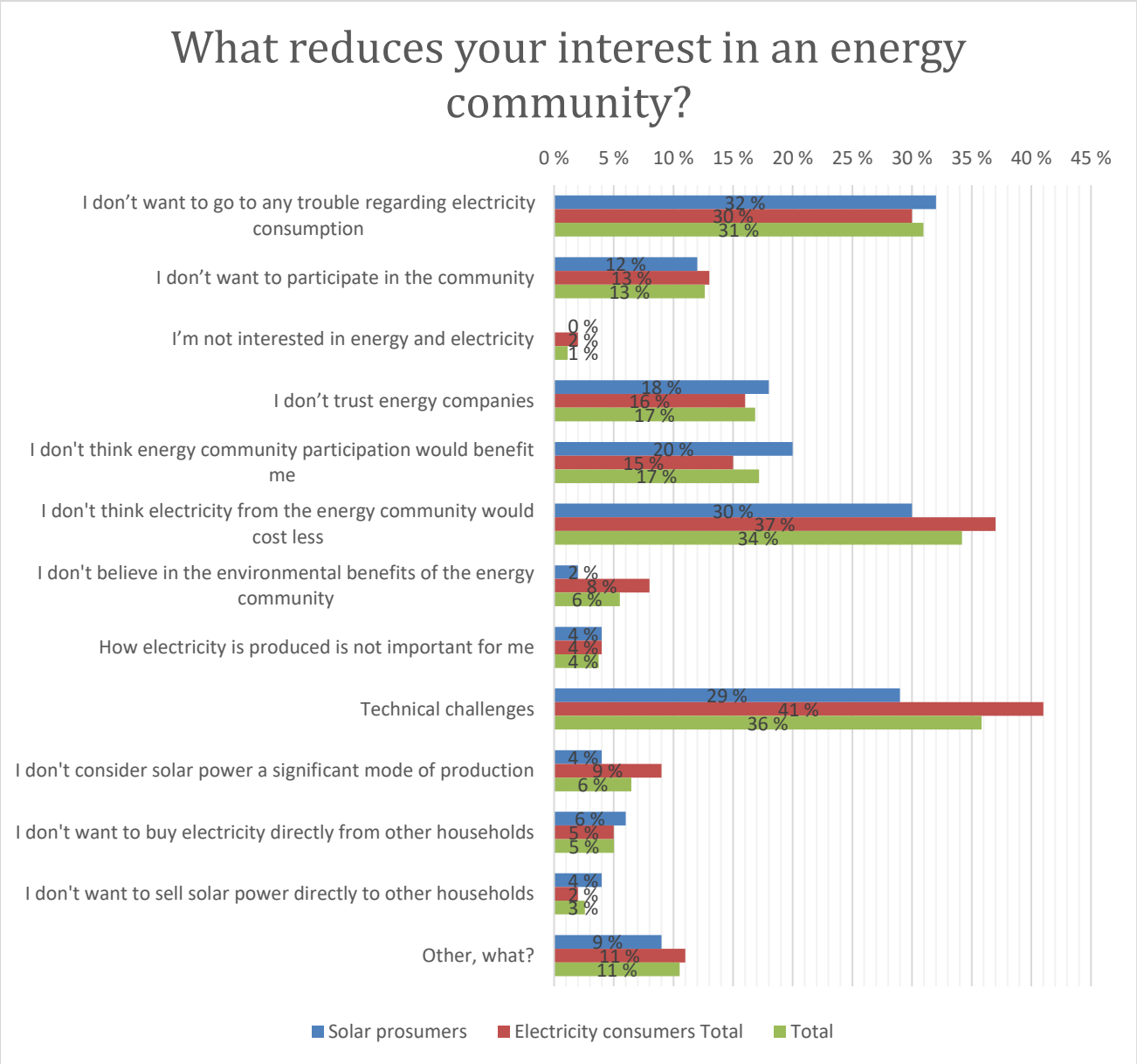

Figure 3. Factors that reduce interest in participating in an energy community (up to 3 options per respondent).

Preferred type of energy community

Respondents’ preferences concerning the location and formation of an energy community were divided (see Figure 4). Almost half thought it should be formed locally, for example, in their own town or in the neighborhood. More than a third felt that the energy community members’ location was not significant. Only one in ten thought it should be national, and very few preferred that an energy community would comprise family or friends. Figure 5 indicates it was challenging for the respondents to estimate a good number of participating households, with 39% answering "I don't know". A fifth thought the energy community should have more than 50 households, whereas one in six preferred a smaller energy community of 10-20 households. Both a very small energy community of less than 10 and one with 21-50 households were preferred by one in nine respondents. When it came to the matter of what form of organization the energy community should take, Figure 6 indicates that over half of the respondents considered the energy company should be a non-profit, and slightly less than half preferred a co-operative comprised of the community members. A fifth felt the energy community should be managed by the public sector, for example, a municipality or city. Slightly less preferred an energy community owned by an energy

company or an SME. Hardly anyone wanted to participate in an energy community owned by a large private company.

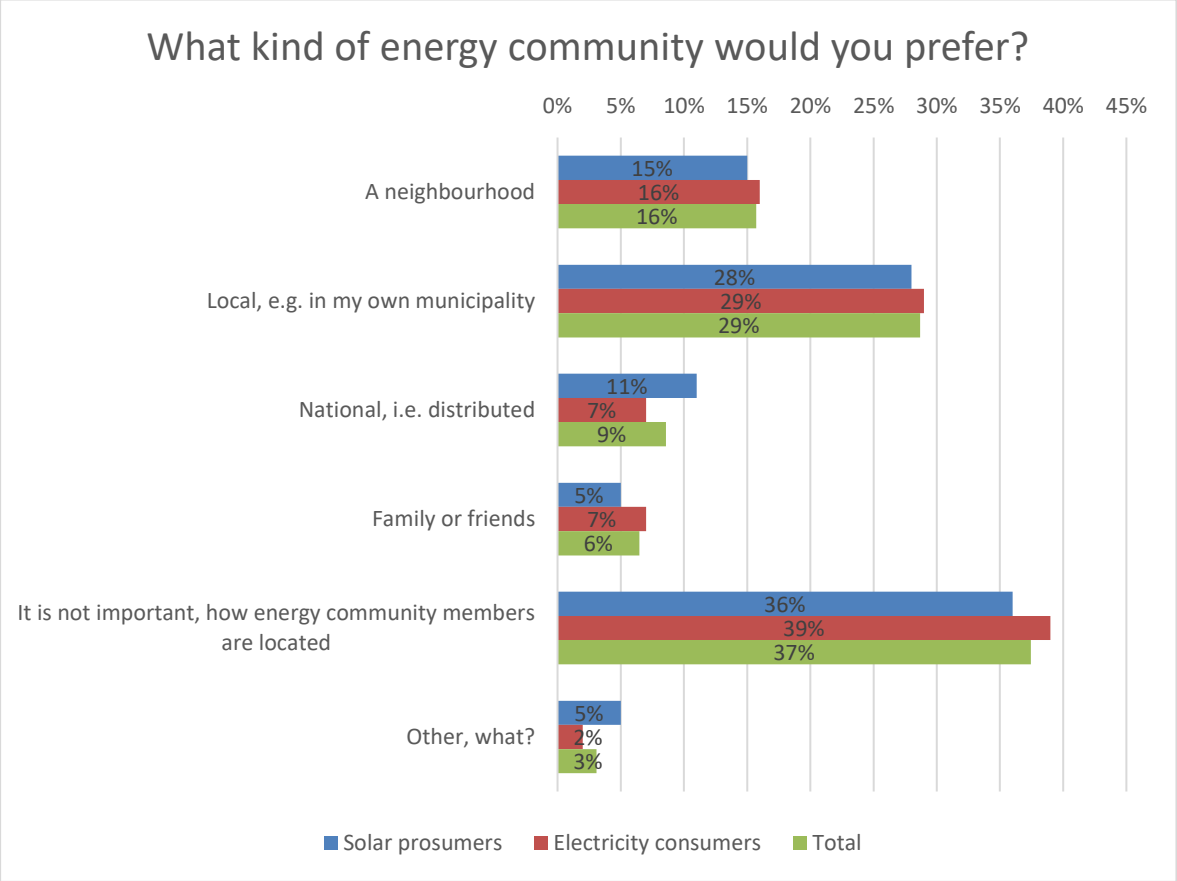

Figure 4. Preferences on the type of energy community.

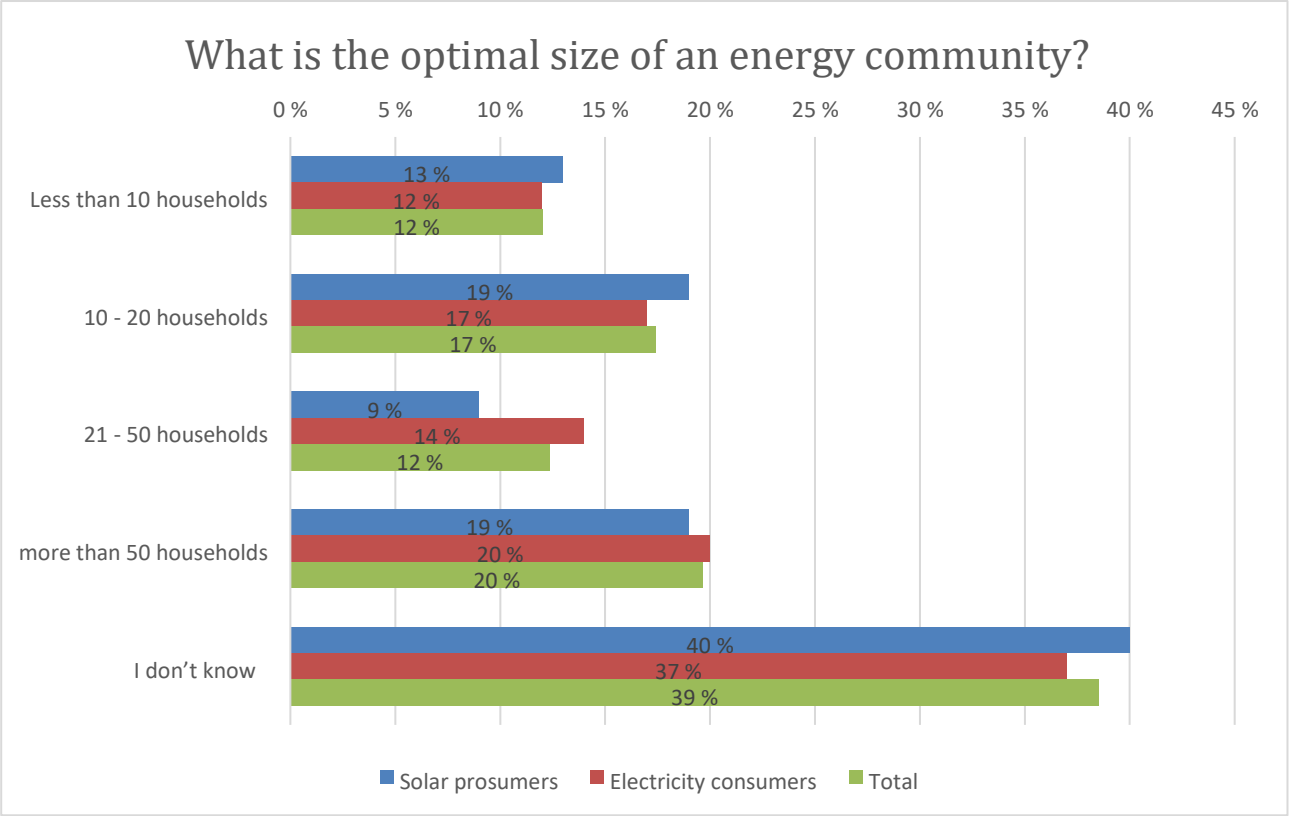

Figure 5. The optimal size for an energy community.

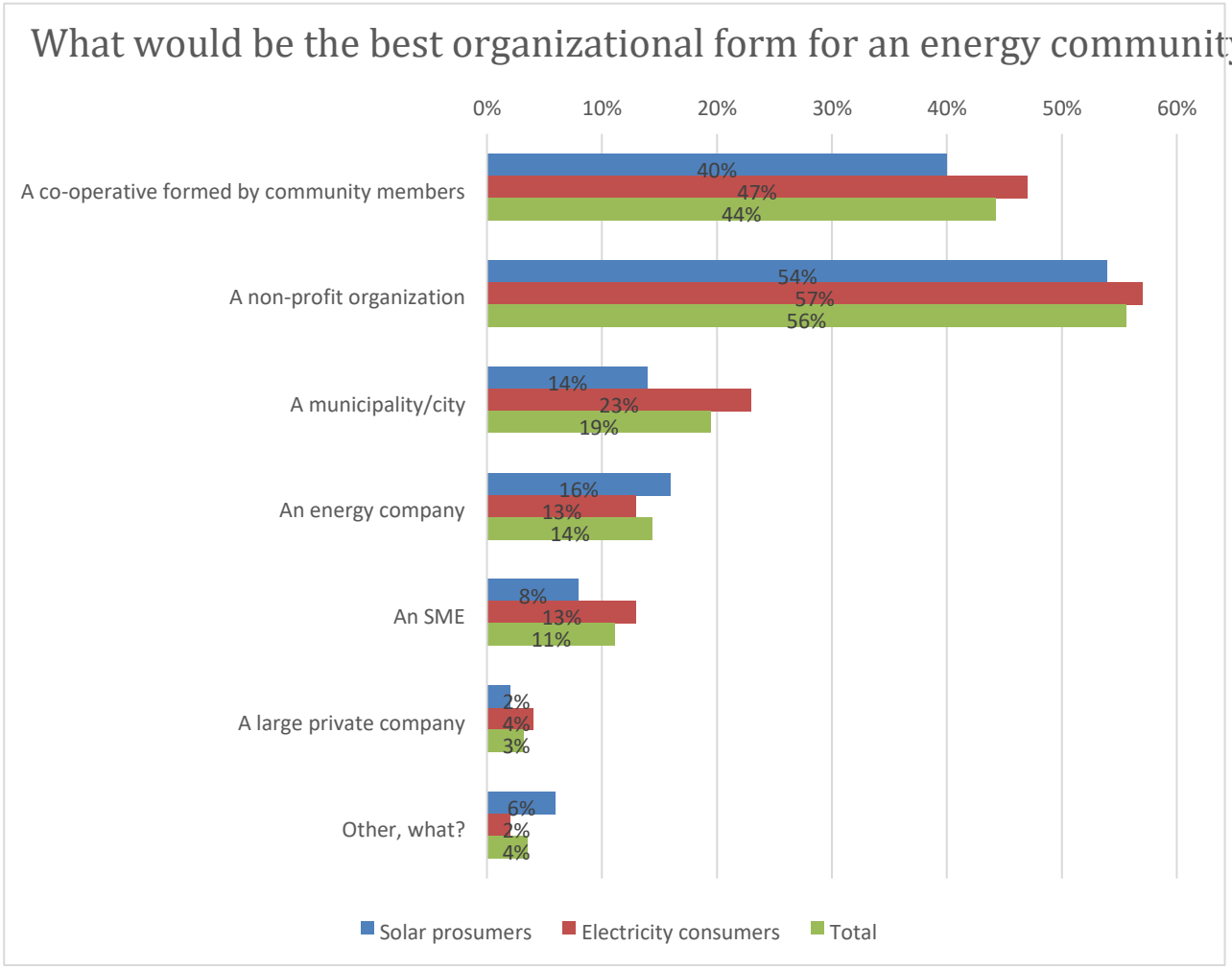

Figure 6. Preferences concerning the responsible organization for the energy community.

Features of the energy community

Highlighting the importance of P2P energy trading, the majority of those who responded felt that an energy community should provide its participants with the potential to buy and sell energy (see Figure 7). Also, around half of the respondents were interested in the potential to acquire common energy storage systems and common PV systems through the energy community. An energy account showing the benefits gained in the energy community was important to a third of respondents.

A small minority suggested the energy community should offer a service to monitor household energy use (19%), tips for energy saving (16%), and the potential to compare your own electricity consumption with that of other community members (12%). It was somewhat surprising that only 15% indicated they would like to have a demand flexibility service in the energy community. This might be due to a lack of awareness of demand response and the needs and capitalizing possibilities of demand flexibility.

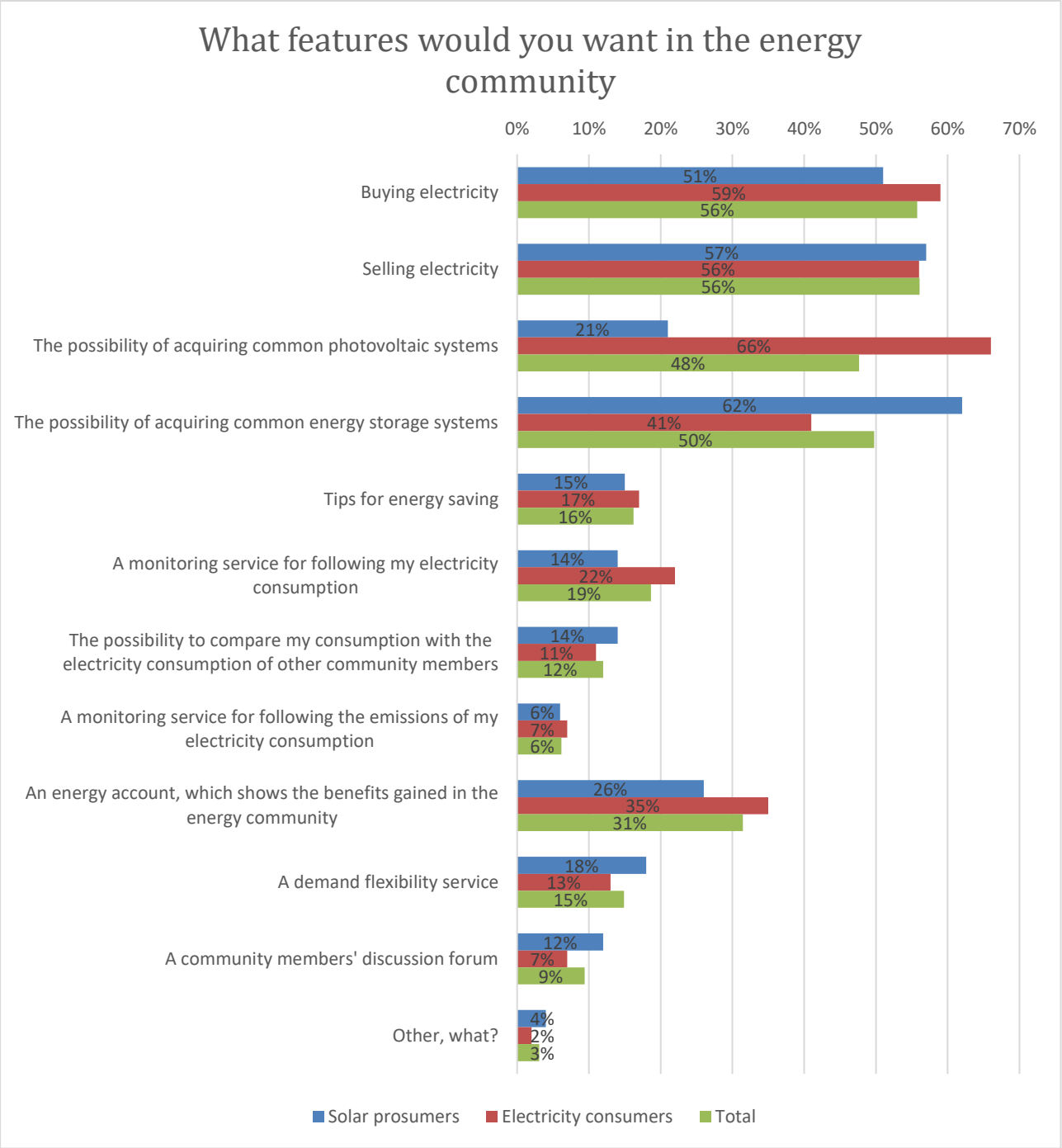

Figure 7. Desired features of an energy community.

Solar prosumers vs. electricity consumers

Solar prosumers and electricity consumers would presumably differ in terms of experience and awareness on energy micro-production and energy communities. Therefore, we expected the motives and preferences of the two groups to be more diverse. Contrary to expectations, solar prosumers and electricity consumers were relatively unanimous in their views on most questions. In both groups, most were to some extent interested in participating in an energy community. Only one fifth of solar prosumers and one in seven electricity consumers were not at all interested. Surprisingly, more solar prosumers were not at all interested in participating in the energy community than were electricity consumers. The four most common motives for participation were economic gains (55% solar prosumers, 69% electricity consumers),

environmental friendliness (49% and 54%), independence from the big energy companies (30% and 39%) and curiosity an experimenting (31% and 20%).

The most significant difference between the solar prosumers and electricity consumers was in their responses to the question on the features they would like to have in the energy community. Two-thirds (66%) of the electricity consumers wanted to be able to acquire common PV systems, versus only 21% of the solar prosumers. On the other hand, a larger share (62%) of the solar prosumers was interested in the possibility to acquire common storage systems through the energy community, whereas only 41% of electricity consumers considered it important. Also, more electricity consumers expected economic gains from the energy community (69%) than did solar prosumers (55%), yet they were more doubtful on the potential for cheaper electricity in the energy community (37%) than were the solar prosumers (30%). A larger share (41%) of electricity consumers than solar prosumers (29%) believed technical challenges would reduce their interest in the energy community.

Respondents contributed 98 comments and ideas in the survey's open comments field. Most (23; 10 solar prosumers, 13 electricity consumers) reflected concerns about too high electricity transmission and distribution costs. Some electricity consumers (12) and even a few solar panel owners (3) considered solar panels too expensive and inefficient in the North, thus decreasing the opportunity for a successful energy community based on sharing solar energy. Solar panel owners raised the need for storage (5) and net billing (5) as factors fostering energy communities. Besides the transmission and distribution costs as well as the profitability of solar panels, there were other kinds of doubt over energy communities, such as how to construct a good business model (4), potential disagreements between community members (1), and the extra effort that involvement in an energy community would require of the energy user (3). Nevertheless, 16 respondents made positive comments about the interesting topic and research, and two said they had learnt about new and exciting opportunities through the questionnaire.

Discussion

This research looked to increase our knowledge on the preferences of two key stakeholder groups in the energy community: solar prosumers, and electricity consumers without their own energy micro-generation. To explore the views of potential users, we conducted a survey receiving 607 responses. The study provides a basis to understand end-users and participants in the energy community, and an agenda for future research.

The survey results elucidate what kind of energy community the users would prefer, and the minor differences between the solar prosumers and electricity consumers. Energy community may still be a distant and unclear concept to many respondents, yet half were either interested or very interested in participating in an energy community. Only one in six were not at all interested. It would appear that extrinsic factors, that is, seeking external rewards, such as cost savings and personal benefits, are more important for interest and participation in an energy community than intrinsic motivations that relate to the enjoyment of participation and energy management. The factors which reduce interest in an energy community may reflect also the users' understanding of the fact that initiating and operating the energy community is rarely technically and economically feasible without creating exceptions in regulations and support schemes (Brummer, 2018). The findings are in line with previous research where a lack of information, investment costs, long payback time, and a lack of proper business models were found to slow the adoption of clean energy technologies (Peñaloza, et al., 2022). Although our results differ slightly from the previous findings stating that high environmental awareness increases the likelihood of adoption of clean energy technologies (Peñaloza, et al., 2022; Perlaviciute, Steg, Contzen, Roeser, & Huijts, 2018; Werff & Steg, 2016), it can nevertheless be argued that environment friendliness is an important factor for participation in the energy community. The results also indicate the need for information campaigns on

energy communities, as well as further clarification of the concept and business models for different types of energy community.

As expected, the survey results show there are strong barriers to interest and participation in an energy community, and doubts regarding the community's feasibility and financial rationality. Two in five electricity consumers doubt electricity would cost less in the energy community. Technical challenges are also seen as a barrier to either building or participating in an energy community. Solar prosumers have fewer reservations concerning the energy community's technical challenges or economic benefits, but are reluctant to expend time or effort on energy consumption. Also, a fifth of the respondents did not think participation in the energy community would benefit them. Besides the members' (un)willingness to participate (Doci & Vasileiadou, 2014; van der Schoor & Scholtens, 2015), other studies have brought up other digital energy ecosystem barriers, such as strong dependency on national policy and legal frameworks (Herbes, Brummer, Rognli, Blazejewski, & Gericke, 2017), and on public support (Herbes, Brummer, Rognli, Blazejewski, & Gericke, 2017; Seyfang, Hielscher, Hargreaves, Martiskainen, & Smith, 2014).

In terms of the organizational form of the energy community, users lack trust in energy companies and other businesses, preferring a co-operative or other non-profit structure. Solar prosumers are slightly more in favor of energy companies, while a quarter of consumers consider a municipality or city the preferred energy community organizer. As for size and locality, four in ten respondents said it is not important where energy community members are located. On the other hand, one-third said it should be local, for example, in their own municipality. The optimal size for an energy community depends greatly on its objectives and functionalities, and 40% of the respondents could not estimate an optimum. In order to capitalize flexibility in the energy markets, the flexible load volume should be big, that is, aggregated from a large number of households (Powells & Fell, 2019). On the other hand, a local RE community may comprise a small number of households. In the digital energy ecosystem, both scaling up and scaling down are evidenced. For example, many utilities are expanding into global markets, but at the same time local energy production and use is becoming more common. Energy community is an umbrella concept that covers both trends: a virtual power plant energy community may pool demand flexibility loads and locally produced energy, and sell it to international energy markets, whereas local RE initiatives may provide opportunities for people to produce renewable energy together with others, and share it locally. However, the concept 'energy community' is currently too ambiguous and would require more precise definition to be understandable to users. The preferences of solar prosumers and consumers concerning the energy community are largely in accordance, and no significant differences were found between them, aside from desired features. Two-thirds of solar prosumers are interested in having common energy storage systems through the energy community, compared to 41% of consumers. On the other hand, two-thirds of consumers would like the opportunity to acquire solar panels together with others in the energy community. Unsurprisingly, buying and selling energy interests more than half of both user groups, in relation to which users would like to have an account that shows transactions and illustrates the benefits gained in the energy community. A demand flexibility service, monitoring and comparing energy consumption, and tips for energy saving are less important features, and a discussion forum with other users, or monitoring the emissions from your own energy consumption, interest less than one in ten users.

Further interdisciplinary research is needed to bridge the gap between EU clean energy and energy citizen ambitions and the reality of energy community development, as well as the potential for the development and wider dissemination of new forms of such communities (Blasch, et al., 2021) and a holistic understanding of the digital energy ecosystem dynamics and new business models resulting from the energy transition (Nolden, Barnes, & Nicholls, 2020).

Energy communities present promising potentiality for increased RE production and use, energy resilience, and citizen activation on sustainability efforts. Despite this potential and wide interest, energy communities

still today play a marginal role in the digital energy ecosystem, and seem vulnerable to shutting down (Seyfang, Hielscher, Hargreaves, Martiskainen, & Smith, 2014; Vernay & Sebi, 2020). Energy communities demonstrate the common understanding that solving energy issues requires integrated solutions at all ecosystem levels: societal, technological, business, and institutional (Klein & Coffey, 2016; Vernay & Sebi, 2020). To realize the full potential of energy communities in the digital energy ecosystem, and to accelerate energy transition by the energy community's key actors, we need a wider understanding on the preferences, objectives and barriers involved. Our study provides considerable insight into solar prosumers' and energy consumers' preferences, highlighting strong interest in participating in the energy community, and shared end-user objectives. However, users are aware of the numerous barriers and hindrances to building and/or participating in energy communities. These results have implications also for other digital energy ecosystem actors, as they face questions concerning their purpose, offerings and transition to digital technology. Ultimately, the prosumers and consumers will make the decisions that determine the role of the energy community in the digital energy ecosystem, and thereby shape energy transition.

The most important limitation of the survey results lies in the fact that the concept 'energy community' is highly ambiguous and rapidly changing. Thus, the preferences and perceptions of the energy community may be based on very different assumptions and understanding of the concept in question. In addition, since the respondents are identified in the survey as 'households' instead of individuals with demographic attributes, we are unable to break down the responses by age, gender, occupation, or other factors. There might be different preferences within a household, and we encourage the reader to bear this in mind.

We have continued the research with solar prosumers and electricity consumers, with a special focus on the values of potential energy community users. The interview research results will be published in 2022. In addition, we aim to combine the survey data used in this study with another survey's data focusing on the determinants of residential solar PV adoption. The latter data also include the respondents of this study, and enable more detailed quantitative analyses on the effects of sociodemographic and home characteristics on household preferences for energy communities.

Further research should be conducted on awareness and motives to participate in and initiate energy communities. The survey responses presented here came from the person who carries the main responsibility for decisions concerning energy use and investments in the household. Usually, that person is the male adult in the family. Interest and activity in energy-related issues is highly gendered and more characteristic of affluent, middle-aged men. Further studies are needed on the different roles and agencies in energy communities and in the energy transition, and to find ways to increase awareness regarding energy systems and markets in all social groups.

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