Identification of the Key Criteria for Designing Social Innovations in the Energy Sector

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Abstract

Social innovations such as energy cooperatives, energy aggregators, and crowdfunding projects are important for strengthening energy democracy and promoting active citizen participation in the energy transition. However, the multitude of criteria and constraints in the design of social innovations complicates the decision-making process. It is therefore important to understand the criteria that need to be considered when designing a social innovation in the energy sector, as they influence the possible design solutions and the designer's decision. Thus, the objective of this paper is to define the key criteria for the design process of a social innovation in the energy sector. To achieve this goal, this work is based on a bibliographic survey and a field study. The state-of-the-art is mainly concerned with the social innovation design process in the energy sector and its success criteria, while the field study is based on interviews with members and leaders of four use cases. The findings are the key criteria for designing social innovations in the energy sector identified in this research work. They are presented with an arborescence and an I-P-O framework, a multifaceted picture that presents the inputs, outputs, and the key criteria of a social innovation design process.

Key words: Design process, Design criteria, Social Innovation, Sustainability, Energy transition.

Introduction

Social Innovations in the energy sector (SIE) are an important lever to empowering citizens as pilot actors for a fair and sustainable energy transition. There are a variety of different types of SIE (e.g., energy cooperatives, local electricity exchange, energy crowdfunding…). The transformation of the energy system depends not only on technological development, but also on public support, as it involves the profound changes. Therefore, technological solutions alone may no longer be sufficient to achieve the goals of the European Green deal (a set of policy initiatives proposed by the European Commission with the overarching goal of making Europe climate neutral by 2050) [23]. The energy system transition will also be driven by changes in the different roles and relationships of actors and the different activities they perform. These changes require citizens to become active participants in the energy system, for example, by contributing to the financing of renewable energy projects through crowdfunding platforms or by becoming involved in a local energy community. Most importantly, consumers can become energy producers themselves. For example, by equipping their roof with solar panels, former consumers can become energy producers themselves, known as prosumers [24]. Social innovations in the energy sector have several qualitative and quantitative success factors. This makes their design a multi-criteria problem with many dimensions. It is therefore important to have a clear understanding of the criteria involved in the design of SIE to ensure a more successful development of this type of innovation. In this context, this paper aims to identify the key criteria that are considered in the design of SIE.

Research methodology

The research was carried out in two steps. The first step was a literature review in search of success factors for the development of SIE. The second step was an empirical study in the form of interviews based on four case studies to identify the criteria considered in the development of SIE. We describe in the following the case studies participating in the interviews:

- I-ENER (France): Citizen society focusing on the development of renewable energy projects, mainly the production of electricity and heat (e.g., photovoltaic)
- EnergEtica (Spain): Consumer cooperative whose aim is to provide electricity coming from renewable resources to its members. It offers energy services, such as energy audits or the dimensioning of self-consumption installations.
- REGEA (Croatia): Crowdfunding platform that finances photovoltaic system installation projects
- Power Parity/GoParity (Portugal): Cooperative and the first Portuguese crowdlending platform for renewable energy and energy efficiency.

To identify the factors for the successful construction of a SIE, interviews were conducted based on the experiences of the four case studies. The semi-structured

design method was used to conduct the interviews. They were pre-prepared with open ended and closed ended questions and were divided into two main parts. We began with general questions about their backgrounds, areas of activity and major projects, followed by questions, that more focused on the core study, and addressed the key criteria they use in developing their socially innovative projects. The interviews were conducted via videoconference. Each interview lasted between 120 and 150 minutes, and the number of participants ranged from 2 to 4 persons per interview. The profiles of the interviewees were project leader, project manager, solar powered entrepreneur, technical-innovation manager and members of the management team. The analysis of the interviews results leads to the identification of key criteria for the design of SIE, considered by the use cases. To summarize the findings from the literature review and the case studies, an I-P-O framework is proposed that represents the key criteria, inputs, and outputs of a SIE design process. Several studies from different disciplines have applied the I-P-O framework in their studies to identify inputs, outputs, and factors that support or hinder the phenomena under study. For example, [12] have used the I-P-O framework as an underlying structure to design vocabulary-based serious games for children with autism spectrum disorder and [4] to conceptualize the electronic word-of-mouth (eWOM) activity. To identify the inputs and outputs of a SIE design process, the following section provides a literature review of what SIE is. The key criteria of SIE development were identified through a literature review and a study of four use cases.

Literature revue

Social innovation in the energy sector (SIE) – Definitions

Since the 1970s and 1980s, there have been some initial definitions of social innovation. First, [25] defined social innovation as an innovation on which social activists and entrepreneurs meet social needs by doing things in a new way. [6] associated social innovation with action that enables the creation of new social structures, new social relationships, and new forms of decision-making to solve social problems. This action is based on the individualized, then collectivized, measurement of the discrepancy between a factual situation perceived as unacceptable or dissatisfactory, and the desired situation. According to [3], "Schematically, social innovation covers the process that leads from awareness to empowerment". Thus, social innovation is characterized by the participation of users in the process, from the recognition of the need to the design of the project and its implementation. On this topic, Chambon *et al.* say that "the essential condition for the existence of social innovation is the participation". Social innovation is driven by the need "to allow the group involved in the project to control the design and implementation of the project". [14] define social innovation as a practice that enables a new question to be asked, a new answer to be given, or an existing or emerging social need to be addressed differently. It is an approach that places people at the center of the process and involves them

as much as possible, enriches national and local social policies, and allows them to evolve. In this definition, social innovation is characterized by participation of beneficiaries and actors. The Center for Research in Social Innovation (Crises) highlights the desire for social change directed by social actors to respond to social concerns [5]. According to [2], social innovation is a new approach, practice, intervention, or product developed to improve a situation or solve a social problem that has found a consumer at the level of institutions, organizations, and communities. This definition emphasizes the outcome (novelty) and purpose (solving a social problem) of the social innovation, but also its diffusion in different networks. Social innovation refers to the reconfiguration of social practices to respond to societal challenges and improve the well-being of society through the engagement of civil society actors [21]. [9] links social innovation to the use of social means to achieve social goals.

The scientific literature shows that social innovation is to respond to missing or insufficiently satisfied social needs and to improve the well-being of society, while establishing a strong link between the innovation and the participation of social actors. We also note that social innovation is mainly defined by its innovative character, its positive social impact, and its process, as well as by an indispensable characteristic: the active participation and involvement of stakeholders. Society occupies a multiple place in social innovation: it is not only a beneficiary, but also intervenes in the construction of the innovation. Social innovation projects address major social problems, particularly the transition to a more secure, sustainable, competitive, and affordable energy system for citizens. This paper focuses exclusively on social innovations in the energy sector (SIE) and the key criteria for designing the SIE. However, the concept of SIE is still poorly contested in the literature [22, 30]. Social innovation in the energy transition concerns practices and processes that involve social, economic, technological, regulatory, and/or policy innovations that can meet energy needs and contribute to a low-emission energy transition [13]. At the same time empowering vulnerable social groups, and cultivating democratic civic traditions of trust, fairness, and solidarity. Hoppe and De Vries [10] provided a definition from cross-academic disciplines that consider social innovation from an energy perspective as "innovations that are social in their means and contribute to the low-carbon energy transition, citizen empowerment, and social goals related to the overall well-being of communities". [28] synthesize the definition as "a combination of ideas, objects, and/or actions that transform social relations and involve new ways of doing, thinking and/or organizing energy." Maruyama and al., use the term “social innovation”, to refer to a new system of social dynamics that changes the rules for the distribution of risks and benefits and the roles of social actors around new technology, in wind energy [16].

This literature review reveals the significant potential of social innovation to accelerate the energy transition and empower citizens to be the essential actors of a sustainable energy transition. In this paper, we define social innovation in the energy sector as an innovation that promotes the transition to clean, sustainable, renewable, and fair energy. It is social by its goal of improving society and by the involvement of citizens/customers in its development process. In most

cases, it is emergent and stems from citizen initiative. It is innovative in the sense that it involves new ways of doing, thinking, and organizing energy.

Key criteria for the development of SIE

The design of any innovation is influenced by several criteria. This is also true for social innovations. A social innovation designer must consider these criteria before designing in order to create “winning” designs. Designing SI and mainly SIE faces many challenges in practice due to the complexity and diversity of the criteria involved in the SIE design process. In this section, a literature review of the key criteria for developing social innovations has been held.

[5] have defined two dimensions of social innovation; one dimension relates to the process itself (e.g., mobilization of actors, participation) and the second dimension relates to the outcome (e.g., new and improved means of collaborative action, new governance structures). The two dimensions are closely dependent, and the evolution of the process dimensions are essential to the success of the social innovation as its outcome [17]. [18] focus on the character of sustainability that SI must-have and has proposed a set of criteria that must be innovative in terms of user, context, or application; it must satisfy needs better than existing alternatives; it must offer long-term solutions; and it must be adopted beyond the initial group/network that developed it. In further research work [19] classified the success factors of SI into three levels. The first level concerns the factors which are important to the success of the global innovation process: relative advantage, compatibility, complexity, trialability and observability. The second level focuses on the determinant factors that influence the " flexibility " of the network of SI actors. Such factors include culture, funding resources, organizational structures, legal framework to which the process is subject, and the availability of higher-level public administration to support the process. The third level refers to the factors that influence the participation process behind a social innovation. [8] identify six key factors that are particularly important for successful participation processes. These characteristics are the commitment of the actors involved, the capacities of the actors, the organizational structure, the quality of the functional concept, the acceptance and cooperation, and the access to financial resources. [11] agree that cooperation among heterogeneous actors, collective learning, and the transfer and exchange of explicit and implicit knowledge at the regional and/or local level seem to be crucial for the success of social innovations. [20] confirm that the success of any social innovation depends on the active participation and support of local stakeholders. Furthermore, the sustainability of a social innovation depends on the support and commitment of partners outside the local community.

In the literature, most of works on the SI key development criteria do not refer specifically to the energy sector. Some of works refer to the energy sector. [27] identified three types of potential success factors for social innovations in the energy sector: factors related to the organization itself, the interactions with the local community, and the governance framework and connection to government. [1] proposed a further classification of factors influencing the development of social innovations in the energy sector into four categories: the emergence of an opportunity to introduce social innovations in the energy sector, local perception of the energy

community, local support and acceptance of the energy community, and evaluation of the renewable energy technology applied. Thus, in addition to the importance of the robustness of the applied technology, other dimensions such as acceptance and participation of all stakeholders are also important to design a successful SIE. [29] defined a basic acceptance model (the triangle of social acceptance of renewable energy innovations) in which they set three interpretive dimensions of social acceptance: Socio-political acceptance (of technologies and policies by the public, the key stakeholders, and the policymakers), community acceptance (procedural justice, distributive justice, trust), and market acceptance (consumers, investors, intrafirm). The term "social" here refers to both society and individual groups such as communities, and cultural or political groups. The term "acceptance" refers to low or high levels of approval or disapproval of renewable energy projects based on the interaction of different values (beliefs, knowledge, opinions, and motivations) of individuals or groups [15].

In our opinion, studying “key design criteria”, refers also to remove the barriers that hinder the development of SIE. Thus, we consider the main barriers listed in [7] to the progress of SI: (i) audit or regulatory practices that are inconsistent with the mission; (ii) conservative organizational cultures, and complicated administrative procedures; (iii) closed systems that promote single-problem solutions developed within groups of organizations that lack mutual awareness, communication, networking, and trust; (iv) limited capacities (resources, infrastructure, and intermediaries) and skills (training, design tools, monitoring, validation, and evaluation); and (v) insufficient long-term and consistent funding throughout all the phases of the innovation cycle. [26] identified eight barriers to the emergence of social innovations: lack of funding, administrative and bureaucratic hurdles, lack of access to necessary information, passivity of society, low support from stakeholders, lack of openness of society to the experiences of other groups, lack of legal framework and complicated administrative procedures, and lack of experience in implementing social innovation projects.

Design criteria are those controllable factors that are appropriately modified to achieve the desired performance. Similarly, in social innovations, there are criteria that influence the efficiency of the outcome by improving or reducing them. There are a variety of criteria that can be considered in the design of SI. However, after this literature review, a few criteria have been identified (represented in table 1 in appendix) that are the most common, and that we categorize into six dimensions*:* Innovativeness, Environmental, Economic, Technological, Participatory, and Social (I-E-E-T-P-S). The most important criteria are mainly related to actors, relationships between the actors, and citizens/consumers participation. These criteria have been grouped under the dimension "participatory", which we consider crucial for the success of social innovation. Moreover, most of the works that have addressed the problem of dimensioning SI assumes that the factors that influence citizen (or end-user) participation affect the acceptance, and therefore the success, of this innovation. However, most of the literature identifies the key success criteria for SI in general, rather than for a specific sector such as the energy sector. To refine the space of SIE design parameters and gain a better understanding of those related to the energy sector, interviews were conducted with the four case studies described

above. In the next section, an analysis of these interviews is presented as well as the results obtained.

Main Findings

This section presents the findings of this work related to the objective of this paper, which is the identification of the space of the design parameters of SIE. It presents the analysis of the responses from the interviews conducted and the results. The information collected from the notes of the 4 interviews led to the identification of 33 criteria for the development of SIE (arborescence in Figure 1). The main design criteria considered by the studied cases are broadly consistent with those identified in the literature. The analyze of the collected data leads to a categorization of the identified criteria under the 6 dimensions already defined (I-E-E-T-P-S). The case studies make a stronger focus on the environmental and economic dimensions.
Through the interviews conducted, 14 new key criteria were identified which were considered by the use cases and not mentioned in the literature. We summarize the findings from the literature and the use cases in the table 1 of the appendix.
Regarding the environmental dimension, the use cases suggest that several criteria are considered in addition to those mentioned in the literature (En_1.. En_3). They require that the proposed social innovative solution reduces CO2 emissions (En_4), they also claim that the energy produced shall be consumed collectively (En_8), they consider as well that the provision of energy to all, in the context of energy democracy, is a key criterion for the success of SIE (En_6) and therefore decentralizing the energy (En_5). Finally, they mention that increasing the consumer's energy autonomy is a factor to consider, i.e., producing their own energy needs (En_7).
In terms of technological dimension, a new criterion has been noticed compared to the literature: the origin of the tools used for the proposed solution. In fact, the case studies prefer that the materials used are European origin (T_7).
New criteria were identified for the economic dimension in addition to those mentioned in the literature (Ec_1.. Ec_3). First, the analyzed case studies consider that the investments made by citizens to finance renewable energy projects are an important criterion for the success of SIE (Ec_4). The higher this capital, the greater the number of projects. The second new criterion for the economic dimension is the (Ec_7), i.e. in the context of SIE users can share their resources to participate in the development of the energy transition and they have some advantages (e.g. free electricity) which is different from the exchange of goods in a traditional market. So, the third criterion is the (Ec_5), which is an important criterion to consider because it encourages citizens to participate more in financing renewable energy projects. Fourth, concluded from the interviews, one of the goals of SIE is to offer affordable energy, so reducing the (Ec_6) is one of the criteria to consider. Finally, the use cases consider the creation of new local jobs as a criterion in the development of SIE (Ec_8).
The use cases confirm the importance of al the criteria identified in the literature for the social dimension (S_1.. S_5).
Regarding the participatory dimension, the use cases show that SIE should be considered as a multi-actor phenomenon. This strengthens the role of citizens in the

energy transition. In addition to the criteria of the participatory side mentioned in the literature (P_1.. P_3, P_7, P_9, P_{10}), the studied use cases also consider the number of citizens willing to participate in the development of SIE (P_8) and the number of local stakeholders (P_5).

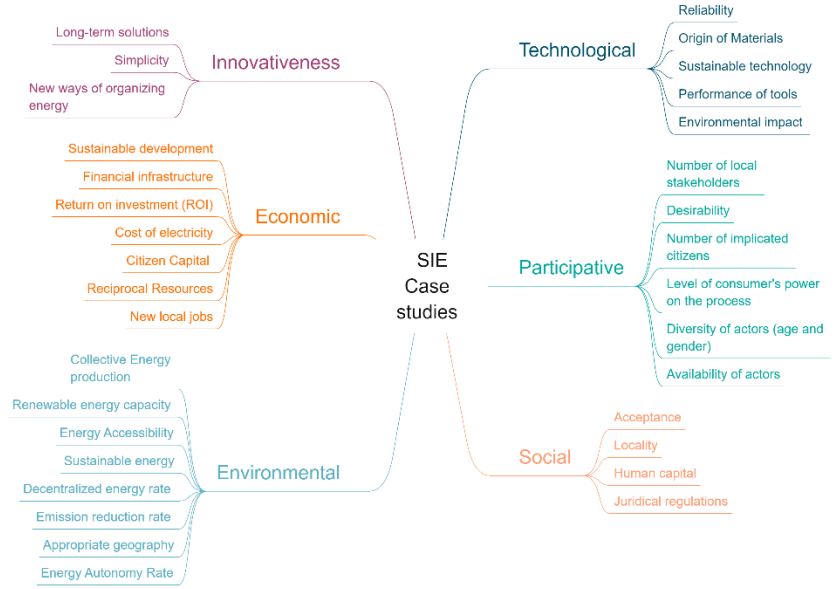

Figure 1: Arborescence of the criteria considered by the 4 case studies in the design of SIE (REGEA, I-ENER, GoParity, EnergEtica)

In terms of innovativeness dimension, it has been noted that the case studies take into account the proposal of a new way of organizing energy (I_5) in addition to the criteria mentioned in the literature (I_1.. I_4).

The analysis of the interviews confirms our choice of the I-E-E-T-P-S indicator set, which represents the six dimensions for designing a SIE. Among these six dimensions, 44 criteria were identified, 14 of which are new compared to what is already mentioned in the literature. All the criteria mentioned in the literature and interviews are important for the successful design of SIEs. These criteria should be maximized and/or minimized as needed. Therefore, they can be classified as cost-benefit type. Attributes of cost type, i.e., the lower the value of the criterion, the more undesirable the alternative. Attributes of the benefit type, i.e., the higher the value of the criterion, the more advantageous the alternative. The criteria to maximize; $Benefit_C$ = {I_1 .. I_5 , P_1 .. P_{10}, S_2.. S_6, Ec_1, Ec_3.. Ec_5 , Ec_7 , T_1 ..T_4 , T_6 , T_7, En_1.. En_3, En_5.. En_8 }, those to minimize are $Cost_C$ = { S_1 , Ec_2, Ec_6, Ec_8, T_5 , En_4}.

To summarize the finding from the literature and interviews, an I-P-O framework is proposed for the SIE design process (Figure 2). Any design process is triggered to address a problem, satisfy a need, or achieve a desired aspiration through a set of shared values, skills, and knowledge. Same for the SIE design process, where actors share their knowledge, skills, and values with other actors throughout the process

to respond to the challenges of the energy transition. Then, in a context of co-creation, all the criteria already defined must be considered to develop socially innovative solutions in the energy sector. This will finally allow to solve the initial problems and allow the actors to acquire new values, new knowledge, and new skills.

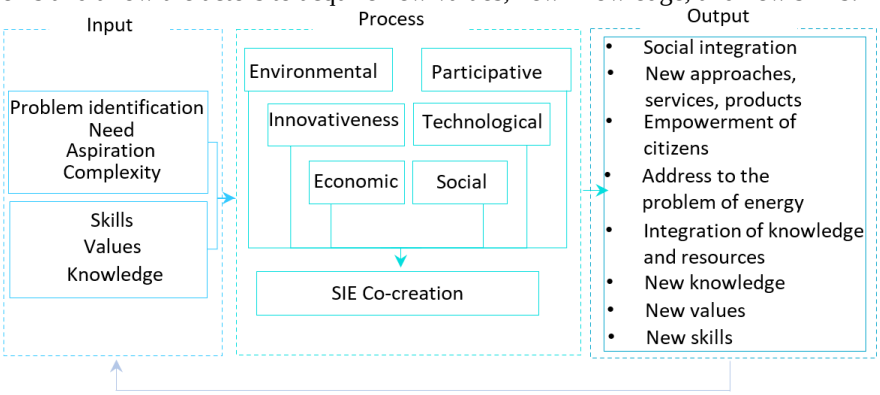

Figure 2: The I-P-O framework for the SIE design process

Conclusion

Success factors of social innovation have already been studied in other fields, but little about the energy transition and hardly ever from a design engineering perspective. In this paper, a set of indicators composed of six dimensions for the design of social innovations in the energy sector has been defined (I-E-E-T-P-S): innovative, environmental, economic, technological, participatory, and social. Each dimension was assigned a set of criteria (44 criteria were identified in total). These criteria are modifiable; they can be maximized and/or minimized depending on the desired performance. Therefore, based on a cost-benefit classification, two subgroups have been proposed ($Benefit_c$ and $Cost_c$) that divide the criteria into different categories. From this survey, citizen participation in the design process from the beginning is essential for success SIE. An I-P-O framework is proposed that considers the involvement of stakeholders in the design process of SIE to describe the inputs, outputs of this process and the position of the defined dimensions in the SIE design process (currently in a validation phase). In conclusion, the finding results of this paper are meaningful to help designers on the exploration of the design space of social innovations in the energy sector to support them in the decision-making process. The next steps of our research will be to define an exploration model of the SIE design space that considers all the identified criteria and the interaction between them.

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Appendix

Table 1 Criteria considered to develop SIE

	Criteria	Code	Literature support	Our use cases
Environmental	Sustainable energy	En_1	[18, 27,13,28]	*
	Appropriate geography	En_2	[18, 27,13,28]	*
	renewable energy capacity	En_3	[18, 27,13,28]	*
	CO2 Emission rate	En_4		*
	Decentralized energy rate	En_5		*
	Energy Accessibility	En_6		*
	Energy Autonomy Rate	En_7		*
	Collective energy	En_8		*
Techno-logical	Robustness	T_1	[1,16]	
	Reliability	T_2	[1,16]	*
	Performance	T_3	[1,16]	*

	Maturity	T_4	[1,16]	
	Environmental impact of used technology	T_5	[1,16]	*
	Sustainable technology	T_6	[1,16]	*
	Origin of materials	T_7		*
Economic	Financial infrastructure	Ec_1	[18, 10,13,28]	*
	Costs-effectiveness	Ec_2	[18, 10,13,28]	
	Sustainable development	Ec_3	[18, 10,13,28]	*
	Citizen Capital	Ec_4		*
	Citizen's return on investment	Ec_5		*
	Cost of electricity	Ec_6		*
	Reciprocal Resources	Ec_7		*
	New local jobs	Ec_8		*
Social	Juridical regulation	S_1	[5,16,29,20,18,1,26,21,19,9,27,10,13]	*
	Compatibility	S_2	[5,16,29,20,18,1,26,21,19,9,27,10,13]	
	Acceptance	S_3	[5,16,29,20,18,1,26,21,19,9,27,10,13]	*
	Locality	S_4	[5,16,29,20,18,1,26,21,19,9,27,10,13]	*
	Human capital	S_5	[5,16,29,20,18,1,26,21,19,9,27,10,13]	*
participatory	Flexibility of actors	P_1	[5,8,16,11,7,20,2,19,9,10,27,28]	
	Desirability	P_2	[5,8,16,11,7,20,2,19,9,10,27,28]	*
	Level of consumers power	P_3	[5,8,16,11,7,20,2,19,9,10,27,28]	*
	Availability of actors	P_4	[5,8,16,11,7,20,2,19,9,10,27,28]	*
	Number of local stakeholders	P_5		*
	Collective learning	P_6	[5,8,16,11,7,20,2,19,9,10,27,28]	
	Diversity of actors (age and gender)	P_7	[5,8,16,11,7,20,2,19,9,10,27,28]	*
	Number of implicated citizens	P_8		*
	Communication	P_9	[5,8,16,11,7,20,2,19,9,10,27,28]	
	Collaboration	P_{10}	[5,8,16,11,7,20,2,19,9,10,27,28]	
Innovativeness	Long-term solutions	I_1	[14,2,18,19]	*
	Simplicity	I_2	[14,2,18,19]	*
	Observability	I_3	[14,2,18,19]	
	Trialability	I_4	[14,2,18,19]	
	New ways of organizing energy	I_5		*