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Identifying and prioritizing barriers to implementation of smart energy city projects in Europe: An empirical approach

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ABSTRACT

Successful implementation of smart energy city projects in Europe is crucial for a sustainable transition of urban energy systems and the improvement of quality of life for citizens. We aim to develop a systematic classification and analysis of the barriers hindering successful implementation of smart energy city projects. Through an empirical approach, we investigated 43 communities implementing smart and sustainable energy city projects under the Sixth and Seventh Framework Programmes of the European Union. Validated through literature review, we identified 35 barriers categorized in policy, administrative, legal, financial, market, environmental, technical, social, and information-and-awareness dimensions. We prioritized these barriers, using a novel multi-dimensional methodology that simultaneously analyses barriers based on frequency, level of impact, causal relationship among barriers, origin, and scale. The results indicate that the key barriers are *lacking or fragmented political support on the long term* at the policy level, and *lack of good cooperation and acceptance among project partners*, *insufficient external financial support*, *lack of skilled and trained personnel*, and *fragmented ownership* at the project level. The outcome of the research should aid policy-makers to better understand and prioritize implementation barriers to develop effective action and policy interventions towards more successful implementation of smart energy city projects.

1. Introduction

Global energy challenges and climate change have urged governments and institutions at local, regional, national, and supra-national levels to optimize urban energy systems. In response, numerous European SEC[1] projects have been initiated and developed, aiming at optimizing urban energy systems and improving quality of life for citizens (Vanolo, 2014; Washburn et al., 2010). A universally accepted, unambiguous definition of a SEC project appears to be missing. The existing related definitions are very technical and do not focus on the urban perspective but are more concentrated on technical elements, considering smart energy *systems* (e.g., Lund, 2014) or smart energy *networks* (e.g., Chai et al., 2013). Here we follow the definition of Mosannenzadeh, p 151) (2016) who (based on Mosannenzadeh et al., 2017) defines a SEC project as *one that aims at sustainability of energy systems and services through optimized integration of increased energy conservation, energy efficiency and use of local renewable energy sources. SEC projects have a specific period; they apply smart energy solutions to integrate multiple energy domains, and enforce collaboration of multiple stakeholders, while evaluating sustainability of their measurements* (Mosannenzadeh, 2016). These projects have become popular during the last two decades, specifically due to considerable support by both the European Union –under the EU sixth Framework Programme (FP6) and seventh Framework Programme (FP7), and more recently Horizon 2020– and the private sector (e.g. IBM).

SEC projects have faced the challenge of meeting their goals due to various financial, administrative, technical, and social barriers –i.e. difficulties that hinder project activities– especially in the crucial implementation stage (Di Nucci et al., 2010). Overcoming these barriers is necessary in order to facilitate and accelerate the successful accomplishment of SEC projects. Therefore, it is important to not only identify but also prioritize these barriers in order to efficiently allocate efforts and resources to abate the key obstacles hindering effective action (Nagesha and Balachandra, 2006). This research aims at supporting decision makers to better understand and prioritize implementation barriers in order to develop effective action and policy interventions towards implementation of smart energy city projects.

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[1] Smart Energy City

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Due to the novelty of SEC projects, the specific barriers to implementation of these projects have not been yet treated in the academic literature in a systematic way. The discussion, to our knowledge, has focused mostly on specific technologies such as smart grid (e.g. Luthra et al., 2014; McMorran et al., 2012) and combined heat and power (Wright et al., 2014). However, gray literature, including deliverables and reports of CONCERTO and SEC projects examined the specific barriers to design and implement such projects (Di Nucci et al., 2010; Di Nucci and Spitzbart, 2010; Pezzutto et al., 2015). As a result, there is still a need for a systematic identification and analysis of barriers to the implementation of SEC projects.

The mere identification of barriers alone is by no means sufficient for selecting appropriate policy interventions to mitigate barriers (Nagesha and Balachandra, 2006). In order to make decisions for future mitigation policies and the resulting resource allocation, the analysis and prioritization of barriers is crucial. Although there is a vast body of literature on barriers to implementation of energy-related policies such as energy efficiency (e.g., Cagno et al., 2013; Reddy, 2013; Rohdin and Thollander, 2006; Sorrell et al., 2011) and renewable energy (e.g., Beck and Martinot, 2004; Painuly, 2001; Pîrlogea, 2011; Reddy and Painuly, 2004), only a few studies have made an effort or have suggested methodologies to systematize the large number of barriers in order to prioritize them for appropriate policy solutions (i.e. Sizhen et al., 2005; Nagesha and Balachandra, 2006; Mathiyazhagan et al., 2013; Ren et al., 2015). These studies, as explained below, have considered three main aspects in prioritization of barriers to energy-related interventions: importance of a barrier (related to intensity and impact), level of effort required to tackle a barrier, and interaction among barriers.

Sizhen et al. (2005) prioritized barriers to promotion of clean technology in China through an analytic hierarchy process based on the importance given by stakeholders. Nagesha and Balachandra (2006) used similar method to prioritize barriers to energy efficiency in India considering barrier intensity, required effort for barrier removal and the expected positive impact of barrier removal on energy efficiency and economic performance. Ren et al. (2015), improved this methodology to prioritize barriers to sustainable shale gas revolution in China by considering importance and interaction among barriers through the application of an analytic network process. Mathiyazhagan et al. (2013) performed an Interpretive Structural Modeling (ISM) qualitative analysis based on stakeholder opinion to identify the most dominant (important) barrier to adoption of green supply chain management in India. To our knowledge, a systematic and quantitative barrier prioritization by a simultaneous consideration of all these three aspects has not been yet investigated.

The specific objectives of this paper are (*i*) to identify barriers to implementation of urban scale SEC projects in Europe; and (*ii*) to provide a systematic, dual-approach (i.e. quantitative and qualitative), and multi-dimensional prioritization of barriers by considering barrier importance, level of effort required to tackle a barrier and interaction among them. It is fundamental that barriers to the implementation of SEC projects are especially project-specific, meaning that their occurrence depends on numerous internal and external characteristics of the project (Di Nucci et al., 2010; Painuly, 2001). The examples of these characteristics include project design, the planned implementation process, the existing driving forces as well as numerous influential social, economic, environmental, and legal conditions (Cagno et al., 2013; Di Nucci et al., 2010). However, before defining the relationship between project characteristics and barriers, it is necessary to first identify the common barriers that occur in SEC projects due to their major aspects. Therefore, in this manuscript, we aimed at exploring the emerging barriers due to major aspects of SEC projects. Consequently, we did not perform a detailed analysis of project-specific aspects.

To address the research specific objectives, we take an empirical approach and analyze the results and supporting documents of 43 European cities and communities that have implemented sustainable and smart energy projects under the EU FP6 and FP7 initiative, named CONCERTO.[2] The use of CONCERTO results appears appropriate for the purpose of our study especially because it fits the above mentioned definition of SEC project, and provided the “lessons learnt” for future generations of SEC developments.

In more detail, the CONCERTO initiative supported local communities towards sustainability of energy systems through local innovative energy efficiency interventions and by integrating local renewable energy sources in both new and existing urban districts (CONCERTO, 2015a). The CONCERTO Communities demonstrated the feasibility and integration of innovative technologies such as renewable-based cogeneration, sometimes smart grids, district heating/cooling systems and energy management systems in districts (CONCERTO, 2015a; Di Nucci et al., 2010). A number of these activities, especially those with a focus on refurbishment, were accompanied by socio economic research activities, specifically targeted to involve the relevant stakeholders or residents and increase the level of acceptance of the implemented measures. Moreover, the CONCERTO cities and communities are various in size and environmental, socio-economic, and political aspects, offering a rich source of information. The first batch of CONCERTO projects started in 2005 under EU FP6 (CONCERTO, 2015b). Until now, CONCERTO projects are all completed and information on the projects, including barriers to implementation of each case, can be found within the supporting platforms “Concerto Plus” and then “Concerto Premium”. This information is also available in several publications of the initiative (CONCERTO, 2015a).

The present investigation builds upon and complements the research activities carried out within the Deliverable 2.1 “SWOT analysis report of the refined concept/baseline” of the FP7 SINFONIA project (Pezzutto et al., 2015). The paper is organized as follows. Section 2 explains the research methodology. Section 3 describes and discusses the identified barriers and the results of the barrier prioritization. Section 4 gives implications for project coordinators and policy makers; and Section 5 concludes the paper with the main contributions and recommendations for future research.

2. Methodology

The methodology is subdivided into two research steps: barrier identification and barrier prioritization.

2.1. Barrier identification

Following Painuly (2001), our methodology is based on an empirical research, validated through a literature review. First, we created a dataset of 43 CONCERTO cities and communities and barriers to their implementation. We used data previously gathered within the CONCERTO Initiative through the semi-structured questionnaire named “CONCERTO policy questionnaire” (accessible through CONCERTO, 2015c). This data was gathered and classified firstly for the first generation of CONCERTO projects (i.e. 27 projects) in 2009–2010 and then again completed for all CONCERTO projects in 2012 as part of the monitoring process of the CONCERTO initiative. In the questionnaires, the project coordinators were asked, among others, to indicate the barriers (or obstacles) that hindered the project implementation. The project coordinators listed these barriers in bullet-wise or narrative language under five categories: administrative, technical, social, legal, and economic.[3] To our knowledge, further analyses of this data has not been performed and published. Our raw dataset, built upon this data, included 212 barriers. Following Boor et al. (2008),

[2] In this paper, we denote these cities and communities as “CONCERTO projects”.

[3] One of the authors was directly involved in preparing the questionnaires and in systematizing and classifying the responses (for the first generation of CONCERTO projects under the platform Concerto Plus).

these barriers were coded on the basis of barrier categories and subsequently coded again in order to find barriers in each category.

In the next step, the categories and barriers were checked for validation and terminology against literature on barriers to realization of smart and sustainable energy projects. To this purpose, an extensive bottom-up exploratory literature review on barriers to implementation of smart energy technologies (e.g. Luthra et al., 2014; Wright et al., 2014), renewable energy (e.g. Beck and Martinot, 2004; Painuly, 2001; Pîrlogea, 2011; Reddy and Painuly, 2004) and energy efficiency policies (e.g. Cagno et al., 2013; Reddy, 2013; Rohdin and Thollander, 2006; Sorrell et al., 2011) was carried out. Furthermore, we reviewed CONCERTO publications, specifically, "Planning and Implementation Process assessment Report" (Di Nucci et al., 2010), which identified barriers and drivers affecting the success or failure of the process of planning and implementation of the CONCERTO measures. The report classified barriers from three broad perspectives, micro (project/end user), meso (organization), and macro (state, market, civil society). We revised and adjusted the terminology of the identified barriers with respect to the literature and arrived at the identification of 35 barriers. Finally, based on 35 identified barriers and the coded raw dataset, we created a final dataset that shows the barriers that appeared in each project.

2.2. Barrier prioritization

We propose a new multi-dimensional approach to prioritize barriers to implementation of SEC projects based on the importance of barriers, relationships among barriers, and level of effort required to tackle them. To analyze barriers, we used information specific to the CONCERTO projects. For those dimensions (i.e. level of impact and origin, explained in the following paragraphs) that specific information for CONCERTO projects was not available, we used related literature to derive required information.

As for the importance of barriers, we borrowed the indicator *criticality* used in risk-analysis as a function of two indicators: (i) frequency (of barriers in investigated projects) and (ii) level of impact (Marle et al., 2013). Frequency of a barrier is defined as the number of projects in which the barrier appeared divided by all 43 investigated CONCERTO projects. For example, if a barrier appeared in five projects, its frequency is 5/43=0.12. We measured the frequency of barriers from our final dataset (see Section 2.1), which shows the barriers that appeared in each project. We adopted the level of impact previously investigated by Pezzutto et al. (2015) through a structured questionnaire on barriers to smart city projects. Pezzutto et al. (2015) used a six-point Likert scale ranging from zero (neutral or no impact) to five (very high impact). The questionnaires were filled in through a phone interview with 30 experts –i.e. people, who have been involved in coordination of at least one smart city project.[4] The average of values assigned by experts was used to indicate the level of impact per barrier (Pezzutto et al., 2015).

A criticality graph similar to Fig. 1 enables policy makers and project coordinators to categorize barriers as high, medium, or low criticality. For example, we defined three arbitrary criticality areas based on visual grouping (i.e. visually separating the clusters of barriers from each other based on criticality in Fig. 1): low criticality area, in which $frequency * impact < 0.1$; medium criticality area, in which $0.1 =< frequency * impact < 0.6$; and high criticality area, in which $0.6 =< frequency * impact$.

We investigated the causal relationships among barriers. A causal relationship between barrier (a) and barrier (b) occurs, when an increase in the barrier (a) can result in the emergence or increase in the barrier (b) (Cagno et al., 2013). We investigated causal relationships among barriers through a qualitative and exploratory approach, using expert knowledge in two stages. In the stage one, we applied the narrative data collected in the dataset of CONCERTO barriers. For example, from the sentence "Due to the financial crisis, housing associations, which traditionally have had a sound financial standing, lost money through bad investments", we derived a causal relationship between economic crisis and restricted access to capital. In the stage two, the result was cross-checked and completed by one of the authors using the knowledge gained through the direct monitoring of CONCERTO projects and through various visits of CONCERTO sites in different stages of the implementation of the projects, which allowed a sort of "participant observation".

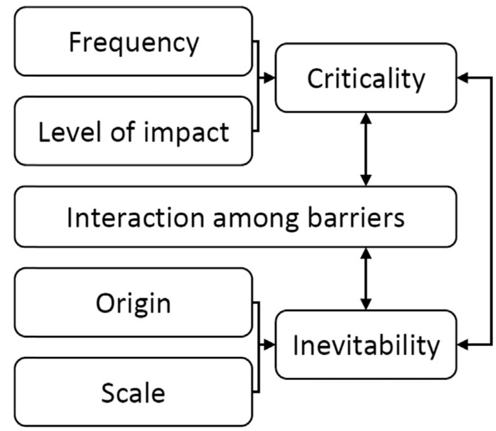

Fig. 1. A multi-dimensional approach to prioritization of barriers to smart energy city projects.

As for the level of effort required to tackle a barrier, we combined two possible approaches –used in risk-management– to tackle barriers (Xia and Chen, 2011): avoiding the emergence of the barrier, and reducing the impact of an already emerged barrier. The former is strongly related to the origin of the barrier, which can be internal or external to the project (Cagno et al., 2013). Internal barriers are those barriers originated within the project, while external barriers are originated outside the project. We adopted the origin of barriers from Cagno et al. (2013). The latter is related to the barrier scale, for which we apply micro-meso-macro scale model by Reddy (2013) and Di Nucci et al. (2010). Micro barriers can be tackled at the design level of the project. Meso barriers can be tackled at the organizational level of the project. Macro barriers are difficult to be dealt with by the project, unless the project has the power to influence policy, market, or culture. We adopted the scale of barriers from Di Nucci et al. (2010), who analyzed barriers to the implementation of first generation of CONCERTO projects to three micro, meso, and macro scales.

We combined origin and scale to create a new indicator named *inevitability*, which denotes the level of effort required to tackle a barrier. In general, we define three different levels of inevitability. A lowly inevitable barrier is originated inside the project and could be avoided and/or weakened through project design and organization. A moderately inevitable barrier is originated outside the project but can be weakened through project organization and design. Highly inevitable barriers are the most difficult to avoid; they are originated outside the project and hard to influence by project activities. Fig. 1 shows the proposed multi-dimensional approach to prioritize barriers.

3. Results and discussion

3.1. Barriers to implementation of smart energy city projects in Europe

We identified 35 barriers, each assigned to one of the nine

[4] Including CONCERTO projects, projects founded in Market Place of the European Innovation Partnership on Smart Cities and Communities (EC, 2014) and the Amsterdam smart city projects (Amsterdam smart city, 2015)

Table 1
Barriers to implementation of smart energy city projects: frequency and level of impact.

Barrier Category	*Barrier*	Barrier code	Frequency	Level of Impact[a] (from 0 to 5)
Policy	Lack of long-term and consistent energy plans and policies	B_{01}	0.05	2.67
	Lacking or fragmented local political commitment and support on the long term	B_{02}	0.14	3.1
Administrative	Difficulty in the coordination of high number of partners and authorities	B_{03}	0.16	1.3
	Lack of good cooperation and acceptance among partners	B_{04}	0.26	2.9
	Lack of public participation	B_{05}	0.07	2.07
	Lack of institutions/mechanisms to disseminate information	B_{06}	0.02	3.07
	Long and complex procedures for authorization of project activities	B_{07}	0.19	1.93
	Time consuming requirements by EC concerning reporting and accountancy	B_{08}	0.12	4.0
	Complicated and non-comprehensive public procurement	B_{09}	0.12	2.3
	Fragmented ownership	B_{10}	0.19	4.0
Legal and Regulatory	Inadequate regulations for new technologies	B_{11}	0.09	1.13
	Regulatory instability	B_{12}	0.07	1.37
	Non-effective regulations	B_{13}	0.02	1.48
	Unfavorable local regulations for innovative technologies	B_{14}	0.12	1.6
	Insufficient or insecure financial incentives	B_{15}	0.19	1.22
Financial	High costs of design, material, construction, and installation	B_{16}	0.07	2.37
	Hidden costs	B_{17}	0.21	0.8
	Insufficient external financial support and funding for project activities	B_{18}	0.26	2.8
	Limited access to capital and cost disincentives	B_{19}	0.23	0.83
	Economic crisis	B_{20}	0.21	2.4
	Risk and uncertainty	B_{21}	0.07	1.07
Market	Split incentives	B_{22}	0.05	0.8
	Energy price distortion	B_{23}	0.05	1.02
Environmental	Negative effects of project intervention on the natural environment	B_{24}	0.06	4.33
Technical	Shortage of proven and tested solutions and examples	B_{25}	0.16	2.03
	Lack of skilled and trained personnel	B_{26}	0.28	3.07
	Deficient planning	B_{27}	0.16	1.13
	Lack of well-defined process	B_{28}	0.12	1.93
	Retrofitting work in dwellings in occupied state	B_{29}	0.05	1.7
Social	Inertia	B_{30}	0.16	2.03
	Lack of values and interest in energy optimization measurements	B_{31}	0.16	0.67
	Low acceptance of new projects and technologies	B_{32}	0.16	1.77
Information and Awareness	Insufficient information on the part of potential users and consumers	B_{33}	0.16	2.03
	Lack of awareness among authorities	B_{34}	0.02	2.03
	Perception of interventions as complicated and expensive, with negative socio-economic or environmental impacts	B_{35}	0.14	2.03

[a] Level of impact changes on a range of 0 (neutral or no impact) to 5 (very high impact). The values indicated in this table are found by Pezzutto et al. (2015).

categories: policy, administrative, legal and regulatory, financial, market, environmental, technical, social, and information and awareness (see Table 1, the columns *barrier category, barrier, and barrier code*. The other two columns are discussed in Section 3.2.1). Nevertheless, each barrier has its own policy, administrative, economic, legal, and social aspects (Weber, 1997). The identified barriers result mostly from increasingly emerging main aspects of SEC projects, which can be considered as major trends in "smart city" policies and plans. These aspects are defined as a unique integration of *innovative, rational, and integrated applications of new technologies*, *collaboration of key stakeholders*, and *integration of multiple [energy] domains* in a sustainable way (Mosannenzadeh et al., 2017). Consequently, we classified the identified barriers with respect to the mentioned SEC aspects as well as the specific spatial scale (i.e. large-scale) and time-period of CONCERTO projects. A bullet-wise explanation of all identified barriers with examples from CONCERTO projects is presented in the Appendix. The examples from CONCERTO projects are distinguished by the name of the city (or community) and the name of the project, written as city-project (in capital letters).

3.1.1. Innovative, rational, and integrated application of new technologies

The Innovative application of new technologies (specifically ICT) is intrinsic to the SEC development (Mosannenzadeh and Vettorato, 2014) and brings about critical technical barriers, most importantly, the *lack of skilled and trained personnel (B_{26})*. Continuous technology transfer requires trained staff, especially engineers, operators, and managers for the deployment and operation of new technologies as well as for analytics, data management, and decision support (Painuly, 2001; Pîrlogea, 2011; Wright et al., 2014). In addition, due to novelty of technologies, there is a *shortage of proven and tested SEC solutions and examples (B_{25})* particularly in local contexts. This exacerbates the lack of expertise and know-how to implement projects.

Legal and regulatory barriers occur because of the novelty of the SEC technologies, reflected in more *long and complex procedures for authorization of project activities (B_{07})* (mentioned by Pîrlogea, 2011) and non-updated and *inadequate regulations for new technologies (B_{11})* (mentioned by Luthra et al., 2014). This is accompanied, in some projects, by *complicated and non-comprehensive public procurement (B_{09})* –i.e. regulations on the purchase of services and material by the public sector (Thai, 2008), leading to prolonged procedures for project execution (Dutton, 2007; Thai et al., 2005). These barriers discourage investment and complicate the implementation (Luthra et al., 2014; Painuly, 2001).

Unfavorable local regulations for innovative technologies (B_{14}) (mentioned by Painuly, 2001) occurs when local restrictions related to building aesthetic, structure, or safety hinder project implementation. In particular, regulations for historical preservation of buildings have proved hard to match with the installation of new technologies. For example, in Italy, Spain, and France, where the number of historical buildings is very high, it is difficult to reconcile historical preservation and environmental aspects, in particular in the case of solar panel installations on buildings. This aspect was observed in a number of CONCERTO communities (Di Nucci et al., 2010).

The application of SEC technologies brings about market and financial barriers to implementation of SEC projects as well. Energy efficient technologies, renewable energy and new technologies are characterized by relatively *high costs of design, material, installation, and construction (B_{16})* and higher *risk and uncertainty (B_{21})* (mentioned by Luthra et al., 2014; Pîrlogea, 2011; Sorrell et al., 2000; Wright et al., 2014). *Hidden costs (B_{17})* (mentioned by Nichols, 1994; Thollander et al., 2010) such as general overhead costs of project implementation are typically higher for new technologies (Nichols, 1994) as well. Hence, individuals with low-income and companies with a limited access to capital are not able to invest in such technologies. High investment costs and hidden costs are highlighted in comparison to conventional energy costs, acting as *cost disincentives (B_{19})*. For example, in Neckarsulm-ENERGY-IN-MINDS, the interest for using small pellet boilers in heating systems was very low due to higher investment costs compared to oil or natural gas. Similarly, *energy price distortion (B_{23})* (mentioned by Cagno et al., 2013; Hirst and Brown, 1990; IEA, 2010) in shape of subsidized conventional energy, reduces the competitiveness of renewable energies (Painuly, 2001) and alters the understanding of the real value of energy efficiency. Consequently, energy use reduction becomes less appealing. In contrast, financial incentives such as feed-in-tariffs, tax exemption, subsidies (Piscitello and Bogach, 1998), credit facilities and third-party financing mechanisms for innovative technologies are among the measures to smooth investment (Painuly, 2001) in smart energy technologies. *Insufficient or insecure financial incentives (B_{15})* for renewable technologies (e.g. photovoltaic and wind power) makes these technologies less attractive.

Even if technical, regulatory, and financial barriers are handled, there are still critical social obstacles –such as *inertia (B_{30})* (mentioned by Cagno et al., 2013; Sorrell et al., 2000; Thollander et al., 2010; Rohdin and Thollander, 2006) and *low acceptance (B_{32})* for the adoption of new technologies due to unfamiliar procedures and cemented behavioral patterns. Furthermore, information and awareness barriers occur due to *lack of knowledge about costs and benefits of SEC new technologies among both consumers and authorities (i.e. B_{33}, B_{34})* (IEA, 2010). This, along with the *perception of interventions as complicated and expensive, with possible negative socio-economic or environmental impacts (B_{35})* (mentioned by Painuly, 2001; IEA, 2010) reduces acceptance and inhibits making rational decisions on consumption and investment (IEA, 2010). By some SEC technologies there are also concerns about *negative effects of project intervention on the natural environment (B_{24})*, as in the case of wind turbines and their threat for birds, or biogas plants and their possible negative effects on the local environment (e.g. bad odors). In this regard, presence of institutions/mechanisms to disseminate information on real costs and benefits of SEC interventions are very helpful. *Lack of institutions/mechanism to disseminate information (B_{06})* (mentioned by Painuly, 2001) was mentioned as a barrier in few CONCERTO projects.

Furthermore, SEC dependency on big data management and the possible disclosure of data on personal consumptions bring about administrative, legal, and social challenges, including *low acceptance of projects (B_{32})* due to privacy concerns. Respectively, Luthra et al. (2014) state “lack of regulations for data privacy and data security” as a barrier to smart grid. This barrier, however, did not emerge critically in our study because there are only a few CONCERTO projects with a focus on smart metering and smart grid.

3.1.2. Collaboration of key stakeholders

Collaboration of key stakeholders is reflected in SEC projects particularly as involvement of multiple stakeholders from different policy levels, socially inclusive procedures, and shared investments (Mosannenzadeh et al., 2017).

Involvement of multiple stakeholders from different policy levels in SEC projects is faced with administrative challenges. SEC projects often include many partners from different sectors. *Difficulty in the coordination of high number of partners and authorities (B_{03})* (mentioned by Pîrlogea, 2011) is a barrier that occurs due to different schedules of authorities, conflicting interests of multiple partners (Cagno et al., 2013) or unclear sub-division of tasks and multiple responsibilities of various actors. This leads to a *lack of good cooperation and acceptance among partners (B_{04})* (mentioned by IEA, 2010) required for common agreements. CONCERTO projects were all partially funded under EU FP6. Consequently, *time consuming requirements by the European Commission concerning reporting and accountancy (B_{08})* was a barrier in many CONCERTO cases, particularly those with no previous experience in this type of projects.

Socially inclusive procedures are central to SEC projects, enabling a bottom-up collaboration for finding solutions to urban problems (Mosannenzadeh et al., 2017). *Lack of public participation (B_{05})* or low attention to involve key players and the public during the whole lifetime of the project may lead to misplaced priorities (Painuly, 2001). It can also decrease the rate of adoption of project decisions among target groups, which may result in lack of support and acceptance of the proposed interventions (Reed, 2008). For example, in Weilerbach-SEMS, for implementation of the planned district heating system in the rural area, key operators were not contractual project partners, which caused problems in implementing the project.

Respectively, *lack of values and interest in energy optimization measurements (B_{31})* (mentioned as *lack of value-based driving forces* by Song (2006), and mentioned as *values* by Rohdin and Thollander (2006) and Sorrell et al. (2000)) from both sides of target groups and project partners reduces acceptance and becomes a significant barrier to SEC project implementation. For example, in Birštonas-ECOLIFE, although low-income residents were exempted from payments for the building modernization, they were not interested in modernization and did not want to participate in the project. In addition, long-lasting negotiations and customized advisory services were necessary to convince private developers to adopt ambitious energy performance standards. CONCERTO could demonstrate that “spontaneous” innovation in relation to building energy performance is still an exception in the private real-estate market.

Shared investment of public and private bodies and the combination of different external financial sources in SEC projects (Mosannenzadeh et al., 2017) brings about complications in implementation. Many CONCERTO projects were funded through a combination of EU funds with public –national, regional, and local– and private funds. Consequently, *insufficient external financial support and funding for project activities (B_{18})* (mentioned by Pîrlogea, 2011) was a barrier in many CONCERTO projects. For example, in Birštonas-ECOLIFE, although national support schemes were available, there were difficulties in combining the national and project financial support together. Some CONCERTO projects, e.g. Ajaccio-CRRESCENDO were significantly belated because the communities received external funds with delay. Other problems in providing external financial support were related with the difficulty to find an appropriate financing scheme, public-private partnerships, and contracting models as there were restrictions on eligibility of organizations/actors for a CONCERTO-grant (e.g. in Óbuda-STACCATO).

3.1.3. Integration of multiple energy domains

Integration of multiple energy domains and various energy strategies complicates the development of a suitable plan and a well-defined process for project operation. *Deficient planning (B_{27})* that does not accurately consider the conditions of both natural and built environment, makes implementation difficult. For example, in Lambeth-ECOSTILLER, roof-mounted wind turbines were planned; however, these turbines could not be installed because the wind speed was not sufficient. *Lack of well-defined process (B_{28})* for project activities was evident in many CONCERTO projects such as Geneva-TETRAENER, in which the methodological phase of the project was run in parallel with the actual planning and implementation phase rather than preceding it.

One common barrier related to lack of well-defined process and specific to retrofitting of existing buildings was emphasized as a separate barrier: *Retrofitting work in dwellings in occupied state (B_{29})* while the tenants are living inside the building. This put large burden on all tenants due to temporary disconnection of heating and water systems, disrupting privacy, and possible visual/noise/air pollution. This barrier was successfully avoided in the cases where participative approaches –involving residents in the renovation process– were initiated at an early phase of the project and supplemented by directed information; e.g., in Hanover-ACT2, Zaragoza-RENAISSANCE, and Turin-POLICITY (Di Nucci and Spitzbart, 2010).

3.1.4. Large-scale projects

CONCERTO projects either at district or at city-wide level are *large-scale* projects. In large-scale projects, policy and regulatory barriers become critical. *Lacking or fragmented local political commitment and support on the long term (B_{02})* (mentioned by Kaminker and Stewart, 2012; Pîrlogea, 2011), usually due to changes in local government, endangers project implementation. Similarly, *lack of long-term and consistent energy plans and policies (B_{01})* (mentioned by Ellis and Kamel, 2007) or non-effective energy policy due to *Non-effective regulations (B_{13})* (local, regional, and national) (Austin, 2005) may lead to unclear objectives and inconsistent political support, making investors cautious (Kaminker and Stewart, 2012). *Regulatory instability (B_{12})* (mentioned by Painuly, 2001) is a result of uncertain governmental policies (Kaminker and Stewart, 2012) resulting in an uncertain investment situation and therefore hinders investment in new technologies. It may also increase the cost of the project due to changes in project activities created by instable regulations (Painuly, 2001).

Large-scale projects most likely include multiple properties (e.g. real-estate, buildings, flats, and technology infrastructure). *Fragmented ownership (B_{10})* of these properties appears as a barrier, due to potential limited cooperation of all owners for implementing project interventions (Ferranto et al., 2013). It may also create difficulties in contracting procedures. For example, in Valby-GREEN-SOLAR-CITIES, fragmented ownership of solar panels and buffer tanks created complications for contracting. One common problem in smart energy building retrofitting is when a majority agreement of flat owners is required. In Tudela-ECOCITY, for example, the agreement for retrofitting apartment buildings was hindered because some home owners were against the interventions due to financial problems, among others. *Split incentives* (B_{22}) (mentioned by IEA, 2010; Sorrell et al., 2000; Hirst and Brown, 1990; Thollander et al., 2010; IEA, 2010) exacerbate this problem because the home owners who do not live in their apartments (i.e. have tenants) do not directly benefit from reduced energy bills. For example, in Amsterdam-ECOSTILER, although tenants benefited from lower energy bills following energy efficiency improvements, housing companies were not allowed to increase the rent and; recover their investment costs for energy efficiency measures.

3.1.5. Time-period of the projects

Finally, one identified barrier, *economic crisis (B_{20})*, was specific to the time-period of the CONCERTO projects of the first generation. The economic crisis in 2007 resulted in lack of capital (mentioned by Di Nucci et al., 2010; Trianni and Cagno, 2012) and provoked serious problems for CONCERTO cities, especially in France and Spain, where the effects of the crisis were further aggravated by an approximate 20% rise in the cost of building materials. This discouraged many investors from commencing large retrofitting projects or investments in renewable energy sources. Moreover, in a number of CONCERTO countries, local authorities faced financial difficulties as the global banking and property crisis reduced tax revenue and provoked shortfalls in municipal budgets. This was further aggravated by the fact that at the community level, the funding of CONCERTO demonstration activities was in competition with other economic and social priorities and interests.

All the identified barriers are prioritized through a multi-dimensional approach, as explained in the following section.

3.2. A multi-dimensional approach to prioritize barriers to implementation of smart energy city projects

We prioritized barriers in a multi-dimensional approach according to three indicators: criticality, causal relationships among barriers, and inevitability. The result of prioritization by each indicator and in a multi-dimensional approach is presented as follows.

3.2.1. Criticality

Criticality, mentioned as “importance” or “size” in the literature (Du et al., 2014; Rohdin and Thollander, 2006; Sorrell et al., 2011), provides the first methodological step to prioritize barriers. A barrier is defined as critical not only if it is frequent, but also if it has a high negative impact on project implementation. A list of barriers and their frequency and level of impact is presented in Table 1. Based on Table 1, we subdivided barriers into three criticality areas (Fig. 2) as a function of their frequency and level of impact (see Section 2.2). High criticality area includes four barriers –i.e. *lack of good cooperation and acceptance among partners* (B_{04}), *fragmented ownership* (B_{10}), *insufficient external financial support and funding for project activities* (B_{18}), and *lack of skilled and trained personnel* (B_{26}). Medium criticality includes most of the barriers; e.g. *lack of public participation* (B_{05}) and *economic crisis* (B_{20}). Low criticality area covers eight barriers, including market barriers (B_{22}, B_{23}), the *non-effective regulations* (B_{13}), and *risk and uncertainty* (B_{21}).

3.2.2. Causal relationships among barriers

Causal relationships among barriers are shown in Fig. 3. The *key influencing barriers* are those that cause many other barriers. The key influencing barriers are *lacking or fragmented local political support on the long term (B_{02})*, *lack of public participation (B_5)*, and *economic crisis (B_{20})*, each causing three or four other barriers. On the contrary, some barriers are caused by numerous other barriers. We call these barriers *highly dependent barriers*, including *insufficient external financial support* (B_{18}), *lack of trained and skilled personnel* (B_{26}), *lack of values (B_{31})* and *low acceptance of new technologies (B_{32})*.

It is worth also to identify the interaction between three key influencing barriers. The key influencing barriers are mostly independent from each other, except for *lack of public participation* (B_{02}) that results in *lacking or fragmented local political support on the long term (B_{05})*. Lack of public participation is defined as low involvement of key stakeholders –including political party– from the beginning of the project. Neglecting involvement of relevant policy makers (such as local and regional policy makers) in the project reduces the likelihood of (consistent) political support for the project implementation. Furthermore, the barriers caused by each key influencing barrier are different from barriers caused by the other key influencing barriers. This implies that addressing the three key influencing barriers will automatically limit or eliminate a sum of nine other barriers as well.

A sequential causal relationship is observed when, for example, *fragmented political support on the long term* (B_{02}) causes *regulatory instability (B_{12})*, which in turn increases *risk and uncertainty (B_{21})*,

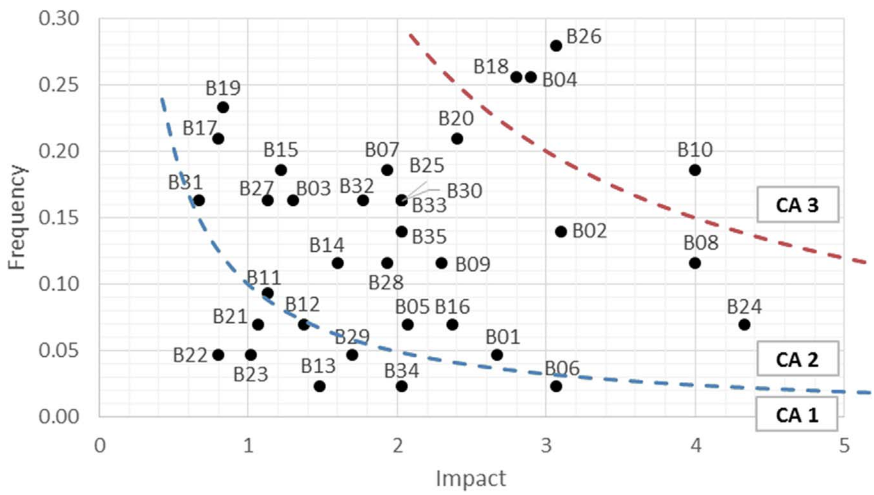

Fig. 2. Criticality of barriers. CA stands for criticality area: a barrier in *CA 1* has low criticality (frequency * impact < 0.1), in *CA 2* has medium criticality (0.1= < frequency * impact < 0.6), and in *CA 3* has high criticality (0.6= < frequency * impact).

which reduces the *acceptance and interest in investment in new projects and technologies* (B_{32}). This means that to tackle B_{32}, mitigation policies and plans would be more effective if they correspondingly address not only B_{21}, but also B_{12} and B_{02}.

3.2.3. Inevitability

We propose the *inevitability* of a barrier by upgrading *barrier scale*, introduced by Reddy (2013) and Di Nucci et al. (2010), by adding the barrier *origin* (Cagno et al., 2013) (see Section 2.2). The inevitability of barriers –as a function of origin and scale– is illustrated in Fig. 4. Several administrative, technical, and financial barriers –e.g. lack of public participation (B_{05})– are lowly inevitable. Several legal barriers and all social, information and awareness barriers are moderately inevitable. For example, lack of interest in energy efficiency measures from the side of target groups (B_{31}) is external to the project because it relates to cultural characteristics of the target group. However, it is possible to weaken it through project design and organization and by providing incentives or increasing awareness of energy efficiency benefits. All policy barriers, as well as the economic crisis, are highly inevitable.

The inevitability indicator can show the level of required action for tackling a barrier. A barrier which is lowly inevitable needs action from project coordinators; a barrier which is moderately inevitable needs action from both project coordinators and policy makers; and a barrier which is highly inevitable requires action mainly from policy makers. This can clarify which barriers have a higher priority at the project level and which barriers have a higher priority for policy makers.

3.2.4. Multi-dimensional analysis

Barriers are not usually independent; some barriers, although not highly critical by themselves, may originate more critical barriers (Marle et al., 2013). Therefore, integrating two indicators "the causal relationships among barriers" and "criticality" can help improving barrier prioritization. The combination of criticality and causal relationships shows that key influencing barriers have a rather higher level of impact (i.e. level of impact higher than two). This is plausible because the negative impact of key influencing barriers on the project implementation is intensified since they cause many other barriers as well. In contrast, highly dependent barriers are among the more frequent barriers (i.e. a frequency higher than 0.16) most likely because they will arise due to occurrence of many other barriers. Most of barriers with low criticality (i.e. low frequency and low level of impact) affect only one other barrier, most of which have a low/moderate criticality (i.e. criticality lower than 0.33).

Critical barriers are important to be addressed. However, some critical barriers such as economic crisis are highly inevitable, meaning that the project coordinators and policy makers can not directly influence them. The combination of inevitability and criticality (as in

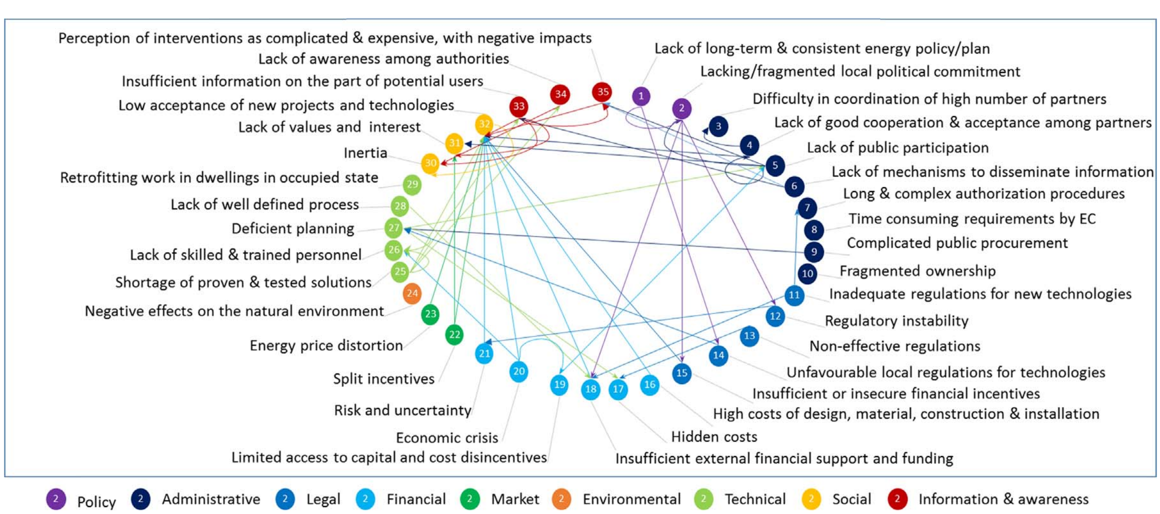

Fig. 3. Casual relationships among barriers. Each barrier is shown as a filled circle, and the relationships are shown as arrows. The arrow direction shows the direction of the causal relationship.

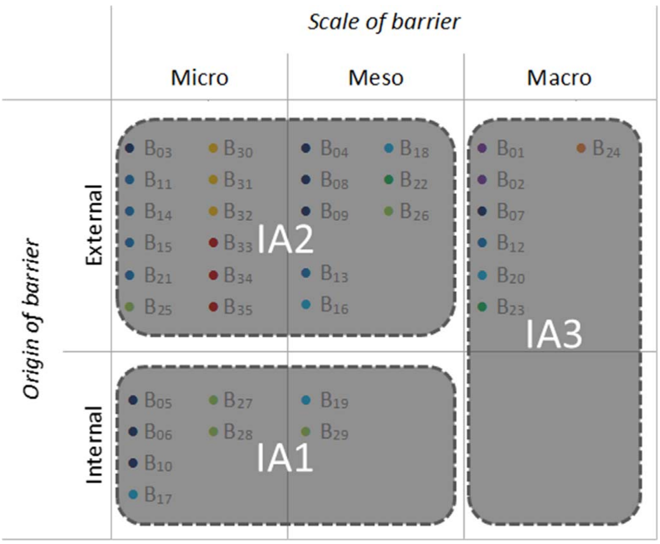

Fig. 4. Inevitability of barriers. Inevitability denotes the level of effort required to tackle a barrier. It is defined by combination of *origin* and *scale*. *origin of barrier* is internal if the barrier is originated inside the project, or external if the barrier is originated outside the project. As for *scale of barrier*, *micro* barriers can be tackled at the design level of the project; *meso* barriers can be tackled at the organizational level of the project; *macro* barriers are most likely difficult to be dealt with by the project. Accordingly, three inevitability areas (IA) are identified. IA1 –lowly inevitable: barriers in this area have internal origin and are at micro or meso scale. IA2 –moderately inevitable: barriers in this area have external origin and are at micro or meso scale. IA3 –highly inevitable: barriers in this area are at macro scale (with internal or external origin).

Fig. 5) shows that among the four most critical barriers, *fragmented ownership* (B_{10}) and *insufficient external financial support and funding for project activities* (B_{18}), are lowly inevitable, implying that they can be dealt through an appropriate project design and organization. On the other hand, *lack of good cooperation and acceptance among partners* (B_{04}) and *lack of skilled and trained personnel* (B_{26}) are moderately inevitable; therefore, project coordinators would try to treat them through an appropriate project organization.

Similarly, it is possible to combine causal relationship among barriers with *inevitability* in order to understand which barriers can be directly influenced by project coordinators and by policy makers. Among three key influencing barriers (i.e. *lacking or fragmented local political support on the long term* (B_{02}), *lack of public participation* (B_{05}), and *economic crisis* (B_{20})), B_{02} and B_{20} are highly inevitable and B_{05} is lowly inevitable. This means that *lack of public participation* (B_{05}) is the only key influencing barrier which can be addressed through an appropriate project design and organization.

Above all, it is possible to combine all three indicators together for a comprehensive understanding of barrier priorities. Fig. 6 illustrates an analysis of the four most critical barriers for a project coordinator. To tackle *lack of skilled and trained personnel* (B_{26}) in a comprehensive manner, the project coordinator could invest on all the barriers causing it –i.e. *shortage of proven and tested solutions and examples* (B_{25}) and *economic crisis* (B_{20}). However, B_{20} is highly inevitable and most probably not influenced by project design or organization. Therefore, the coordinator may decide not to invest on B_{20}. With a similar logic for the other three most critical barriers, the coordinator may finally decide to allocate resources to tackle four groups of barriers: the first group concerns *fragmented ownership* (B_{10}). The second group concerns barriers related to collaborative and participatory planning, including *lack of good cooperation and acceptance among partners* (B_{04}) and *lack of public participation* (B_{05}). The third group concerns regulatory and administrative barriers to external funding of the project, including *insufficient external financial support and funding for project activities* (B_{18}), *inadequate regulations for new technologies* (B_{11}), and *lack of well-defined process* (B_{28}). The fourth group concerns barriers related to skills, including *lack of skilled and trained personnel* (B_{26}) and *shortage of proven and tested solutions and examples* (B_{25}).

It is clear that the characteristics of implementation mechanisms can hardly be detached from diverse national contexts as the context significantly affects the technical and political feasibility of the implemented measures. The administrative implications of the implementation procedures, for example, pose different adjustment challenges to different national regulatory structures, approaches and attitudes. In this regard, a multi-dimensional barrier prioritization based especially on local traits represents a more effective way for appropriate action.

4. Implications for project decision makers and policy makers

Allocation of responsibility in critical project issues, including site approval and authorization procedures, vary from country to country and project to project. The implementation of most initiatives rests at regional/local level with local authorities and local investors, and not at macro or Member State level. Promotion of SEC projects seems

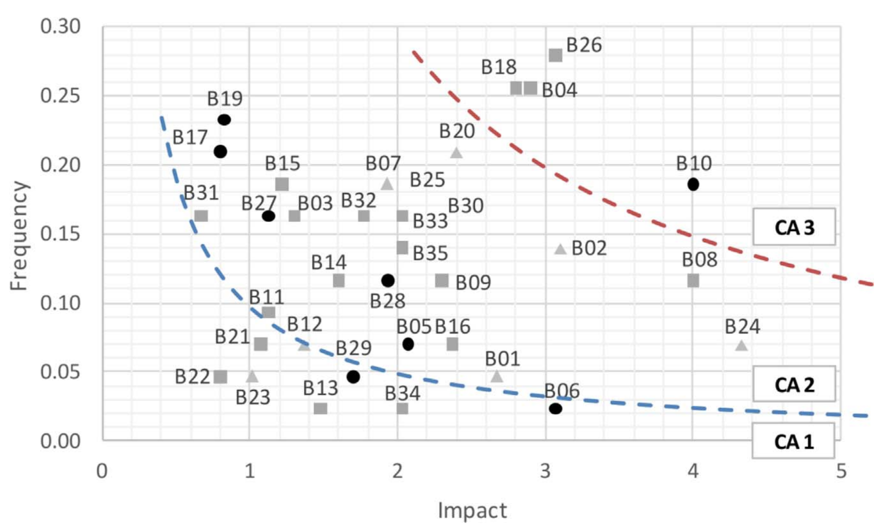

Fig. 5. Combining criticality and inevitability of barriers. CA 1 indicates low criticality area; CA 2 indicates medium criticality area; CA 3 indicates high criticality area. The colors and shapes represent inevitability: a black circle represents lowly inevitable; a gray square represents moderately inevitable; a gray triangle represents highly inevitable. The arrows indicate the direction of the causal interaction.(For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article).

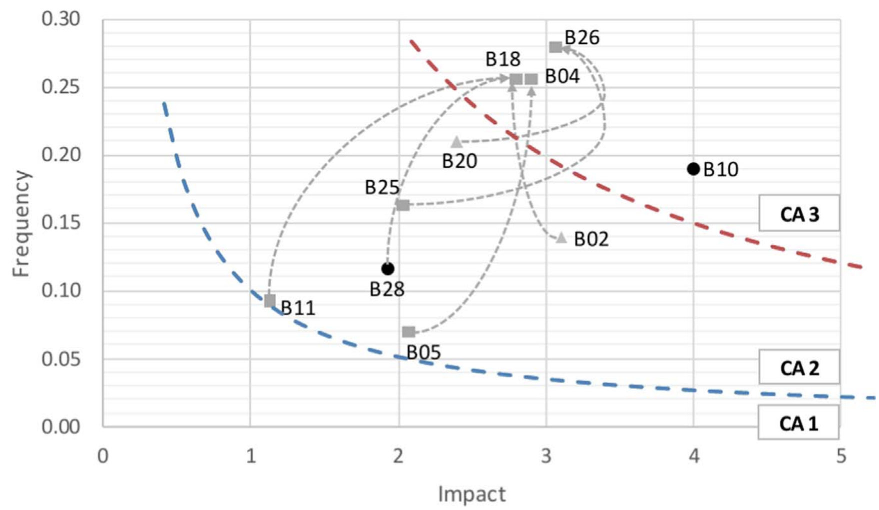

Fig. 6. Criticality, inevitability, and interaction among barriers for the most critical barriers. CA 1 indicates low criticality area; CA 2 indicates medium criticality area; CA 3 indicates high criticality area. The colors and shapes represent inevitability: a black circle represents lowly inevitable; a gray square represents moderately inevitable; a gray triangle represents highly inevitable. The arrows indicate the direction of the causal interaction.(For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article).

irreversible despite many barriers. In light of the analysis above, we derive following implications to tackle the barriers to implementation of SEC projects.

4.1. Implications for project coordinators

Considering the pivotal role of new technologies in SEC projects and numerous barriers associated with it, the selection of a technology should be preceded by careful consideration of related regulations and financial incentives, social acceptability and previous experience and expertise. Accordingly, employment of skilled and trained staff especially operators, and managers for deployment and operation of new technologies is paramount for project success. Consequently, education and training within the project can improve project implementation.

The coordination of all contractors and a continuous strong project management become very important in the implementation phase, when previously established contracts and agreements between all stakeholders need to be taken into consideration.

Proper stakeholder cooperation, while considering financial incentives can provide further motivation for all involved partners to accomplish project execution, and therefore, help speeding up the process. Public-private partnerships and contracting models are proving to offer sound alternatives for financing efficiency measures in public buildings. Internal data platforms, transparency and effective communication, beside application of collaborative methods and tools are necessary.

Improving integration of multiple energy domains is key to project success. A precise plan that clarifies subsequent operational steps and subdivision of tasks and duties is critical.

Coordination of monitoring activities such as energy performance monitoring, early involvement of key stakeholders and a continued dialogue with target groups are central to success. Monitoring details in most cases have been agreed upon in earlier phases such as the design phase and need to be carried out and evaluated for several years during the operation phase.

The involvement of the municipal utilities, and using their support in negotiating with building owners is a key factor in overcoming the legal and social barriers related to implementation of community energy systems.

Finally, acceptance by the target groups and a readiness to change behavioral patterns are important factors for successful implementation. Involvement of target groups from the early stage and taking into account residents' needs and attitudes in advance is crucial for abating acceptance barriers.

4.2. Implications for policy makers

There is a need for upgrading national, regional, and local regulations for the adoption of new technologies. Regulatory and support schemes stability at the national level is a fundamental feature for reducing investment risks and encouraging the private sector to take on new technologies. Accordingly, provision of new and appropriate business models, e.g. for public-private partnerships is essential for an appealing and successful collaboration between the public and private sector.

Provision of wide-scale platforms and networks is fundamental for learning from other experiences and building knowledge around new technologies. This should be part of policies for general increase of information and awareness among all stakeholders, specifically general public and authorities on real costs and benefits of smart energy solutions in short to long term.

Finally, the prioritization analysis of barriers shows that a consistent political support during the long term is paramount for successful implementation of SEC projects. This can be ensured through integrated long-term national and local policies and plans.

5. Conclusions

This paper identified the barriers to the implementation of SEC projects in Europe and proposed a multi-dimensional approach for barrier prioritization applicable by project coordinators and policy makers. In general, predicting barriers in advance and trying to avoid them is decisive to avoid unexpected losses of project resources. When barriers occur during the implementation phase, they need to be handled capably and dealt with quickly in order to advance the project and avoid jeopardizing its outcomes.

Our research makes five main contributions to the scientific discussion of barriers to SEC development. First, we identified 35 barriers to the implementation of SEC projects through an empirical approach, gathering information on 43 communities of the CONCERTO Initiative and validating it through literature review. We categorized these barriers into nine groups: policy, administrative, legal, financial, market, environmental, technical, social, and information and awareness. We also showed how major aspects of SEC projects lead to what barriers. Second, we suggested and applied a novel multi-dimensional approach to prioritize barriers to SEC projects, combining the frequency, level of impact, causal relationships, scale, and origin of barriers. It is possible to consider each of these aspects independently, but prioritization is most effective if all aspects are simultaneously considered together. Third, we borrowed the concept of "criticality", applied in risk-analysis, for evaluating the importance of a barrier. Criticality of a barrier is a function of its frequency and impact. Fourth, we investigated and applied interaction among barriers instead of treating barriers in an isolated and piecemeal way. Fifth, we introduced a new indicator for the level of action required for tackling a barrier, namely inevitability. Inevitability is derived from combining barrier origin and scale. It shows if a barrier is more likely to be influenced at the project level, or policy level, or both.

Our proposed methodology for barrier prioritization is applicable to other types of barriers as well; e.g. barriers to energy efficiency or technology diffusion. Further research can concentrate on more recent smart energy projects and also drivers or success factors of these projects.

We showed how administrative, legal, financial and social barriers are strongly correlated with the projects' and communities' specific features. While policies and initiatives to promote SEC are essential at the macro level, implementation and uptake depend on key local actors such as investors and developers and local authorities. Thus, commitment of local administrations, choice of accompanying activities such as dissemination of information, use of appropriate communication tools, awareness raising, active involvement of relevant decision makers, user groups and market actors are crucial success factors (Di Nucci and Pol, 2009).

To conclude, this research provided a multi-dimensional classification of barriers to the implementation of SEC projects. The outcomes of this research may help project coordinators and policy makers to better understand, predict and prioritize implementation barriers facing them and to develop proper action and policy interventions to ensure successful implementation of SEC projects.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.enpol.2017.02.007.

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