DOCTORAL SCHOOL IN CIVIL, ENVIRONMENTAL AND MECHANICAL ENGINEERING

Smart Energy City Development in Europe: Towards Successful Implementation

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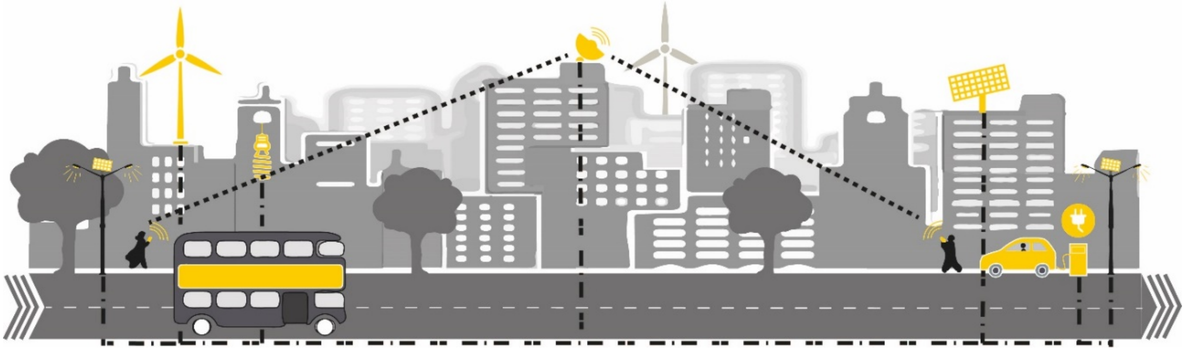

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“*There is no logic that can be superimposed on the city; people make it, and it is to them, not buildings, that we must fit our plans.*”

— Jane Jacobs

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Summary

Smart energy city (SEC) development is a component of the urban development initiative smart city, which has been a popular response to the global energy challenge in Europe during the past two decades. SEC development aims to increase the sustainability of urban energy systems and services. Since 2011, SEC development has been supported by the European Commission as part of the Strategic Energy Technology plan (SET-Plan) and through the European Union Programmes for Research and Technological Development (specifically FP7 and Horizon 2020). This, along with the promising vision of SEC development and considerable financial support by the private sector, has encouraged numerous European cities to initiate SEC projects. Successful implementation of these projects at the urban scale is crucial to achievement of urban energy objectives and sustainability of future urban development.

The here presented thesis aims to support urban decision-makers towards successful implementation of urban scale smart energy city development in Europe. The study includes three stages. The first stage is dedicated to conceptual analysis. Within this stage, I conceptualized smart city through a keyword analysis of existing literature on the concept. Then, within the context of the smart city concept, I defined SEC development through literature review and expert knowledge elicitation. The second stage is dedicated to empirical investigation. Using the definition of SEC development, I distinguished and investigated 43 previously implemented SEC projects to identify common barriers that hinder successful implementation of SEC development. In addition, I proposed a new multi-dimensional methodology that allows a simultaneous prioritization of barriers against their probability, the level of impact, scale, origin, and relationship with other barriers. The third stage of the thesis is dedicated to learning methodologies that allow efficient transfer of knowledge from the past SEC experiences to the new SEC developments. I introduced the application of two learning methodologies that support decision-makers to predict barriers to the implementation of a new SEC project: case-based learning and decision tree learning. The former predicts barriers based on internal similarities between the new SEC project and the past projects. The latter uses the past projects and creates a predictive model for each barrier based on internal and external project characteristics. These models are later used to predict barriers to a new SEC project. Both methodologies were tested in a new SEC project, named SINFONIA.

The conceptual analysis revealed that application of information and communication technologies, the collaboration of multiple stakeholders, integration of multiple urban domains, and sustainability evaluation are the constant characteristics (i.e. principles) of

smart city and SEC development. It resulted in, to the best of my knowledge, the first multi-dimensional and comprehensive definition of SEC development, revealing its principles, objectives, domains of intervention, stakeholders, time and spatial dimensions. Furthermore, a list of smart energy solutions in each SEC domain of intervention was provided. The empirical investigation of the past SEC projects resulted in the identification of 35 common barriers to the implementation of SEC development, categorized in policy, administrative, legal, financial, market, environmental, technical, social, and information and awareness dimensions. The barrier prioritization showed that barriers related to collaborative planning, external funding of the project, providing skilled personnel, and fragmented ownership should be the key action priorities for SEC project coordinators. Application of case-based learning methodology resulted in identifying five past SEC projects that were the most similar to the SINFONIA project in terms of project internal characteristics. Investigating the barriers to the similar projects revealed that *fragmented ownership* is the most probable barrier to implementation of SINFONIA project. Application of the decision trees methodology resulted in generation of 20 barrier models, four of which showed a very good performance in prediction of barriers: *lack of values and interest in energy optimization measures, time-consuming requirements by European Commission concerning reporting and accountancy, economic crisis*, and *local unfavorable regulations for innovative technologies.* None of these four barriers were predicted to occur in the SINFONIA project. The application of this method in the SINFONIA showed a higher predicting power when a barrier was absent.

The findings of the here presented thesis contribute to successful implementation of SEC development by supporting decision-makers in different phases of SEC projects. The results of the conceptual analysis contribute to a common understanding and foster the dialogue on the concept among various SEC stakeholders, particularly decision-makers and urban planners. The results of the empirical investigation lead to a better comprehension and evaluation of the barriers to the implementation of SEC projects in order to efficiently allocate resources to mitigate barriers. The proposed learning methodologies proved to be promising in helping decision-makers to identify similar projects to a new SEC development and to predict barriers to the implementation of new SEC projects.

The thesis concludes that SEC is an outstanding urban development that can make a valuable contribution to the sustainability of urban energy systems. The specific characteristics of SEC development pose new challenges to the future smart and sustainable urban planning. Nevertheless, SEC development brings about unprecedented opportunities for integration and application of advanced quantitative techniques with current urban planning methods. This allows efficient knowledge transfer in not only intra-urban but also inter-urban levels in order to provide a collaborative, integrated and constructive movement towards successful implementation of SEC projects and sustainability of future urban development.

Thesis Outline

This thesis is composed of a general introduction, five main chapters, written as stand-alone manuscripts, and a general discussion. The general introduction provides the overall context of the thesis, state of the art and key gaps, the main aim and the specific objectives, and the research structure of the thesis. Each main chapter addresses one of the specific research objectives and contains an introduction, methodology, results, discussion and conclusion. In the general discussion, the main findings of the thesis are discussed and the overall contribution to the main aim of the thesis is demonstrated, followed by a general conclusion and an outlook for potential future studies.

The manuscripts are either published (Chapter 2), under review (Chapters 3, 5 and 6), or in the preparation stage to be submitted to peer-reviewed journals (Chapters 4). The authors' contribution to each manuscript is stated as follows.

Chapter 2

Based on: **F. Mosannenzadeh, D.** Vettorato (2014) Defining smart city: a conceptual framework based on keyword analysis, *Tema, Journal of Land Use, Mobility, and Environment*, special issue, June 2014.

Author contributions (abbreviations of author names above are used):

FM and DV initiated the project. **FM** held the literature review, designed and performed the analysis. **FM** and DV conceptualized the manuscript. **FM** drafted the manuscript. All the authors revised the manuscript.

Chapter 3

Based on: **F. Mosannenzadeh**, A. Bisello, R. Vaccaro, V. D'Alonzo, G. W. Hunter, S. Pezzutto, D. Vettorato. Smart energy city development: a story told by urban planners (under review, journal of Cities)

Author contributions (abbreviations of author names above are used):

FM and DV initiated the study. **FM** provided the framework for literature review and coordinated the expert focus groups. **FM**, AB, RV, VD, and GWH held the literature review. **FM**, AB, RV, VD, GWH, SP, and DV were involved in the expert focus groups. **FM**, VD, and GWH held the expert interviews. **FM**, RV, GWH, and VD coordinated the meetings with research group leaders. All the authors conceptualized the manuscript. **FM** drafted the manuscript and AB, RV, VD, and GWH contributed to the writing of the manuscript. AB mainly elaborated the visual definition. All the authors revised the visual definition and the manuscript.

Chapter 4

Based on: **F. Mosannenzadeh**, M. R. Di Nucci, D. Vettorato, S. Pezzutto. Identifying and prioritizing barriers to implementation of smart energy city projects in Europe: an empirical approach (to be submitted)

Author contributions (abbreviations of author names above are used):

FM and SP gathered the data, coded them, and validated them against literature. FM held the literature review. FM and SP designed the criticality analysis. FM designed relationship and inevitability analysis. FM implemented the methodology, conceptualized and drafted the manuscript. All the authors revised the manuscript.

Chapter 5

Based on: **F. Mosannenzadeh**, S. Pezzutto, A. Bisello, C. Diamantini, G. Stellin, D. Vettorato. A case-based learning methodology to overcome barriers to implementation of smart and sustainable urban energy projects (under review, journal of *Cities*)

Author contributions (abbreviations of author names above are used):

FM and SP created the database and conceptualized and implemented the methodology. **FM**, SP, and DV conceptualized the manuscript. **FM** drafted the manuscript. All the authors revised the manuscript.

Chapter 6

Based on: **F. Mosannenzadeh**, C. Diamantini, D. Vettorato, A. O. Schmitt. Using decision tree learning to predict barriers to implementation of smart energy city projects (under review, journal of Knowledge-based Systems)

Author contributions (abbreviations of author names above are used):

FM, CD, and DV initiated the study, selected the variables and designed the questionnaire. **FM** designed the database, performed data collection, and created the database. **FM** and AOS designed the methodology for data analysis and evaluation of the models. **FM** performed the data analysis and the application of the models in the case study. CD and DV supervised the study. **FM** and AOS conceptualized the manuscript. **FM** drafted the manuscript. All the authors revised the manuscript.

Key to abbreviations

SEC	Smart energy city
EC	European Commission
EU	European Union
FP 6	Sixth European Union’s Framework Programme for Research and Technological Development
FP7	Seventh European Union’s Framework Programme for Research and Technological Development
ICT	Information and Communication technology
Ec	Energy conservation
EE	Energy efficiency
RES	Renewable energy sources
DSS	Decision support system
IBM	International Business Machines Corporation
PV	Photovoltaic

Part I

Chapter 1

General Introduction

1.1 Context

1.1.1 Cities and sustainable energy development

Energy is the core to successfully achievement of interrelated social, economic, and environmental objectives of sustainable human development (UNDP, 2010). However, today’s energy systems are unsustainable, meaning that the balance of energy produced and consumed does not support human development over the long term and in all its social, economic, and environmental dimensions (UNDP, 2010). The main aspects of energy unsustainability include inequity of access to modern fuels; lack of reliable and affordable energy supply; and negative local, regional, and global environmental impacts of energy production and consumption, which threatens the well-being of current and future human generations (UNDP, 2010; World Energy Council, 2010).

Cities, including 54 % of the world population in 2014 (UN, 2014), are responsible for 75% of global primary energy consumption (UN habitat, 2016). The percentage of urban population is projected to increase to 66% by 2050 (UN, 2014). This will result in even more energy consumption if urban energy management continues to act as before (UNDP, 2000). Moreover, cities are hubs of governance, communication, transportation, and commerce and enforce socio-economic and political changes (UNDP, 2000). Focusing appropriate energy policies on cities would affect large numbers of people, communities, and services (UNDP, 2000). Therefore, cities potentially play a key role in both reducing energy consumption and enforcement of policies and actions for achievement of sustainable energy objectives (World Energy Council, 2010). This urges all urban governments to take appropriate policies and action towards a more sustainable energy future.

1.1.2 Smart City development in Europe

The discourse on initiatives for sustainable energy at urban level is lately gaining more attention in Europe. In 2011, European Commission (EC) launched European Initiative on Smart Cities as part of the Strategic Energy Technology plan (SET-Plan). The strategic objective of this initiative was to demonstrate the feasibility of rapid progress towards energy and climate objectives at the local level, while improving local economies and quality of life for citizens through investments in energy efficiency and reduction of carbon emissions (EC, 2016). One of the specific objectives of this initiative was to effectively spread, across Europe, best practices of sustainable energy concepts at the local level (EC, 2016). This initiative was followed in July 2012 when European Commission launched the “Smart Cities and Communities European Innovation Partnership”. This partnership aimed to pool resources to support the demonstration of energy, transport, and information and communication technology (ICT) solutions in order to enhance sustainability in cities and communities (EC, 2015a). The activities of this partnership were financially supported by the Seventh Framework Programme for Research and Technological Development and later by Horizon 2020 (Vanolo, 2014) –i.e. funding programs provided by the EU in order to promote research in the European Research Areas (EC, 2015b). In response, 370 commitments were made from 31 European countries aiming at addressing the objectives of Smart City Initiative (EC, 2015c).

The popularity of smart city development in European cities during the past two decades (Angelidou, 2015) is due to not only EU political and financial support but also a mix of other driving factors. First, the vision of smart city illustrates the image of “*clean, liveable, technologically advanced cities far removed from the economic crisis*” (Vanolo, 2014, p. 12). The smart city vision claims not only sustainability of urban energy systems, but also enhancement of participatory and effective urban governance (Nam and Pardo, 2011; Odendaal, 2003), improvement of quality of life for citizens (Lazaroiu and Roscia, 2012; Nam and Pardo, 2011), and fostering urban economy and competitiveness (Angelidou, 2014; Batty et al., 2012; Odendaal, 2003). Second, smart city financial support is not limited to the EC and the public body; there is also considerable investment from large private companies, such as IBM, CISCO, and ENEA (Söderström et al., 2014; Vanolo, 2014). Third, recent advancements in ICT and decreased prices for technology provides urban governments with unprecedented opportunities to enhance integration and collaboration among different urban domains (Lazaroiu and Roscia, 2012; Pol et al., 2012). This allows, among others, improved efficiency, interoperability, and financial feasibility of urban systems and services (Geerlings and Stead, 2003; Nam and Pardo, 2011; Wondolleck and Yaffee, 2000). The smart city is therefore enforced, taking advantage of these opportunities by putting ICT as a central aspect of its development (Komninos, 2002; Lazaroiu and Roscia, 2012; Lee et al., 2013; Odendaal, 2003). Encouraged by mentioned driving forces, numerous European cities have initiated smart city development in the last 20 years (Angelidou, 2015).

1.1.3 Smart energy city and urban development

Smart energy city (SEC) is a popular component of the whole complex concept of smart city (Giffinger et al., 2007; Nielsen et al., 2013; Perboli et al., 2014) that concentrates on urban energy systems and services (Lund, 2014). Perboli et al. (2014) state that the aim of smart energy is to reduce energy consumption and carbon footprint, develop alternative fuels and mobile energy resources, and create a single smart electricity grid. SEC is considered as the core to the concept of the smart city in some studies (Nielsen et al., 2013; Pol et al., 2012), providing citizens with a liveable, affordable, climate-friendly and engaging environment (Nielsen et al., 2013).

In practice, the actualization of SEC objectives takes place in SEC projects. Many SEC projects have been initiated and accomplished in Spain, Italy, and France (Perboli et al., 2014). Such projects are initiated by either public or private sectors businesses. The public sector aims at enhancing sustainability while the private sector seeks for increasing its efficiency and competitiveness (Perboli et al., 2014). SEC projects involve various stakeholders, including city administration, enterprises, universities and citizens (Leydesdorff and Deakin, 2011; Perboli et al., 2014). The scale of SEC projects varies, starting from in-home material and devices, such as electrical cooking, to international online systems such as the Smart Cities Information System (CONCERTO, 2015a).

SEC projects at the urban scale –i.e. building blocks, urban districts, or city-wide– are strongly connected to urban development policies and plans. On one hand, urban policies and urban development regulations influence implementation of SEC projects (Papa et al., 2013). On the other hand, SEC projects, revolutionizing urban energy systems and services, influence sustainability of future urban development (Anthopoulos and Vakali, 2012). Therefore, inaccurate and/or unsuccessful implementation of SEC projects at the urban scale not only hinders achieving urban energy objectives (Di Nucci et al., 2010), but also might result in negative socio-economic, and environmental impacts (Hollands, 2008), and therefore, reduce sustainability of urban areas. Considering the great interest of European cities in SEC projects, successful implementation of these projects is crucial, not only to accelerate achievement of urban governments' energy objectives, but also to ensure sustainability of future urban developments. Respectively, initiators of these projects and urban decision-makers –i.e. influential individuals and organizations, at the urban level, with the responsibility and authority to adopt policies and define implementation measures (Seitz et al., 2013)– need support to successfully implement SEC development at the urban scale.

1.2 State of the art and key gaps

Investigation of SEC development is not possible without considering it within the bigger framework of the smart city. The smart city is recent in both the concept and practice. Hollands (2008) and Vanolo (2014) show that the idea of smart city is born by combining two concepts in planning literature: Smart Growth, promoted by the New Urbanism movement in the USA in the 1980s, and intelligent city, a technology-based urban development (Komninos, 2002). According to Söderström et al. (2014), the first appearance of the phrase “smart city” was in the mid-1990s. In that period, cities named themselves smart, when they applied ICT solutions in their development (Hollands, 2008). The promotion and wide use of the concept passed two momentums in 2008 and in 2011; the former, on an international scale, and the latter at the European scale. In 2008, as explained by Söderström et al. (2014), the Information Technology (IT) sector, particularly IBM, started an extensive smarter planet advertisement after IBM CEO gave a speech entitled “A Smarter Planet: The Next Leadership Agenda” on 06 November. In this speech, it was argued that in order to get more sustainable and economically efficient, the world and the cities must become smarter [mainly more ICT based]. This has been followed by IBM until the present day in the shape of a trademark: SMARTER CITIES, in which IBM collaborates with urban governments to make their cities smarter. In 2011, the development of smart city and smart energy city took another step forward in Europe due to new political and financial support by European Commission, launching the Smart City Initiative. This initiative has been also followed until the present (see 1.1.2).

In spite of pivotal role of SEC in the whole smart city concept (Nielsen et al., 2013; Perboli et al., 2014; Pol et al., 2012), scientific work on SEC discourse is yet limited. A search for the term “smart energy city” in “google scholar” shows that the term appeared in English scientific literature for the first time in 2009, where Vergragt (2009) mentioned SEC, in the Netherland “Energy Report”, as one of three future energy visions for Netherland. Since 2009, the term “smart energy” has gotten increasing usage mainly in the fields of technical energy infrastructure, big data, and energy policy (e.g. Hargreaves et al., 2010; Rietbergen and Blok, 2010; Zhang et al., 2015), and rarely in the field of urban development (Lund, 2014; Nijkamp and Volwahsen, 1990).

Since the first emergence of the concept until the present moment, both smart city and SEC developments have encountered a number of challenges that have hindered them from successfully meeting their initial objectives. Angelidou (2015) states that the problem roots in a great misunderstanding about what smart [energy] cities actually are and not being clear on how to realize them in practice. Inspired by Angelidou (2015), in the following, I review the state of the art of the implementation of SEC development at the urban scale in Europe, in three levels: the concept, the practical implementation, and opportunities for new developments. This review highlights a number of key gaps and challenges that face urban decision-makers in the implementation of SEC development. The highlighted gaps shape the basis for specific objectives of the here presented thesis.

1.2.1 The concept

An extensive discussion on the concept of smart city has taken place during the past two decades and among multiple urban stakeholders (Angelidou, 2015; Giffinger et al., 2007; Hollands, 2008; Nam and Pardo, 2011); however, suffering from multiple interpretations, a universally acknowledged definition does not yet exist (Allwinkle and Cruickshank, 2011; Angelidou, 2014; Hollands, 2008; Nam and Pardo, 2011). The most prevalent scientific definition is provided by Giffinger et al. (2007, p. 11), who define smart city as "*a city well performing in a forward-looking way in six characteristics: smart economy, smart people, smart governance, smart mobility, smart environment, and smart living. It is built on the 'smart' combination of endowments and activities of self-decisive, independent and aware citizens*". One might state that a common definition of smart city might not be required due to diversity of cities; however, scholars warn that lack of a common definition may result in distorted interpretation and implementation of the smart city projects (e.g. Hollands, 2008; Söderström et al., 2014; Vanolo, 2014) as well as lack of common understanding and dialogue among stakeholders (Kitchin, 2014). Therefore, an illumination of the concept of smart city is crucially required, providing a framework for dialogue among all stakeholders, particularly decision-makers.

Fewer investigations focused specifically on the concept of SEC. Chai et al. (2013, 2011) and Belanger and Rowlands (2014) define smart energy network and Lund (2014) defines smart energy system. These definitions, although specific, concentrate only on energy networks, and therefore, lack a holistic overview. In addition, they do not clarify the actual connection of smart energy city to smart city development. There exists, however in gray literature, a more holistic definition of SEC by Nielsen et al. (2013). They recognize that The SEC is a core to the concept of the smart city (Nielsen et al., 2013). They define smart energy city as a city "*that is highly energy and resource efficient and increasingly powered by renewable energy sources; it relies on integrated and resilient resource systems, as well as insight-driven and innovative approaches to strategic planning. The application of information, communication and technology are commonly a means to meet these objectives*" (Nielsen et al., 2013, p. 3). This definition, however, lacks some key aspects of smart energy city such as stakeholders, target fields, and temporal and spatial scale. Accordingly, a scientific, systematic, and comprehensive definition of SEC development that includes these key aspects is required.

In addition, the boundaries between SEC, smart city, and sustainable city are nebulous (Hollands, 2008; Kitchin, 2014). It is not clear if smart city (and consequently SEC) is a new label substituting sustainable city; or if it is a distinct technological vision overlapping with it (see Tregua et al., 2015). In this regard, the sustainability –meaning e.g. social, economic and environmental impacts– of the smart city and SEC developments is the subject of concern, particularly due to the specific emphasis on technology and ICT embodied in the concept (Viitanen and Kingston, 2014). For example, Holland (2008) asserts that smart cities will trigger marginalization of poorer residents and traditional communities with lower access to schooling and technology. Viitanen and Kingston (2014) also concern about the increase of e-waste due to instrumenting cities in order to make them smart, considering the short shelf-life of technologies and the tendency of end-users to upgrade. This raises the need to clarifying the relationship of SEC and smart city with the sustainable city within the SEC concept.

1.2.2 The practical implementation

In practice, SEC development has not been totally successful in meeting its goals due to various social, technical, administrative, and economic barriers –i.e. difficulties that may hinder or fail the implementation of the projects (Di Nucci et al., 2010). Successful implementation of SEC development is not possible unless these barriers are effectively mitigated. To take effective action and efficiently allocate resources for mitigating barriers, urban decision-makers need to identify and prioritize these barriers (Nagesha and Balachandra, 2006).

The barriers to implementation of SEC projects are scarcely investigated in the scientific literature. The discussion, to my knowledge, has focused only 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). The discussion could also benefit from the valuable contribution, given by gray literature (including deliverables and reports of SEC projects), which has investigated barriers to the implementation of few SEC projects (Di Nucci et al., 2010; Di Nucci and Spitzbart, 2010). The identified barriers in these publications include: technical barriers, such as lack of knowledge on integrating new innovations in energy infrastructure; regulatory barriers, such as low capacity of existing frameworks to integrate smart energy solutions; administrative barriers, such as complexity of providing coherence between different actors and stakeholders with conflicting interests; financial barriers, such as difficulties to involve private capitals in implementation; and social barriers, such as reluctance of people towards smart energy solutions. However, there is still a gap of scientific identification and prioritization of barriers to the implementation of SEC development at the urban scale.

1.2.3 Opportunities for new developments

New generations of SEC projects are yet emerging, specifically in response to EU Horizon 2020. Successful implementation of such projects ideally requires eliminating all factors and conditions that may act as a barrier to them. More practically, prediction of barriers in early stages of the project (i.e. initiation and planning stages) helps to anticipate effective action to avoid and mitigate them. To this end, practical experiences of previously implemented projects is a rich source of knowledge (Painuly, 2001). Not surprisingly, effective transfer of knowledge, across Europe, on experiences of local smart [energy] city projects is one of the specific objectives of European Union Initiative on Smart Cities (EC, 2016). This raises the need for methodologies and tools that support urban decision-makers to effectively disseminate knowledge from the past experiences to new projects.

There are several experiences in SEC development. These projects usually put their lessons learned in project publications (see for example, Immendoerfer et al., 2014). Current methods for knowledge transfer in urban energy development include recognizing best practices and generalizing their lessons learned for application to new projects (e.g. Friedl and Reichl, 2016; Kennedy and Basu, 2013; Rupf et al., 2015). These methods, however, have two specific deficiencies.

First, current methods do not systematically differentiate projects based on their characteristics (see for example Rupf et al., 2015). Projects are complex identities (Marle et al., 2013) and barriers to their implementation 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). Internal characteristics are specific to the project; e.g., the project collaborators, the planned implementation process, or the project funding resources. External characteristics are originated outside the project, including a wide and interrelated set of social, economic, environmental, and legal conditions (Cagno et al., 2013; Di Nucci et al., 2010). This highlights that a barrier occurred in a past project may not appear in a new project with different characteristics. In fact, a filtering technique is required to derive relevant and applicable knowledge for a specific project with its unique combination of internal and external characteristics.

Second, SEC projects are characterized by producing and sharing a large amount of data on the urban energy sector and management (Taylor and Richter, 2015). In the presence of a large amount of data that describe various features of a project, traditionally statistical methodologies that could generalize small samples to larger populations are hardly relevant. In fact, in SEC development, the problem is not generalization, but data filtration and abstraction (French et al., 2015).

Therefore, for transfer of knowledge from the past experiences to new developments, urban decision-makers need methodologies that are able to deal with high complexity and to handle a large amount of data. These methodologies should be able to filter and condense data to relevant and applicable knowledge for a specific project. Respectively, French et al. (2015) suggest application of advanced data analysis methods that are familiar to computer scientists and have proven to be promising for prediction in a complex and data-rich environment.

Among others, two broad learning methodologies with both functions of data compression and prediction are case-based learning (Aha, 1991) and machine learning (Bramer, 2013).

Case-based learning is stated to have a high potential for prediction purposes in urban planning (Yeh and Shi, 1999). The principle in case-based learning is to create predictions for a specific new case, based on learning from previous similar cases (Aha, 1991). Case-based learning is useful in addressing complex and site-specific problems with several alternative solutions (Remm, 2004). However, this methodology has not been applied so far for predicting barriers to sustainable urban development projects. Machine learning methods are currently used widely in many fields for predicting purposes (Keramati et al., 2014; Patel et al., 2016; Woolery and Grzymala-Busse, 1994). In urban planning, machine learning methods have been applied for simulating or modeling urban development (Liu et al., 2008; Veerbeek et al., 2015), classifying urban locations (Torija and Ruiz, 2016), and predicting the behaviour of service users (Rasouli and Timmermans, 2014). Among various predictive approaches in machine learning, decision tree learning methods are widely used in a variety of disciplines due to their flexibility, easy application, visualization, and interpretation (Keramati et al., 2014). Decision trees can derive association rules from a training known dataset (i.e. the past projects) and use those rules to make predictions for a new unknown case (i.e. a new project) (Bramer, 2013). However, best to my knowledge, decision trees are also not previously used to predict barriers to sustainable urban development projects.

1.3 Research Objectives

This thesis aims to support urban decision-makers towards successful implementation of smart energy city development at the urban scale in Europe. To this aim, the more specific research objectives are framed in three levels: (*i*) conceptual analysis, (*ii*) empirical investigation, and (*iii*) learning methodologies for the new developments.

(*i*) Conceptual analysis

1. Conceptualizing smart city
2. Defining smart energy city in urban development

(*ii*) Empirical investigation

3. Identifying and prioritizing barriers to the implementation of SEC projects at the urban scale within Europe

(*iii*) Learning methodologies for new developments

4. Testing the application of case-based learning methodology to predict barriers to the implementation of new SEC projects, using the past experiences
5. Testing the application of decision tree learning methodology to predict barriers to the implementation of new SEC projects, using the past experiences

1.4 Research structure

Based upon research objectives, the main body of the thesis is structured in three main parts (Figure 1.1). Part II deals with conceptual analysis of SEC development. More specifically, Chapter 2 conceptualizes smart city through an extensive review and analysis of scientific, governmental, and industrial literature. This sets the context for Chapter 3, which provides a multi-dimensional and comprehensive definition of smart energy city development from urban planners' perspective. This definition shapes the basis for the following parts of the thesis. Part III deals with empirical investigation of SEC development. In particular, Chapter 4 investigates a set of past SEC projects (introduced in Appendix 1), and identifies the barriers to implementation of SEC development at the urban scale in Europe. In addition, Chapter 4 suggests and applies a novel multi-dimensional methodology for prioritization of identified barriers. Part IV deals with methodologies for learning from the past experiences in order to predict barriers for a new SEC development. In particular, Chapter 5 suggests and tests a case-based learning methodology to support decision-makers to predict barriers to the implementation of a new SEC project, based on the projects internal similarities. Chapter 6 suggests and tests the application of decision trees to find the association rules between barriers and SEC project internal and external characteristics. Based on identified association rules, it predicts barriers to a new SEC project.

Finally, a general discussion is provided in Part V, Chapter 7, reviewing the results of the main chapters, showing how the findings –joint together– address the main aim of the thesis, deriving the key conclusions, and suggesting directions for future studies.

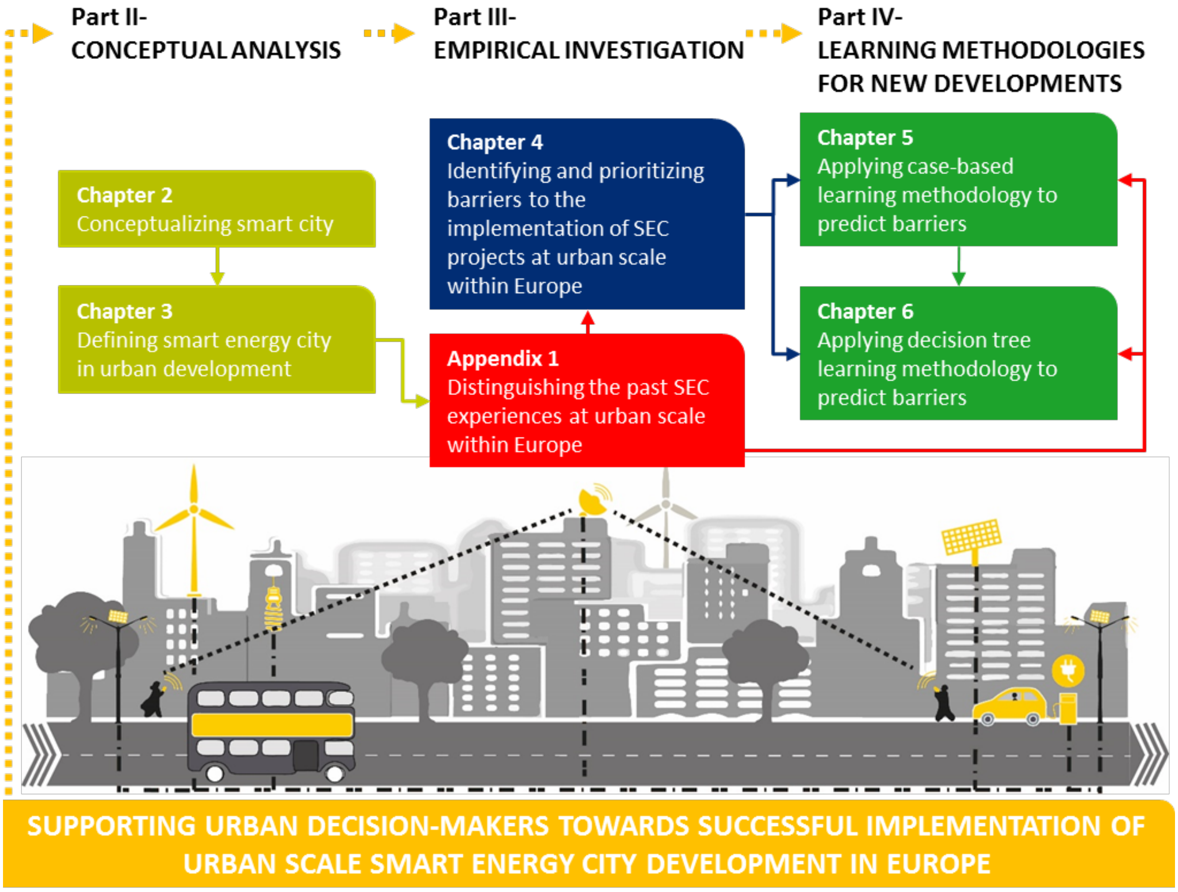

Figure 1.1 Overview of the thesis structure based on the specific research objectives (boxes on top of the schematic illustration of smart energy city). The orange box at the bottom of the picture states the main aim of the thesis.

Part II

Conceptual Analysis

Chapter 2

Defining Smart City: A Conceptual Framework Based On Keyword Analysis

Based on:
F. Mosannenzadeh, D. Vettorato (2014) Defining smart city: a conceptual framework based on keyword analysis, *Tema, Journal of Land Use, Mobility, and Environment*, special issue, June 2014.

Summary of the chapter

The smart city is a concept that has been the subject of increasing attention in urban planning and governance during the past 20 years. The first step to creating a smart city is to understand its concept. However, a brief review of the literature shows that the concept of the smart city is the subject of controversy. Thus, the main purpose of this chapter is to provide a conceptual framework to define the smart city. To this aim, an extensive literature review was done. Then, a keyword analysis on literature was held against main research questions (why, what, who, when, where, how) and based on three main domains involved in the policy decision-making process and smart city plan development: academic, industrial and governmental literature. This resulted in a conceptual framework for the smart city. The results clarify the definition of the smart city while providing a framework to define each sub-system of the smart city. Moreover, urban authorities can apply this framework to smart city initiatives in order to recognize their main goals, main components, and key stakeholders.

2.1 Introduction

Smart city is a concept that has been the subject of increasing attention in urban planning and governance during past 2 decades (e.g. Anthopoulos and Vakali, 2012; Leydesdorff and Deakin, 2011; Washburn et al., 2009). It is a response to recent urban challenges, such as rapid expansion of urban population, the 70% share of cities in global energy consumption and greenhouse gas emissions, economic competitiveness, and rising citizen’s expectations (Washburn et al., 2009). Meanwhile, it exploits new opportunities such as growing information and communication technology (ICT) advancements (Lee et al., 2013). However, some experts cast doubt on some smart city initiatives by introducing them as a celebratory label (see Hollands, 2008).

The first step towards the creation of a smart city is to understand its concept. A brief review of literature on smart city definition shows there are still many open questions that refer to following issues:

- The necessity of creation of smart city (why?)
- The main aspects of smart city (what?)
- The key actors in smart city (who?)
- The ways to create smart city (how?)
- The right time and place to create a smart city (when? and where?)

Answering these questions helps to clarify the definition of the smart city. Thus, this chapter aims to provide a conceptual framework for the smart city. The objectives are to understand why it is necessary to create a smart city. What are the main components of a smart city? Who are the key actors to create a smart city? How to create the smart city? When to create the smart city? And where to create the smart city?

2.2 Methodology and procedure

In order to answer the questions related to the definition of the smart city concept, an extensive literature review is held. Following Onwuegbuzie et al. (2012) the literature review and the keyword analysis were chosen as tools for analyzing and interpreting literature sources, taking into consideration both scientific and gray literature. The sources have been divided into three main domains, involved in the policy decision-making process and plan development of the smart city development: academic, industrial and governmental.

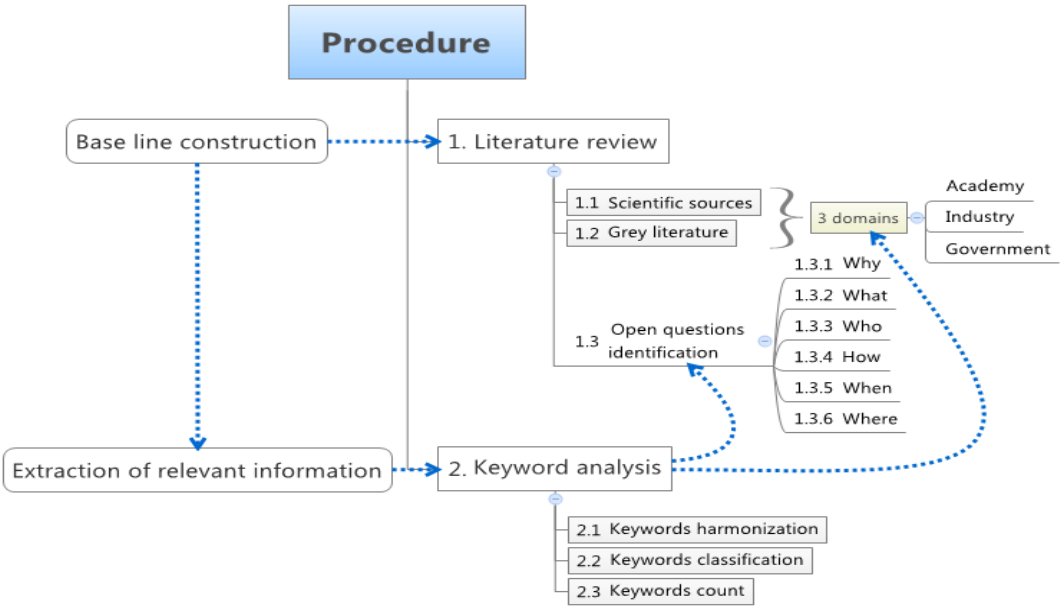

Figure 2.1 Research procedure

A keyword analysis (Onwuegbuzie et al., 2012) was used to extract relevant information from the analyzed literature. This resulted in a conceptual framework for the smart city that identified different sub-systems of the concept. The research procedure scheme is presented in Figure 2.1.

2.3 State of the art: an overview of the smart city definition in literature

There are various definitions of the smart city in literature and the phrase "smart city" has been used in many different situations and by different stakeholders (e.g. Hollands, 2008; Lee et al., 2013; Rios, 2012). The research presented in this chapter analyzed existing literature on the topic in order to provide a framework to define the Smart city concept. Reviewing the literature shows that the concept of the smart city has been developed in three main areas: (i) academic, (ii) industrial, and (iii) governmental. Reviewing these literature shows two important points: first, the meaning of smart city is not settled yet; however, there is an agreement on the significant role of ICT in smart urban development. A simple keyword analysis of existing literature shows the disparity of words used in different definitions which are a sign of controversy in the concept.

Second, a difference of viewpoints exists between the three domains (academic, industrial, and governmental). It derives from the different interests of each domain, as well as diverse interpretation of the word "Smart". In academic literature, with an interest in knowledge and information development, the meaning of "Smart" covers a range of technological characteristics, such as self-configuring, self-healing, self-protection, and self-optimizing (Nam and Pardo, 2011). In industrial literature with a tendency in business and industrial instruments, “smart” refers to intelligent-acting products and services, artificial intelligence, and thinking machines (Nam and Pardo, 2011). Finally, governmental documents, which aim to manage urban development, interpret “smart” with regard to an urban planning theory, “smart growth”, which was emerged in the United States in the early 90s to avoid urban sprawl (Herrschel, 2013). Smart growth supports compact, mixed-use and walkable cities and aims to make development decisions predictable, fair and cost-effective. It encourages community and stakeholder collaboration in development decisions (US EPA, 2014).

Smart city definition in the three domains has the same logic. In academic literature, including publications of scientific journals and universities, smart city concept has been applied to cover a wide range of characteristics being very detailed in some cases (Winters, 2011), and very general in some others (Canton, 2011) (Table 2.1). In spite of this variety in definitions, the use of technology and social innovation seems to be the core issue in the concept. An example is the Smart Vision illustrated by Moss Kanter and Litow (2009): *Someday soon, leaders will combine technological capabilities and social innovation to help produce a smarter world.* One of the most influential definitions in academic literature is presented by Giffinger et al. (2007, p. 11): “*A smart city is a city well performing in a forward-looking way in six characteristics. It is built on the ‘smart’ combination of endowments and activities of self-decisive, independent and aware citizens*.”

In Industrial literature, including publications of some international corporations such as ENEA, IBM, and CISCO, some more practical values have been added to the concept. IBM’s idea of smart city considers cities as systems of systems. It defines smart city as one that uses technology to transform its core systems and optimize the return from largely finite resources. Smarter cities make their systems *instrumented*, *interconnected* and *intelligent* (Dirks and Keeling, 2009). Instrumented means to digitize systems in order to make their function measurable and to create information. Interconnected means that different parts of a core system can communicate information to each other; and intelligent refers to the ability to use the information to create behavioral patterns and anticipations in order to establish informed actions (Dirks and Keeling, 2009).

Finally, the third domain includes governmental literature, published by urban public authorities and aim to transform cities to smart city. This literature has more emphasize on the administrative and financial aspects of the smart city, as well as the importance of meeting global energy and environmental targets such as energy efficiency and greenhouse gas emissions.

Table 2.1 Smart city definitions by academic literature

Definition	*Reference*
A city that monitors and integrates conditions of all of its critical infrastructures, including roads, bridges, tunnels, rail/subways, airports, seaports, communications, water, power, even major buildings, can better optimize its resources, plan its preventive maintenance activities, and monitor security aspects while maximizing services to its citizens.	Hall (2000)
A smart community initiative becomes an integrated approach to helping entire communities go on-line to connect local governments, schools, businesses, citizens, and health and social services in order to create specific services to address local objectives and to help advance collective skills and capacities. In the same spirit, the optimum use of ICT is presented rightly as an essential element of smart communities but has a tendency to become the deus ex machina from which collective intelligence and social learning stem.	Coe et al. (2001)
A Smart city or region is one that capitalizes on the opportunities presented by ICT in promoting its prosperity and influence.	Odendaal (2003)
The percentage of the adult population that holds bachelor’s degrees.	Glaeser and Berry (2006)
A smart environment is an environment that is able to acquire and apply knowledge about its inhabitants and their surroundings in order to adapt to the inhabitants and meet the goals of comfort and efficiency.	Marsa-Maestre et al. (2008)
The Smart city provides new instrumentation that enables observation of urban systems at a micro-level.	Harrison and Donnelly (2011)
“Smart city” would be metropolitan areas with a large share of the adult population with a college degree.	Winters (2011)
Key conceptual components of the smart city are three core factors: technology (infrastructures of hardware and software), people (creativity, diversity, and education), and institution (governance and policy). Given the connection between the factors, a city is smart when investments in human/social capital and IT infrastructure fuel sustainable growth and enhance a quality of life, through participatory governance.	Nam and Pardo (2011)
The Smart city concept is connected to notions of global competitiveness, sustainability, empowerment and quality of life, enabled by broadband networks and modern ICTs. Its implementation requires the development of migration paths regarding Internet infrastructures, test bed facilities, networked applications, and stakeholder partnerships.	Komninos et al. (2011)
The Smart city is one that will use advanced technology and sciences – computing, neuroscience, nanoscience, and information science – to address the challenges of the future of the city such as energy, health, safety, and commerce.	Canton (2011)
Smart city applies the capacities that recent intelligent cities have sought to develop as the technical platform across a host of service-related domains. At this stage of development the point of emphasis and intervention begins to shift from innovation to application, from the back-office to front-line services, and in policy terms, the emphasis also shifts from the corporate to the civic, from the market to the community, and from the bureaucratic administration of the economy to a liberal democratic governance.	Allwinkle and Cruickshank (2011)
The Smart city is a new way of leaving and considering the cities. The optimization of available and new resources, as well as of possible investments is required. The achievement of smart city objective can be reached through the support of various information and communications technologies. These can be integrated in a solution considering the electricity, the water, and the gas consumptions, as well as heating and cooling systems, public safety, wastes management and mobility.	Lazaroiu and Roscia (2012)
A Smart city is a synthesis of hard infrastructure (or physical capital) with the availability and quality of knowledge communication and social infrastructure. The latter form of capital is decisive for urban competitiveness…smart city is also instruments for improving competitiveness in such a way that community and quality of life are enhanced.	Batty et al. (2012)
The “Smart city" concept essentially advocates the integration of the components of an urban energy system (supply, distribution and demand; thermal, electrical and gas networks; heat and electricity generation; energy providers and end-users; planners, developers, policymakers and investors) to make it more energy efficient, less carbon intensive and more robust. This applies to the planning and implementation of the system (or more precisely of its transition towards becoming a "smart" urban energy system) as well as to its operation. In all cases, monitoring plays an essential role.	Pol et al. (2012)
The concept of the Smart city of which there are many initiatives, projects, and demonstrators, is generally underpinned by one or more ambient systems parts that require a mediation process to deliver the interconnectedness required by an ambient system.	Gui and Roantree (2012)
a city that is managed by a network and which supplies its citizens with services and content via the network using both fixed and mobile Smart city infrastructure, based on high-performance ICT.	Lee et al. (2013)

The most effective governmental literature is published by “The Smart City Stakeholder Platform” (SCSP), initiated by the European Commission (EC, 2014a) in order to identify and spread relevant information on Smart city for both practitioners and policy makers (EC, 2014b). In the “10 year rolling agenda”, published by Smart city Stakeholder Platform’s Roadmap Group, Egenhofer and Saritas (2013, p. 5) state that *Smart city are meant to increase the quality of life of city-dwellers; enhance the efficiency and competitiveness of the local and European Union economy; and move towards the sustainability of cities by improving resource efficiency and meeting emission reduction targets*. This document recognizes the integration of ICT in different urban sectors as the core of this objective and emphasizes on the importance of highly integrated systems on various scales: from residential to national scale.

To summarize, Smart city definitions are various due to the diverse interests of different stakeholders. A common definition of the smart city is not yet established; however, a brief review of literature implies that smart cities are future urban areas that aim to help human beings overcome their problems. They use ICT to improve urban functions in its different aspects and they require the collaboration of urban stakeholders. A better understanding of the concept requires detailed investigation. Thus, in the following sectors of this chapter, the definition of the smart city is investigated in a more detailed and systematic way.

2.4 Keyword analysis

The keyword analysis was done in three parallel ways. First, each definition was categorized into three main domains of (i) academic, (ii) industrial, and (iii) governmental. Then, each definition was analyzed against the six questions of the study (why, what, who, where, when, and how). Then, the keywords were derived and the repetition of each keyword was counted, divided by each category and group. It is important to acclaim that in some cases, different keywords referred to a similar meaning (e.g. the meanings of the keywords “technology”, “IT”, and “ICT” are alike). Thus, in order to harmonize the definitions and make the keyword analysis meaningful, the keywords were not automatically derived by software, but derived and harmonized by the authors. For instance, for the mentioned example, the authors chose “ICT” as the most repeated and the representative keyword.

2.4.1 Why creating smart city is necessary?

Recent rapid growth in urban population, along with economic and technological changes caused by the globalization, has led to many challenges as well as opportunities for cities services and infrastructure. These are one of the main drivers for smart city development. Smart city aims to decrease cities’ challenges, including scarcity of resources (such as energy, healthcare, housing, and water), inadequate and deteriorating infrastructure (like drinking water, energy, roads, schools, and transportation), energy shortage and price instability, climate change, and demand for better economic opportunities and social benefits (Washburn et al., 2009).

On the other hand, the smart city aims to exploit recent opportunities provided by recent changes in the world. Cities are the locations of physical capital as well as human capital concentration. This attracts business activities and transforms cities to centers of global competitiveness. This is aligned with the global political transformation from nation-state model towards more multi-level governance, which gives cities more power and freedom to act. Moreover, recent advancements in ICT, aligned with technology cost reduction, such as cheap mobile apps, free social media, cloud computing, and cost-effective ways to handle the high volume data, provide cities with better opportunities and tools to understand, communicate, and predict urban functions (Berst et al., 2014; Dirks and Keeling, 2009).

Table 2.2 presents the most repeated keywords on Smart city main goals and drivers divided based on literature in three main domains (academic, governmental, industry). It shows that academic literature has a holistic approach and covers a wider range of issues. It is mostly concentrated on improvement in three main aspects: governance, community/social development, and the environment. In industrial point of view, the smart city emerges mainly due to the interaction between competitiveness and sustainable urban development. In addition efficiency and sustainable environment and community/social development are amongst smart city main objectives. Finally, governmental literature is more concerned with international challenges including quality of life, economic growth, environment, energy, sustainability, health and safety, and mobility.

Table 2.2 Keyword analysis: why?

Academic	*Industry*	*Governmental*	*Total*
Improved Governance	Economic growth	Quality of life	Economic growth
Community/social development	Sustainability	Economic growth	Sustainable environment
Sustainable environment	Efficiency	Sustainable environment	Sustainability
	Sustainable environment	Sustainability	Quality of life
	Community/social development	Improved Mobility	Improved Governance
		Health and Safety	Community/social development
		Energy	Efficiency
			Improved Mobility
			Health and Safety

2.4.2 What are the main components of the smart city?

By the components of the smart city, we mean the most important urban domains in creating the smart city. These are the main targets for stakeholders to put in their attention and investment. Giffinger et al. (2007) indicate different domains of smart city as the economy, people, environment, governance, mobility, and building. While Dirks and Keeling (2009) has a more practice-oriented division. It defines main components (systems) of smart city as people, business, transport, communication, water, and energy. Berst et al. (2014) consider different smart city domains, universal aspects, built environment, energy, telecommunication, transportation, water and wastewater, health and human services, public safety, and payments.

Table 2.3 Keyword analysis: what?

Academic	*Industry*	*Governmental*	*Total*
Economy	Transportation	Transportation	Services
Environment	Energy	Energy	Transportation
Community	Buildings	Buildings	Community
Governance	Services		Governance
Infrastructure			Energy
			Buildings

Table 2.3 presents the most repeated keywords on Smart city main components, divided based on literature in three main domains (academic, governmental, industry). As it is seen, the academic literature has a more holistic but general view about the main smart city components, while industrial and governmental literature have a more practical and short-term approach. They mainly concentrate on urban sectors that can be directly affected by urban authorities, such as transportation, energy, and buildings.

The aggregation of keywords for all three domains results in the most repeated components: services, transportation, people, governance, energy, and buildings. In addition, there are other important keywords in literature with lower repetition: health, safety, mobility, environment, education, economy, infrastructure, and water. However, further analysis is required to identify smart city main components. For example, transportation is a sub-sector of mobility, and energy could be a sub-system of the natural environment. These inter-relationships lead us to choose the following sectors as the main components of smart city: government, mobility, services, community, economy, natural environment, and built environment.

In this study, governance means administrative and organizational part of the city. Mobility mainly includes soft and hard networks such as transportation network and the internet. Services mainly include health and safety. Community means the people and neighborhoods in terms of innovation and creativity. Economy includes the economic domain of the city including the market of the smart city. Natural environment mainly includes water and energy, and finally, built environment is mainly buildings.

2.4.3 Who is involved in the creation of Smart city?

The main actors in the creation of smart city are those who have an active engagement in the creation of the smart city. Leydesdorff and Deakin (2011) introduce University, industry, and government as three main actors of the smart city whose functions are subsequently organized knowledge production, economic wealth creation, and reflexive control. Later, Lombardi et al. (2012) revised Triple-helix by introducing Civil Society as the fourth main actor. Aoun (2013) in a publication by "Schneider electric" states that smart city involves business and local stakeholders, with city leadership. It introduces governments, private investors, industry suppliers, non-governmental organizations (NGOs) and associations, utilities, and planners and developers as different stakeholders of the smart city. These stakeholders should collaborate to achieve smart city.

CONCERTO, a European Union initiative, suggests that in order to create the smart city, policy makers should bring all actors together, including investors, local authorities, material suppliers, designers, urban planners, developers, energy utilities, contractors, engineers, tenants, and owners (Bahr, 2013).

Table 2.4 presents the keyword analysis of different domains about main stakeholders involved in the creation of the smart city. This table shows that academic literature presents a holistic and general point of view. The keyword analysis for academic literature shows four main groups as the key actors of smart city: people, companies/industries, government, and university. This is while industrial literature has a more detailed and practical approach by adding NGOs, investors, planners and developers, contractors, etc.

Table 2.4 Keyword analysis: who?

Literature	*References*	*People*	*Companies*	*Government*	*Built infrastructure*	*University*	*Private investors*	*NGOs*	*Planners*	*Industry suppliers*	*Utilities*	*Contractors*
Academic	Cosgrave et al. (2013)	*	*									
	Yovanof & Hazapis (2009)	*	*	*								
	Leydesdorff & Deakin (2011)		*	*		*						
	Lombardi et al. (2012)	*	*	*		*						
Industrial	Aoun (2013)		*	*	*		*	*	*	*	*	*

Governmental documents, especially those related to real practices, have the most precise and practical point of view. Smart city Stakeholder Platform (see EC, 2013), for example, considers all the following groups as smart city key stakeholders: mayors/politicians, city administration, utilities, energy service companies, network operators, developers, architects, planners, construction companies, industries, component manufacturers, renewable energy industry, ICT companies, financial institutions, research and development institutes and universities, and inhabitants.

To summarize, the literature suggests four main groups of stakeholders involved in the creation of smart city: people, government, companies/industries, and universities. In addition, some lateral groups of planners, developers, financing organizations and NGOs are also involved in smart city development. Each of these groups consists of many stakeholders. For example, government includes local/regional policy makers and authorities, municipal authorities, and other municipal and administration authorities.

2.4.4 How to create the smart city?

Answering how to create smart city might be the most important part of conceptualizing the smart city. While most literature in all three domains agrees on the important role of ICT in smart city development (e.g. Lee et al., 2013; Odendaal, 2003), they emphasize that technology is not solely enough (Hollands, 2008); to create smart city, governmental, social, economic, and environmental aspects should get smart as well (Giffinger et al., 2007; Hollands, 2008; Pol et al., 2012).

The keyword analysis confirms the central role of ICT-based infrastructure and services in smart city creation. Different domains are briefly unanimous on the main ways to develop the smart city. However, industrial literature has a more instrument-based approach (Dirks and Keeling, 2009) and governmental literature emphasizes on proactivity and necessity of creating metrics in order to measure the function of urban systems (Moss Kanter and Litow, 2009) (see Table 2.5).

To summarize, the application of ICT in urban services and infrastructure is the core to achieve smart city. Meanwhile, ICT is not enough; it should be combined with other strategies: investment in social capital, the collaboration of different stakeholders, and integration of different components of the city. This requires gathering data and knowledge in all domains and of all stakeholders, and communicating this data through a comprehensive and interconnected urban network in order to have an integrated collaborative urban development.

Table 2.5 Keyword analysis: how?

Academic	*Industry*	*Governmental*	*Total*
Technology/ICT (mainly in infra & services) Collaboration Integration (interconnection) Gather data/knowledge Social capital	Technology/ICT (mainly in infra & services) Collaboration Social capital	Technology/ICT (mainly in infra & services) Collaboration Social capital Proactivity Metrics	Technology/ICT (mainly in infra & services) Collaboration Integration (interconnection) Gather data/knowledge Social capital

2.4.5 When to create the Smart city?

The results of the keyword analysis show no serious concerns about the timing of smart city development. The most common time reference in definitions of the smart city is the “future” (e.g. Canton, 2011; Hall, 2000; Komninos et al., 2011), which means there has been no time limit for creation of the smart city. This could be due to the continuous nature of smart city (Aoun, 2013).

2.4.6 Where to create the Smart city?

Which cities can get smart? Are there some criteria such as the size of the city, the level of technological development and policy and legal framework that is required to get smart? According to the literature, since smartness is a continuous improvement of urban situations, each city can be smarter (Aoun, 2013). Obviously, many factors can accelerate or hinder this "continuous improvement". For example, existing policy frameworks for smart city, recent practices in the integration of technology in urban infrastructure, and high level of technology advancement in a city can lead to better success in smart development. However, there is no absolute limitation against the implementation of the smart city.

2.5 A conceptual framework for smart city

With respect to the analysis, a conceptual framework for the smart city is provided (Figure 2.2). The first layer (yellow ring in Figure 2.2) answers why it is necessary to create the smart city. The second layer (blue ring in Figure 2.2) answers what are the main components in the creation of the smart city. The third layer (green ring in Figure 2.2) answers who are the main stakeholders involved in the creation of the smart city, and finally, the fourth layer (purple boxes in Figure 2.2) answers how to create the smart city. According to the analysis, each city can be smart in the future (the answer to when and where to create smart city).

Thus, smart city is a sustainable and efficient city with high quality of life that aims to address urban challenges (improve mobility, optimize use of resources, improve health and safety, improve social development, support economic growth and participatory governance) by application of ICT in its infrastructure and services, collaboration between its key stakeholders (citizens, universities, government, and industry), integration of its main domains (environment, mobility, governance, community, industry, and services), and investment in social capital.

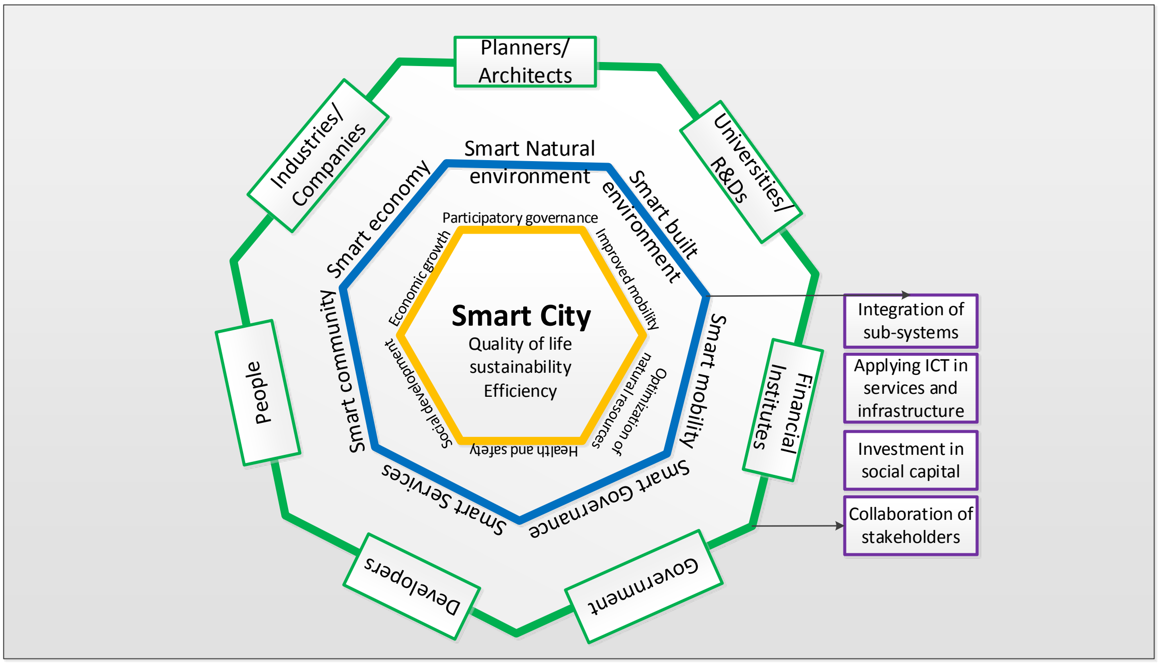

Figure 2.2 A conceptual framework for smart city

2.6 Discussion and conclusions

Smart city is a holistic approach that aims to address recent urban challenges and exploit recent opportunities provided by advancements in ICT and urbanization. The first step to creating smart city is to understand the nature of the concept. This chapter provided a framework to conceptualize smart city by holding a keyword analysis to find the most used phrases in existing literature. However, it is not necessary to stick to the proposed keywords. Since each city has its unique economic, social and administrative situation, as well as different priorities, we suggest that authorities keep the main structure as the basis of the conceptualization, and then regenerate their own concept with respect to their priorities and context. Nevertheless, application of ICT in urban services and infrastructure, integration of different systems in planning and implementation, the collaboration of different stakeholders in all the stages of urban development, and investment in social capital and innovation are basic alphabets of smart city concept.

Thus, creating smart city, it is necessary to identify the main goals of smart city plans (why), the main sub-systems and their relationships (what), and the key stakeholders involved in the plans (who). Then, application of ICT to enhance the functionality of urban services and infrastructure, integrated planning and implementation of sub-systems, and collaborative work between stakeholders (how) should be considered to create a smart city. It is also important to carefully consider the temporal (when) and spatial (where) dimensions of smart city plans.

This research is based on literature review as the main source of information. Further development could include also other sources like interviews with experts in order to confirm or discuss the results of this work. Another development could analyze specific sub-systems of the smart city concept that emerged from this work (e.g. smart energy city).

Chapter 3

Smart Energy City Development: a Story Told by Urban Planners

Based on:
F. Mosannenzadeh, A. Bisello, R. Vaccaro, V. D'Alonzo, G. W. Hunter, S. Pezzutto, D. Vettorato. Smart energy city development: a story told by urban planners (under review, journal of *Cities*)

Summary of the chapter

Smart energy city is an emerging concept in urban development, aiming to optimize urban energy systems and improve quality of life for citizens. However, smart energy city development requires a well-defined and consistent conceptual core in order to ensure its accurate interpretation and successful implementation. This research aims to define smart energy city development not only in a theoretical context but also in terms of practical solutions. We adopt the 5W+1H (why, what, who, where, when, how) model integrated with literature review and expert knowledge elicitation, i.e. focus groups and interviews. This results in (i) clarification of general interrelationship between smart energy city, smart city, and sustainable city; (ii) a multidisciplinary and comprehensive conceptual framework of smart energy city, revealing its principles, objectives, domains of intervention, stakeholders, time and spatial scale; and (iii) a set of smart energy practical solutions and technologies categorized in the six domains of intervention: buildings and districts, transportation and mobility, energy and information and communication technology infrastructures, collaborative planning, consumer behaviour management, and energy and data management. We suggest that sustainable application of information and communication technology, collaboration of multiple stakeholders, and integration of multiple urban energy domains, mainstreamed in energy specific targets, allow distinguishing real from labelled smart energy city development. We suggest that smart energy solutions are mostly effective, when combined with other sustainable solutions. This research is applicable for all smart energy city stakeholders, particularly decision-makers and researchers, in order to enhance a common and comprehensive understanding of the smart energy city concept and its practical solutions in order to foster sustainable smart energy city development.

3.1 Introduction

Smart energy city (SEC) is an emerging urban development strategy in Europe. It is aimed at assisting cities to exploit recent opportunities in technology and economy in order to provide citizens with a better quality of life, while addressing urban energy challenges such as climate change, shortage of energy resources, and inadequate and deteriorating energy infrastructure (Coe et al., 2001; Washburn et al., 2009).

Appearance of multiple SEC initiatives in European cities lacks a well-defined conceptual basis (Hollands, 2008; Söderström et al., 2014; Vanolo, 2014). This creates confusion in devising SEC strategies and plans, and allows distorted or simplistic interpretation and application of the concept (Vanolo, 2014). A simplistic approach arises when cities label themselves "smart" as they utilize some types of Information and Communication Technology (ICT) solutions (Hollands, 2008); while scholars emphasize that smartness is beyond solely application of technology or ICT solutions (Coe et al., 2001; Hollands, 2008; Nam and Pardo, 2011). Therefore, a common and comprehensive concept for SEC development is necessary to ensure its correct and successful design and implementation.

Current academic literature on SEC concept has approached the topic under three general perspectives. The first accepts SEC as a "good thing" per se and seeks to actualize it through technological solutions for specific problems that affect the urban energy systems (e.g. Chai et al., 2013; Krajačić et al., 2011). The second accepts eligibility of SEC as well; however, it attempts to define and analyze SEC in a holistic way by considering its different components, aims and characteristics (Belanger and Rowlands, 2014; Chai et al., 2011; Nielsen et al., 2013). The third, conversely, criticizes the concept of smart city in general (which is extendable to SEC as well) and alarms about the risks and challenges implicit in blindly acceptance of distorted smart city interpretations (Hollands, 2008; Söderström et al., 2014; Vanolo, 2014). Considering these three perspectives, following main gaps and concerns in SEC development arise.

The genealogy of the concept and its components are not clear and validated (Kitchin, 2014). Söderström et al. (2014) doubt the concept as a story told by IBM, which positions IBM and similar ICT companies as inevitable key actors in cracking urban problems. This highlights a need to define SEC from a coherent point of view, with a holistic and multi-disciplinary scope that puts public benefit as the first priority in short to long term (Söderström et al., 2014). In addition, the boundaries between SEC (as a component of smart city) and sustainable city are nebulous (Hollands, 2008; Kitchin, 2014). It is not clear if SEC is a new label substituting sustainable city; or if it is a distinct technological vision overlapping with it (see Tregua et al., 2015).

The sustainability of the SEC development is the subject of concern as well. Social, economic and environmental impacts of SEC development have received skepticism, particularly because it emphasizes on application of technology and ICT (Viitanen and Kingston, 2014). Holland (2008) concerns that smart cities (and therefore, SEC) will lead to marginalizing traditional communities and poorer residents that have limited access to schooling and technology. Viitanen and Kingston (2014) concern about an increase in e-waste if SEC is instrumented by technology and ICT, considering the short shelf-life of technologies and the desire of end-users to upgrade.

SEC discourse raises further concerns, including the reduction of urban future to a single technology-centric vision that ignores other non-technological but creative and effective solutions to urban problems (Vanolo, 2014); underestimation of dissimilarities between cities by indicating prefabricated solutions that should work for all SEC developments; and a lack of dialogue and collaboration between stakeholders (Kitchin, 2014).

Finally, the connection between the general SEC theoretical definition and the specific and detailed practical solutions is not well-clear (Kitchin, 2014). Consequently, urban decision-makers and planners ask for a better understanding on how to locate SEC practical solutions in the wide SEC concept.

With respect to the mentioned concerns, we aim to develop the concept of SEC development from the urban planners' perspective and at a European scale, following three objectives: first, briefly clarifying the general interrelationship between SEC, smart city, and sustainable city; second, developing a theoretical definition of SEC development that considers sustainability evaluation, reflects location specificity, and recognizes SEC key stakeholders and the dialogue between them; and third, understanding how SEC practical solutions and technologies with high level of technicality can fit in the SEC comprehensive and general theoretical context.

The present investigation retreats and develops the concept of smart energy city briefly presented within the Deliverable 2.1 "SWOT analysis report of the refined concept/baseline" of the FP7 SINFONIA project (Pezzutto et al., 2015). This chapter is structured as follows: in section two, research methodology is illustrated. In sections three, four, and five, the three research objectives are addressed sequentially. Section 6 concludes the chapter by pointing out open discussions on the research results and suggestions for further investigations.

3.2 Methodology

Since SEC concept is not totally explored and development of its concept in two layers of theory and practice is required, we targeted both literature and experts for knowledge elicitation (following Shadbolt and Smart, 2015). The detailed explanation of methodology to address each objective is presented as follow.

3.2.1 Clarifying interrelationship between smart energy city, smart city, and sustainable city

To address the first objective, we reviewed the scientific literature using three sets of search terms: [(“smart city” OR “smart energy city”) AND (definition OR concept* OR defining)], [“sustainable city” AND (definition OR concept* OR defining)], [(smart AND sustainable) AND (city OR urban OR planning)]. Similar to Payne and Frow (2005), the literature review shaped the basis for expert focus groups. Expert focus group method is appropriate because it has a better performance than individual interview in generating “original” responses and perform at least as good as individual interviews concerning “quality” and “acceptance” of responses (Massey and Wallace, 1991). Following Massey and Wallace (1991), a small and diverse group was selected – i.e. six experts with international academic and professional experience in urban and regional planning, environmental and energy planning, building engineering, energy economics, and transportation planning, from Iran, Jamaica, India, China, Austria, Germany and Italy. A regular series of expert focus group meetings (2 to 4 meetings per month) was possible continuously and in the long-term (March to October 2015) because at the time of working on this research, the experts were all involved at Research Group of Urban and Regional Energy Systems in the Institute for Renewable Energy in European Academy of Bolzano/Bozen (EURAC). EURAC is a leading research institute in Europe with more than 400 employees and is involved as a (leading) partner in multiple European and international energy projects (EURAC, 2016).

3.2.2 Developing a theoretical definition

To address the second objective, we applied the model 5W+1H (why, what, where, who, when, how) adopted in Chapter 2 of the here presented thesis and Jia et al. (2015). The 5W+1H model leads to the following detailed questions: why SEC development is required (objectives)? What are SEC main domains of intervention (key target fields)? Who are SEC key stakeholders? When is the time for SEC development? Where is the right place for it? How to ensure SEC development (principles)?

We held a systematic review of literature in three main domains: academia, European policies (e.g. European Strategic Energy Technology Plan, or European Innovation Partnership on Smart Cities and Communities-Operational Implementation Plan (EC, 2014c)) and actual previous experiences in SEC development (e.g. European Union CONCERTO projects (CONCERTO, 2015b)). The literature review included two sets of search terms: [“smart energy” AND (city OR concept* OR definition OR defining OR network)], [(“smart city” OR “smart energy city”) AND (stakeholder OR actor OR aims OR objectives OR goals OR time OR place OR method*”)]. Similar to the previous section (2.1), the literature review provided the basis for six expert focus groups, one for each question. The results of the focus groups were aggregated and presented for discussion and amendment in two other sessions, which resulted in an explanatory text for the concept of SEC development. In the three next sessions, we provided a visual scheme for the concept.

3.2.3 Understanding smart energy solutions within the theoretical context

The results ascertained in the first phase provided the analytical framework of the second phase, which was developed following two explicit questions: what are notable smart energy solutions and technologies in each SEC domain of intervention? What is the spatial scale for each solution?

Similar to the previous section, the questions were answered by a review of both scientific and gray literature for smart energy solutions in each domain of intervention, searching for terms [(“smart city” OR “smart energy”) AND (solution* OR technolog*”] and [smart AND (building OR district OR mobility OR transportation OR grid OR network OR governance OR planning)]. Due to limitation of publications on the topic and high level of technicality of solutions, we combined literature review with six semi-structured expert interviews, including open questions referring to the predefined domains and sub-domains of solutions (see section 4.3). In order to cover all identified domains, six experts were selected from technical research groups of EURAC research Institute of Renewable Energy (i.e. Sustainable Heating and Cooling Systems, Photovoltaic Energy Systems, Energy Efficient Buildings, Energy Retrofit of Historic Buildings, and Urban and Regional Energy Systems). They possess the following technical and professional expertise: sustainable energy in buildings and districts, heating and cooling systems, digital signal processing for smart grid, photovoltaic production and grid integration, electro-mobility and sustainable mobility, energy strategies and planning, low carbon policies and technologies. Each interviewee was presented with the results of the first phase; then, they were asked to name and categorize SEC solutions applied technologies and spatial scale of each solution. The results of interviews and literature review were aggregated in one synoptic table of SEC solutions and referred to the experts for validation and revision. The result was discussed, revised and validated in two meetings with the research group leaders of EURAC Institute of Renewable Energy to arrive at the final list of solutions.

3.3 Interrelationship between smart energy city, smart city, and sustainable city

SEC is a component of smart city (Lazaroiu and Roscia, 2012; Nielsen et al., 2013), overlapping and interacting with other smart city components such as governance, mobility, economy, and community (Giffinger et al., 2007). The general position of SEC to sustainable city is therefore deductible from interaction between smart city and sustainable city. Shmelev and Shmeleva (2009, p. 10) define sustainable city as "*a holistic system, in which social, economic, environmental and institutional aspects of development are harmoniously integrated*".

Reasoning as follows, we understand that smart city is (ought to be) a component of sustainable city. Berardi (2013) discusses that sustainable is different from energy efficient, green [and smart]; in fact, sustainability includes more dimensions; for example, sustainable city includes more solutions compared to smart city. That is because smart city solutions are traditionally characterized by application of ICT (as indicated in Chapter 2), while sustainable solutions might or might not be ICT-based. Besides, sustainability of cities is relevant even without considering smart city approaches (Tregua et al., 2015). However, according to our understanding, and although not always recognized (Hollands, 2008), smart city is firmly connected to sustainability: on one hand, smart city aims to contribute to sustainability of urban areas (Khansari et al., 2014; Nam and Pardo, 2011); on the other hand, smart city, similar to every urban development, ought to meet sustainability requirements. Based on this knowledge, we conclude that sustainable city is a concept more extensive than smart city (Figure 3.1). Specifically, we define smart city as a cutting-edge urban development strategy that contributes to urban sustainability.

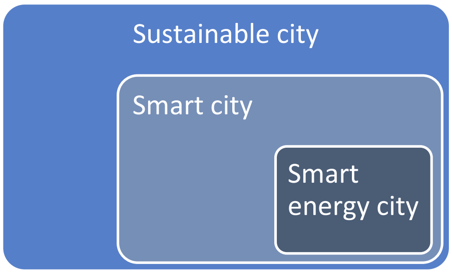

Figure 3.1 The relationship between smart energy city, smart city, and sustainable city

3.4 A theoretical definition of Smart Energy City development

Integrating and synthesizing six aspects of SEC development (i.e. why, what, who, where, when and how) we define SEC development as following.

Smart energy city development is a component of smart city development aiming at a site-specific continuous transition towards sustainability, self-sufficiency and resilience of energy systems, while ensuring accessibility, affordability and adequacy of energy services, through optimized integration of energy conservation, energy efficiency and local renewable energy sources. It is characterized by a combination of technologies with information and communication technologies that enables integration of multiple domains and enforces collaboration of multiple stakeholders, while ensuring sustainability of its measures.

Figure 3.2 visualizes the definition of SEC by introducing all its six dimensions, which are explained in the following subsections in detail. This figure retreats and develops the figure previously presented in Pezzutto et al. (2015, p. 3).

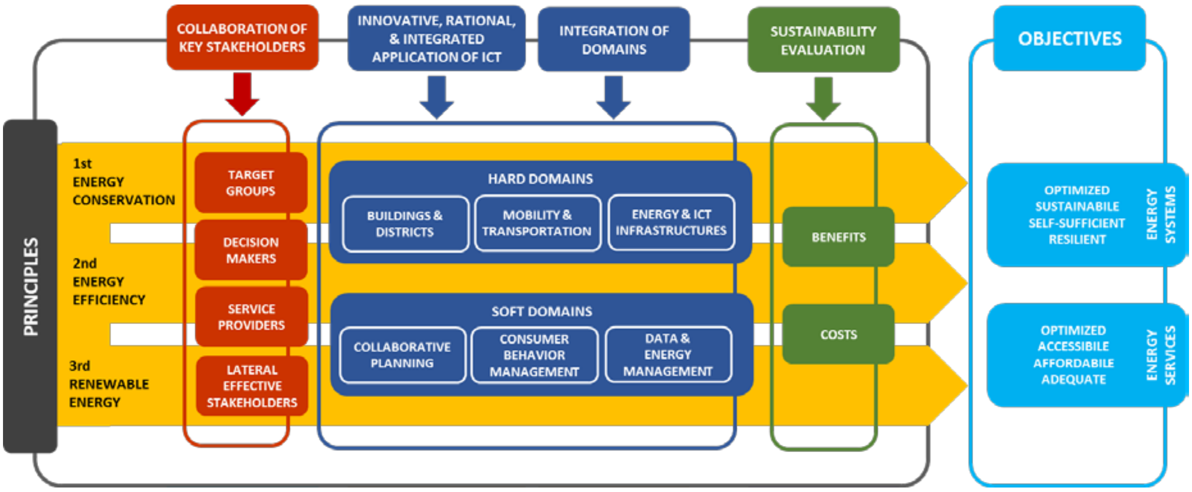

Figure 3.2 Smart Energy City (SEC) Development: the black outer box passes through SEC general principles; three yellow arrows reflect SEC energy specific principles pointing to the light blue box showing SEC objectives. The red small boxes indicate SEC key stakeholder groups, dark blue small boxes indicate SEC domains of intervention, and green small boxes reflect SEC sustainability evaluation aspects. ICT stands for Information and Communication technology.

3.4.1 Smart energy city principles

Principles are fundamental rules and philosophy, describing how SEC development acts. We recognize both general and energy specific principles. The former applies to all smart city components, while the latter is more specific for the energy domain.

3.4.1.1 General principles

Innovative, rational, and integrated application of new technologies (particularly ICT) is a pillar of SEC development (Lee et al., 2013; Nam and Pardo, 2011; Odendaal, 2003). Technological (particularly ICT-based) networks, instruments, devices, methods, and tools applied in different urban domains act as an enabler to empower and involve people and improve urban functions. Application of technologies in an innovative and integrated way, combined with big data collection and processing, allows better understanding of people behavior, enhanced decision making, and improved interoperability between urban energy components. However, in order to reduce the risk of technological solutions (Hollands, 2008), rational application of technologies is crucial.

Collaboration of key stakeholders is a paramount characteristic of SEC (Batty et al., 2012; Coe et al., 2001; Cosgrave et al., 2013; Nam and Pardo, 2011). Advanced communication infrastructures and collaborative tools allow better collaborative relationship (Gray, 1985). Such relationship helps understanding and consensus building between stakeholders (Innes and Booher, 1999; Wondolleck and Yaffee, 2000), and generating joint decisions that are more acceptable among target groups and more effectively implemented (Wondolleck and Yaffee, 2000). SEC particularly enables bottom-up collaboration and social inclusion, at the core of SEC, to create solutions for urban problems (Batty et al., 2012; Coe et al., 2001; Cosgrave et al., 2013; Nam and Pardo, 2011). In addition, SEC aims to bridge spatial and sectorial divisions of urban governance setting rules, specifically so far problematic collaboration between public and private sectors in urban governance (see Deakin and Al Waer, 2011), which most often focus on shared investments and new business models (Vanolo, 2014).

Integration of domains, brought through advances in inter-connected communicative hard and soft infrastructure (Andreottola et al., 2014; Nam and Pardo, 2011), means combining different SEC components into an integral whole through dialogue and transparent information sharing. It improves interoperability among SEC components (Nam and Pardo, 2011; Yovanof and Hazapis, 2009), by providing pair or multiple solutions that support one another in achieving SEC objectives. Integrating solutions makes the whole system more efficient and financially feasible; is more acceptable to target groups; and has less or compensated negative side effects (Geerlings and Stead, 2003). In many cases, SEC includes a distributed automated control that intelligently integrates the actions of all users connected to different components (suppliers, consumers, both) in order to efficiently deliver sustainable, economic, and secure energy supply and storage (Lund, 2014).

Sustainability evaluation: we emphasize SEC is part of sustainable city and it should fit in the framework of sustainability. We believe that the urban development is smart only if it is sustainable –i.e. it evaluates economic, environmental, and social benefits and costs at different urban spatial scales and in short to long term (Xing et al., 2009).

3.4.1.2 Energy specific principles

Energy conservation means energy demand decrease, while keeping the same level of useful energy services and preventing or avoiding other unnecessary energy services (Lovins, 2004). This principle is strictly related to an urban customer needs analysis in order to discover if undesired (e.g. street lighting partially oriented to the sky) or useless (e.g. street lighting during daytime) services are in place. The result of such analysis and sequential optimization should lead to energy saving almost without "hard" technology replacement, and acting more specifically on personal habits.

Energy efficiency increase means less energy consumption for the same level of services (e.g. replacing traditional street light points technology with LED lamps), or the same energy consumption for higher level of services (e.g. after replacing with LEDs, increasing the number of light points to eliminate dark areas) (Lovins, 2004). Energy efficiency is defined as the ratio between a useful output of a process and the energy input into a process (Lovins, 2004). It is often called “the hidden fuel” (IEA, 2014) due to its economic importance and quantitative relevance despite being, up to now, underused, overlooked, and misunderstood (Lovins, 2004).

Renewable energy refers to increasing share of local renewable energy sources. It means prioritizing generation of energy derived from local natural processes instead of from fossil fuels. Renewable energy source exploitation concerns changes in energy supply arising from fuel switching, including changes in technology; i.e. a fossil fuel based system is replaced exploiting the local renewable energy sources. Renewable sources that are applicable in the city include wind, solar, geothermal, hydro, biomass, biogas and waste-to-energy sources (US EPA, 2011).

3.4.2 Objectives

Objectives are the main goals that the transition towards SEC aims to achieve, and are here presented under two different categories: energy services and energy systems.

According to Lovins (2004, p. 384), an energy service is “*the desired function provided* [to a customer] *by converting energy in an end-use device*”. Therefore, the basis for planning the transition to the SEC should be to address the demand for energy service by appropriate mean (Ward and Mohammed, 2009), and to satisfy the final goal of ensuring the physical benefit, utility or good, required for citizens (Sauter and Volkery, 2013). In order to meet the demand for energy services, we need to ensure their accessibility. However, the mere accessibility is not in itself sufficient; the energy service should be also affordable, especially for low-income people (Ryan and Campbell, 2012; Ward and Mohammed, 2009) and adequate (Lovins, 2004).

Energy systems traditionally concern different energy infrastructures and their elements, from generation plant to the delivery point. Electricity grid, as well as thermal and gas networks, has been traditionally sectorial designed and operated; considering them in an integrated way is the starting point for achievement of smart energy systems. Moreover, as many local entities and cities make efforts to increase their energy self-sufficiency (Carley et al., 2011), such systems should enable them to satisfy locally the energy demand of a given urban area. Therefore, smart energy systems must operate under high energy efficiency requirements, coupled with distributed generation from renewable sources. Although reshaping system architecture and integrating new technologies requires substantial changes, it also gives the chance to improve the resilience of such systems to climate change hazards (Farzaneh et al., 2014) or other disruptions (Ryan and Campbell, 2012).

3.4.3 Domains of intervention

Domains of intervention are the key target fields for SEC development activities, investment, and stakeholders' attention (as indicated in Chapter 2). SEC domains of intervention are identified as "hard" and "soft" with respect to the difference between tangible (e.g. transport infrastructures, energy distribution networks, and natural resources) and intangible assets (e.g. human/intellectual/organizational capital and software) (Neirotti et al., 2014). SEC activities may concern new or existing elements within both types of domains.

The European Commission considers the biggest energy savings to be made in the sectors of residential and commercial buildings, transport, and manufacturing industry with approximately 27%-30%, 26%, and 25% potential for energy saving, sequentially (EC, 2008). Accordingly, we consider SEC hard domains as buildings and districts, transportation and mobility, and energy and ICT infrastructures (similar to EC, 2013). A district is a geographic urban area with relatively consistent character that includes buildings, land use, social groups and economic activities (Bourne, 1982). Transportation and mobility concern the end-to-end movement of people and goods through specific paths of time and space (Kaufmann et al., 2004). Energy and ICT infrastructures include those infrastructures that concern ICT and energy production, transmission, distribution and storage, including electricity, thermal (Lund, 2014), and data infrastructure. The soft domains deal with intangible assets such as collaborative planning, consumer behaviour management, and data and energy management. Due to the active nature of these domains, they are explained in more detail in section 5.2 of this chapter.

Hard and soft domains have a cross and transverse relationship. Indeed, changes of behaviour, better data management, or collaborative tools can be implemented within all the hard domains; e.g. changes of behaviour can happen in buildings, in mobility and in ICT or energy infrastructures (Figure 3.3).

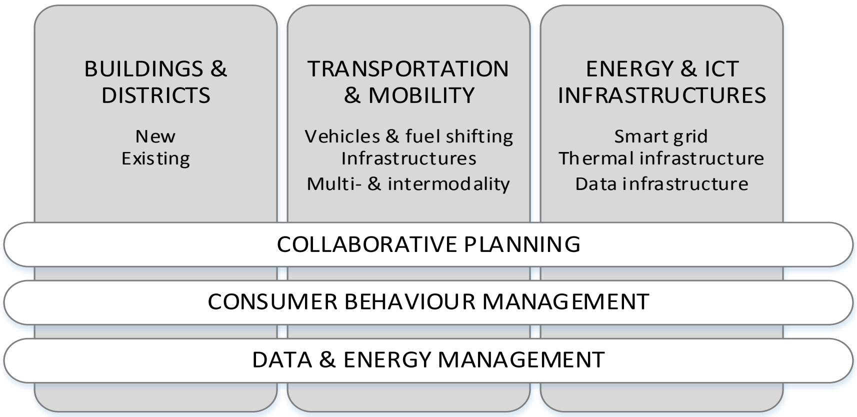

Figure 3.3 Interaction between hard and soft domains of intervention in smart energy city development; the gray vertical boxes represent hard domains and sub-domains of intervention; white horizontal boxes represent soft domains of intervention; hard and soft domains have a cross and transverse relationship

3.4.4 Stakeholders

A stakeholder is any group or individual who can affect or is affected by the achievement of the project objectives (Freeman, 2010). SEC key stakeholders were accrued into four broad categories, including: decision-makers, service providers, target groups, and lateral effective stakeholders (Figure 3.4).

Decision-makers refer to influential individuals and organizations, at different administrative levels, with the responsibility and authority to adopt policies and define implementation measures, especially those that determine future direction and strategy (Seitz et al., 2013). Service providers are organizations, businesses or individuals, which offer energy related or energy management services to others for charges (Khatib et al., 2014). Target groups are persons or groups that SEC policies and plans aim to influence in the way they receive and ultimately use the good, service, or technology. Lateral effective stakeholders are those social groups that are not directly involved in SEC plans, but can influence behavior of other stakeholders in favor or against SEC plan direction.

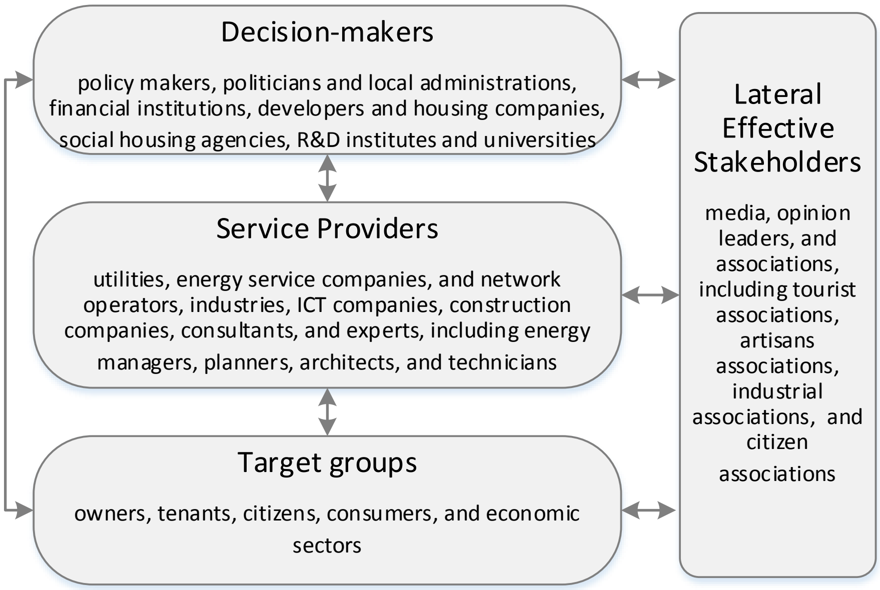

Figure 3.4 Smart energy city stakeholders; each box encloses one stakeholder group, and the arrows imply the interaction between stakeholders

3.4.5 Temporal dimension

Transition towards SEC is a constant improvement of urban energy systems and services. In more detail, the “time” issue related to SEC is addressed in three scales: firstly, optimizing constant fluctuation in energy demand and energy supply in every moment (Ponnambalam et al., 2010). Secondly, optimizing daily, monthly, and yearly fluctuation of energy in order to balance production and demand. Finally, ensuring long-term transition from existing city to SEC, which needs to modify the structure of different energy systems and to implement multiple smart energy measures.

3.4.6 Spatial dimension

Transition towards SEC is site-specific (Kitchin, 2014). Each city is a unique combination of economic, social, environmental, and institutional conditions, which results in various needs, priorities, and capacities for SEC development (Kitchin, 2014). SEC development may not be the priority in some cases, such as technology-poor affordable housing. Furthermore, the SEC development potential is higher in a city with an updated regulation in favor of new technologies, an accepting and flexible society, and trained and experienced staff in operation and management of energy projects. In addition, spatial scale is pivotal in SEC development. Energy interventions in a single building scale seek totally different operational considerations than districts, citywide, or regional interventions. In any scale, SEC development is based on local traits, while learning from international experiences.

3.5 Smart energy solutions

In this section, based on our SEC theoretical definition, we introduce a list of practical smart energy solutions for decision-makers in each SEC domain of intervention. The list is not exhaustive; nevertheless, it individuates and provides a wide set of examples of common solutions on the European market. For each solution, the spatial scale is included, which refers to the extension of applicability of the solution, namely single building, block, district, or city-wide level.

3.5.1 Hard domains

Smart energy solutions in the domain of *Buildings and Districts* are categorized, according to their applicability, to existing or new buildings and districts (Tables 3.1 and 3.2). The distinction becomes relevant only when comparing: (i) solutions that are applicable to both categories similarly; (ii) solutions that are relatively more complicated to be applied in existing buildings and districts. Solutions in this domain particularly allow more comfort, functionality, and flexibility through integration of energy generation, storage, distribution, and automated control. The spatial scale of these solutions concerns mostly building scale, but also larger scales. Solutions in this domain are most effective if combined with other sustainable solutions such as building insulation and solar passive solutions.

Smart energy solutions in the domain of *Transportation and Mobility* include a) fuels and vehicles shift, which comprises shifting conventional vehicle technologies and oil-based fuels towards the use of alternative vehicle technologies and renewable energy sources. b) Inter-modality and multimodality solutions that increase the use of all modes of public transport; intervene within the last-mile freight logistics within the urban areas; and improve connection of transport modes, nodes and mobility services to enable integrated public transport and new urban traffic and transport management solutions. c) Urban mobility and integrated infrastructures solutions, which are intended as enablers to support the market development of the first two solution categories as well as increase the usability of urban spaces by sustainable transport modes. These solutions cover all spatial scales larger than building level.

Smart energy solutions in the domain of *Energy and ICT Infrastructure* are divided in three groups: electricity infrastructure (smart grid), thermal infrastructure, and data infrastructure. Solutions in this domain enable the infrastructure to be more resilient. They allow integration of renewable resources into energy infrastructure. In addition, they allow interconnection, monitoring and control, and two-sided energy flow inside the networks. The spatial scale of thermal solutions is at district and city level, while data and electricity infrastructure most commonly address all spatial scales. In addition, the process from current infrastructure to smart energy infrastructure involves a complex range of solutions including market design, organizational, regulatory and technical issues that fit into soft domains.

The crosscutting solutions include integration of all domains and their communication through internet of things and interacting energy networks in order to address SEC targets and principles through balancing energy demand with energy supply in an optimized way. Due to complexity of these solutions, they cover multiple spatial scales.

3.5.2 Soft domains

Soft domains include solutions in collaborative planning, consumer behaviour management, and energy and data management. These solutions are applicable in all spatial scales.

Solutions in *Collaborative Planning* domain include tools that help coordination, as well as communication of data, knowledge, and ideas among stakeholders. They also include tools that enable and facilitate collaborative decision making, such as multi-stakeholder decision support systems, simulations and scenario analysis tools.

Solutions in *Consumer Behaviour Management* domain concern increasing information and awareness among stakeholders about their energy consumption, their options to reduce energy use, and application of other smart energy solutions. Other solutions in this domain include demand management actions to reduce energy demand through changing consumer behaviour.

Solutions in the domain of *Energy and Data Management* include the actions that optimize the overall energy system, from the side of both energy supply (generation, distribution) and energy demand. These solutions cover a wide range of tools and instruments that enable management, analysis, forecasting and monitoring of SEC domains through wide collection, storage, processing, and transformation of data.

Crosscutting solutions in soft domains include improving energy resilience as well as development of innovative financing mechanisms and models that improve marketing and financing of SEC solutions.

Table 3.1 Smart energy solutions and technologies in hard domains of intervention with spatial scale

Domain	*Sub-domain*	*Solution*	*Examples of applied technologies*	*Spatial Scale*			
				Building	*Block*	*District*	*City*
Buildings & Districts	Existing (difficult) /New	- Improve conditioning system	- Insulation of pipes, radiant panels	x			
		- Improve conditioning control (heating/cooling)	- Sensors, self-learning algorithms, versatile design	x	x		
		- Improve heat recovery	- Recuperators (air, waste water)	x	x	x	x
		- Connection with high efficiency grids	- District heating, district cooling	x			
		- Thermal storage	- Tanks, thermal inertia, Phase-change material (PCM)	x			
		- Mechanical ventilation	- Centralized or distributed ventilation machine	x			
		- Hybrid ventilation systems	- Active overflow ventilation	x			
	Existing / New	- Adaptive facade systems	- Biomimetic facade	x	x	x	x
		- Solar active solutions	- Solar thermal, photovoltaic, active shading	x	x	x	x
		- High efficiency generators	- Heat pumps, biomass & condensing boilers, chillers	x			
		- Improve lighting system	- LED lamps	x	x	x	x
		- Improve lighting control	- Photocells, presence and lux control	x			
		- Electric storage	- Batteries	x	x	x	x
Mobility & Transportation	Vehicles & Fuel shifting	- Shift vehicle technology: electric vehicles, hydrogen vehicles	- Plugin, battery, hydrogen/electricity produced by renewable energy sources, second generation of biofuels	x	x	x	x
	Multimodality & inter-modality	- Multi-modal and shared transportation: instrumenting vehicles for car-sharing	- Mobile applications, integrated payment options, real-time multi-modal information system, vehicle location technologies		x	x	x
		- Shift to other modes of transportation & personalizing travel	- Similar to previous solution		x	x	x
		- Improve public transportation: exploiting ticketing, social media, routing, and mobile data	- Similar to previous solution		x	x	x
	Infrastructures	- Design transportation infrastructure: charging points, filling stations, hydrogen stations for H_2 vehicles, intelligent parking systems	- Plugins, induction charger, wall-boxes, H_2 technologies, sensors		x	x	x
Energy & ICT Infrastructure	Electricity infrastructure (smart grid)	- Smart metering (monitoring)	- Smart meter, smart sensors	x	x	x	x
		- Automated distributed control to manage fluctuating production	- Smart switches, smart breaker, Transformer On-Load Tap Changer (OLTC)			x	x
		- Active loads	- Electrical vehicles, storage	x	x	x	x
		- Renewable and Distributed Energy generators	- Photovoltaic, Heat Pump, Wind	x	x	x	x
		- Electrical energy storage	- Batteries, hydrogen fuel-cells, electric vehicles, flywheels	x	x	x	x
		- Cyber security	- Encryption algorithm	x	x	x	x
	Thermal infrastructure	- Smart District Heating & Cooling (DHC)	- Meters, control, hydraulic equipment			x	x
		- Thermal energy storage	- Excavation, hydraulic equipment, large water pits			x	x
		- Enhance Geothermal Systems (EGS)	- Drilling, hydraulic equipment			x	x
		- Improve waste management/incineration	- Biodigesters				x
		- Industrial heat recovery	- Databases, market information			x	x
	Data infrastructure	- Big data center for gathering data	- Green servers			x	x
		- Digital and communicational infrastructure	- Power Line Communication, fiber optic	x	x	x	x
Cross-cutting	-	- Energy dashboard	- Wi-Fi, web, electronic devices	x	x	x	x
		- Interacting energy networks	- Meters, control, hydraulic and electric equipment			x	x
		- Internet of things	- Wi-Fi, auto management, smart meters & switches	x	x	x	x

Table 3.2 Smart energy solutions and technologies in soft domains of intervention.

Domain	*Sub-domain*	*Solution*	*Examples of applied technologies*
Collaborative Planning	Collaborative tools	- Stakeholder cooperation platform	- Database, digital platforms
		- Process-based collaborations	- Cognitive maps, card sorting
		- Innovative ways to frame & analyze data	- Hackathons, social innovation labs
		- Building & urban simulation & scenario planning tools	- Infographics, network analysis, simulations
		- Decision support systems	- Modeling tools, Geographic Information Systems (GIS)
		- Shared frameworks	- Decision support systems
		- Performance based public procurement	- Performance metrics
Consumer Behavior Management	Information & awareness	- Social media for disseminating information	- E-services
		- Open access information dissemination platform	- Database, digital platforms
		- Serious games	- Mobile applications, sensors, alarms
		- Feedback measures: improving availability & accessibility of knowledge on energy use	- Energy dashboards, energy apps, alarms
		- Education and training	- Information campaigns, e-learning
	Demand management	- Car sharing, car-pooling, teleworking, last mile logistics, mobile ITS (location-based route/travel information and traffic light systems)	- GPS, mobile applications, internet, Wi-Fi, supply chain technology, shared logistic networks, sensors, devices; databases, centralized distribution systems
		- Intelligent community-based initiatives	- Sensors, information platform
		- Energy auditing tools and procedure	- Sensors, Wi-Fi, databases
		- Demand response strategies	- Time varying pricing, interruptible and voluntary load reduction
Energy & Data Management	Management	- Energy network and infrastructure management system	- Wireless technologies, controller-embedded gateways & servers, sensors
		- Building management system	- Performance monitoring, optimized managing tools, self-learning systems, “dynamic energy profiles”
		- Interoperability and data protocols between city domains	- Database, standards, open data, big data
	Analysis	- Local resource and consumptions assessment systems (roof/energetic/ground cadaster)	- Databases, GIS
		- Zoning: quarters/district energy islands	- Databases, GIS
		- Special building cadaster	- Databases, GIS
	Forecasting	- Spatial demand forecast systems (electric, thermal, gas)	- Database, big data, GIS
		- Spatial renewable sources forecast systems (sun, wind, water)	- Database, algorithms, GIS
		- Mobility forecast systems	- Databases, algorithms
	Monitoring	- Monitoring tools for the continuous improvement of the system	- Sensors, Wi-Fi, databases
Cross-cutting	Energy resilience	- Connect key information sources with city monitoring systems (sensors, people), with city ‘life-lines’ infrastructures (transport, power, water & communication)	- Sensors, Wi-Fi, databases
	Financing	- Innovative financing mechanisms (crowd funding), encourage dynamic models of PPP (e-government), smarter procurement (cloud-based software), dynamic pricing schemes	- Internet, database

3.6 Discussion and conclusions

We establish a theoretical and practical framework for the smart energy city (SEC) development from urban planners' perspective. This provides rationale to urban decision-makers, supporting them in leading their cities toward an effective smart and sustainable energy development. This perspective incorporates multi-dimensionality, pluralism, continuality, and sustainability considerations (i.e. socio-economic and environmental considerations) into smart energy city concept. We recognize that the key concern of urban energy sphere is not merely to be smart, but to be sustainable.

We define SEC development within the wider concepts of smart city and sustainable city. We point out that SEC is a component of smart city and it should be considered in relation to other economic, community and governmental components (explained by Giffinger et al., 2007; Chapter 2). Smart city is not a substitute nor a continuation, nor an addition to sustainable city; smart city is a cutting-edge urban development strategy that enables integration of different urban systems in order to enhance sustainability.

In order to overtake existing definitions suggested by other stakeholders including ICT companies, engineers (see e.g. Chai et al., 2011, 2013) or gray literature such as whitepapers or deliverables of European Union projects (e.g. Belanger and Rowlands, 2014; Nielsen et al., 2013), we built our definition upon, among others, the conceptual framework of smart city provided in Chapter 2 of the here presented thesis. Accordingly, we applied the 5W+1H model to systematically explore different aspects of a SEC development –i.e. principles, objectives, domains, stakeholders, spatial and temporal dimensions. Therefore, we extend previous definitions by adding temporal and spatial dimensions, pushing the concept towards a more holistic and comprehensive scope (see Berardi, 2013). This emphasizes that SEC is better described as a site-specific process rather than a universal, modular upshot.

Principles, among others, may be recognized as the key factors of our definition because they are the essential rules that distinguish not only SEC from other urban developments such as eco-cities, green cities, and knowledge cities (Belanger and Rowlands, 2014), but also *real* smart projects from *labeled* smart projects (Hollands, 2008). This suggests that SEC development is specifically characterized by rational, innovative, and integrated application of new technologies with ICT, integration of its domains, collaboration of stakeholders, and sustainability evaluation. Application of new technologies combined with ICT is a principle of SEC; however, we should avoid simplifying complexity and multi-dimensionality of urban problems to data management and technical questions; we emphasize that ICT is not an end, but an enabler. Integration of SEC domains is a key component to smartness. With respect to interactions within the SEC development, it seems inappropriate to consider SEC domains in isolation. Collaboration of stakeholders concerns the necessity of social inclusion and investment in social capital at the core of SEC (Batty et al., 2012; Hollands, 2008; Nam and

Pardo, 2011; Rios, 2012). Social inclusion is defined as one type of collaboration among stakeholders because target groups, implicitly people, play an active role in SEC development by producing energy, investing in SEC solutions, communicating their needs and desires to local government, and participating in design of SEC solutions. Thus, we put them in the similar class with other groups of stakeholders, including decision-makers, service providers, and media. Sustainability evaluation in SEC, although necessary, is complicated since it depends on both temporal and spatial dimensions. It depends on the available knowledge during SEC development. Rapid advancements in technologies may result in new smart energy solutions, making previously sustainable solutions unsustainable. In addition, promotion of a smart energy solution in a place far from its production site, or in an inappropriate site, may make the solution unsustainable (Berardi, 2013). An effective way to ensure sustainability of SEC development is to include socio-economic and environmental considerations in the early stage, while ensuring that the other SEC principles are included as well. Essentially, SEC principles are part of the same whole and they need to be promoted together.

Our definition is in line with the recent Paris Agreement (December 2015), mentioned to be the *first-ever universal, legally binding global climate deal* (EC, 2015d). Point 8 of article 6 of this agreement emphasizes the "*importance of integrated, holistic, and balanced non-market approaches* [to implementation of mitigation and adaptation actions]... *in the context of sustainable development..., through technology transfer*, [among others],...a*iming to promote mitigation and adaptation ambitions; enhance public and private participation...; and enable coordination across instruments and relevant institutional arrangements"* (UN, 2015, p. 23).

We developed a list of SEC solutions with their associated technologies and spatial scale in each SEC domain of intervention. Integration of multiple solutions in different SEC domains arises complexity of new solutions. However, we emphasize that numerous creative and efficient solutions to urban problems, although not being called "smart", may provide equally satisfactory answers, e.g. traditional building passive approach, like Persian wind-catchers that provide a high efficient ventilation system for buildings without leaning on ICT (Montazeri and Azizian, 2008). Integration of these solutions with smart solutions will result in higher sustainability.

The theoretical definition can be used to evaluate the degree of smartness of smart energy city development. At the conceptualization stage, a checklist can be provided requiring the following questions: are the plan objectives in line with SEC development objectives (mentioned in section 4.2)? Is sustainability evaluation of the plan and its implementation considered? Are key SEC domains of integration and the potential interaction among them identified (section 4.3)? Are key SEC stakeholders recognized and involved in the plan (section 4.4)? Does the plan consider site-specific characteristics in planning and implementation? Does it consider membership in local, national, or supra-national networks to learn from other experiences? Does the plan consider time-specific targets? Consequently, further development of this work could be deriving assessment indicators according to SEC definition, particularly SEC principles, to evaluate performance of new SEC developments (similar to Nielsen et al., 2013).

The lists of practical solutions are applicable by policy makers and urban planners in order to know various practical solutions and their broad application. The stakeholders with more technical focus, such as engineers and operators, can use this list to understand how each specific solution can contribute to the big picture of SEC development. Overall, these tables provides a common ground for a dialogue between various mentioned groups of stakeholders. It can be considered as a starting point for a participative process for selection, integration and analysis of solutions.

Considering the results of all three objectives of this chapter, we conclude that smart energy city development and consequently smart energy solutions are not the unique way of addressing urban energy objectives. Thus, SEC development is more effective when it is accompanied with other sustainable solutions such as conventional or innovative-non-technological answers (as mentioned above). Such combinations are possible through multi-criteria analysis of solutions considering energy saving potential, investment cost, return on investment, and social acceptance among others.

Overall, this research provides a common and multi-dimensional understanding of the SEC concept and solutions. This will particularly sustain an effective interaction among SEC stakeholders and foster SEC development.

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Part III

Empirical Investigation

Chapter 4

Identifying and Prioritizing Barriers to Implementation of Smart Energy City Projects in Europe: an Empirical Approach

Based on:
F. Mosannenzadeh, M. R. Di Nucci, D. Vettorato, S. Pezzutto. Identifying and prioritizing barriers to implementation of smart energy city projects in Europe: an empirical approach (to be submitted)

Summary of the chapter

Successful implementation of smart energy city projects in Europe is crucial for the sustainable transition of urban energy systems and improvement of the quality of life for citizens. The manuscript aims 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 cities and communities implementing smart city projects under the European Union sixth and seventh research framework programmes. Validated through literature review, we identified 35 barriers categorized in policy, administrative, legal, financial, market, environmental, technical, social, and information and awareness dimensions. We prioritize these barriers, using a new multi-dimensional methodology that analyzes barriers based on probability, the level of impact, relationship with other barriers, origin, and scale. The results indicate that lack of good cooperation and acceptance among project partners, insufficient external financial support, lack of skilled and trained personnel, and fragmented ownership are the key barriers to be addressed by project coordinators. On the other hand, lacking or fragmented political support for the long term is the key barrier to be addressed by policy makers. The outcome of the research provides a multi-dimensional classification that should aid decision-makers to better understand and prioritize implementation barriers in order to develop proper action and policy interventions.

4.1 Introduction

Global energy challenges and climate change have urged governments at all local, regional, national and supra-national levels to optimize urban energy systems. In response, numerous European smart energy city (SEC) projects have initiated and developed, aiming at optimizing urban energy systems and improving the quality of life for citizens (Vanolo, 2014; Washburn et al., 2009). These projects have been very popular during the last two decades, specifically due to considerable support through funding and investments by both the European Union FP6 and FP7 and more recently Horizon 2020) and the private sector.

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. However, it is important to not only identify but also prioritize these barriers in order to efficiently allocate efforts and resources on abating key barriers for effective action (Nagesha and Balachandra, 2006). This research aims at supporting decision-makers to better understand and prioritize implementation barriers; this helps to develop proper action and policy interventions towards removal of barriers.

Due to the novelty of SEC projects, the specific barriers to implementation of these projects have not been 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 also examined the specific barriers to design and implement such projects (Di Nucci et al., 2010; Di Nucci and Spitzbart, 2010; Pezzutto et al., 2015).

Prioritization of barriers to energy-related interventions has considered three main aspects in literature: the importance of a barrier (related to intensity and impact), the level of effort required to tackle a barrier, and relationship with other barriers. Sizhen et al. (2005) prioritize barriers to the promotion of clean technology in China through analytic hierarchy process based on the importance given by stakeholders. Nagesha and Balachandra (2006) use a 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), improve this methodology to prioritize barriers to sustainable shale gas revolution in China by considering the importance and also the relationship with other barriers through the application of analytic network process. However, barrier prioritization by simultaneous consideration of all these three aspects has not been yet investigated.

The specific objectives of this chapter are (*i*) to identify barriers to implementation of urban scale SEC projects in Europe; and (*ii*) to provide a multi-dimensional prioritization of barriers by considering barrier importance, the level of effort required to tackle a barrier and relationship with other barriers. To address these objectives, we take an empirical approach and analyze the results and supporting documents of 43 European cities and communities that have implemented SEC projects under an EU FP6 and FP7 initiative, named CONCERTO.

The CONCERTO Initiative supported local communities in developing and demonstrating concrete strategies and actions that are both sustainable and highly energy-efficient. The first batch of CONCERTO projects started in 2005 under EU FP6 (CONCERTO, 2015b). CONCERTO projects integrate local innovative energy efficiency interventions and local renewable energy sources in both new and existing urban districts. The CONCERTO Communities demonstrate the feasibility and integration of renewables-based cogeneration, sometimes smart grids, district heating/cooling systems and energy management systems in districts (CONCERTO, 2015c; 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. The supporting platforms “Concerto Plus” first and then “Concerto Premium” investigated and systematized the barriers that hindered achieving these goals. The diversity of CONCERTO communities in size and socio-economic, environmental, and political aspects provides a wealth of information. Moreover, CONCERTO projects are mostly completed or are in the final stage of completion, and information on barriers to implementation of each city/community is available through several publications of the initiative (CONCERTO, 2015b).

The present investigation retreats and develops 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). This chapter is organized as following. Section 2 explains the research methodology. Section 3 describes the identified barriers and the result of the barrier prioritization. Section 4 discusses the main findings of our research; section 6 gives implications for project coordinators and policy makers, and section 7 concludes the chapter with the main contributions and recommendations for future research.

4.2 Methodology

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

4.2.1 Barrier identification

Following Painuly (2001), our methodology is based on an empirical research, validated through a literature review.

First, we created a database 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, 2015d), which gathered barriers under five categories: administrative, technical, social, legal, and economic. The whole database included 212 rows of barriers. following Boor et al. (2008), these barriers were coded based on barrier category 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 the realization of smart and sustainable energy city 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 the terminology of the identified barriers with respect to the literature and arrived at the identification of 35 barriers.

4.2.2 Barrier prioritization

We propose a new multi-dimensional approach to prioritize barriers to implementation of SEC projects based on the importance of barriers, relationship with other barriers, and level of effort required to tackle them (Figure 4.1).

As for the importance of barriers, we borrowed the indicator *criticality* used in risk analysis as a function of two indicators: probability and level of impact (Marle et al., 2013). We then calculated the barrier probability based on the frequency of barriers in investigated projects. We adopted the level of impact previously investigated by Pezzutto et al. (2015) through a structured questionnaire on barriers to smart city. Pezzutto et al. (2015) used a six-point Likert scale ranging from ‘‘neutral or not effective’’ to ‘‘very effective’’. 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[1]. The average of values assigned by experts was used to indicate the level of impact per barrier (Pezzutto et al., 2015). This indicator allows classifying barriers based on their criticality. As an example, we define three criticality areas: low criticality area, in which probability * impact < 0.1; medium criticality area, in which 0.1 =< probability * impact < 0.6; and high criticality area, in which 0.6 =< probability * impact.

For the relationship with other barriers, we investigated the causal relationship. 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 the relationship between barriers through a qualitative and exploratory approach, applying narrative data collected in the database of CONCERTO barriers and direct knowledge through the direct work in Concerto Plus and site visits of Concerto projects. 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 lack of access to capital.

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 –or weakening– 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. 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 combine origin and scale to create a new indicator named *inevitability*, which denotes the level of effort required to tackle a barrier.

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

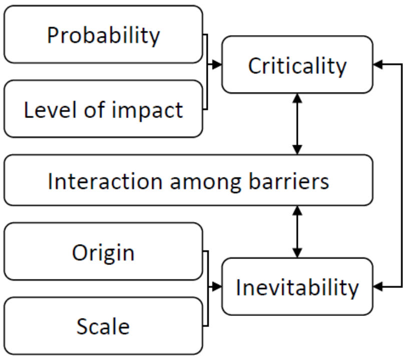


Figure 4.1 A multi-dimensional approach to prioritization of barriers to smart energy city projects

4.3 Results

4.3.1 Barriers to implementation of smart energy city projects in Europe

We identified 35 barriers, each assigned to one of the nine categories: policy, administrative, legal and regulatory, financial, market, environmental, technical, social, and information and awareness. Nevertheless, each barrier has its own policy, administrative, economic, legal, and social aspects (Weber, 1997). We explain each barrier by pointing out examples from CONCERTO projects. The examples are distinguished by the name of the city (or community) and the name of the project, written as city-project (in capital letters).

4.3.1.1 Policy barriers

Barriers related to the national, regional or local policy include:

B_{01} _Lack of long-term and consistent energy plans and policies (as mentioned by Ellis et al., 2007) may lead to unclear objectives and inconsistent political support, making investors wary (Kaminker and Stewart, 2012). For example, in Hartberg-SOLUTION, the lack of a comprehensive energy concept, and in Delft-SESAC, a change in the previously defined energy objectives and targets delayed the projects´ implementation.

B_{02} _Lacking or fragmented local political commitment and support for the long-term (mentioned by Kaminker and Stewart, 2012; Pîrlogea, 2011), usually due to changes in local government, can endanger project implementation. For example, in Cerdanyola-POLICITY in Spain, the previous local government had been in favor of a biomass plant for heating, while the following government did not support the biomass technology and, therefore, the biomass plant was not built.

4.3.1.2 Administrative barriers

Barriers related to the management of the projects include:

B_{03} _Difficulty in the coordination of a high number of partners and authorities (mentioned by Pîrlogea, 2011): may happen 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 actors.

B_{04} _Lack of good cooperation and acceptance among partners: conflicting interests (mentioned by IEA, 2010) hinders a productive and interactive collaboration required for common agreements. In CONCERTO projects, some cities including Milton Keynes-CRRESCENDO and Weilerbach-SEMS had to put up with this barrier.

B_{05} _Lack of public participation: low attention to involving 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 a lack of support and acceptance of the proposed interventions. 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.

B_{06} _Lack of institutions/mechanisms to disseminate information (mentioned by Painuly, 2001) may lead to a lower support from the target groups due to a lack of knowledge of costs and benefits of the project interventions.

B_{07} _Long and complex procedures for authorization of project activities (mentioned by Pîrlogea, 2011) along with a large number of authorities involved in licensing procedures delays project implementation (Pîrlogea, 2011). For example, in Lambeth-ECOSTILER, due to lengthy procedures for obtaining permission for renewable energies, the project implementation lasted longer than planned. The accumulated delays ended up shortening the time for monitoring and the whole project plan had to be changed.

B_{08} _Time consuming requirements by EC concerning reporting and accountancy may occur for projects funded under European Union calls, particularly, if they do not have previous experience in this type of projects, like in several CONCERTO cities.

B_{09} _Complicated and non-comprehensive public procurement, i.e. legislations on the purchase of services and material by the public sector (Thai, 2008) may lead to time-consuming procedures or malpractice (Dutton, 2007; Thai et al., 2005). For example, in Morahalom-GEOCOM, the requirements of public procurement made the procurement last so long and created difficulties in the planning.

B_{10} *_Fragmented ownership* of the project e.g. real estate, buildings, flats, and technology infrastructure, can limit cooperation of all owners for implementing project interventions (Ferranto et al., 2013) or create difficulties in contracting procedures. 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 homeowners were against the interventions due to e.g. financial problems. In Valby-GREEN-SOLAR-CITIES, fragmented ownership of solar panels and buffer tanks created complications in contracting. In general, the private real-estate sector has been under-represented in CONCERTO. The long-lasting negotiations and customized consultancy were necessary to convince private developers to follow 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.

4.3.1.3 Legal and regulatory barriers

Barriers conditioned by supra-national, national or local regulations include:

B_{11} *_Inadequate regulations for new technologies* (as mentioned by Luthra et al., 2014): conventional regulatory systems are not adapted to SEC technologies such as the photovoltaic and smart grid. This may discourage investment in some technologies and complicates the implementation (Luthra et al., 2014; Painuly, 2001). This barrier occurred in Lyon-RENAISSANCE and Grenoble-SESAC, where the rules and regulations were not adapted for PV systems.

B_{12} *_Regulatory instability* (mentioned by Painuly, 2001; or uncertain governmental policies mentioned by Kaminker and Stewart, 2012) results in an unclear 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 unstable regulations (Painuly, 2001). For example, the removal of subsidies for rental properties in Sweden after the elections in 2006 coincided the implementation of the project in Växjö-SESAC. This increased construction cost of the passive houses planned in the project.

B_{13} *_Non-effective regulations* (local, regional, and national) endanger successful implementation of the energy policies (Austin, 2005). Effective regulation is a pivotal tool for building a stable economic situation and ensures incentives for investment. Non-effective regulation may result in non-effective energy policy (Austin, 2005). This barrier occurred in Galanta-GEOCOM.

B_{14} *_Unfavorable local regulations for innovative technologies* (as mentioned by Painuly, 2001) e.g. restrictions related to building aesthetic, safety, or data privacy, hinders project implementation. For example, in Milton Keynes-CRRESCENDO, the retrofit of the PV array on a former bus station had to respect the architectural integrity of the building [i.e. requirement of Milton Keynes Council Development Control planners]. In Cerdanyola-POLYCITY, data privacy regulations in Spain restricted the availability of energy data. Also historical preservation of buildings has 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.

B_{15} _Insufficient or insecure financial incentives: feed-in-tariffs, tax exemption, subsidies (Piscitello and Bogach, 1997), credit facilities and third-party financing mechanisms for innovative technologies are among measures to smooth investment in smart energy technologies (Painuly, 2001). Low or delayed incentives for renewables (e.g. photovoltaic and wind power) makes these technologies less attractive for investment. In Grenoble-SESAC, the uncertainty over the future feed-in tariffs for building integrated PV slowed down private investments and led to delays in the project´s implementation. This barrier occurred also in many other CONCERTO projects including Cernier-SOLUTION, Lapua-SOLUTION, Tudela-ECOCITY, and Tulln-SEMS.

4.3.1.4 Financial Barriers

Obstacles related to financial limitations include:

B_{16} _High costs of design, material, construction, and installation. Energy efficient technologies, renewable energy, and new technologies are characterized by relatively high costs for design, material, installation, and construction. Hence, individuals with low incomes and corporations with a limited access to capital are not able to invest in such technologies.

B_{17} _Hidden costs (as mentioned by Nichols, 1994; Thollander et al., 2010) may include general overhead costs of project implementation, specific costs to a new technology, and losing benefits of a new technology (Nichols, 1994). In CONCERTO projects, this case was mostly related to unforeseen overhead costs.

B_{18} _Insufficient external financial support and funding for project activities (as mentioned by Pîrlogea, 2011), especially for small producers and individuals, restricts individual investment and acceptance of project interventions (Pîrlogea, 2011). 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 delayed because the communities received external funds with delay. Other problems in providing external financial support were the difficulty to find an appropriate financing scheme, public-private partnerships and contracting models as there were restrictions on organizations/actors that

can accept a CONCERTO-grant (e.g. in Óbuda-STACCATO).

B_{19} *_Limited access to capital and cost disincentives* (as mentioned by Luthra et al., 2014; Painuly, 2001; Pîrlogea, 2011; Thollander et al., 2010): low-income individuals and small firms with limited access to capital are not able to invest in costly project interventions. High investment costs are highlighted in comparison to conventional energy costs, e.g. 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.

B_{20} *_Economic crisis* in 2007 resulted in lack of capital (as mentioned by Di Nucci et al., 2010; Trianni and Cagno, 2012) and provoked serious concerns 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. In Helsingør-ECOCITY, Hillerød-SORCER and Hartberg-SOLUTION, the economic crisis reduced the attractiveness of construction activities, which lead to delays in implementation of the projects. 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.

B_{21} *_Risk and uncertainty* (mentioned by Luthra et al., 2014; Pîrlogea, 2011; Sorrell et al., 2000; Wright et al., 2014): higher technical and financial risks accompanied by the uncertain and long-time return on investment, represented by smart energy technologies, inhibit investment in projects. This barrier occurred in Salzbur-GREEN-SOLAR-CITIES, where uncertainty about new technologies discouraged investors to participate in the project.

4.3.1.5 Market barriers

Barriers conditioned by the market include:

B_{22} *_Split incentives* or misplaced incentives (as mentioned by Hirst and Brown, 1990; IEA, 2010; Sorrell et al., 2000; Thollander et al., 2010) occur when the investor cannot capture the benefits of energy interventions (e.g. energy efficiency). For example, in Amsterdam-ECOSTILER, although tenants benefitted from lower energy bills following energy efficiency improvements, housing providers were not allowed to increase the rent; thus, they were not able to compensate their investment costs for energy efficiency activities.

B_{23} *_Energy price distortion* (as mentioned by Cagno et al., 2013; Hirst and Brown, 1990; IEA, 2010): subsidized conventional energy reduces the competitiveness of renewable energies (Painuly, 2001). In addition, it alters the understanding of the real value of energy efficiency, and thus, energy use reduction gets less appealing. This barrier hindered Växjö-SESAC from achieving its energy saving targets.

4.3.1.6 Environmental barriers

Obstacles conditioned by the natural environment include:

B_{24} _Negative effects of project intervention on the natural environment: this barrier is mostly observed with regard to wind turbines and their endangerment for birds (Weilerbach-SEMS), or with regard to biogas plant and its possible negative effects on the local environment (e.g. bad odors). This barrier occurred in Amsterdam-ECOSTILER, Mabjerg-ECOSTILER, and Ostfildern-POLICITY.

4.3.1.7 Technical barriers

Obstacles related to technical and operational limitations include:

B_{25} _Shortage of proven and tested solutions and examples leads to a lack of expertise and know-how to implement projects. This had been a major barrier in many cities including Tudela-ECOCITY (for installing complex biomass systems), Falkenberg-ENERGY-IN-MINDS (for model projects, data, and benchmarking), and Galanta-GEOCOM (for installing photovoltaics).

B_{26} _Lack of skilled and trained personnel: continuous technology transfer requires trained staff especially engineers, operators, and managers for deployment and operation of new technologies, as well as for analytics, data management and decision support (Painuly, 2001; Pîrlogea, 2011; Wright et al., 2014). This barrier is found in many CONCERTO cities. For example, in Mödling-HOLISTIC, there was a shortage of trained and experienced electricians for the installation of photovoltaics, delaying implementation of refurbishment.

B_{27} _Deficient planning (not accurately considering the status quo of both natural and built environment): If the planning is not accurate, the implementation can encounter difficulties. For example, in Lambeth-ECOSTILLER, roof-mounted wind turbines were planned; however, these turbines could not be installed because the speed of wind was not sufficient everywhere for such technology.

B_{28} _Lack of a well-defined process for project activities leads to difficulty in coordination of the projects; e.g. in Geneva-TETRAENER, the methodological phase of the project was run in parallel with the actual planning and implementation phase rather than preceding it. In the case of Ajaccio-CRESSCENDO or Zaragoza-RENAISSANCE, there were delays in implementation of renovation measures due to the unexpected long process to find interested housing companies/associations, willing to participate in the initiative.

B_{29} _Retrofitting work in dwellings in the occupied state is specific to retrofitting of existing buildings while the tenants are living inside the building. This put a 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 observed in a number of CONCERTO cities. However, it could be 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).

4.3.1.8 Social barriers

Obstacles within the society and individuals include:

B_{30} _Inertia (as mentioned by Cagno et al., 2013; Rohdin and Thollander, 2006; Sorrell et al., 2000; Thollander et al., 2010) refers to resistance to change of behavior; e.g. shifting from one technology to another (Reddy and Painuly, 2004), or changing consumption patterns. It weakens the effect of project interventions. Inertia was a barrier in many CONCERTO projects. As stated in Kortrijk-ECOLIFE “Everybody (politicians, administration, etc.) agrees on the importance and necessity; nobody is able or willing to change or transform his bad habits… They are not even aware of their bad attitudes.”

B_{31} _Lack of values and interest in energy optimization measurements , mentioned as lack of value-based driving forces (Song, 2006), values (mentioned by Rohdin and Thollander, 2006; Sorrell et al., 2000), and lack of interest (mentioned by Cagno et al., 2013), denotes lack of motivation to participate in energy-related activities from both sides of target groups and project partners. 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.

B_{32} _Low acceptance of new projects and technologies: low acceptance of energy interventions especially from the side of residents and local authorities (Painuly, 2001; Pîrlogea, 2011; Wright et al., 2014) hampers the project implementation. For example, in Mödling-HOLISTIC, oppositions of target groups against the biogas plant made the implementation more difficult than expected. In addition, developers, architects, facility managers, and the general public tend to be prejudiced about innovative or unknown technologies. This restricted the introduction of renewables and energy efficiency measures in Geneva-TETRAENER and Viladecans-CRESSCENDO for the construction of renewable energy plants or connecting buildings to community energy systems with a high share of renewable energy sources.

4.3.1.9 Information and awareness

Barriers related to limited or imperfect information and awareness include:

B_{33} _Insufficient information on the part of potential users and consumers to make rational decisions on consumption and investment (IEA, 2010): lack of information on costs and benefits of energy-related measures may lead to missing opportunities (Rohdin and Thollander, 2006). Potential users are commonly unaware of available solutions and technologies. However, even installers, architects, and planners suffer from the imperfect information or limited knowledge.

B_{34} _Lack of awareness among authorities can also lead to difficulty in implementation of project activities. This barrier was mentioned in Neckarsulm-ENERGY-IN-MINDS, where it was difficult to convince the relevant authorities and municipal bodies of the necessity of local CO_2 reduction measures.

B_{35} _Perception of interventions as complicated and expensive, with negative socio-economic or environmental impacts (as mentioned by IEA, 2010; Painuly, 2001). For example, in Lambeth-ECOSTILER, people were reluctant towards the implementation of district heating systems due to safety concerns because of a previous explosion in a boiler in one of the houses in the neighborhood. In Turin-POLYCITY, there was a lack of acceptance, from tenants, to connect to district heating network due to concerns about a potential increase in heating costs. In Zlín-ENERGY-IN-MINDS, homeowners were against small scale solar thermal, photovoltaic systems, and retrofitting in general due to their perception of complicated and costly procedures. There were also cases in Austria (Weiz-Gleisdorf-ENERGY-IN-MINDS), where previously well accepted technical systems (e.g. wooden pellets) started encountering problems due to the escalating prices for pellets (Di Nucci et al., 2010).

4.3.2 A multi-dimensional approach to prioritizing barriers to implementation of smart energy city projects

A list of barriers with their probability and level of impact is presented in Table 4.1. Based on Table 4.1, criticality of barriers –as a function of their probability and level of impact (see section 2.2) – is illustrated in Figure 4.2. We subdivided barriers into three criticality areas. Criticality area 3 represents barriers with the highest criticality; 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}). Criticality area 2, representing medium criticality, includes most of the barriers; for example, *lack of public participation* (B_{05}) and *economic crisis* (B_{20}). Criticality area 1 contains barriers with the lowest criticality, including market barriers (B_{22}, B_{23}), the *non-effective regulations* (B_{13}), and *risk and uncertainty* (B_{21}).

Table 4.1 Barriers to implementation of smart energy city projects: probability and level of impact

Barrier Category	*Barrier*	*Barrier code*	*Probability*	*Level of Impact**
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 for 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}	0.07	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

* Pezzutto et al. 2015, adopted

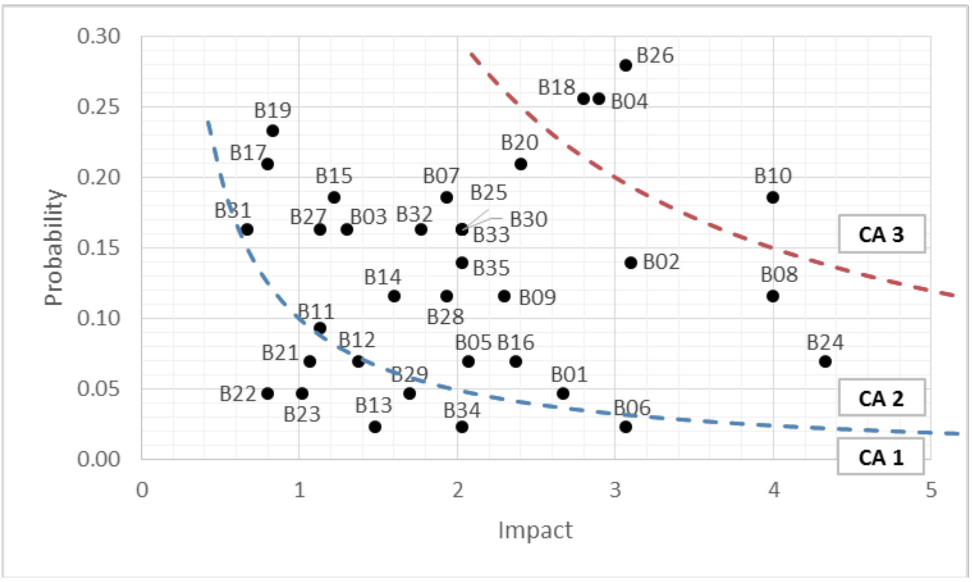


Figure 4.2 Criticality of barriers. CA stands for criticality area: a barrier in CA 1 has low criticality (probability * impact < 0.1), in CA 2 has medium criticality (0.1 =< probability * impact < 0.6), and in CA 3 has high criticality (0.6 =< probability * impact)

Causal relationships among barriers are shown in Figure 4.3. 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. *Lacking or fragmented local political support during the long term* (*B*$_{02}$), *lack of public participation* (*B*$_{5}$), and *economic crisis* (*B*$_{20}$) are key driving barriers, meaning that they cause many other barriers. A sequential relationship is observed when, for example, *fragmented political support in the long term* (*B*$_{02}$) causes *regulatory instability* (*B*$_{12}$), which in turn increases *risk and uncertainty* (*B*$_{21}$), causing *low acceptance of new projects and technologies* (*B*$_{32}$).

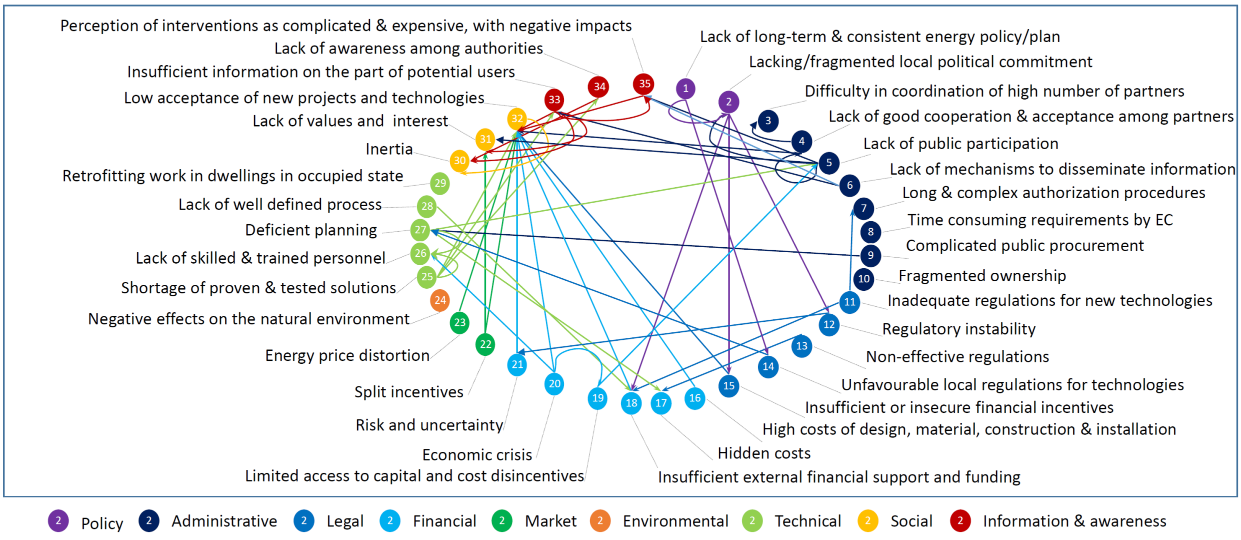
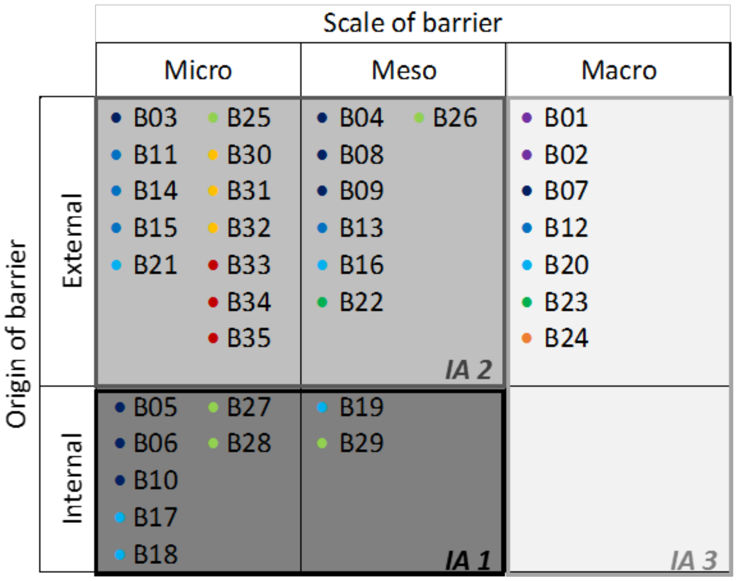


Figure 4.3 Causal relationship between barriers

The inevitability of barriers –as a function of origin and scale (see section 2.2) – is illustrated in Figure 4.4. In general, we define three different inevitability areas, each indicating one level of inevitability. A barrier located in inevitability area 1 is the least inevitable, meaning that it is possible to avoid and/or weaken it through project design and organization. Several administrative, technical, and financial barriers fit in this area. Inevitability area 2 represents the intermediate area, a barrier in which is originated outside the project but can be weakened by project organization and design. For example, lack of interest in energy efficiency measures is external to the project and occurs due to cultural characteristics of the target group. However, it is possible to weaken it through project design and organization by providing incentives or increasing awareness of energy efficiency benefits. Several legal barriers and all social and information and awareness barriers fit in this area. Barriers in inevitability area 3 are the most difficult to avoid; they are originated outside the project and hard to influence by project activities. All policy barriers, as well as the economic crisis, fit in this area.



Origin of barrier	Scale of barrier: Micro	Meso	Macro
External	• B03 • B11 • B14 • B15 • B21 • B25 • B30 • B31 • B32 • B33 • B34 • B35	• B04 • B08 • B09 • B13 • B16 • B22 • B26 IA 2	• B01 • B02 • B07 • B12 • B20 • B23 • B24
Internal	• B05 • B06 • B10 • B17 • B18 • B27 • B28	• B19 • B29 IA 1	IA 3

Figure 4.4 The inevitability of barriers. IA stands for Inevitability area: a barrier in IA 1 is least inevitable; in IA 2 is moderately inevitable, and in IA 3 is most inevitable.

4.4 Discussion

Many critical barriers are conditioned by specific new characteristics of the SEC development: application of new technologies, the involvement of multiple stakeholders from different policy levels, integration of various energy strategies and multiple energy domains, big data management, and high communication and information dissemination (as indicated in Chapter 3).

Application of new technologies (specifically ICT) intrinsic in the SEC development brings about the most critical barrier, *lack of skilled and trained personnel (B*$_{26}$*)*. In addition, due to the novelty of the SEC technologies, the authorization procedures are usually longer and complex (B_{07}) and related regulations are not updated and adequate (B_{11}). Even if technical and regulatory barriers are handled, there are still critical social (i.e. B_{30}, B_{32}), information and awareness (i.e. B_{33}, B_{35}) obstacles for the adoption of new technologies due to unfamiliar procedures and behavioral patterns.

Involvement of multiple authorities and partners in SEC projects is faced with coordination (B_{03}) and cooperation (B_{04}) challenges. Integration of various energy strategies and multiple energy domains triggers interoperability barriers, including fragmented ownership (B_{10}), difficulty in developing an accurate and suitable plan (B_{27}) and providing a well-defined process (B_{28}) for project operation. SEC dependency on data collection, communication, and information dissemination brings about administrative, legal, and social challenges, including low acceptance of projects (B_{32}) due to privacy concerns, or reluctance of departments to share their data. Luthra et al. (2014) state lack of clear standards and guidelines to support system interoperability and lack of regulations for data privacy and data security as barriers to the smart grid. These barriers did not emerge critically in our study because there are only a few CONCERTO projects with a focus on smart metering and smart grid.

We prioritized barriers in a multi-dimensional approach according to three indicators: criticality, relationship with other barriers, and inevitability. 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 critical if it is not only frequent, but also if it has a high negative impact on project implementation. However, barriers are not usually independent and some barriers, although not very critical by themselves, may originate critical barriers (Marle et al., 2013). Therefore, combining relationship with criticality can help improving barrier prioritization. The relationship among barriers, if considered independently, helps to detect key driving barriers that originate or exacerbate others (Cagno et al., 2013; Wang et al., 2008).

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). This indicator can show the level of required action for tackling the barrier. A barrier which is least inevitable needs action only from project decision-makers; a barrier which is moderately inevitable needs action from both project coordinators and policy makers; and a barrier which is most inevitable requires action mainly from policy makers. This can clarify which barriers have a higher priority at project´s level and which barriers have a higher priority for policymakers.

The combination of inevitability and criticality (as in Figure 4.5) 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 the least inevitable, implying that they are mostly treatable 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 through an appropriate project organization.

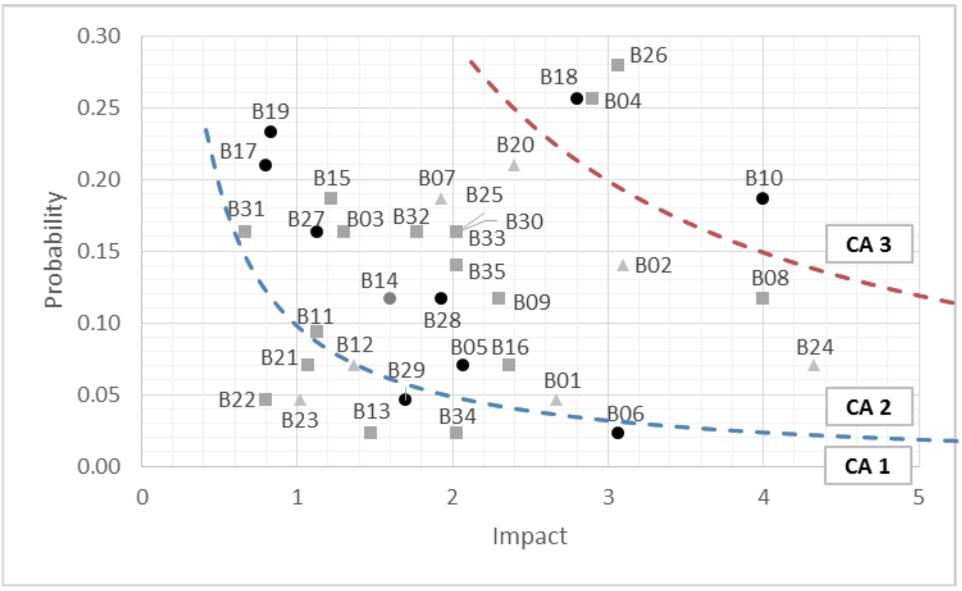


Figure 4.5 Combining criticality and inevitability of barriers. CA 1 indicates low criticality area; CA 2 indicates medium criticality area; CA 3 indicates high criticality area. The colours and shapes represent inevitability: black circle is the least inevitable; gray square is moderately inevitable; gray triangle is the most inevitable. The arrows indicate the direction of the causal interaction.

Above all, it is possible to combine all three indicators together for a comprehensive understanding of barrier priorities. Figure 4.6 illustrates such 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 most 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 the *shortage of proven and tested solutions and examples (B_{25})*.

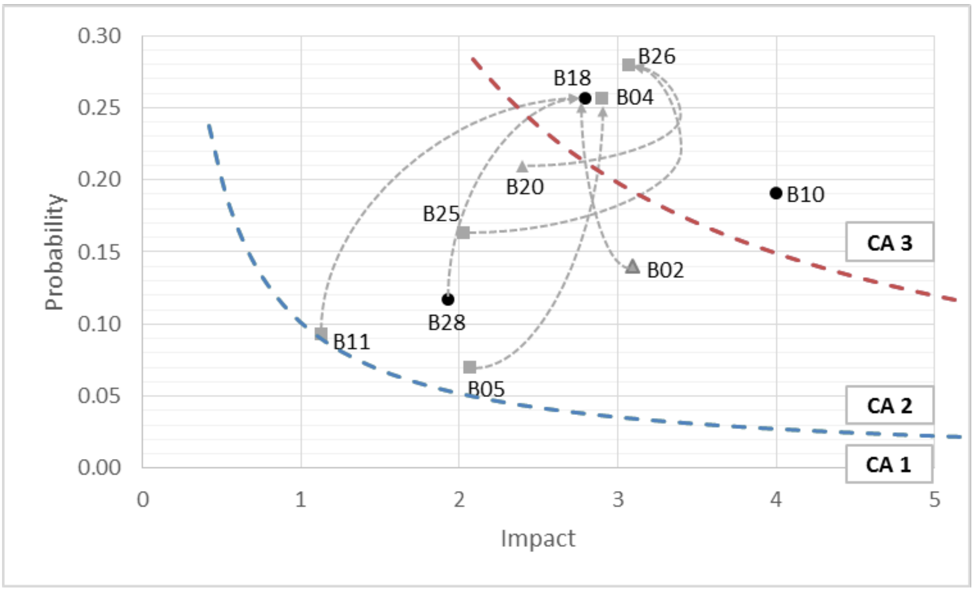


Figure 4.6 Criticality, inevitability, and interaction among barriers for the most critical barriers. CA 1 indicates low criticality area; CA 2 indicates medium criticality area; CA 3 indicates high criticality area. The colours and shapes represent inevitability: black circle is the least inevitable; gray square is moderately inevitable; gray triangle is the most inevitable. The arrows indicate the direction of the causal interaction.

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 on local traits will be the most effective for appropriate action.

4.5 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 the macro or Member State level. Promotion of SEC projects seems irreversible despite many barriers. In light of the analysis above, we derive following implications to tackle the barriers to implementation of SEC projects.

4.5.1 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 critical to 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 abided. 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. The involvement of municipal utilities is valuable, providing their support in negotiation with building owners. This helps to overcome the legal barriers related to enforcement of the use of community energy systems. Internal data platforms, transparency and effective communication, besides application of collaborative methods and tools, are necessary.

Furthermore, 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 are 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.

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.

4.5.2 Implications for policy makers

There is a need for upgrading national, regional, and local regulations for the adoption of new technologies. Legislative and support schemes stability at the national level is fundamental features 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 public and private sector.

Provision of wide-scale platforms and networks is fundamental to learning from other experiences and building knowledge around new technologies. This should be part of policies for the 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, prioritization analysis of barriers shows that a consistent political support during the long term is the critical for successful implementation of SEC projects. This can be ensured through integrated long-term national and local policies and plans.

4.6 Conclusions

This study 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 critical 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. Second, we suggested and applied a novel multi-dimensional approach to prioritizing barriers to SEC projects, combining the probability, level of impact, scale, causal relationships, 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 adopted "criticality", applied in risk-analysis, for evaluating the importance of a barrier. Criticality of a barrier is a function of its probability and impact. Fourth, we investigated and applied relationships with other 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.

It is worth mentioning that projects are complex identities and numerous internal and external characteristics influence their implementation (Marle et al., 2013). Specifically, 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 upon key local actors such as investors and developers and local authorities. Thus, the commitment of local administrations, choice of accompanying activities such as dissemination of information, use of appropriate communication tools, awareness raising, the participation 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 aid decision-makers, specifically project coordinators and policy makers, to better understand and prioritize implementation barriers in order to develop proper action and policy interventions to ensure successful implementation of SEC projects.

Part IV

Learning Methodologies for New Developments

Chapter 5

A Case-Based Learning Methodology to Predict Barriers to Implementation of Smart Energy City Projects

Based on:
F. Mosannenzadeh, S. Pezzutto, A. Bisello, C. Diamantini, G. Stellin, D. Vettorato. A case-based learning methodology to overcome barriers to implementation of smart and sustainable urban energy projects (under review, journal of *Cities*)

Summary of the chapter

Implementation of smart energy projects in urban areas encounters different barriers. These barriers range from common financial shortage to specific constraints, which depend on local socio-economic, environmental and political characteristics of each city. In spite of various experiences of European cities in smart energy city projects, the transfer of lessons learnt on how to manage barriers in new projects is inefficient. The main aim of this chapter is to apply a case-based learning methodology to predict barriers to a given smart energy city project. To achieve this aim, a decision support methodology is proposed and applied to the case study of the city of Bolzano, within SINFONIA project. SINFONIA is a European Commission Seventh Framework Programme (FP7) project for integration of smart energy solutions at urban district level. The decision support methodology operates in two main steps: first, identifying and selecting the most similar European smart energy city cases to the target-case (Bolzano within SINFONIA); second, investigating barriers to implementation of selected cases. The results show that the barriers *fragmented ownership of properties*, *limited access to capital and cost disincentives*, and *perception of interventions as complicated and expensive, with negative social or environmental impacts* are highly probable to occur in Bolzano within SINFONIA. It is possible to translate this methodology to a decision support system. The proposed methodology is applicable and replicable for urban planners and decision-makers in different territorial levels to facilitate and accelerate the implementation of smart energy city projects.

5.1 Introduction

Smart energy city (SEC) development is subject to increasing attention during the past decade as a response to global energy challenges and socio-economic and political changes. SEC development aims to take advantage of information and communication technologies to improve urban services and infrastructure, optimize use of energy resources, and decrease negative social and environmental impacts of high energy consumption (based on EC, 2015g; Washburn et al., 2009). In presence of financial support for smart cities and communities provided by both European Commission funding and huge private corporations, many European cities have initiated SEC development projects in urban areas in order to address EU energy targets (e.g. 20-20-20 goals), while providing their citizens with higher quality of life (Perboli et al., 2014; Vanolo, 2014). However, implementation of these developments encounters different barriers that make the project execution difficult or impossible. These barriers range from common financial shortage to specific constraints, which depend on local socio-economic, environmental and political characteristics of each city as well as characteristics of the projects. In order to support SEC development to proceed, it is necessary to predict these barriers in an early stage of the project in order to avoid or tackle them appropriately. One effective way to predict barriers for an urban development project is to learn from previous similar experiences (Painuly, 2001).

There are numerous experiences in SEC developments and usually their success factors and lessons learnt are published in project deliverables. Current learning methods in urban energy development on how to overcome barriers to implementation of a new SEC project include recognizing best practices and applying their lessons learnt in the new project (e.g. Friedl and Reichl, 2016; Kennedy and Basu, 2013; Rupf et al., 2015). The problem is that not all experiences encounter similar barriers. Projects are complex issues with different characteristics and the barriers to each case may be different (Marle et al., 2013). Therefore, lessons learnt may not be applicable in all new projects. In addition, investigation of all previous experiences may not be possible within project limited time and budget. This may result in missing out some very relevant information. Thus, a relevant question for decision-makers would be how to efficiently find relative information for their specific project? In other words, how to find the most similar cases to their specific case?

To address abovementioned question, we suggest to apply case-based learning methods, which are stated to be potentially very useful for prediction purposes in urban planning (Yeh and Shi, 1999), but has not been used for predicting barriers to urban development. These methods are proved to be effective in weak-theory domains, where recording and representing knowledge is too case-specific (Yeh and Shi, 2001), and where a great number of previous cases exist and provide the opportunity for deduction (Remm, 2004). In case-based learning, the principle is learning from previous similar experiences in order to create predictions for a specific new case. This is done through finding analogies between previous experiences and the target-case (Aha, 1991). Multiple benefits of analogy-based methods enumerated by Shepperd and Schofield (1997) and with respect to this research include: First, they are specifically useful for poorly understood domains because knowledge is based upon what has actually occurred; this advantage suits well SEC development, which is recent and not fully investigated. Second, they address barriers that actually occurred in real practice; this helps decision-makers to prioritize and recognize relevant and practical barriers from theoretical ones. Third, they can address both successful and failed cases; this enables decision-makers to recognize situations with a high potential for failure. Moreover, users are often more open to accept knowledge gained from the analogy-based methods.

The aim of this research is to apply a case-based learning methodology to predict barriers to a given smart energy city project. We suggest a decision support methodology based on an analogy between previous SEC cases and the target-case. We define a case as the site (city or district) in which a project is implemented. A project may have multiple implementation sites, various in characteristics. Therefore, each case is distinguished by the name of the site and the name of the project, written as Site-PROJECT (e.g. Bolzano-SINFONIA).

The present investigation is mainly based on 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). This chapter is structured as follows. In section 2, the methodology is explained in detail. Then in section 3, an application of suggested methodology is illustrated for Bolzano-SINFONIA as case study. In section 4, the main results are discussed and further improvements of the methodology are suggested. Finally, in section 5, remarks and further applications are proposed.

5.2 The decision support methodology

The proposed decision support methodology is elaborated by following two steps: first, identification and selection of the most similar European SEC cases to the target-case; and second, predicting barriers to the implementation of the target-case. The following sectors explain each step.

5.2.1 Selection of the most similar smart energy city cases to the target-case

The aim of this step is to find the most similar SEC cases to the target-case in order to undertake further investigations on their barriers. Applying analogy, the prominent principle is analyzing all cases based on their characteristics. Therefore, completed cases are assembled and then, the most similar ones to the target-case (for which a prediction is required) are identified. This method for prediction is stated to have two challenges: first, how to characterize cases? And second, how to measure similarity? (Shepperd and Schofield, 1997) We add another challenge: how to select cases? Thus, applying this methodology for this study, the following steps are suggested.

a) Gathering a list of SEC cases;
b) Characterizing SEC cases;
c) Comparing SEC cases to the target-case;
d) Selecting the most similar cases to the target-case.

The mentioned steps and how to address each challenge are explained in more detail as follow.

a) Gathering a list of smart energy city cases

In order to gather a list of SEC cases that provide sufficient information to predict barriers to implementation of target-case, three main considerations are suggested: firstly, the cases should share a common context with target-case in terms of funding and general structure of the projects; this will create a first level of background similarity. Secondly, the projects should have been already implemented so that there is meaningful data on encountered barriers to implementation. Thirdly, data should be available for all cases. Thus, for SEC cases funded under EU Sixth and Seventh Framework Programme (FP6 and FP7), we suggest to gather projects funded under EU FP6 and FP7 smart cities and communities calls and those, which are completed before 2015. Hence, there is a commonality between these projects and target-case; they are already implemented; and the list of these projects as well as some general information about each project are available in CORDIS, which is European Commission (EC) primary public portal to disseminate information on all EU-funded research projects (EC, 2015h).

b) Characterizing smart energy city cases

In this step, we select a set of features in order to characterize SEC cases. We apply the 5W+1H model (Jia et al., 2015), which is proved to be a comprehensive and effective analysis tool for smart city developments (Chapters 2 and 3). Based on this model, we characterize SEC cases versus six questions of why, what, who, where, when, and how. To translate these questions to characteristics (i.e. features), we reviewed literature on characterization of smart city projects, urban development plans, and energy projects. Finally, with respect to the target of the research, a set of features were selected based on following criteria: the data for each feature should be available for all cases (Shepperd and Schofield, 1997); features should be sufficiently general to be able to characterize cases (Rich and Knight, 1991); they should be sufficiently significant/detailed to enable distinguishing similarity (Shepperd and Schofield, 1997); and the number of characteristics should be in a rate that are unproblematic to apply.

The selected features include, for each project demo case, objectives (why) (Perboli et al., 2014; Ţăpurică and Tache, 2014), domains of intervention (Chapter 2) and presence of social housing (Di Nucci and Spitzbart, 2010) (what), project partners (who) (Perboli et al., 2014), size of the city involved in the project and spatial scale of the project (where) (Carlos and Khang, 2008; Perboli et al., 2014), project timing (when), applied technologies (Ţăpurică and Tache, 2014) and the overall budget (Carlos and Khang, 2008; Ţăpurică and Tache, 2014) (how) (Figure 5.1).

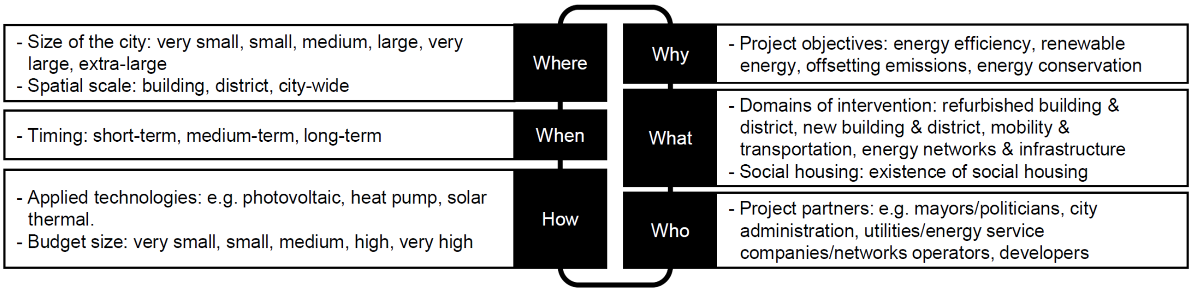


Figure 5.1 Features characterizing smart energy city cases by application of 5W+1H model (based on Mosannenzadeh and Vettorato, 2014)

The feature types are suggested to be categorical (i.e. ordinal or nominal measures) due to simplicity of application for the user (i.e. decision-makers). From all nine features, five features (i.e. objectives, domains of intervention, social housing, project partners, and applied technologies) are nominal variables. The other four features (i.e. size of the city, spatial scale, timing, and budget size) are ordinal variables. Nominal variables are not exclusive, meaning that the case can cover more than one category. For example, a case can have multiple objectives at the same time. On the contrary, ordinal variables are exclusive, meaning that the case fits only in one category. For example, size of the city can fit in only one of the six alternative categories (very small, small, medium, large, very large, and extra-large).

Each feature is divided into relevant categories based on scientific literature, European documents on smart cities, and empirical projects on smart city initiatives: Project objectives include four categories of energy efficiency, renewable energy, energy conservation (Vettorato, 2011) and offsetting emissions (Kylili and Fokaides, 2015). Domains of intervention include four categories of refurbished building and district, new building and district, mobility and transportation, and energy networks and infrastructure (based on EC, 2013). Social housing has one category given by the existence of social housing (Di Nucci and Spitzbart, 2010). Project partners include 16 categories of mayors/politicians, city administration, utilities/energy service companies/networks operators, developers, architects/planners/engineers, housing/construction companies, renewable energy industry, other industries, component manufacturers, information and communication technology (ICT) companies, financial institutions, research and development (R&D) institutes/universities, inhabitants (owners, tenants, etc.) (Friuli Venezia Giulia Region, 2013; Leydesdorff and Deakin, 2011), innovation/technology consultants, energy consultants, and transportation consultants (based on CONCERTO, 2015b). Size of the city includes six categories of very small (less than 50,000 inhabitants), small (50,000 to 100,000 inhabitants), medium (100,000 to 250,000 inhabitants), large (250,000 to 500,000 inhabitants), very large city (500,000 to 1,000,000 inhabitants), and extra-large city (1,000,000 to 5,000,000 inhabitants) (Dijkstra and Poelman, 2012). Spatial scale includes three categories of building, district, and city-wide. Timing includes three categories of short-term (1-2 years), medium-term (3-7 years), and long-term (more than 8 years), Technologies include 63 categories such as heat pump, solar thermal, photovoltaics, etc. (Anderson et al., 2012) and budget size includes six categories of very small (0 to 10 mil.€), small (10 to 20 mil.€), medium (20 to 30 mil.€), high (30 to 40 mil.€), and very high (40 to 50 mil.€) (CONCERTO, 2015b).

c) Comparing smart energy city cases to the target-case

In this step, previously identified and characterized SEC cases are compared to the target-case and the most similar cases are identified. Analogy investigations are based on distances between cases (Aha, 1991). For the present study, the distance measure is normalized hamming distance (Palamara et al., 2011). The normalized hamming distance is appropriate for categorical data sets (Lourenco et al., 2004); moreover, it is not affected by the number of categories inside each feature (Palamara et al., 2011). To find the distance between each case (*C*) and the target-case (*T*), first, we calculate the distance between each of their features D_f (*C*, *T*) as shown in Equation 1.

$$D_f\ (C,T) = \frac{\sum_{j=1}^{n} \delta\ (C_j,T_j)}{n} \qquad with \qquad \delta\ (C_j,T_j) = \begin{cases} 0 & if\ C_j = T_j \\ 1 & if\ C_j \neq T_j \end{cases} \tag{1}$$

where *n* is the number of categories inside the feature; and *j* is the subject of comparison (category). δ is the function of distance between two categories. Then, the total distance of each case to the target-case D_t (*C*, *T*) is calculated as a function of all feature disances as shown in Equation 2.

$$D_t(C,T) = \sqrt{\sum_{i=1}^{m} {D_{fi}}^2} * 100 \tag{2}$$

Where *i* is the feature number; and *m* is the number of features. The total distance is calculated as the Euclidian distance between two cases in an *m* dimensional feature space. This implies that a higher distance leads to lower similarity. We consider no weighting for features, which means that features have equal degree of influence (Shepperd and Schofield, 1997).

d) Selecting the most similar cases to the target-case

After giving a value of similarity to each case, we aim to select *K* number of the most similar cases to the target-case. To this aim, we apply Radius K-nearest neighbor (RKNN) method (Muja and Lowe, 2014), in which the goal is to find the *K* most similar projects to target-case within the distance *R* from it. The *R* value helps to select only those cases, which have at least a certain amount of similarity to target-case. Here, *K* is the sample size of the research. It represents those cases that will be investigated for their barriers in the next step of methodology. The variable *R* stands for the maximum allowed distance from target-case. We suggest that a case is accepted to be similar to the target-case only if its total distance to the target-case is less than 35 percent of maximum possible distance. The maximum possible distance is calculated by the number of project features (*m*).

Finally, in order to get a high level of diversity of results, we add another restriction to selection of sample. This restriction indicates that from each project, only one case can be selected. That means, if there is more than one case with less distance than R in a project, only the one with the least distance is selected.

5.2.2 Predicting barriers to the implementation of the target-case

The objective of this step is to predict barriers to the target-case based on knowledge gained from selected most similar cases. Knowledge on barriers to implementation of many SEC cases is available in the webpage of the projects. It is also retrievable from project publications. These sources, however, are not consistent, which means they do not always exist for all projects and the gathered data are not within the same structure. Another way to gather knowledge is to elicit it from people with expert knowledge (Shadbolt and Smart, 2015), who have enough information about the project implementation (Price et al., 2012). The advantage of the latter source is that it is applicable for all projects. Moreover, it can be gathered in a previously designed and systematic structure in order to fulfill specific aim of the research. For the aim of this study, we suggest knowledge elicitation from project leaders because they are aware of barriers that the project encounters.

Since SEC cases are relatively recent and many barriers to their implementation are not yet investigated, a semi-structured questionnaire with general categories of barriers (e.g. economic, legal, social, and technical) is suggested. Semi-structured questionnaires are a primary method to collect information from individuals on past experiences. Moreover, they allow gathering detailed information in a general structured way (Harrell and Bradley, 2009). The gathered data should be aggregated in an applicable manner for the target-case. The data should be generalized and coordinated with respect to literature on barriers to smart city and energy policies, plans and projects. The number of appearance (frequency) of each barrier in investigated cases can provide the probability of its occurrence in the target-case: *barrier probability = frequency / total number of selected similar cases*.

5.3 Application of the methodology in Bolzano within SINFONIA project

To test the methodology, we selected the city of Bolzano within SINFONIA project as target-case (see SINFONIA, 2015). SINFONIA is a seventh Framework Programme project for integration of SEC solutions at urban district level. This case is selected because Bolzano is a leading city in energy saving and renewable energy in Italy. Besides, the authors of this chapter are partly involved in SINFONIA project and interact with the administration of Bolzano. In the following, each step of the methodology is applied for Bolzano-SINFONIA to predict barriers to its implementation. First, the most similar cases to Bolzano-SINFONIA are identified, and then their barriers are investigated.

5.3.1 Selection of the most similar smart energy city cases to Bolzano-SINFONIA

Following the proposed methodology, in this step, a list of previously completed cases in SEC development are gathered and characterized versus proposed features. This leads to a pair-wise comparison between cases and Bolzano-SINFONIA, which subsequently leads to selection of the most similar cases to Bolzano-SINFONIA.

a) Gathering a list of smart energy city cases

Here we list 22 implemented SEC district projects all within European Commission initiative named CONCERTO. CONCERTO, funded within European FP6 and FP7, started in 2005 and has been co-funded with more than 175 Million Euros in 58 European cities and communities in 23 European countries (CONCERTO, 2015c). CONCERTO projects incorporate innovative energy efficiency interventions and exploiting local renewable energy sources. They demonstrate the feasibility and integration of renewables-based cogeneration, smart grids, district heating/cooling systems and energy management systems in districts. In these projects, innovative interventions are localized, considering specific socio-economic, political, and environmental characteristics of the site (CONCERTO, 2015c). CONCERTO initiative is the subject of this research because the cases are in the same funding context with Bolzano-SINFONIA; they are mostly completed or are in the final period of completion; and finally, the information for characterizing each community (case) inside each project is available through official open access to products and publications of the initiative (CONCERTO, 2015c).

b) Characterizing smart energy city cases

According to the methodology (section *2.1.* part *b*), nine features are selected for characterizing cases. Each feature counts *n* different categories. For example, project objectives count four categories: Energy Efficiency (EE), Renewable Energy Sources use (RES), Offsetting Emissions (OE), and Energy Conservation (Ec). As an example of characterizing cases based on features and categories, Case 1 aims to address the objectives EE, OE, and Ec and Bolzano-SINFONIA aims to address all four objectives (Table 5.1).

Table 5.1 Characterizing Case 1 and Target-case (Bolzano-SINFONIA) for feature 1 (Project Objectives)

Category number (j)		*1*	*2*	*3*	*4*
*Category title**		*EE*	*RES*	*OE*	*Ec*
Cases	· Case 1	×	×	−	×
	· Bolzano-SINFONIA	×	×	×	×

*EE stands for Energy Efficiency; RES stands for Renewable Energy; OE stands for Offsetting Emissions; and Ec stands for Energy Conservation

c) Comparing and selecting the most similar cases to Bolzano-SINFONIA

In this step, we hold a pair-wise comparison between Bolzano-SINFONIA and all cases in our database. In more detail, to compare each case with Bolzano-SINFONIA, we calculate the distance of each feature of the case with the same feature in Bolzano-SINFONIA by application of Equation 1. For example, to calculate the distance of Case 1 and Bolzano-SINFONIA for feature 1 (project objectives) with 4 categories (as *n* in Equation 1), we have $\delta\ (C_1, T_1)$ = 0, $\delta\ (C_2, T_2)$ = 0, $\delta\ (C_3, T_3)$ = 1, and $\delta\ (C_4, T_4)$ = 0; leading to $D_f\ (C, T) =$ (0 + 0 + 1 + 0) / 4 = 1/4 = 0.25. Where *C* represents Case 1 and *T* represents Bolzano-SINFONIA. The distances for all nine features for Case 1 is calculated and presented in Table 5.2 (characteristics of Case 1 is shown in Table 5.3).

Table 5.2 Distances of features between Case 1 and the Bolzano-SINFONIA

Feature number (i)	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
Feature title	Project Objectives	Domains of intervention	Social housing	Project Partners	Size of the city	Spatial scale	Timing	Applied Technologies	Budget size
Distance of feature (D_f)	0.25	0.60	1.00	0.31	0.20	0.50	0.50	0.27	1.00

The total distance of Case 1 to Bolzano-SINFONIA is calculated based on Equation 2 and the content of Table 5.2; and therefore D_t (*C*, *T*) = $\sqrt{\sum_{i=1}^{9} {D_{fi}}^2 * 100}$ = $\sqrt{D_{f1}^2 + D_{f2}^2 + D_{f3}^2 + \cdots + D_{f9}^2 * 100}$ = $\sqrt{(0.25)^2 + (0.60)^2 + (1.00)^2 + \cdots + (1.00)^2 +} * 100$ = 176.96. This process is repeated for all cases.

d) Selecting the most similar cases to the target-case

To illustrate the application of methodology, we found five most similar cases to Bolzano-SINFONIA case. In this example, the K is 5. R is 105, meaning that if an identified similar case has a distance more than 105, it is not accepted for further investigation. We take only one case from each project. The path to select the five most similar cases to Bolzano-SINFONIA is as following: the first case with the least distance to Bolzano-SINFONIA (85.0) is Turin from POLYCITY project. The two next cases are Lambeth within ECOSTILER project (with the distance of 88.3) and Birstonas within ECO-LIFE project (with the distance 94.3). The next case is Amsterdam, which is again within ECOSTILER project; thus, we don't accept it for further investigation. This goes on until we select five cases for further investigation (Figure 5.2). Since all of these cases have a distance less than 105, they are all accepted.

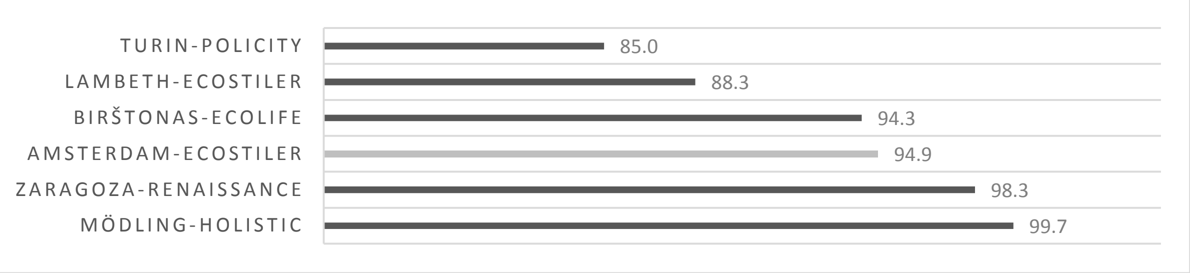


Figure 5.2 Selection of the most similar cases to Bolzano-SINFONIA based on their total distance; the lines show graphical distances and the numbers right to the lines show numerical distances. Black lines show selected cases, gray discarded.

Table 5.3. Comparison of the most similar cases to Bolzano-SINFONIA and example Case 1

Case description	Case	*Project Objectives**	*Domains of intervention***	*Social housing*	*Size of the city (1000 inhabitants)*	*Spatial scale****	*Timing (Years)*	*Budget size*****	*Distance*
Target case	· Bolzano-SINFONIA	EE, RES, OE, Ec	RBD, NBD, NI	Yes	100-250	Bd, Ds	3-7	XL	0
Selected similar cases	· Lambeth-ECOSTILER	EE, RES, OE, Ec	RBD,NI	Yes	250-500	Bd, Ds	3-7	S	88.3
	· Turin-POLYCITY	EE, RES, OE, Ec	RBD, NI	Yes	500-1000	Bd, Ds	3-7	S	85.0
	· Mödling-HOLISTIC	EE, RES, OE, Ec	RBD,TM, NI	Yes	<50	Bd, Ds	3-7	S	99.7
	· Birštonas-ECOLIFE	EE, RES, OE, Ec	RBD, NBD, TM, NI	Yes	<50	Bd, Ds	3-7	S	94.3
	· Zaragoza-RENAISSANCE	EE, RES, OE, Ec	RBD, NBD, NI	Yes	500-1000	Bd, Ds	3-7	S	98.3
Example case	· Case 1	EE, OE, Ec	NBD	No	<50	Bd	1-2	XS	176.96

*EE stands for Energy Efficiency; RES stands for Renewable Energy Sources; OE stands for Offsetting Emissions; and Ec stands for Energy Conservation. **RBD stands for Refurbished Building and District; NBD stands for New Building and District; TM stands for Transportation & Mobility; and NI stands for Networks and Infrastructure. ***Bd stands for Building; and Ds stands for District; ****XS stands for very small; S stands for small; and XL stands for very high.

Selected similar cases and their characteristics are illustrated in Table 5.3. Like Bolzano-SINFONIA, the objectives of most similar cases address EE, RES, OE, and Ec. The domains of intervention, for all of the selected similar cases is Refurbished Building and District (RBD) as well as Networks and Infrastructure (NI); Birštonas-ECO-LIFE and Zaragoza-RENAISSANCE also cover New Building and District (NBD). Like Bolzano-SINFONIA, all similar cases include social housing. The size of the city varies from 50,000 to one million population. The spatial scale of all similar cases covers building and urban district scale. In terms of time line of the similar cases, they are all medium-term plans (3-7 years). The budget of the plan in all similar cases is small scale (S) different from Bolzano-SINFONIA that has a very high budget. The project partners involved in selected similar cases include city administration, utilities, real estate developers, architects and planners, housing companies, component manufacturers, research and development institutes and universities. Most similar applied technologies in selected similar cases among others include insulation, passive cooling, photovoltaic, heat pumps, district heating district heating and cooling, solar thermal, HVAC systems, thermal cooling, combined heat and power, and demand side management. In contrast, Case 1 and its characteristics, also illustrated in Table 5.3, show significant differences between this case and Bolzano-SINFONIA.

5.3.2 Predicting barriers to the implementation of Bolzano-SINFONIA

The barriers for selected projects were investigated through a semi-structured questionnaire that had been previously done as part of CONCERTO projects. The result of this questionnaire is accessible through official open access to CONCERTO products and publications (CONCERTO, 2015c). It includes a detailed description of implementation barriers for each case, divided by five groups of administrative, economic, legal, social, and technical barriers. This information has been gathered, analyzed and categorized on existing five dimensions. Barriers with similar subject have been grouped together. Then, these groups are revised with respect to related scientific literature to validate the terminology and categories of each barrier. Reviewed literature include studies on barriers to implementation of smart energy technologies (Luthra et al., 2014) as well as studies on energy efficiency (e.g. Cagno et al., 2013; Reddy, 2013; Rohdin and Thollander, 2006; Sorrell et al., 2000) and renewable energy policies (e.g. Beck and Martinot, 2004; Painuly, 2001; Pîrlogea, 2011; Reddy and Painuly, 2004).

The list of probable barriers to implementation of Bolzano-SINFONIA is presented in Table 5.4. In this table, the number of appearance of each barrier in investigated cases is shown in parenthesis. We suggest that those barriers with higher number of appearance are most probable to occur in Bolzano-SINFONIA as well. It means that *fragmented ownership of properties*, *perception of interventions as complicated and expensive, with negative social or environmental impacts,* and *limited access to capital and cost disincentives* are most probable to occur in Bolzano-SINFONIA. On the other hand, those barriers that appeared only in one of the investigated cases are less probable to occur in Bolzano-SINFONIA. They include *inadequate regulations appropriate for new technologies, long and complicated procedures for authorization of project activities*, and *long and complicated public procurement procedure*. These barriers are related to city regulatory and social characteristics. However, analysis of Bolzano-SINFONIA against all these barriers is suggested.

Table 5.4 Barriers and their probability to occur in implementation of Bolzano-SINFONIA

Barrier category	*Barrier*	*Probability*
Financial and economic	· Perception of interventions as complicated and expensive, with negative social or environmental impacts (3)* (IEA, 2010; Painuly, 2001)	· 0.60
	· Insufficient external financial support and funding for project activities (2) (Pîrlogea, 2011)	· 0.40
	· Limited access to capital and cost disincentives (3) (Luthra et al., 2014; Painuly, 2001; Pîrlogea, 2011; Thollander et al., 2010)	· 0.60
Policy, institutional and regulatory	· Insufficient financial incentives (2) (Luthra et al., 2014; Painuly, 2001; Piscitello and Bogach, 1997)	· 0.40
	· Inadequate regulations appropriate for new technologies (1) (Luthra et al., 2014)	· 0.20
	· Long and complex procedures for authorization of project activities (1) (Pîrlogea, 2011)	· 0.20
	· Fragmented ownership of properties (4) (Ferranto et al., 2013)	· 0.80
	· Long and complicated public procurement procedure (1) (Dutton, 2007; Thai, 2008; Thai et al., 2005)	· 0.20
Behavioral	· Lack of values and interest in energy optimization measurements (2) (Rohdin and Thollander, 2006; Song, 2006; Sorrell et al., 2000)	· 0.40
	· Low acceptance of new projects and technologies (1) (Painuly, 2001; Pîrlogea, 2011; Wright et al., 2014)	· 0.20
Technical	· Lack of skilled and trained personnel (1) (Painuly, 2001; Pîrlogea, 2011; Wright et al., 2014)	· 0.20
	· Deficient planning (2)	· 0.40

* The numbers in parenthesis show the number of appearance of the barrier

5.4 Discussion

In this chapter, we applied case-based learning methods for supporting decision-makers to systematically find similar SEC cases (site of project implementation) to a target-case. This helps them to predict the probability of barriers to implementation of their new SEC project by learning from previous similar experiences. We tested the application of this methodology in the city of Bolzano within the project of SINFONIA.

We proposed a framework to characterize SEC cases based on nine selected features. Applying this framework for the case study was rather easy to implement and resulted in a certain amount of similarity between cases. However, since this chapter takes the first steps of characterizing SEC projects, it is possible to discuss the characterization in two levels. Firstly, selected features for characterization of projects may vary and new features could be added to the analysis; e.g. project business models or project initiator (Perboli et al., 2014). Secondly, the categories within each feature could be revised based on further information. For example, while analyzing the cases based on main objectives, it was obvious that there are many SEC cases that aim to smooth collaborative planning through collaborative tools such as workshops, data platforms, and local stakeholder networks. This shows the possibility of adding this category to the main objectives. Similar revisions and updates may occur for improvement of the project/case analysis framework.

The comparison of cases to Bolzano-SINFONIA was done through application of distance analysis. Distance analysis is proved to be an effective method for evaluation and clustering of smart city initiatives against an “ideal” configuration, which includes all ideal smart city characteristics (Manville et al., 2014). In this chapter we reintroduce distance analysis as a method to compare SEC cases and find similarity not to an ideal configuration, but to a specific target-case. The result is selection of Lambeth-ECOSTILER, Turin-POLYCITY, Mödling-HOLISTIC, Birštonas-ECO-LIFE, and Zaragoza-RENAISSANCE as the five most similar cases to Bolzano-SINFONIA (Table 5.3). A glimpse on Table 5.3 shows that selected cases are similar to Bolzano-SINFONIA in seven features; only in two features dissimilarities are considerable. The first is size of the city. This may show that different cities in size implemented similar projects. The second difference lies in the budget size of the cases; all selected cases have a small budget size (5-10 mil. €) different from Bolzano-SINFONIA with a very high budget size (20-25 mil. €). One reason could be that from all 58 characterized cases in the data base, the budget of 46 cases (80%) is under 10 million Euros. It means that it is most probable that cases that are most similar to Bolzano-SINFONIA in other features have small budgets.

To compare cases with the target-case, we gave equal weights to all features, meaning that all features have equal influence on similarity. However, it is possible to assign different weights to the features, indicating their level of influence in finding similarity. For example, a higher importance can be given to project objectives rather than project partners (Ishizaka and Labib, 2011). A higher degree of flexibility can be provided as well by allowing decision-makers to assign different weights to the features themselves. This will help decision-makers to get results exactly based on their objectives. The weights are then allocated by the importance the decision-maker assigns to each feature (see for example Macharis et al., 2010). To assign the weights, existing methods such as direct allocation, pair-wise comparison, and the allocation of 100 points can be used (see Nijkamp et al., 2013).

To translate our suggested methodology to a decision support system (DSS), combination of all steps of our proposed methodology is required (see Figure 5.3). The DSS would include a database of previous experiences, characterized as we suggested (see Figure 5.1). As the input to the DSS, the decision-maker would provide project characteristics (i.e. project features; e.g. objectives, stakeholders, and budget), the relative weight or importance for each characteristic, and the number of desired similar cases –i.e. *K*. The DSS would use the distance analysis and RKNN explained in this research (see sections 2.1.c and 2.1.b) to deliver the output: a list of *K* most similar cases to the target case, a graph of the distance of each similar case to the target case (similar to Figure 5.2), and the probability of barriers to the implementation of the target-case, based on frequency of barriers in similar cases. The DSS may also introduce web-links and publications of the selected similar cases. This can be used for searching applied solutions to overcome barriers.

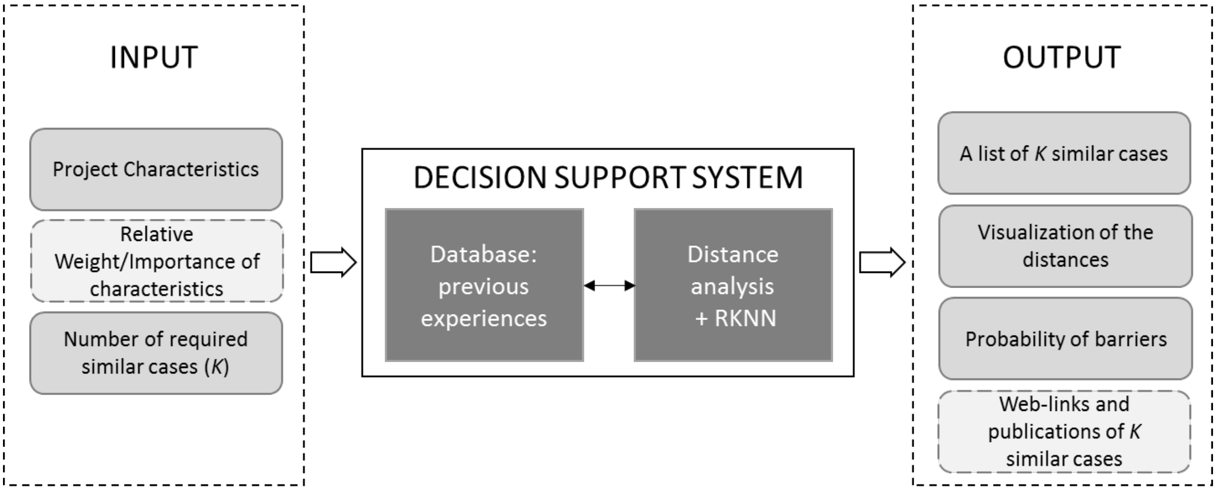


Figure 5.3 Translation of the proposed methodology to a decision support system for predicting barriers to implementation of a target-case; RKNN stands for Radius K-nearest neighbor method.

A small scale application of the methodology is illustrated in the city of Bolzano within SINFONIA project. We gathered a database of previous SEC experiences. Then we characterized Bolzano-SINFONIA based on its features. Then, through the distance analysis, we compared previous experiences with Bolzano-SINFONIA (based on the characteristics) and identified the five most similar previous cases to Bolzano-SINFONIA. This was also illustrated in a graph showing the distances (Figure 5.2). Then, we gathered information on barriers and their frequency to the five most similar cases to Bolzano-SINFONIA. This provided which barriers and to what extend are probable to occur in implementation of Bolzano-SINFONIA (Table 5.4).

Although only five cases were selected, comparative similarities between their barriers is noticeable. The most appeared barrier is *fragmented ownership of properties*, which is strongly connected to project domains of intervention. In fact, in projects that include refurbishment of buildings and districts, it is highly probable that there are problems with multiple ownership of the flats (Immendoerfer et al., 2014). Another barrier with high number of appearance (three times) is *limited access to capital and cost disincentives*. This barrier is strongly connected to *insufficient external financial support and funding for project activities* (appeared two times), which is related to project budget (i.e. funding) and project partners (third party). The dependence of the most appeared barriers to the project characteristics suggests that there are strong connections between project characteristics and encountered barriers. On the other hand, the least appeared barriers are more related to city regulatory and social situations. For example, policy, institutional and regulatory barriers are characterized by a high variability depending on the regional and national regulatory context (Immendoerfer et al., 2014). These barriers may be particularly relevant in countries like Italy, and consequently in Bolzano-SINFONIA case, where the energy related regulatory framework is complicated and instable (Caputo and Pasetti, 2015). However, this variety is not tracked in the suggested methodology. This leads us to the following discussion point.

Barriers not only relate to project characteristics, but also to local, regional, and national characteristics of the site in which the project is implemented (Marle et al., 2013). The example is legal and regulatory frameworks of a country, which have a significant influence on successful implementation of a project (Painuly, 2001). Since suggested characterization by this study mainly addresses barriers on project level, further improvement of the methodology includes adding more features at city scale, regional scale, and national scale. However, it is important to keep simplicity for user application in terms of number of features. Having a system of characteristics will result in more accurate comparison of projects and therefore, better prediction of barriers to the target-case.

This chapter discussed a first phase of "detecting barriers" that may occur in implementation of the SEC projects. Possible further development of this research can focus on analyzing identified barriers e.g. versus their effect on different stakeholders involved in the projects (Cagno et al., 2013). Similarly, the proposed methodology can also be used to learn about potential solutions to overcome the barriers.

5.5 Conclusions

To predict barriers to implementation of a SEC project, this study suggests to our knowledge for the first time, the application of a case-based learning method. This method allows filtering previous experiences in order to find the most similar cases to a target-case. Testing this methodology in the city of Bolzano within SINFONIA project shows a meaningful similarity between selected projects as well as a list of probable barriers to project execution.

Our proposed methodology makes three main contributions to existing methods of learning from previous experiences for overcoming barriers to the implementation of SEC projects. First, filtering previous experiences increases the applicability of knowledge gained through learning process; for example, if barrier *a* occurred in a case similar to the target-case, and barrier *b* occurred in a case different from the target-case, the probability that barrier *a* occurs in the target-case is higher than the barrier *b*. Second, filtering the experiences increases the efficiency of learning process because it allows a focus on few similar cases instead of checking out all available previous experiences. This allows a deeper investigation within given time, budget, and/or human resource constraints. Third, we suggested a framework for characterization of the SEC projects based on which similarity is calculated. This framework is helpful not only for the aim of this research, but also for any other purpose that requires classification of the projects based on their characteristics.

Suggested methodology helps decision-makers at different levels to foreseen bottlenecks in the process of SEC plans, and elaborate a reliable contingency strategy for the future. From a higher perspective, this methodology helps to accelerate transformation of urban energy systems in order to achieve European energy targets. The method can be useful for other stakeholders involved in promotion, development, and financing SEC projects in urban areas as well. For example, universities may apply this method to provide training or communication tools. Banks and other financial institutions may apply this method to design innovative funding schemes for development of SEC projects.

Moreover, proposed methodology is applicable for various urban development objectives (Yeh and Shi, 1999), which require learning from previous similar experiences. For example, for development control (Yeh and Shi, 2001), for finding success factors for sustainable urban development plans (e.g. Nijkamp et al., 2002; Rasoolimanesh et al., 2014; Richards and Palmer, 2010) or finding appropriate methods for participatory planning (e.g. Deng et al., 2015; Roy, 2015). Our methodology helps to filter previous experiences in a systematic and scientific way in order to find the most relevant knowledge for specific aims and cases. This method can also be applied by decision-makers to find relevant cities for cooperation and networking (see Masser, 1990; Tjandradewi and Marcotullio, 2009).

Further development of the methodology can result in a multi-criteria decision making tool for urban planners and decision-makers to investigate previous similar experiences in order to improve their own projects.

Finally, small scale application of the methodology requires that a decision-maker hold all steps by herself. In contrast, application of such methodology in a large scale and through a DSS (as described before) would be very efficient and convenient since the database on projects and their barriers would be previously prepared. Therefore, we suggest to create a DSS, including a database of SEC projects in European or global level. This will facilitate analysis of the projects in a common structured way. It could be a shared platform with a standard framework that leads project authorities share their knowledge in a predefined structured framework. Such DSS can be easily integrated in existing well-known platforms such as covenant of mayors, smart cities and communities stakeholder platform or smart cities and communities information system (CONCERTO, 2015a). Moreover, such DSS can be extended to other topics (e.g. success factors, etc.) and other characteristics (e.g. city, regional, national characteristics) as well.

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Chapter 6

Using Decision Tree Learning to Predict Barriers to Implementation of Smart Energy City Projects

Based on:
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Summary of the chapter

Successful implementation of smart energy city (SEC) projects is essential to optimization of urban energy systems. Our research aims to support decision-makers to predict, and thus, mitigate barriers to the successful implementation of new SEC projects based on project characteristics, through the application of decision trees. Decision trees are predictive models, used in machine learning, which can identify predictive rules from a dataset. We created a dataset that included 43 cities, 35 barriers as response variables and 198 project characteristics as explanatory variables. We applied decision trees on the dataset, and we could build 20 barrier models for prediction of barriers based on independently selected project characteristics. We evaluated and classified the barrier models based on their performance, in terms of accuracy and sensitivity. The models for the *economic crisis*, *lack of values and interest in energy optimization measures*, *time-consuming requirements by European Commission concerning reporting and accountancy*, and *local unfavorable regulations for innovative technologies* revealed very good performances. We then tested the application of the generated models in two new datasets, indicating a new European Union project, named SINFONIA. Three out of four models with very good performances correctly predicted barriers for the SINFONIA project. Our results underline the high potential of decision trees as prediction tools for barriers to the implementation of SEC projects based on project characteristics. The results of this research will support SEC project decision-makers in different territorial levels to enhance project implementation. Application of the method presented here on a larger scale can provide an important contribution to understanding, predicting, and, therefore, overcoming barriers to the implementation of SEC projects.

6.1 Introduction

Smart energy city (SEC) development aims at enhancing the sustainability of urban energy systems and services. It is characterized by the rational and innovative application of information and communication technologies, integration of multiple energy domains, and collaboration of multiple stakeholders (as defined in Chapter 3). In the presence of financial support for smart cities and communities provided by both European Union and private sector, many European cities have initiated SEC development not only to address urban energy targets, but also to improve the quality of life for citizens (Perboli et al., 2014; Vanolo, 2014). However, SEC projects have not been successful to fully achieve their objectives due to several difficulties or barriers, such as financial shortages, social opposition against project activities, or lack of skilled staff (Di Nucci et al., 2010). Supporting decision-makers to predict and overcome these barriers at an early stage is necessary in order to accelerate the sustainable transition of urban energy systems and services.

In order to predict barriers, one needs to know what the potential barriers are (barrier identification) and which factors influence them in which way. There is a large body of literature on identification of barriers to the implementation of sustainable energy projects. Barriers to energy efficiency and to renewable energy are reviewed by Cagno et al. (2013) and Eleftheriadis and Anagnostopoulou (2015). An emerging body of literature on barriers to adoption of specific smart energy technologies, such as smart grid or combined heat and power (e.g. Luthra et al., 2014; Wright et al., 2014) considerably helps to the topic as well. In Chapter 4 of the here presented thesis 35 specific barriers to the implementation of SEC projects were identified. The aforementioned studies most commonly identify barriers and suggest solutions to avoid them; however, a further systematic analysis of factors that influence the occurrence of barriers is rarely done. To the best of our knowledge, an attempt to directly predict barriers based on such factors has never been made.

One of the most promising analyses on barriers to implementation of SEC projects is done by Di Nucci et al. (2010), who investigated the planning and the implementation process of a European Union initiative, named CONCERTO. This study attempts to find associations between project characteristics and the performance of the projects, through a comparative analysis of 27 cities and communities involved in the first generation of the CONCERTO initiative. Di Nucci et al. (2010) assign the cities and communities to one of three clusters: new urban development, large-scale renovation, and measures in towns or rural areas. Then, they create and analyze –qualitatively– a number of small datasets, including less than 15 cities and 7-8 assessment variables such as commitment of stakeholders, or integration of sustainability criteria into the project.

Di Nucci et al. (2010) conclude that barriers to the implementation of projects are associated with multiple internal and external factors. Internal factors are specific to the project planning and implementation; e.g. communication tools used in the project, the anticipated budget, and participation of relevant decision-makers and market actors. External factors include economic, cultural, institutional, legal and political framework conditions (Di Nucci et al., 2010; Marle et al., 2013). In spite of the valuable contribution by Di Nucci et al. (2010), at the time of their study, many CONCERTO projects were not yet completed and some not even yet started (Di Nucci et al., 2010); therefore, the barriers to their implementation had not been totally evident. Moreover, this study revealed that –due to heterogeneity of the projects and their characteristics– more cases and more assessment variables are required for better understanding of the associations between project factors and the quality of project implementation. Understanding such associations helps to predict barriers in an early stage in order to anticipate actions to remove barriers, and therefore, save considerable amounts of money and time for projects. Hence, there is a need to identify these associations through a comparative analysis of already implemented SEC projects.

In urban studies, comparative analysis of multiple cases from multiple countries with a large number of variables encounters lack of comparable data among cases. This is due to the lack of a common framework for data collection and data sharing (Di Nucci et al., 2010). Moreover, analysis of big and complicated datasets requires quantitative methods. Smart city development is associated with large amounts of data produced and shared in the urban energy sector and governance (Taylor and Richter, 2015). This gives an opportunity to provide comparable data for urban analysis. In the same line, French et al. (2015) suggest moving beyond traditional urban development data analysis methods with a limited amount of data towards the application of more quantitative, e.g. machine learning, techniques. This will allow comparative analysis in a wide geographical area, with a large number of variables.

In the here presented research, we aim to apply a machine learning method to support decision-makers to predict, at the early stage of the project, barriers to the implementation of new SEC projects based on project internal and external characteristics (as defined by Di Nucci et al., 2010). Among various predictive approaches in machine learning, we apply decision trees (Breiman et al., 1984), which provide predictive models, and are proved to be a realistic alternative to expert knowledge elicitation (Bramer, 2013). Due to their flexibility, easy application, visualization, and interpretation (Keramati et al., 2014), decision trees are widely used in a variety of disciplines; for example, for predicting which patient characteristics are associated with high risk of heart attack; deciding whether or not to offer a loan to an individual based on individual characteristics; and predicting the rate of return of diverse investment strategies (Breiman et al., 1984). However, to our knowledge, decision trees are not applied for prediction of barriers in the field of energy planning and policy. Our main research questions are: (*i*) How precisely can barriers be predicted from project characteristics by application of decision trees? (*ii*) Which project characteristics are the strongest barrier predictors? (*iii*) How to use the result of decision trees in a new project?

6.2 Methodology

The methodology is divided into two main steps. First, we apply decision trees to generate models that can predict barriers based on project characteristics, using the empirical data on previously implemented SEC projects; this step addresses the research questions (*i*) and (*ii*). Second, we test the application of the generated models in a new European Union FP7 SEC project, named SINFONIA; this step addresses the research question (*iii*).

6.2.1 Applying decision trees to generate predictive models

Our empirical approach concerns 43 communities involved in the CONCERTO initiative. CONCERTO is an EU FP6 and 7 initiative that started in 2005 and aimed to support communities to develop and demonstrate sustainable and energy-efficient strategies and actions (supplementary Figure 6.S1) (CONCERTO, 2015c). The CONCERTO communities provide the legacy for future SEC projects. They are appropriate for our research due to their variety and rich information. The variety of CONCERTO communities in size and social, economic, environmental, and political context allows a comprehensive analysis, for the aim of our research. Moreover, CONCERTO projects have mostly completed the implementation phase; therefore, they have experienced barriers to their implementation. The barriers are evident through several databases and publications of the initiative (CONCERTO, 2015c), including mentioned implementation assessment report by Di Nucci et al. (2010) and Deliverable DP4- Policy Contributions and Recommendations by Immendoerfer et al. (2012), in which an analysis of barriers is performed. Hereafter, we refer to CONCERTO cities and communities as *cases*.

To hold this step of the methodology, we first created the dataset of CONCERTO cases, based on which we generated the models using decision trees technique. Then, we evaluated the performance of the generated models. Each step is explained in the following.

6.2.1.1 Creating the dataset on CONCERTO cases

We created a dataset of 43 CONCERTO cases. Each case is characterized by its implementation barriers as predicted or response variables, and project internal and external characteristics as the predictor or explanatory variables.

The barriers to implementation of each case (predicted variables) have been previously recorded as part of the CONCERTO initiative through a semi-structured questionnaire, and later analyzed in Chapter 4 of here presented thesis resulting in 35 specific barriers (Table 4.1). Since the data on barriers was gathered qualitatively, we took a *quantitizing* approach (Sandelowski, 2000), which means to treat qualitative data with quantitative methods. This approach is accepted for extracting more information from qualitative data (Sandelowski, 2000). In our dataset, we indicate the state of each case against each barrier with a number. The presence of a barrier for a case is indicated by 1 and absence of a barrier is indicated by 0.

As for project characteristics (predictor variables), we defined one level (project) for internal and three levels (city, regional, and national) for external variables (Figure 6.1). We did not consider variables at the European level because they are relevant for all cases and therefore, do not help to differentiate cases. To measure each variable, we selected one or more indicators. We selected the variables and indicators based on (i) existing literature on key smart energy project characteristics (e.g. Perboli et al., 2014) and CONCERTO projects (Di Nucci et al., 2010); (ii) our expert knowledge and experience on potential effective indicators with respect to the 35 investigated barriers; and (iii) availability of harmonized and standard data for the CONCERTO cases.

Case	Predictor variables				Predicted variables
	Internal	External			
	Project level	City level	Regional level	National level	Barriers
	P_{01} P_{02} ... P_{16}	C_{01} C_{02} ... C_{14}	R_{01} R_{02} ... R_{19}	N_{01} N_{02} ... N_{29}	B_{01} B_{02} ... B_{35}
S_{01} S_{02} ... S_{43}	16 variables: - 70 categorical - 2 numerical	14 variables: - 34 categorical - 12 numerical	19 variables: - 10 categorical - 17 numerical	29 variables: - 22 categorical - 31 numerical	35 variables - 35 categorical (0/1)

Figure 6.1 Schematic view of database; internal characteristics include variables at the project level; external characteristics include variables at the city, regional, and national level. Each variable includes one or more indicators that are categorical or continuous with respect to the type of variable and the data available in data sources.

Data collection for selected variables had to respect harmony and standardization among cases in order to allow meaningful comparative analysis. Considering that our 43 cases are distributed over a wide geographical area (i.e. Europe) located in 18 countries, our data source was limited to databases that provide harmonized data for all cases. Accordingly, four main sources were used to gather data for selected variables:

(i) EUROSTAT database (EC, 2015e) providing required data at regional and national level. The regional data was gathered within NUTS 2 regions (Nomenclature of territorial units for statistics), which are basic regions in a hierarchical system for dividing up the economic territory of the European Union for socio-economic and political regional analysis, and development and harmonization of regional statistics (EC, 2015f). (ii) CONCERTO initiative databases and publications, providing us with required data at project, city, regional, and national level. Most specifically the "CONCERTO policy questionnaire" (accessible through CONCERTO, 2015d) and the CONCERTO "Planning and Implementation Process Assessment Report" (Di Nucci et al., 2010). (iii) the SINFONIA project (SINFONIA, 2015) created a database of CONCERTO cases, providing us with required data at the project level.

(iv) Beside the mentioned sources, we also created a structured questionnaire (Appendix 2) to gather specific data on CONCERTO cases at the city level. The questionnaires were sent by email to 43 CONCERTO municipalities; the response rate was 47% which is higher than the expected 30% for a postal questionnaire (Oppenheim, 2000). All data was collected and inserted in a dataset for the statistical analysis.

6.2.1.2 Generating the models based on the dataset

Decision tree analysis is a widely applied technique for the construction of a predictive model from a dataset (e.g. Banerjee and Chowdhury, 2015; Ekasingh et al., 2005; Wu et al., 2009). This method is often claimed to have the advantage of being meaningful and easy to interpret compared to other approaches for data representation and prediction (Bramer, 2013). A decision tree has two different functions, namely data compression and prediction (Bramer, 2013), which perfectly fits the aim of this research. In addition, generated decision rules are transparent to the user, compared to other techniques that act as a "black-box" and do not directly provide the user with decision rules (Keramati et al., 2014). This quality allows identification of the strongest predictors among different project characteristics (answering research question *ii*). Furthermore, decision tree analysis is an appropriate method for our dataset because it can work with a small amount of training data compared to other classification techniques (Keramati et al., 2014); it can work with both numerical and categorical data; and it allows missing data in the dataset (Bramer, 2013).

A model which is generated by a decision tree analysis is a tree-shaped structure that consists of a number of branches, each originating from a root node and leading to a leaf node (Bramer, 2013). Each branch represents a set of decision rules. Once the tree is created for a complete training dataset, it can be used to predict values for a new dataset, where the information for the response variable is not given. A simple example of a decision tree is provided in Figure 6.2, used to predict the probability that “Joe will go for running”.

For a predictive model like a decision tree, a minimum number of five samples per class is required to get high prediction accuracy with statistical consistency (Indira et al., 2015); therefore, we performed the analysis on 22 barriers, which had a frequency of 5 or higher in our data set (see supplementary Table 6.S1, frequency). For each barrier, we created one decision tree (i.e. model), hereafter called barrier model. Predicted values by each decision rule represent the probability that the project encounters that barrier. Hereafter, we refer to predicted values as “barrier probability”.

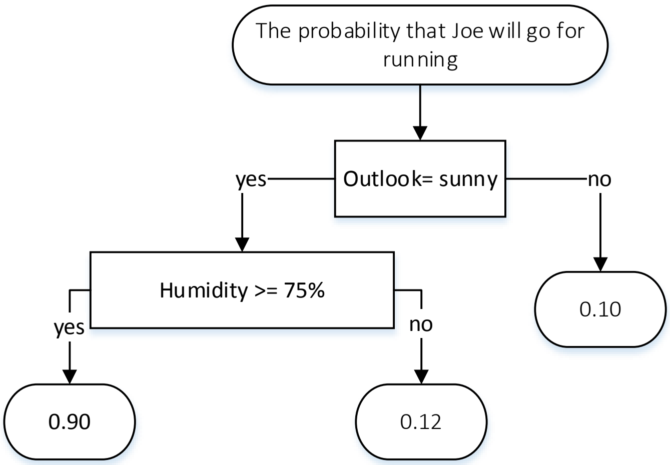

Figure 6.2 An example of a decision tree: the probability that Joe will go for running. It splits the data on weather outlook = sunny and humidity >= 75%, resulting in three decision rules: (i) if the weather outlook is not sunny, the probability that Joe goes for for running is 0.10; (ii) if the weather outlook is sunny and the humidity is equal or less than 75%, the probability that Joe goes for running is 0.12; (iii) if the weather outlook is sunny and the humidity is higher than 75%, the probability that Joe goes for running is 0.90.

Decision trees do not necessarily use all explanatory indicators to create the model because including all the indicators will result in large, complex, and over-fitted trees (Keramati et al., 2014). Instead, a set of variables for the creation of decision trees is selected independently. Bramer (2013) highlights the importance of a good strategy for selection of variables, explaining the risk of obtaining meaningless decision trees. To avoid this risk, we apply R-package *r.part* (Therneau et al., 2015) (R-Development-Core-Team, 2010), which applies entropy minimization (equivalently information gain maximization) (Quinlan, 1986) for selection of variables and generating meaningful decision trees (Bramer, 2013). We used a minsplit value of 10; minsplit is the minimum number of observations that must exist in a node in order for a split to be attempted. The indicators that appear in each barrier model are the strongest predictors for the barrier for which the model is generated.

6.2.1.3 Evaluating the performance of the generated models

To evaluate the performance of generated models, each model is given a dataset of known data on which training is done (training dataset), and a dataset of unknown data against which the model is evaluated (testing dataset) (Bramer, 2013). We applied a leave-one-out cross-validation method (Kohavi, 1995), in which one case is left out as the testing dataset and the rest of the 42 cases are used as the training dataset. We repeated this process randomly 22 times so that from each two cases, one is given a chance to be the testing dataset.

The barrier probability ranges from 0 to 1. For the purpose of performance evaluation, we selected 0.6 as the threshold to decide if a barrier is present or absent. This means that if the predicted value was less than 0.6, we gave it the value of 0 (absent) and if it was more than or equal to 0.6, we gave it the value of 1 (present). Then, for each barrier model, we created one 2*2 contingency table similar to the one in Table 6.1, in which the result of a model prediction is compared to the actual presence or absence of the barrier. Note that by present we mean that the barrier is present in the case; otherwise, it is absent. In this table, a, b, c, and d can be seen as the number of *truly present, falsely predicted present, falsely predicted absent*, and *truly absent*, cases, respectively.

Table 6.1 Contingency table for prediction of presence or absence of a barrier

		Actual observation		
		Present	*Absent*	*sum*
Prediction	Present	a	b	a+b
	Absent	c	d	c+d
	sum	a+c	b+d	N=22

To test the reliability of predictions, we used two performance indices applied in performance evaluation of predictive models with binary classification (e.g. Wu et al., 2009): sensitivity and accuracy. Sensitivity is the probability that the model predicts correctly the presence of a barrier. Accuracy is the proportion of all correct predictions made by the model. The mathematical formulas for these indices are: $Sensitivity = a/(a+c)$; and $accuracy = (a+d)/N$ (Wu et al., 2009). Opting for these indices is highly related to the aim of the prediction. Sensitivity and accuracy are known as a measure of completeness and exactness, respectively (Keramati et al., 2014). In this research, the aim is to predict the barrier for appropriate mitigation action. If the model can correctly predict the presence of a barrier, it helps decision-makers to allocate appropriate resources to avoid or mitigate a barrier in advance. If the model incorrectly predicts the absence of a barrier, the actual presence of the barrier could significantly hinder project implementation since mitigation action is not foreseen. Therefore, sensitivity and accuracy are meaningful measures for the aim of this research.

In addition to these indices, we applied Pearson's chi-squared test, which is a statistical test to calculate the statistical significance of the results of the predictive models. The prediction was tested at a significance level of $p \leq 0.1$. However, the performance of this test is not possible, if the results of the model prediction are always absent for a barrier, i.e. $(a + b) = 0$.

Accordingly, we used sensitivity, accuracy, and the p-value (if available and significant) to classify the models against their performance. We classified the model performance as very good, if $sensitivity >= 0.50$, $accuracy >= 0.75$, and $p\text{-}value =< 0.1$; good if $sensitivity < 0.50$ and $accuracy > 0.75$; and low if $sensitivity < 0.50$ and $accuracy =< 75$.

6.2.2 Application in the case study

We tested the application of the generated barrier models in the case-study of the SINFONIA project. The SINFONIA project is an SEC five-year European Union FP7 initiative, which has started in 2014 and is aiming to deploy large-scale, integrated and scalable smart and sustainable energy solutions in mid-sized European cities. The specific targets of the project are 40 to 50% primary energy savings and 20% increase in the share of renewable energy sources in the energy mix. SINFONIA integrates multiple smart energy solutions in three broad domains of intervention: building retrofitting, electricity grid, and district heating and cooling. SINFONIA involves multiple stakeholders, including city administration, university, research and development institutes, and industry, among others (SINFONIA, 2015). The two pioneer cities of SINFONIA are Bolzano (Italy) and Innsbruck (Austria).

We selected SINFONIA, or more specifically Bolzano and Innsbruck, as our case-study because they are leading cities in SEC development in Italy and Austria. They are similar in some characteristics (e.g. size of the city (Bolzano: 105,713 inhabitants; Innsbruck: 122,458 inhabitants) and geographical location), but different in national characteristics (e.g. political and legal frameworks). This makes them interesting cases for comparison for the aim of this research. Moreover, the authors of this chapter are partly involved in the SINFONIA project and, therefore, closely interact with the different stakeholders, particularly administration, of these cities. This provides the opportunity of access to the required data, and potential impact and application in city administration.

In order to apply the barrier models in SINFONIA, we created a new dataset including Bolzano and Innsbruck as new cases, and 44 indicators (identified as the strongest predictors in the previous section), as predictor variables. Data for indicators at project and city level was mainly gathered through SINFONIA material (i.e. description of work, internal databases, and deliverable 2.1) and contacting the person with required knowledge in the SINFONIA professional network (e.g. project district leaders and city administration). Data for indicators at regional and national level was mainly gathered in the Eurostat database. We ran our previously generated barrier models on the new dataset and predicted barriers for both cities.

6.3 Results

6.3.1 Generated barrier models based on CONCERTO cases

We created 22 barrier models, two of which (B_{02} and B_{28}) showed no significant classification (all predicted values ranged from 0 to 0.50 for B_{02} and 0 to 0.33 for B_{24}), meaning that they would always predict the absence of the barrier, independent from project characteristics. Therefore, they were excluded from further analysis.

We evaluated the performance of the other 20 models, specifically based on sensitivity, accuracy, and p-value (Figure 6.3); the complete values of performance evaluation are presented in supplementary Table 6.S2. Four barrier models revealed very good performances, including *economic crisis* (B_{20}), *lack of values and interest in energy optimization measures* (B_{31}), *time-consuming requirements by European Commission (EC) concerning reporting and accountancy* (B_{08}), and *local unfavorable regulations for innovative technologies* (B_{14}). Eight barrier models revealed good performances, examples of which are the *lack of skilled and trained personnel* (B_{36}) and *insufficient external financial support and funding for project activities* (B_{18}). Eight barrier models revealed low performances, examples of which are *fragmented ownership* (B_{10}) and *lack of well cooperation and acceptance among partners* (B_{04}).

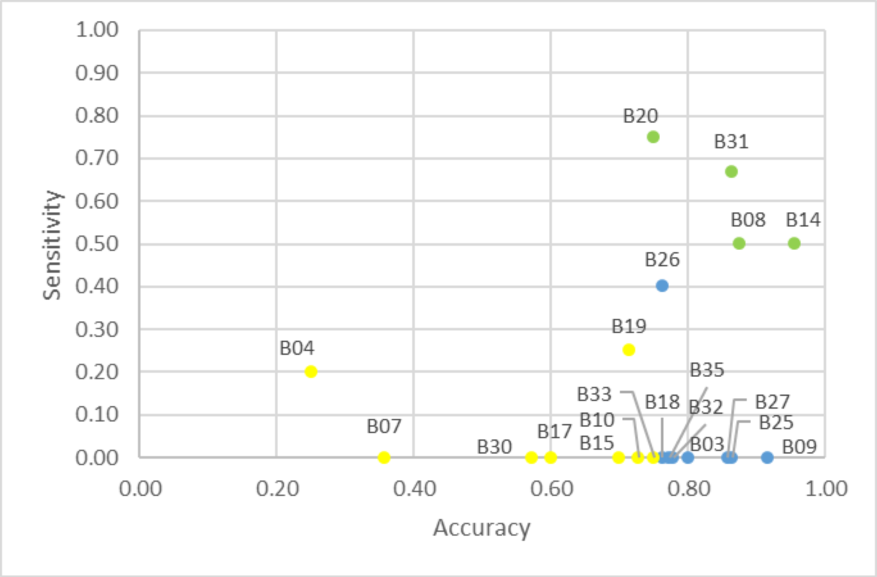

Figure 6.3 Performance of the models based on sensitivity, accuracy, and p-value; the colours show the classification of barriers based on their performance: green bullets are models with very good performance (sensitivity >= 0.50, accuracy >= 0.75, p-value =< 0.1); blue bullets are models with good performance (sensitivity < 0.50, accuracy > 0.75); and yellow bullets mark low performance (sensitivity < 0.50 and accuracy =< 75).

6.3.2 Project characteristics that are the strongest barrier predictors

Decision trees transparency allows understanding which characteristics influence each barrier in which way. In total, out of 198 indicators, decision trees selected 44 indicators as the strongest predictors: 14 indicators at the project level, 12 at city, 9 at regional, and 11 at the national level. Table 6.2 shows all indicators that appeared in each barrier model, and therefore, the strongest predictors for the corresponding barrier.

Table 6.2 The strongest predictors for barriers (continuing to the next page)

Barrier Category	*Barrier*	*Code*	*Indicators*
Administrative	Difficulty in coordination of high number of partners and authorities	B_{03}	Energy service company as project business model (P_{11_2}); project planning instruments (obligation to connect to district heating) (P_{08_5}); Existence of a long term energy efficiency plan or programme or policy (C_{01_3})
	Lack of good cooperation and acceptance among partners	B_{04}	Existence of an energy office in municipality (C_{03}); Real growth rate of regional GDP at market prices (R_{08}); Population in semi-detached housing type (N_{12_2}); Number of inhabitants involved in the project (P_{17})
	Long and complex procedures for authorization of project activities	B_{07}	Harmonized Indices of consumer prices for energy (N_{10}); Presence of budgetary autonomy at municipality level (C_{07}); Level of citizens' confidence in EC (N_{14})
	Time consuming requirements by EC concerning reporting and accountancy	B_{08}	Geographical area, covered by the project (P_{13}); Gross inland energy consumption (N_{19}); application of active thermal mass technology within project (P_{07_17})
	Complicated and non-comprehensive public procurement	B_{09}	Application of thermal collector technology within the project (P_{07_2}), share of human resources in science and technology (R_{11}); Share of government budget appropriations or outlays on research and development (N_{29})
	Fragmented ownership	B_{10}	Population in flats in a building with ten or more dwellings (N_{12_4}); Disposable income of private households (R_{09}); funding project by regional grants (P_{10_4}); total intramural R&D expenditure (R_{06})
Legal and Regulatory	Local unfavorable regulations for innovative technologies	B_{14}	Population in flats in a building with ten or more dwellings (N_{12_4}); geographical longitude (C_{17_2})
	Insufficient financial incentives	B_{15}	Financial contribution by individual (P_{19}); Population density (R_{20}); presence of subsidies/soft loans for energy (C_{02_3}); presence of energy efficiency as a project objective (P_{12_1})
Financial	Hidden costs	B_{17}	Total intramural R&D expenditure (R_{06}); application of hydro power technology within project (P_{07_4}); share of gross electricity consumption, generated from renewable sources (N_{21})
	Insufficient external financial support and funding for project activities	B_{18}	Geographical latitude (C_{17_1}); Budget (P_{09});geographical latitude (C_{17_2}); Existence of a long term renewable energy plan or programme or policy (C_{01_2})
	Limited access to capital and cost disincentives	B_{19}	Number of students in primary, lower, and upper secondary education (R_{14_2}); project planning instruments (existence of master plan) (P_{08_1}); share of researchers total employment (R_{10}); disposable income of private households (R_{09})
	Economic crisis	B_{20}	Experience of municipality in heat pump technology (C_{09_13}); Gross inland electrical energy consumption (N_{19_4}); Organizations & sites with Eco-Management & Audit Scheme registration (N_{26})
Technical	Shortage of proven and tested solutions and examples	B_{25}	Home ownership rate (N_{13}); Existence of energy related education (C_{12_2}); Investment by institutional sectors (N_{09})
	Lack of skilled and trained personnel	B_{26}	National Households saving rate (N_{08}); planning instruments (existence of master plan) (P_{08_1}); share of gross electricity consumption, generated from renewable sources (N_{21}); experience of municipality in implementation of energy efficient mobility projects (C_{08_3})
	Deficient planning	B_{27}	Presence of taxes for energy as financial incentive (C_{02_1}); Existence of a general regional sustainable energy policy, plan, or programme (R_{01_1}); disposable income of private households (R_{09})
Social	Inertia	B_{30}	Planning instruments (obligation to submit an energy strategy within the project) (P_{08_7}); application of photovoltaic technology within the project (P_{07_3}); type of stakeholders (other than university, industry, municipality) (P_{04_11})
	Lack of values and interest in energy optimization measurements	B_{31}	Geographical longitude (C_{17_2}); Number of inhabitants involved in project (P_{17})
	Low acceptance of new projects and technologies	B_{32}	Number of students in post-secondary non-tertiary education (R_{14_3}); project intervention in socio-economic issues (P_{06_4}); percent of total population in the age 25-67 (C_{14_6})

(continuing from the previous page)

Barrier Category	*Barrier*	*Code*	*Indicators*
Information and Awareness	Lack of sufficient information on the part of potential users and consumers	B_{33}	Type of stakeholders (other than university, industry, municipality) (P_{04_11}); access to internet (share of individuals who ordered goods or services over the internet for private use in the last year) (R_{19}); application of heat-pump technology within the project (P_{07_16})
	Perception of interventions as complicated and expensive, with negative socio-economic or environmental impacts	B_{35}	Size of the city (population) (C_{16}); application of poly-generation technology within the project (P_{07_16})

In (P_n), *n* stands for the indicator number; *P*, *C*, *R*, or *N* show that the indicator is at project, city, regional, or national level respectively.

Here, we explicate the four barrier models with very good performances (Figure 6.4). The other 16 models are presented in supplementary Figure 6.S2.

The presence of the barrier *local unfavorable regulations for innovative technologies (*B_{14}*)* follows three decision rules, extracted from the dataset (Figure 6.4a): (i) if the proportion of *people living in a building flat with ten or more dwellings* is more than 42 %, the barrier probability is 0.80. (ii) if this proportion is lower than 42 %, consider *longitude*, if it is less than 1.6 ° (west of Europe), the barrier probability is 0.33. (iii) if the proportion of *people living in a building flat with ten or more dwellings* is lower than 42 %, and the *longitude* is more than 1.6 °, the barrier is absent.

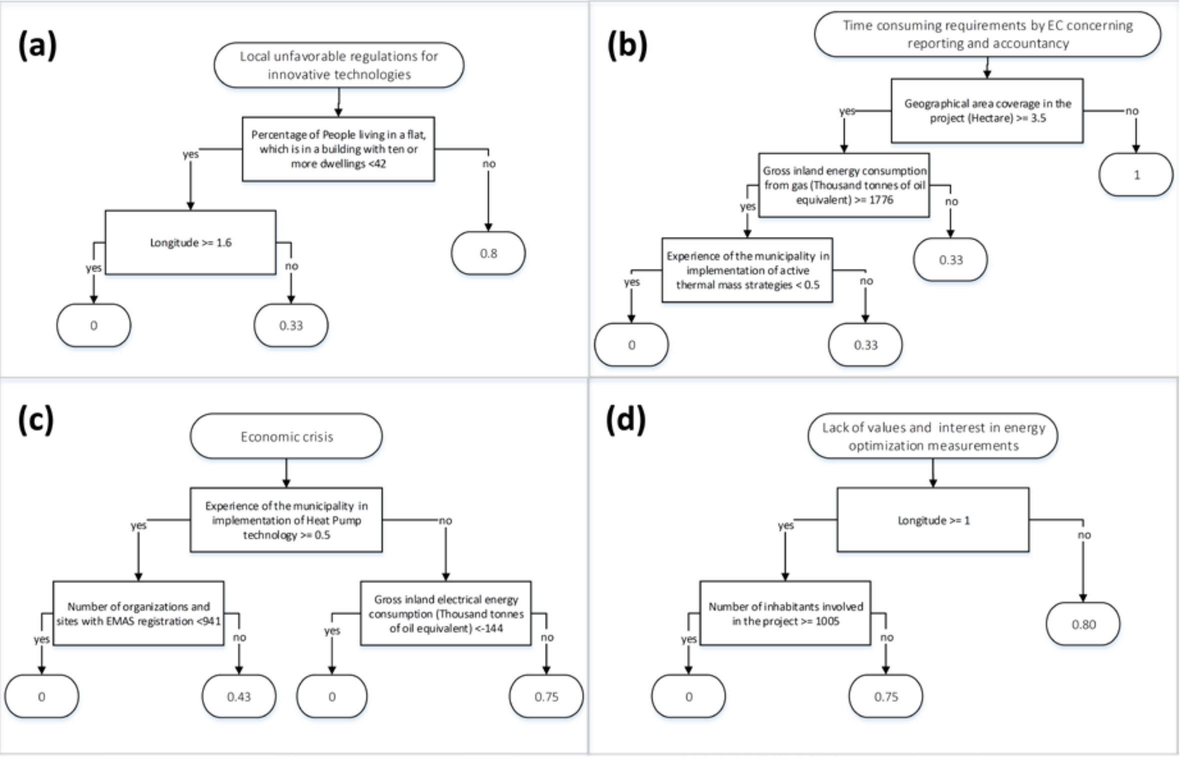

Figure 6.4 The decision trees for the four models with very good performances: (a) local unfavourable regulations for innovative technologies (B_{14}); (b) time consuming requirements by EC concerning reporting and accountancy (B_{08}); (c) economic crisis (B_{20}); (d) lack of values and interest in energy optimization measurements (B_{31})

Presence of the barrier *time-consuming requirements by EC concerning reporting and* accountancy (*B_{08}*) follows four decision rules, extracted from the dataset (Figure 6.4b): (i) if the *geographical area, covered by the project* is less than 3.5 hectare, the predicted barrier probability is 1. (ii) if it is more than 3.5 hectare, consider *gross inland energy consumption from gas*; if it is less than 1776 thousand tonnes of oil equivalent[2] (TOE), the predicted barrier probability is 0.33. (iii) if the *geographical area, covered by the project* is more than 3.5 hectare, and *gross inland energy consumption from gas* is more than 1776 thousand TOE, consider the experience of the municipality, if it has *previous experience in implementation of active thermal mass storage*, the predicted barrier probability is 0.33. (iv) if the *geographical area, covered by the project* is more than 3.5 hectare, and *gross inland energy consumption from gas* is more than 1776 thousand TOE, and the municipality does not have *experience in implementation of active thermal mass storage*, the barrier is predicted to be absent.

Presence of the barrier *economic crisis* (*B_{20}*) follows four decision rules, extracted from the dataset (Figure 6.4c): (i) if the municipality has *previous experience in implementation of heat pump*, consider the number of *organizations and sites with eco-management and audit scheme (EMAS) registration*[3] in the country; if it is less than 941, the barrier is absent. (ii) if it is more than 941, the barrier probability is 0.43. (iii) if the municipality does not have *experience in implementation of heat pump*, consider *gross inland electrical energy consumption*; if it is less than -144 TOE, the barrier is absent. (iv) if it is more than -144 thousand TOE the barrier probability is 0.75.

The presence of the barrier *lack of values and interest in energy optimization measures* (*B_{31}*) follows three decision rules, extracted from the dataset (Figure 6.4d): (i) if the *longitude* is less than 1° (west of Europe), the barrier probability is 0.80. (ii) if the *longitude* is more than 1°, consider the number of *inhabitants involved in the project*; if it is less than 1005 persons, the barrier probability is 0.75. (iii) If the *longitude* is more than 1°, and the number of *inhabitants involved in the project* is more than 1005 persons, the barrier is absent.

6.3.3 Predicted barriers for SINFONIA

Based on generated barrier models, we predicted the probability of barriers for the cities of Bolzano and Innsbruck (Table 6.3). In total, the models predicted high probability for five

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[2] The tonne of oil equivalent is a standardized energy unit defined as a net calorific value of 107 kilocalories (41 868 MJ), which is roughly the net energy equivalent of a tonne of crude oil. TOE equals the export + bunkers + direct use is higher than primary production + primary product receipt + other sources + recycled products + imports + stock changes. http://ec.europa.eu/eurostat/cache/metadata/en/nrg_10_esms.htm

[3] The Eco-Management and Audit Scheme (EMAS) is a voluntary environmental management system implemented by companies and other organisations from all sectors of economic activity including local authorities to evaluate, report on and improve their environmental performance. For more information, see http://ec.europa.eu/eurostat/web/products-datasets/-/tsdpc410

barriers in Bolzano and three barriers in Innsbruck, ranging from 0.60 to 0.75.

Two administrative barriers (B_{04} and B_{10}) and one technical barrier (B_{25}) are predicted with higher probability in Bolzano than in Innsbruck. For the rest of the barriers, including all of legal and regulatory, financial, social, and information and awareness barriers, the predicted probability is equal for both cities.

Table 6.3 Predicted barrier probability for cities of Bolzano and Innsbruck

Barrier Category	*Barrier*	*Code*	*Bolzano*	*Innsbruck*
Administrative	Difficulty in coordination of high number of partners and authorities	B_{03}	0	0
	Lack of well cooperation and acceptance among partners	B_{04}	0.71	0
	Long and complex procedures for authorization of project activities	B_{07}	0	0
	Time consuming requirements by EC concerning reporting and accountancy	B_{08}	0.33	0.33
	Complicated and non-comprehensive public procurement	B_{09}	0.33	0.33
	Fragmented ownership	B_{10}	0.75	0
Legal and Regulatory	Local unfavorable regulations for innovative technologies	B_{14}	0	0
	Insufficient financial incentives	B_{15}	0	0
Financial	Hidden costs	B_{17}	0.50	0.50
	Insufficient external financial support and funding for project activities	B_{18}	0.75	0.75
	Limited access to capital and cost disincentives	B_{19}	0.33	0.33
	Economic crisis	B_{20}	0	0
Technical	Shortage of proven and tested solutions and examples	B_{25}	0.11	0
	Lack of skilled and trained personnel	B_{26}	0	0
	Deficient planning	B_{27}	0	0
Social	Inertia	B_{30}	0.42	0.42
	Lack of values and interest in energy optimization measurements	B_{31}	0	0
	Low acceptance of new projects and technologies	B_{32}	0.66	0.66
Information and Awareness	Lack of sufficient information on the part of potential users and consumers	B_{33}	0.60	0.60
	Perception of interventions as complicated and expensive, with negative socio-economic or environmental impacts	B_{35}	0.33	0.33

6.4 Discussion

6.4.1 How precisely can decision trees predict barriers to the implementation of SEC projects?

To the best of our knowledge, this research is the first attempt to apply a machine learning method, decision tree analysis, in the field of urban planning to predict barriers to implementation of SEC projects. Our dataset included 43 cases, 35 barriers as response variables and 198 project characteristics as predictor variables. We could create 20 barrier models (decision trees) for barriers with frequency of five or more (within all 43 cases), and with distinguishable classification. Evaluating the performance of the generated barrier models based on sensitivity, accuracy, and p-value resulted in four models with very good performances, eight models with good performances, and eight models with low performances. Our results underline that decision tree is a promising tool to predict barriers to the implementation of SEC projects based on project characteristics.

In theory, a minimum frequency of five for each barrier is sufficient for a small scale application of decision trees (Indira et al., 2015). However, the result of the research presented here shows that prediction of barriers is a considerably complex task in reality. Projects are complex identities (Marle et al., 2013), and our research findings revealed that projects are heterogeneous in characteristics that influence barriers to the project implementation. Considering the fact that the accuracy of predictive models improves with increasing the sample size (Morgan et al., 2003), we conclude that using larger sample sizes for future research is required to generate models with higher accuracy and statistical consistency.

As suggested by Sandelowski (2000), the *quantitizing* approach, used in our research, allows extraction of more information from qualitative data. However, the collected data is subject to uncertainty since it allows individual interpretation, different levels of detail in each filled-in questionnaire, and interchangeable statement of similar barriers; e.g., *inertia*, *lack of values and interest in energy optimization measurements*, and *low acceptance of new projects and technologies* are all different aspects of social resistance to project interventions. On the other hand, applying quantitative methods (e.g. structured questionnaires) to collect data on barriers may result in more certain results and might increase the model sensitivity.

6.4.2 Which SEC project characteristics are the strongest barrier predictors?

The result of this research shows that occurrence of each barrier is influenced by different project characteristics. Most commonly, a barrier is spontaneously influenced by variables at different levels (project, city, regional, and national). This highlights the importance of a multi-scale analysis in barrier prediction. Accordingly, both internal and external characteristics can significantly influence barriers. Domination of the number of the strong predictors at the project level may imply a more important role of project characteristics compared to city, regional or national characteristics. This may highlight that in spite of external conditions, the robust design and organization of the project is able to improve – considerably– the quality of the project implementation. In addition, similar numbers of strong predictors at city and national level may imply the equally important role of both city and national characteristics in occurrence of barriers. This emphasizes, again, the importance of the multi-scale analysis of barriers.

Since we used similar barriers as in the CONCERTO project, we tried to compare the results of our four models with very good performance to the result of the qualitative analysis of barriers done in CONCERTO (Immendoerfer et al., 2012):

The result of the barrier model shows that presence of *local unfavorable regulations for innovative technologies* (B_{14}) is strongly associated with higher (more than 42) percentage of population living in multi-flat dwellings, and slightly associated with lower *longitude* (i.e. west of Europe; including Nantes, Milton Keynes, and Zaragoza). CONCERTO barrier analysis also suggests that this barrier occurs in projects located in countries with long tradition of using renewable energies; it further explains the barriers' appearance in each country; for example, data privacy law in Spain that hampered data sharing in Cerdanyola del Valles (Immendoerfer et al., 2012).

The result of the barrier model shows that presence of *time-consuming requirements by EC concerning reporting and accountancy* (B_{08}) is strongly associated with smaller geographical area, covered by the project (less than 3.5 hectares). This in line with CONCERTO qualitative analysis, stating that this barrier occurred particularly in small communities that neither had the internal skilled staff nor could pay for external skilled consultancy for this task (Immendoerfer et al., 2012). This may suggest a need for financial or technical solutions that support smaller communities and projects in filling this gap.

The result of the barrier model shows that presence of *economic crisis* (B_{20}) is strongly associated with lack of the municipality previous experience in implementation of heat pump, and higher (more than -144) gross inland electrical energy consumption. The CONCERTO qualitative analysis mainly discusses the consequences of this barrier, in a number of projects, such as reduction of the number of involved buildings and focusing on public building developers instead (Immendoerfer et al., 2012).

The result of the barrier model shows that presence of *lack of values and interest in energy optimization measures* (B_{31}) is strongly associated with the lower *longitude* (west of Europe). If the project is located in larger longitudes, then the barrier occurrence is associated with smaller number of *inhabitants involved in the project* (less than 1005 persons). CONCERTO qualitative analysis implies that this barrier is a result of lack of information and communication about the benefits of optimization measurements (Immendoerfer et al., 2012). We can argue that communication is more feasible within larger populations because bigger projects usually have larger budgets.

The comparison of our results with qualitative barrier analysis by CONCERTO does not suggest a clear and easy-to-grasp correlation. Only few meaningful correlations are derivable. This may be, on the one hand, due to concentration of CONCERTO barrier analysis on consequences and solutions to overcome barriers, rather than analyzing the actual causes that affect barrier occurrence; only in few legal barriers a brief cause and effect analysis is done, which has been mainly demonstrating national legal diversities. On the other hand, quantitative analysis by decision trees can find hidden association rules that might not be easily visible for human analysts. In this regard, further analysis of our discovered rules may provide valuable insights into barrier analysis, prediction, and treatment.

For example, 80 percent of the cases with the barrier *lack of values and interest in energy optimization measures* are located in longitudes less than 1º, which in fact, covers a relatively small area of Europe. This is in line with the study of De Groot and Steg (2007) that found out that value-base orientation towards environmental concerns varies in different geographical areas. This suggests that such value decreases systematically from East to West of Europe. Understanding why such significance distinction exists can be the subject of further research on values to energy conservation and energy optimization measures.

6.4.3 Are the models applicable in a new project?

We predicted the probability of each barrier for the cities of Bolzano and Innsbruck, the pilot cities of SINFONIA project. The predicted results for the two cities are equal, except for three barriers. This is due to similar internal (i.e. project) characteristics as well as some external characteristics, particularly at city level. This conforms the more important role of project characteristics in occurrence of barriers, as highlighted in sub-section 6.4.2. The predicted results for the two cities are different in administrative barriers (higher probability in Bolzano than in Innsbruck); this can be a consequence of different legal and administrative contexts in Italy and Austria; emphasizing the influence of legal and administrative systems in project implementation.

Here, we compare the predicted barrier probabilities with the actually identified barriers of SINFONIA project, presented in the project deliverable 2.1 in form of a SWOT analysis; therein, barriers are represented as weaknesses and threats (see Pezzutto et al., 2015). The comparison is presented in Table 6.4, ordered in each performance class with respect to sensitivity and accuracy, respectively, from high to low values.

Out of four models with very good performances (B_{20}, B_{31}, B_{08}, B_{14}) three models (B_{20}, B_{31}, and B_{08}) correctly predicted the barrier probability for both cities of Bolzano and Innsbruck. Out of eight models with good performances, seven models correctly predicted the barrier probability for Innsbruck and three models correctly predicted the barrier probability for Bolzano. This shows that in general, the model has a better performance in the city of Innsbruck. This might be partially explained by the following argument.

The models appeared to have a better performance when predicting the absence of a barrier; i.e. 22 correct predictions out of 28 observed absent barriers. This ratio increases to 15 out of 17 if we only consider models with very good and good performances. The better performance of decision tree models in predicting absence of a phenomenon (compared to presence of the phenomenon) is common, when predicting complex issues, as observed particularly in medical sciences (e.g. Dunkley et al., 2003; Kuo et al., 2001; Tanner et al., 2008).

Table 6.4 Comparing the result of barrier prediction with actually identified barriers in SINFONIA

Model performance class	*Barrier model*	*Code*	*Bolzano*		*Innsbruck*		*Sensitivity*	*Accuracy*	*p-value*
			P	*O*	*P*	*O*			
Very good	Economic crisis	B_{20}	0	0	0	0	0.75	0.75	0.10
	Lack of values and interest in energy optimization measurements	B_{31}	0	0	0	0	0.67	0.86	0.02
	Time consuming requirements by EC concerning reporting and accountancy	B_{08}	0	0	0	0	0.50	0.88	0.09
	Local unfavorable regulations for innovative technologies	B_{14}	0	1	0	1	0.50	0.95	0.00
Good	Lack of skilled and trained personnel	B_{26}	0	1	1	1	0.40	0.76	0.17
	Lack of good cooperation and acceptance among partners	B_{04}	1	0	0	0	0.20	0.25	0.08
	Complicated and non-comprehensive public procurement	B_{09}	0	1	0	0	0.00	0.92	-
	Shortage of proven and tested solutions and examples	B_{25}	0	0	0	0	0.00	0.86	-
	Difficulty in coordination of high number of partners and authorities	B_{03}	0	0	0	0	0.00	0.80	-
	Perception of interventions as complicated and expensive, with negative socio-economic or environmental impacts	B_{35}	0	0	0	0	0.00	0.77	-
	Insufficient external financial support and funding for project activities	B_{18}	1	0	1	0	0.00	0.76	-
	Deficient planning	B_{27}	0	1	0	0	0.00	0.86	0.74
Low	Low acceptance of new projects and technologies	B_{32}	1	0	1	1	0.00	0.78	0.65
	Lack of sufficient information on the part of potential users and consumers	B_{33}	1	0	1	0	0.00	0.75	0.53
	Limited access to capital and cost disincentives	B_{19}	0	0	0	0	0.25	0.71	0.74
	Insufficient financial incentives	B_{15}	0	0	0	0	0.00	0.70	0.43
	Fragmented ownership	B_{10}	1	0	0	0	0.00	0.73	0.48
	Hidden costs	B_{17}	0	0	0	0	0.00	0.60	0.28
	Inertia	B_{30}	0	1	0	0	0.00	0.57	0.21
	Long and complex procedures for authorization of project activities	B_{07}	0	1	0	0	0.00	0.36	0.08

*P stands for predicted and O stands for observed; the grey cells show the correct predictions. 0.6 has been the threshold to decide if a barrier is present (1) or absent (0).

6.5 Conclusions

Successful implementation of SEC projects is essential to addressing urban energy challenges in Europe. We aimed to support decision-makers to predict, and therefore, overcome barriers to successful implementation of SEC projects. We applied the decision trees (a machine learning technique) to investigate 43 previously implemented SEC projects. We used this technique to find association rules between project internal and external characteristics and implementation barriers. Based on derived association rules we predicted barriers to implementation of a new SEC project.

At the best of our knowledge, this is the first time that decision trees are applied for barrier prediction in the field of urban energy planning and energy policy. The findings showed that application of decision trees allows significant prediction of barriers to the implementation of SEC projects. The findings suggest those project characteristics that are the strongest barrier predictors. Furthermore, we observed that decision trees are able to find undiscovered association rules between project characteristics and the project implementation process. Our research proved the applicability of the barrier models to predict barriers to implementation of new SEC projects.

Future work might include developing a more comprehensive dataset for decision trees by including more project variables and gathering quantitative data on barriers-i.e. the response variables. In addition, the existing investigation needs to involve more SEC cases to better address the complexity of the issue in reality and improve the predictive power of the models for a variety of cities. The discovered association rules open new topics for future research to understand why such association rules exist.

Our applied methodology can also be used for prediction of barriers to other energy relevant topics, such as barriers to the adoption of energy-saving technologies (Du et al., 2014), barriers to diffusion of renewable energy sources (Eleftheriadis and Anagnostopoulou, 2015), and barriers to adoption of specific solutions such as smart grids (Battaglini et al., 2012). Furthermore, the methodology can be applied to or combined with analysis of success factors for a more comprehensive view of the SEC implementation process.

To conclude, decision trees are promising for large-scale application (i.e. at national, European or international scale) in the field of urban planning and policy. The discovered association rules by decision trees are applicable by urban decision-makers to (a) predict and overcome difficulties to implementation of new SEC projects; and to (b) plan their cities to be friendlier towards new SEC developments. This contributes urban decision-makers to accelerate transition towards more sustainable urban energy future.

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Supplementary material of Chapter 6

Figure 6.S1 Location of the cities and communities involved in CONCERTO initiative (CONCERTO, 2015c)

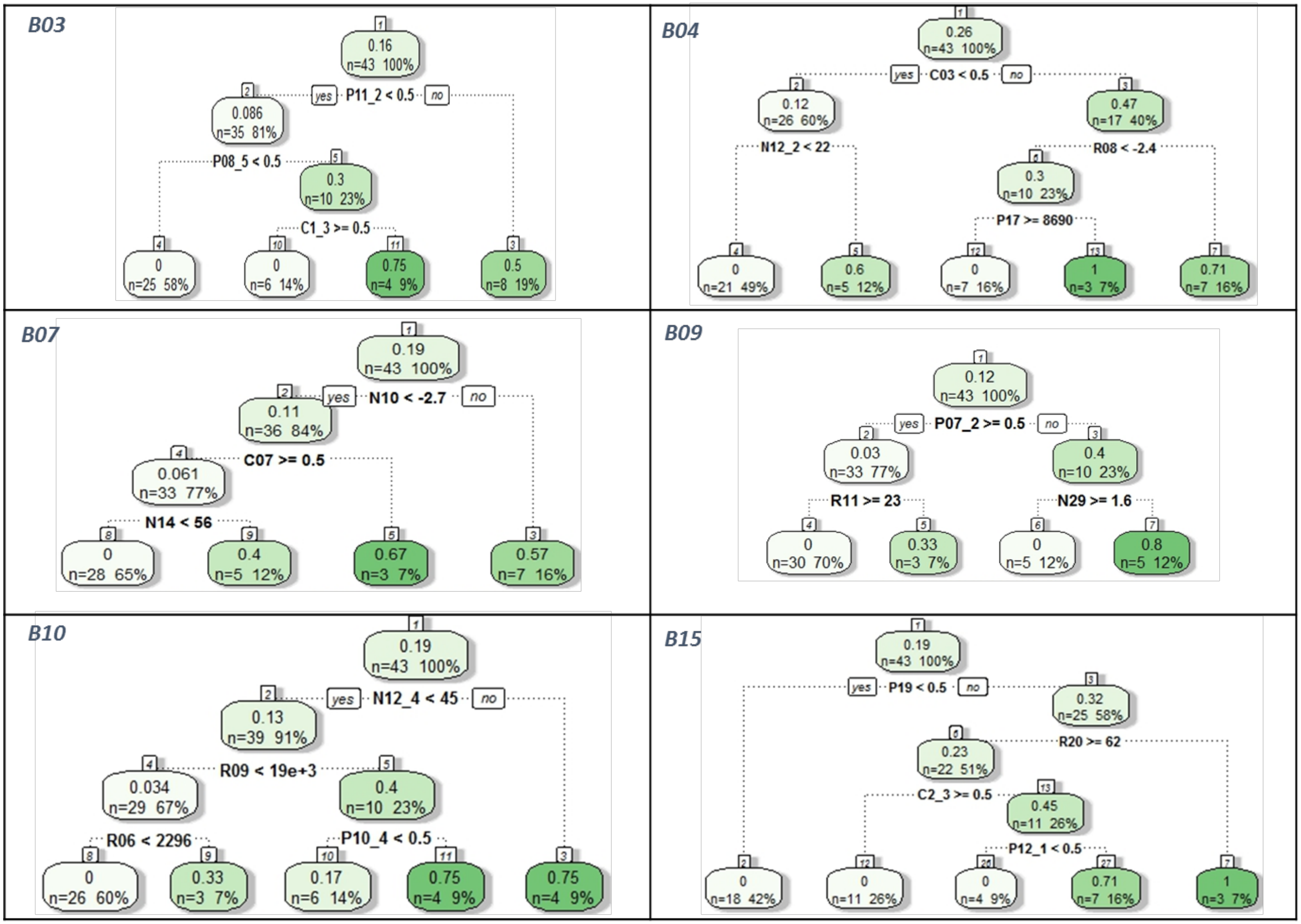

Figure 6.S2a The decision trees for barriers B03, B04, B07, B09, B10, and B15 (up-left corner of each decision tree). The description of each barrier code and the explanation for indicator abbreviations is provided in Table 6.2. Each node encloses a number (mostly decimal) on top, n at left down corner, and a percentage at right sown corner, representing respectively, barrier probability, the number, and the ratio of observed cases in that node. The numbers above each node show the number of the node.

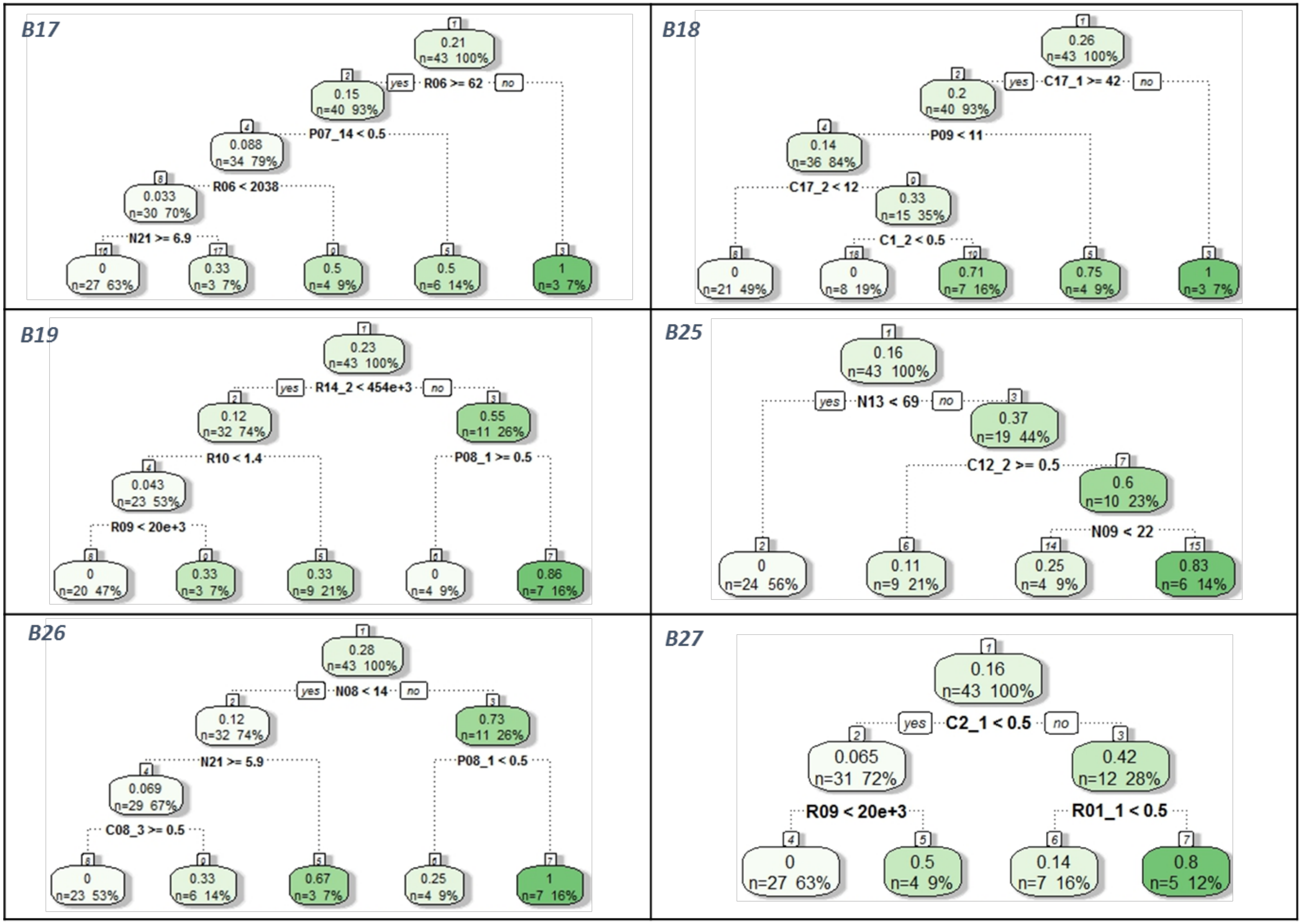

Figure 6.S2b The decision trees for barriers B17, B18, B19, B25, B26, and B27 (up-left corner of each decision tree). The description of each barrier code and the explanation for indicator abbreviations is provided in Table 6.2. Each node encloses a number (mostly decimal) on top, n at left down corner, and a percentage at right sown corner, representing respectively, barrier probability, the number, and the ratio of observed cases in that node. The numbers above each node show the number of the node.

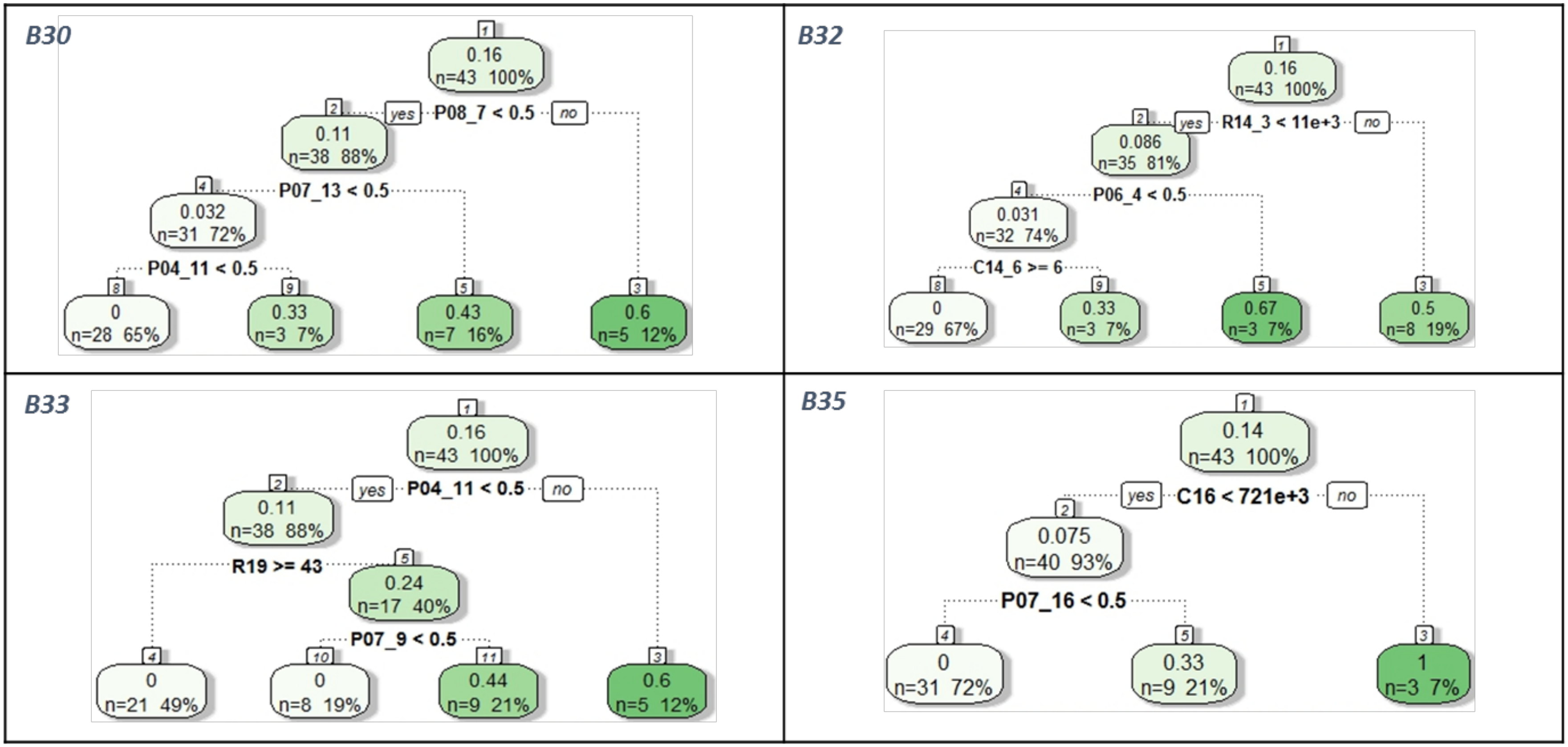

Figure 6.S2c The decision trees for barriers B30, B32, B33, B35 (up-left corner of each decision tree). The description of each barrier code and the explanation for indicator abbreviations is provided in Table 6.2. Each node encloses a number (mostly decimal) on top, n at left down corner, and a percentage at right sown corner, representing respectively, barrier probability, the number, and the ratio of observed cases in that node. The numbers above each node show the number of the node.

Table 6.S1 Barriers to implementation of CONCERTO projects

Barrier Category	*Barrier*	*Barrier code*	*Frequency**
Policy	Lack of long-term and consistent energy plans and policies	B_{01}	2
	Lacking or fragmented local political commitment and support for the long-term	B_{02}	6
Administrative	Difficulty in the coordination of high number of partners and authorities	B_{03}	7
	Lack of good cooperation and acceptance among partners	B_{04}	11
	Lack of public participation	B_{05}	3
	Lack of institutions/mechanisms to disseminate information	B_{06}	1
	Long and complex procedures for authorization of project activities	B_{07}	8
	Time-consuming requirements by EC concerning reporting and accountancy	B_{08}	5
	Complicated and non-comprehensive public procurement	B_{09}	5
	Fragmented ownership	B_{10}	8
Legal and Regulatory	Inadequate regulations for new technologies	B_{11}	4
	Regulatory instability	B_{12}	3
	Non-effective regulations	B_{13}	1
	Unfavorable local regulations for innovative technologies	B_{14}	5
	Insufficient or insecure financial incentives	B_{15}	8
Financial	High costs of design, material, construction, and installation	B_{16}	3
	Hidden costs	B_{17}	9
	Insufficient external financial support and funding for project activities	B_{18}	11
	Limited access to capital and cost disincentives	B_{19}	10
	Economic crisis	B_{20}	9
	Risk and uncertainty	B_{21}	3
Market	Split incentives	B_{22}	2
	Energy price distortion	B_{23}	2
Environmental	Negative effects of project intervention on the natural environment	B_{24}	3
Technical	Shortage of proven and tested solutions and examples	B_{25}	7
	Lack of skilled and trained personnel	B_{26}	12
	Deficient planning	B_{27}	7
	Lack of well-defined process	B_{28}	5
	Retrofitting work in dwellings in occupied state	B_{29}	2
Social	Inertia	B_{30}	7
	Lack of values and interest in energy optimization measurements	B_{31}	7
	Low acceptance of new projects and technologies	B_{32}	7
Information and Awareness	Insufficient information on the part of potential users and consumers	B_{33}	7
	Lack of awareness among authorities	B_{34}	1
	Perception of interventions as complicated and expensive, with negative socio-economic or environmental impacts	B_{35}	6

*Frequency shows the frequency of presence of barriers in 43 CONCERTO cases

Table 6.S2 Performance evaluation of the models

Barriers	*Sensitivity*	*Specificity*	*Precision*	*Negative predictive value*	*Accuracy*	*Chi square*	*p-value*
B03	0.00	1.00	-	0.80	0.80	-	-
B04	0.20	0.29	0.17	0.33	0.25	3.09	0.079
B05	0.00	1.00	-	0.95	0.95	-	0.078
B07	0.00	0.56	0.00	0.50	0.36	3.11	0.078
B08	0.50	0.93	0.50	0.93	0.88	2.94	0.086
B09	0.00	1.00	-	0.92	0.92	-	-
B10	0.00	0.80	0.00	0.89	0.73	0.49	0.484
B11	0.00	1.00	-	0.84	0.84	-	-
B12	0.00	1.00	-	0.91	0.91	-	-
B14	0.50	1.00	1.00	0.95	0.95	10.48	0.001
B15	0.00	0.82	0.00	0.82	0.70	0.62	0.430
B16	0.00	0.89	0.00	0.89	0.81	0.23	0.630
B17	0.00	0.71	0.00	0.80	0.60	1.18	0.278
B18	0.00	1.00	-	0.76	0.76	-	-
B19	0.25	0.82	0.25	0.82	0.71	0.11	0.736
B20	0.75	0.75	0.60	0.86	0.75	2.74	0.10
B25	0.00	1.00	-	0.86	0.86	-	-
B26	0.40	0.88	0.50	0.82	0.76	1.87	0.17
B27	0.00	0.95	0.00	0.90	0.86	0.11	0.74
B30	0.00	0.71	0.00	0.75	0.57	1.54	0.21
B31	0.67	0.89	0.50	0.94	0.86	5.49	0.019
B32	0.00	0.93	0.00	0.82	0.78	0.21	0.65
B33	0.00	0.88	0.00	0.83	0.75	0.39	0.53
B35	0.00	1.00	-	0.77	0.77	-	-

Sensitivity is the probability that the model predicts correctly the presence of a barrier. Specificity is the probability that the model correctly predicts the absence of a barrier; precision is the proportion of predicted barrier that was indeed present; negative predictive value is the probability that a barrier, which was predicted to be absent, is indeed absent; and accuracy is the percentage of all correct predictions made by the model.

Part V

Chapter 7

General Discussion

The main aim of the here presented thesis was to pave the way for urban decision-makers to successfuly implement smart energy city development at the urban scale in Europe. To this aim, I defined five specific research objectives (posed in Chapter 1), framed in the three levels of conceptual analysis, empirical investigation, and learning methodologies for new developments. This chapter recalls the main contributions of the previous chapters to the specific research objectives within each level. Then, it demonstrates how the findings, joint together, serve the main aim of the thesis; this is presented as applications for decision-makers. Finally, a general conclusion conveying the key messages of the thesis is presented, followed by current limitations and recommendations for future research.

7.1 Review of the key conclusions with respect to the research objectives

To support decision-makers towards successful implementation of European SEC projects at the urban scale, I went through three crucial steps in here presented thesis: i) defining SEC development within the context of smart city concept and in the framework of sustainable city development; ii) identifying and prioritizing barriers to the implementation of urban scale SEC development in practice within Europe; and iii) learning from the previous experiences to overcome barriers to new SEC projects. The following paragraphs explicate the research process and the key conclusions in each step (illustrated in Figure 7.2).

7.1.1 What is the definition of SEC development?

SEC is an inseparable component of smart city (Nielsen et al., 2013); therefore, conceptualizing SEC development, it is inevitable to first conceptualize smart city in order to set the context.

I conceptualized smart city through an extensive review and analysis of both scientific and gray literature (Chapter 2). The result was a systematic analysis of the discourse based on six aspects of the concept –i.e. principles, objectives, stakeholders, domains of intervention, temporal and spatial dimensions (using 5W+1H model, following Dantas et al. (2005)). Moreover, the result distinguished the discourse, for the first time, versus three main fields in which the concept has been mainly created and developed: academic literature, governmental, and industrial literature. The first key conclusion was that the interpretation of the concept varies among three above-mentioned fields, with respect to their specific interests. However, three characteristics (i.e. principles)[4] found to be central to the concept of smart city, independent from the field that developed the concept: The overriding principle is the application of technology and ICT in smart city systems and services. This principle is traditionally incorporated within the smart city concept; in fact, decoupling smart from ICT is not possible, unless one ignores the background of the concept. The two other principles are the collaboration of stakeholders and integration of multiple urban domains. Although smart city is site-specific and its different aspects –i.e. objectives, domains of intervention, and involved stakeholders– vary in each specific project, these three principles are essential to be included in all smart city developments. The second key conclusion was that application of the 5W+1H model is highly appropriate for analyzing the definition of smart city and each of its domains –e.g. smart energy city. This highlighted the necessity to incorporate spatial and temporal dimensions into the concept as well.

Within the stated concept of smart city (Chapter 2) and build upon the key conclusions mentioned above, I provided a structured and comprehensive definition for SEC development, specifically from urban planners’ perspective (Chapter 3). The definition was elaborated by using 5W+1H model, combined with both literature review and methods for expert knowledge elicitation. Best to my knowledge, the elaborated definition is the first comprehensive and multi-dimensional definition of SEC development in the scientific literature on urban studies. This definition goes beyond theoretically describing SEC development by listing a set of smart energy practical solutions and showing how each solution fits in the SEC theoretical definition (see Tables 3.1 and 3.2). A key conclusion of this chapter was that SEC, as a component of smart city, must fit in the framework of the sustainable city. In fact, if a “labeled” SEC development does not meet sustainability requirements, it should not be considered as “real” SEC development (Figure 7.1). This resulted in adding one principle to the concept, named sustainability evaluation. This principle helps to keep the initial integrity of sustainable urban development, meaning that SEC development should not act only in one dimension –i.e. energy optimization– but should consider and evaluate other social, environmental, and economic dimensions in an integrated way. This led to another key conclusion: SEC development and consequently smart energy solutions are more effective when accompanied with other sustainable conventional or innovative-non-technological answers.

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[4] In the Chapter 2, there is a fourth principle, named *social inclusion*. In the next steps of the study, *social inclusion* was integrated within *stakeholder collaboration* because citizens and communities play a key and active role in SEC development, and are considered as one stakeholder group.

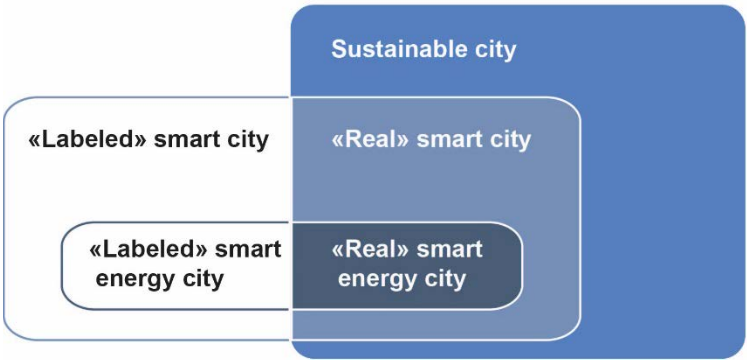


Figure 7.1 Relationship between smart energy city, smart city, and sustainable city, based on the conclusions of the here presented thesis: a smart energy city is not "real" if it does not meet sustainability requirements.

7.1.2 What are the key barriers to the implementation of urban scale SEC development in Europe?

In order to identify the key barriers to the SEC development, I performed an empirical approach, first identifying and then prioritizing barriers. Using the definition of SEC development (provided in Chapter 3), I identified 43 European cities and communities that had previously implemented SEC projects at an urban scale (Appendix 1). These projects are distributed in 18 European countries, supporting local communities in development and demonstration of concrete sustainable energy strategies and actions. The diversity of these communities in size and socio-economic, environmental, and political conditions embodies a rich source of knowledge. Moreover, these projects are completed or are in the final period of completion, and the information for the barriers to implementation of each community is evident.

Through a systematic qualitative investigation of the 43 experiences, I identified 35 common barriers, each assigned to one of the following nine categories: policy, administrative, legal, financial, market, environmental, technical, social, and information and awareness (Chapter 4). I compared and validated the results of the empirical research with the scientific literature on barriers to sustainable energy (e.g. barriers to renewable energy reviewed by Cagno et al. (2013), and energy efficiency reviewed by Eleftheriadis and Anagnostopoulou (2015)). A key conclusion was that SEC development has encountered new barriers that are not previously declared in the literature –e.g. lack of public participation, and interoperability barrier. The new barriers show a strong connection to the specific and new SEC characteristics (defined as SEC principles in Chapter 3).

To prioritize barriers to implementation of SEC development, I proposed and applied a new multi-dimensional methodology for barrier prioritization (Chapter 4). The proposed methodology is built upon and completes previous scientific efforts to rank barriers to sustainable energy development. It combines criticality –i.e. a function of frequency and impact (Ren et al., 2015; Sizhen et al., 2005)– inevitability –i.e. a function of origin (Cagno et al., 2013) and scale (Nagesha and Balachandra, 2006)– and interaction with other barriers (Ren et al., 2015). The inevitability analysis –which is defined in the here presented thesis for the first time– particularly shows which barriers are of a higher priority for SEC project coordinators and which barriers are of higher priority for policy makers. The barrier prioritization revealed that barriers related to collaborative planning, external funding of the project, providing skilled personnel, and fragmented ownership are the key barriers to be addressed by SEC project coordinators.

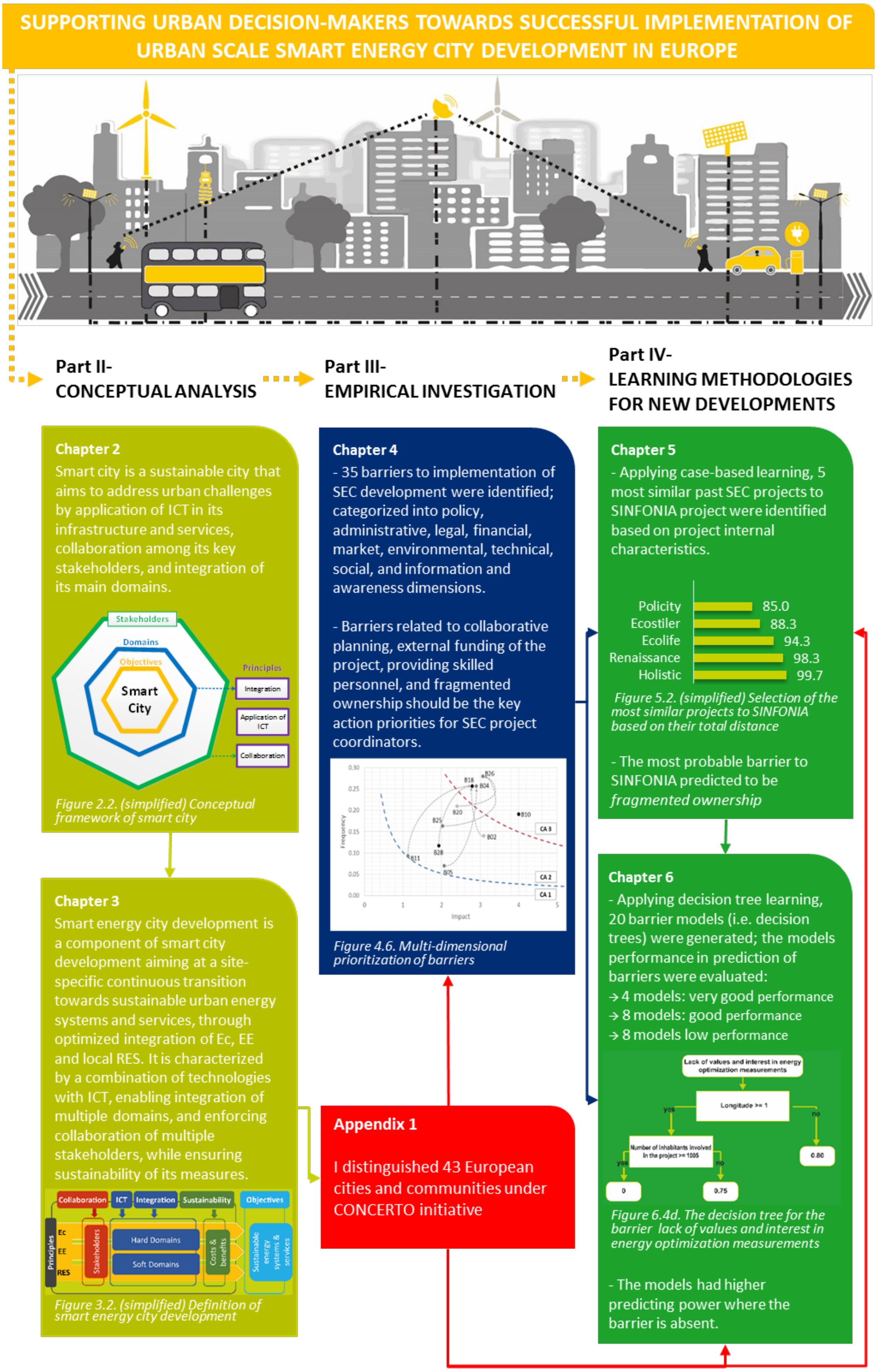
7.1.3 How to learn from previous experiences to predict barriers to implementation of a new SEC project?

I made the first attempt to apply advanced quantitative learning methods in predicting specific barriers to implementation of a new SEC project, named SINFONIA. SINFONIA is a five year EU FP7 project that started in 2014. The two demo cities of SINFONIA project are Bolzano (Italy) and Innsbruck (Austria). To predict barriers, I used two different methodologies: case-based learning (Chapter 5) and decision tree learnong (Chapter 6).

In the application of the case-based learning methodology (Chapter 5), I characterized the past and the new SEC projects based on project characteristics. The characterization framework followed the 5W+1H model (proposed based on Chapter 2). I identified five most similar cases to Bolzano within the SINFONIA project, using the normalized hamming distance and Radius K-nearest neighbour techniques. This resulted in a meaningful similarity between projects, based on which I predicted a list of the most probable barriers to the implementation of SINFONIA project. Accordingly, the most probable barrier to SINFONIA project was predicted to be *fragmented ownership [of buildings]*. The comparison of the results with the actually identified barriers of SINFONIA in Bolzano (presented in Chapter 6) showed that fragmented ownership, although predicted with 80% probability, did not occur in Bolzano. That is because the ownership of SINFONIA refurbished buildings in Bolzano is public (SINFONIA, 2015), and therefore, fragmented ownership –which is usually a substantial problem in multi-owner refurbishment– is not an issue. A key conclusion is that other internal characteristics (e.g. ownership) need to be added to the analysis. In addition, involving both internal and external indicators in the analysis is necessary for an improved prediction. Since application of the proposed methodology on a small scale requires much effort to gather the first database, a way to transform this methodology to a decision support system (DSS) was suggested (Chapter 5). Creation of this DSS would be promising in large-scale –e.g. at European or international level– for predicting barriers to a given SEC project.

In the application of decision trees, 20 predictive barrier models were generated based on a dataset of the past experiences (Chapter 6). Each barrier model is able to predict probability of the occurrence of the associated barrier based on project characteristics. I evaluated the predictive performance of each barrier model through leave-one-out cross-validation of half of the cases. Four barrier models showed a very good performance and eight barrier models showed a good performance. A key conclusion is that decision trees are effective in making significant predictions about the occurrence of barriers. I tested the application of the models by predicting the probability of barriers for Bolzano and Innsbruck. I compared the findings with actually identified barriers to the SINFONIA project (presented in Chapter 6). The result of comparison showed higher predicting power where the barriers were absent. The findings also implied that more study cases, less missing data, and more accurate data are required to improve the applicability of the methodology for a large-scale application.

Both methodologies represent high potential in predicting barriers for a new specific project. The strength point of the case-based learning methodology is its applicability even when the number of the past experiences is limited. In addition, once the most similar experiences are identified, learning in a vast range and on different aspects of knowledge is possible. However, selection of the characterization features, as the basis for similarity evaluation, is a problem in this method. On the contrary, the decision tree learning methodology is able to independently identify the most relevant characteristics (i.e. the strongest predictor variables) that influence the barriers. However, this methodology requires a large dataset –including numerous cases and numerous indicators– for the first time application. Hence, a hybrid methodology that uses decision trees for application in case-based learning could result in a promising solution (similar to Cardie, 1993). It would identify the most relevant criteria through application of decision trees, and use those criteria as characterization features for application in case-based learning. Therefore, the similar past projects to a given project can be found more accurately. Another shortcoming of case-based learning methodology is its dependency on a dataset for any new application. This is the opposite of decision trees, where once the models are generated, the prediction for a new case is independent from the dataset on the past experiences –the only required data would be for the already reduced number of variables for the new project. Selection of each methodology, therefore, largely depends on the specific objectives of the application and the available resources.



SUPPORTING URBAN DECISION-MAKERS TOWARDS SUCCESSFUL IMPLEMENTATION OF URBAN SCALE SMART ENERGY CITY DEVELOPMENT IN EUROPE

Part II-
CONCEPTUAL ANALYSIS

Part III-
EMPIRICAL INVESTIGATION

Part IV-
LEARNING METHODOLOGIES FOR NEW DEVELOPMENTS

Chapter 2

Smart city is a sustainable city that aims to address urban challenges by application of ICT in its infrastructure and services, collaboration among its key stakeholders, and integration of its main domains.

Figure 2.2. (simplified) Conceptual framework of smart city

Chapter 3

Smart energy city development is a component of smart city development aiming at a site-specific continuous transition towards sustainable urban energy systems and services, through optimized integration of Ec, EE and local RES. It is characterized by a combination of technologies with ICT, enabling integration of multiple domains, and enforcing collaboration of multiple stakeholders, while ensuring sustainability of its measures.

Figure 3.2. (simplified) Definition of smart energy city development

Chapter 4

- 35 barriers to implementation of SEC development were identified; categorized into policy, administrative, legal, financial, market, environmental, technical, social, and information and awareness dimensions.

- Barriers related to collaborative planning, external funding of the project, providing skilled personnel, and fragmented ownership should be the key action priorities for SEC project coordinators.

Figure 4.6. Multi-dimensional prioritization of barriers

Appendix 1

I distinguished 43 European cities and communities under CONCERTO initiative

Chapter 5

- Applying case-based learning, 5 most similar past SEC projects to SINFONIA project were identified based on project internal characteristics.

Figure 5.2. (simplified) Selection of the most similar projects to SINFONIA based on their total distance

- The most probable barrier to SINFONIA predicted to be *fragmented ownership*

Chapter 6

- Applying decision tree learning, 20 barrier models (i.e. decision trees) were generated; the models performance in prediction of barriers were evaluated:

→ 4 models: very good performance
→ 8 models: good performance
→ 8 models low performance

Figure 6.4d. The decision tree for the barrier lack of values and interest in energy optimization measurements

- The models had higher predicting power where the barrier is absent.

Figure 7.2 Summary of the thesis chapters and their interrelationships

7.2 Applications for urban decision-makers: towards successful implementation of urban scale SEC development in Europe

Di Nucci et al. (2010) state that a common process for SEC projects includes four phases. It starts with *initiatiation* phase, continues with *design/planning* phase, follows by *implementation* phase, and finally, finishes with *operation* phase. Beyond the specific objectives of the research, the different chapters of the here presented thesis can support decision-makers in each project phase in order to improve the quality of SEC development in practice. The following paragraphs explain how the research outcomes of the here presented thesis support urban decision-makers towards the successful implementation of SEC development (Figure 7.3).

In *the initiation* phase, the development location is selected and priorities are defined; the funding is organized, and commitments are made with other stakeholders (e.g. service providers); in addition, pre-feasibility studies are done and criteria are designed for development (Di Nucci et al., 2010). In this phase, project initiators can use the SEC principles and objectives (defined in Chapter 3) as a guideline to define development priorities. They can use the list of the SEC stakeholders (proposed in Chapter 3) to recognize key project partners. In pre-feasibility studies, the common barriers to SEC development (Chapter 4) are considerable, giving an overview of the potential problematic matters, e.g. conflict among partners, legal restrictions for some technologies, and social oppositions.

In *design/planning* phase, the objectives are clearly defined, the technologies are selected, and other stakeholders are called for; the energy systems in buildings and districts are designed, implementation process is planned, and the quality of interventions is ensured (Di Nucci et al., 2010). The SEC definition (Chapter 3) can be used in this phase as a checklist to revise the design and planning of the project (see Frame 1). The list of practical solutions (provided in Chapter 3) is applicable in this phase for decision-makers to recognize various practical solutions and their broad application. This allows a dialogue with stakeholders, including consultants, developers, and urban planners, in order to select development solutions. In addition, it is possible to create further indicators to characterize smart energy solutions based on energy saving potential, investment cost, return on investment, and social acceptance, among others. This could lead to elaboration of a multi-criteria analysis tool for selection of the solutions in an optimized way. After the internal project characteristics are fixed, both of the suggested learning methodologies (Chapters 5 and 6) can help project decision-makers to predict the probable barriers to the implementation of the project, which would help project coordinators to revise the project design and plan in order to mitigate those barriers. Furthermore, the proposed multi-dimensional methodology for barriers prioritization (Chapter 4) assists decision-makers to efficiently allocate their resources to mitigate barriers. The barriers that are avoidable at project level might be treated by internal revisions in the project design and organization, and those that are inevitable might be carefully considered. Beside the direct application of the case-based learning methodology (Chapter 5), proposed in this thesis, project coordinators can use this methodology to find the most similar past experiences to their own project. This provides an opportunity to learn also about success factors, business models, and barrier mitigation actions, and any other purpose that requires learning from previous experiences; besides, this provides an opportunity to make new collaborations, get external consultancy, and/or send delegates.

Frame 1 A checklist to revise the design and planning of an SEC project:

- Are the plan objectives in line with SEC development objectives?
- Is sustainability evaluation considered within the project?
- Are key SEC domains of integration and the potential interaction among them identified?
- Are key SEC stakeholders recognized and involved in the plan?
- Does the plan consider site-specific characteristics in planning and implementation?
- Does the plan consider membership in local, national, or supra-national networks to learn from other experiences?
- Does the plan consider time-specific targets?

In *the implementation* phase, coordination of development procedures, the construction of new buildings and districts and refurbishment of existing areas take place; in addition, the end-users are informed about the project activities (Di Nucci et al., 2010). In this phase, the experiences of identified similar projects through case-based learning methodology (Chapter 5) is applicable to find solutions for overcoming unexpected barriers that may occur during the implementation phase. The definitions of smart city and SEC development (Chapters 2 and 3) can help to inform end-users about the concept of smart city and SEC and its benefits for them in short to long term.

In *operation* phase, monitoring of the implemented energy systems takes place (Di Nucci et al., 2010). In this phase, further development of the SEC definition (Chapter 3) could result in deriving assessment indicators to evaluate the performance of the project activities (similar to Nielsen et al., 2013).

Beside the contribution of each piece of this thesis to each specific project phase, the definitions of smart city and SEC development (Chapters 2 and 3) provide a common ground for better dialogue and understanding among all relevant stakeholders during the whole lifecycle of the project.

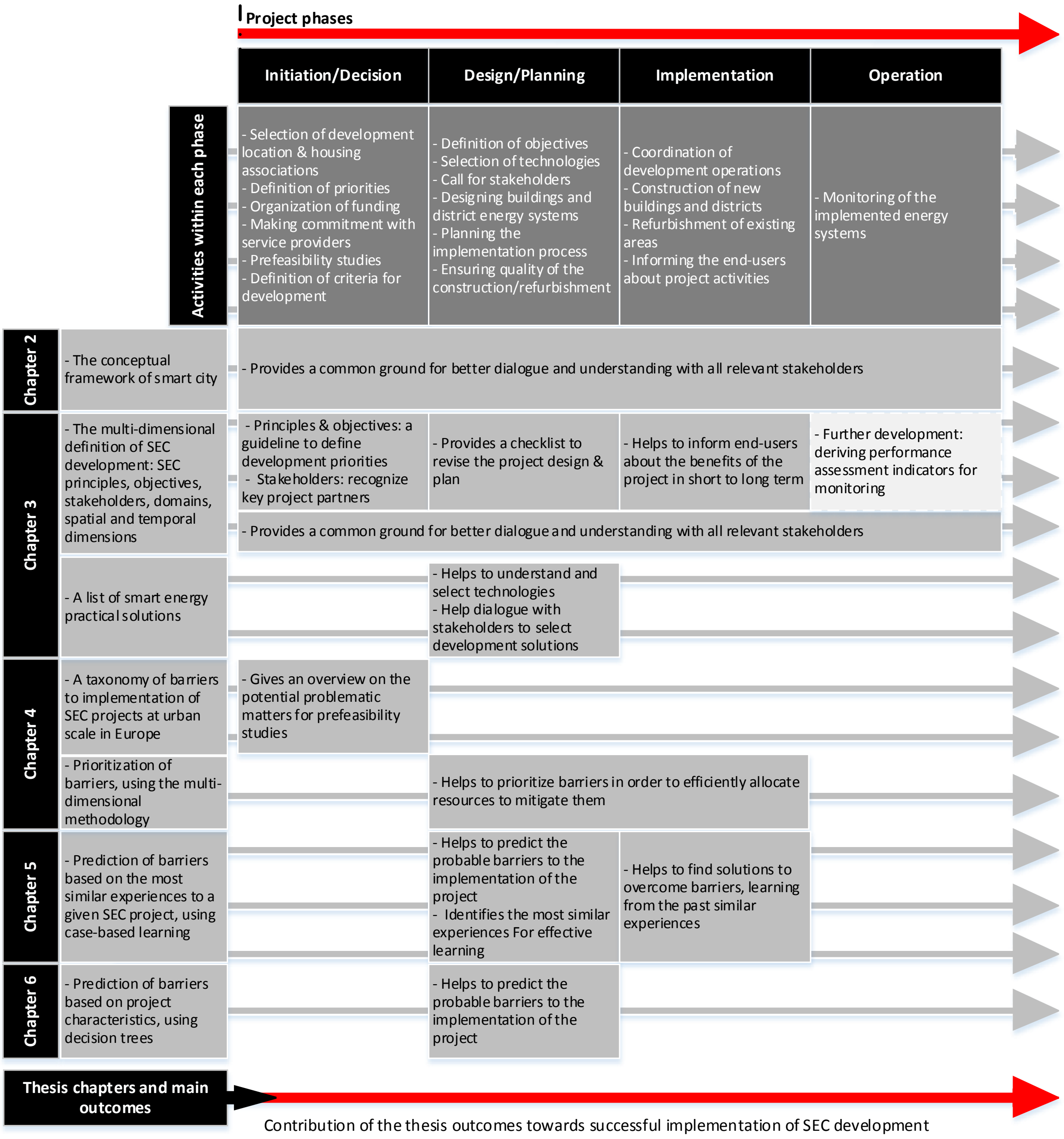


Figure 7.3 Thesis contribution towards successful implementation of SEC projects (Di Nucci et al., 2010; modified)

7.3 General conclusions

Smart energy city development at the urban scale is currently a popular response in Europe to the global energy challenge. This popularity, however, raises the urge to guarantee successful implementation of SEC projects not only to accelerate achievement of urban energy objectives but also to ensure sustainability of future urban development. In order to support urban decision-makers towards successful implementation of urban scale SEC projects in Europe, the here presented thesis made six main contributions to the scientific knowledge on the topic. First, it provided a conceptual definition for smart city as the context to SEC development. Second, it provided the first multi-dimensional and comprehensive definition of SEC development. This definition helps a common understanding and dialogue on the concept among all SEC stakeholders, particularly decision-makers. Third, it identified, for the first time in scientific literature, common barriers that hinder successful implementation of SEC projects, considered as a holistic integrated development. Fourth, it suggested a new multi-dimensional framework to prioritize barriers to the implementation of SEC development in order to arrange actions and allocation of resources for overcoming barriers. Fifth, it introduced, according to my knowledge for the first time, the application of case-based learning methodology to find similar past experiences to a new specific SEC project in order to predict barriers to the project implementation. Sixth, it introduced, according to my knowledge for the first time, the application of decision trees to create predictive models for barriers to implementation of SEC projects. The key conclusions of this thesis are presented as follows.

SEC is an outstanding approach in sustainable urban development that can make a valuable contribution to addressing current urban energy challenges and improve the sustainability of cities. This development is distinguished by application of innovative technologies combined with ICT, the collaboration of multiple stakeholders, and integration of multiple urban domains. However, due to these specific characteristics, SEC development is not the unique way of addressing urban energy sustainability. In fact, SEC development will be more effective if combined with other sustainable urban solutions, such as conventional or innovative-non-technological answers.

An enhanced integration of SEC and urban development is required. SEC development ought to adopt the knowledge gained through long period experience in urban development. This includes, on one hand, integrating sustainability evaluation in SEC plans and policies, considering a multi-scale planning for SEC development –considering the function of the city within the regional, national, and supra-national scale– as well as considering the interactions of the city with its surrounding rural area. On the other hand, urban development should take advantage of SEC popularity, strategies, and solutions in order to get more integrated, participatory, collaborative, and sustainable.

Integration of SEC with urban development poses new challenges to future smart and sustainable urban planning. These challenges lie in the specific characteristics of SEC development. Application of innovative technologies seeks for refinements in policy, legal and regulatory frameworks in all local, regional, national, and supra-national levels. Effective public-private partnerships require innovative business models. Education and training are crucial for developing skilled personnel. Increasing knowledge and awareness of all stakeholder groups, specifically authorities and end-users is crucial to improving project acceptance and facilitating behavioral changes.

In spite of common challenges to SEC development, project-specific characteristics considerably smooth or hinder the implementation of the projects. Application of advanced quantitative methods –e.g. case-based learning or decision trees– is promising for understanding the complicated association rules between project characteristics and the quality of the project implementation. SEC development –characterized by large amount of data collection, management, and distribution– brings about unprecedented opportunities for application and integration of such methods with current urban planning methodologies. This allows efficient knowledge transfer in not only intra-urban but also inter-urban levels in order to predict and consequently overcome the barriers, and enhance the quality of the project implementation. Application of such methodologies, however, requires standard and shared data frameworks to facilitate learning among SEC initiators.

To conclude, the here presented thesis supports urban decision-makers to understand and successfully implement SEC development. This would consequently contribute to addressing the global energy challenge and enhancing the sustainability of energy systems.

7.4 Current limitations and recommendations for future research

SEC development is the subject of high popularity and attention from European urban governments. Yet, it is rather recent, and therefore, not fully developed in both conceptual and practical levels. This is while new SEC characteristics introduce unprecedented opportunities for application of innovative methodologies in this topic. These three factors –popularity, infancy, and new characteristics– provide a great deal of necessity, space, and support for future innovative research in the field of SEC development. The here presented work faced the limitation of lacking literature and methodologies on the topic. Clarifying and defining the basic concepts, collecting the raw data, and elaborating the methodologies were required in each step. The outcomes of the presented work have no claim of exhaustiveness; nonetheless, they might pave the way for future research towards successful implementation of SEC development. To this aim, supported by findings and experiences gained during the three-year of my Ph.D. program, I present a number of recommendations for future research.

Conceptualizing all domains of smart city independently and within the context of smart city definition, is required. The here presented research, defined SEC development by using 5W+1H model, combined with literature review and expert knowledge elicitation (Chapter 3). A similar methodology is suggested for defining other domains of smart city (presented in Chapter 2) –e.g. smart government and smart community.

Sustainability evaluation of smart energy solutions is essential before applying them on a large scale. There are yet questions on the sustainability of e-waste produced due to instrumenting cities (Viitanen and Kingston, 2014), or of marginalization of non-educated social groups in SEC development (Hollands, 2008). This thesis provided the first solution by introducing long-term sustainability evaluation as a must-consider principle of SEC development. Future research might make effort to put this principle into practice by evaluating the sustainability of SEC plans and policies as well as smart energy solutions and technologies in terms of their socio-environmental and economic impacts.

Respectively, development of key performance indicators for SEC development is required to ensure successful implementation of SEC development. The definition of SEC development elaborated in the here presented thesis (Chapter 3), specifically SEC objectives and principles, can be a starting point to derive such assessment indicators (similar to Nielsen et al., 2013).

The here presented study discovered barriers to the implementation of SEC projects that were already implemented in 2013 (beginning of the here presented thesis). However, new SEC projects have emerged later, using more innovative smart energy technologies. Further research might use the identified barriers in this research (Chapter 4) as the basis (e.g. as a structured questionnaire) for investigating more recently implemented projects. In addition, this study discovered barriers by considering projects as an integrated whole (Chapter 4), finding barriers related to collaboration or integration aspects. Future research might focus on identifying particular barriers to the specific smart energy solutions (similar to Wright et al. (2014) for combined heat and power and Luthra et al. (2014) for smart grid), e.g. photovoltaics or district heating and cooling.

The identification of barriers provides insight to enhance the projects' success. Further efforts might be dedicated to investigating the success factors of SEC projects, as a complementary investigation to the here presented research.

The multi-dimensional methodology to prioritize barriers to the implementation of SEC projects can provide deeper insight into the barrier mitigation for both SEC project coordinators and policy makers (Chapter 4). Future research can test the application of the proposed methodology for barriers to other types of urban development; e.g. low carbon development.

The work presented here suggested two different learning methodologies for predicting barriers based on knowledge gained through the past SEC experiences. The case-based learning methodology for prediction of barriers to a given new SEC project (Chapter 5) can be further exploited, being transformed to a DSS (as illustrated in Chapter 5). I particularly suggest a large-scale application of the DSS through developing a database of SEC projects on a European or global level. The second methodology, which used decision trees to model barriers to SEC projects based on project characteristics (Chapter 6), showed significant predictions while applied on a rather small dataset. We used a small dataset because the number of projects implemented until 2013 (the beginning of the here presented research) were limited. In addition, it is more efficient to test the first application of the methodology in a small scale and in case the result is promising, go for higher scales. Therefore, further development of the methodology might consider more cases (at least 100 cases), and gather data on barriers through quantitative methods (e.g. structured questionnaire, based on the list of barriers identified in Chapter 4). This will result in more accurate and consistent results. Furthermore, a hybrid methodology that uses decision trees for application in case-based learning (similar to Cardie, 1993) could result in an even more promising solution (as explained in section 7.1.3).

Overall, I suggest further development of the findings of the presented research in order to provide a European DSS, applicable specifically for project coordinators, in order to model and predict barriers to a given new SEC project. Such DSS could use the methodologies proposed in this thesis on a common, standardized, and growing European database, providing a shared platform with a predefined structured framework for gathering all SEC projects information. Such DSS can be easily integrated into existing well-known platforms such as covenant of mayors, smart cities and communities stakeholder platform or smart cities and communities information system (CONCERTO, 2015a). Moreover, such DSS can be extended to other topics (e.g. project success factors) as well. In conclusion, it is crucial to produce and share knowledge on SEC development on a European scale and to combine different (new) methodologies to support decision-makers towards successful implementation of SEC development at the urban scale in Europe.

Bibliography

Aha, D.W., 1991. Case-based learning algorithms. Presented at the Proceedings of the 1991 DARPA Case-Based Reasoning Workshop, pp. 147–158.

Allwinkle, S., Cruickshank, P., 2011. Creating Smart-er Cities: An Overview. J. Urban Technol. 18, 1–16. doi:10.1080/10630732.2011.601103

Amsterdam smart city, 2015. Present projects [WWW Document]. Amst. Smart City. URL http://amsterdamsmartcity.com/projects

Anderson, O., Attenborough, M., Livingstone, M., 2012. “Smart City” - Intelligent energy integration for London’s decentralised energy projects.

Andreottola, G., Asimov, R., Bogomolov, A., 2014. Energy Systems for Smart Cities (White Paper). IEEE Smart Cities Inaugural Workshop, Trento, Italy.

Angelidou, M., 2015. Smart cities: A conjuncture of four forces. Curr. Res. Cities CRoC 47, 95–106. doi:10.1016/j.cities.2015.05.004

Angelidou, M., 2014. Smart city policies: A spatial approach. Cities, Current Research on Cities 41, Supplement 1, S3–S11. doi:10.1016/j.cities.2014.06.007

Anthopoulos, L.G., Vakali, A., 2012. Urban planning and smart cities: Interrelations and reciprocities, in: The Future Internet. Springer, pp. 178–189.

Aoun, C., 2013. The smart city cornerstone: Urban efficiency. Publ. Schneider Electr.

Austin, A., 2005. Energy and power in China: domestic regulation and foreign policy. Lond. Foreign Policy Cent.

Bahr, V., 2013. What Smart city can learn from CONCERTO, Summarising the results of the 58 cities and communities co-financed by the CONCERTO initiative.

Banerjee, S., Chowdhury, A.R., 2015. Case Based Reasoning in the Detection of Retinal Abnormalities Using Decision Trees. Procedia Comput. Sci., Proceedings of the International Conference on Information and Communication Technologies, ICICT 2014, 3-5 December 2014 at Bolgatty Palace & Island Resort, Kochi, India 46, 402–408. doi:10.1016/j.procs.2015.02.037

Battaglini, A., Komendantova, N., Brtnik, P., Patt, A., 2012. Perception of barriers for expansion of electricity grids in the European Union. Energy Policy 47, 254–259. doi:10.1016/j.enpol.2012.04.065

Batty, M., Axhausen, K.W., Giannotti, F., Pozdnoukhov, A., Bazzani, A., Wachowicz, M., Ouzounis, G., Portugali, Y., 2012. Smart cities of the future. Eur. Phys. J. Spec. Top. 214, 481–518. doi:10.1140/epjst/e2012-01703-3

Beck, F., Martinot, E., 2004. Renewable energy policies and barriers. Encycl. Energy 5, 365–383.

Belanger, N., Rowlands, I.H., 2014. Smart Energy Networks: Progress and Prospects.

Berardi, U., 2013. Clarifying the new interpretations of the concept of sustainable building. Sustain. Cities Soc. 8, 72–78. doi:10.1016/j.scs.2013.01.008

Berst, J., Enbysk, L., Williams, C., 2014. SMART CITIES READINESS GUIDE, The planning manual for building tomorrow’s cities today.

Boor, K., Teunissen, P.W., Scherpbier, A.J.J.A., van der Vleuten, C.P.M., van de Lande, J., Scheele, F., 2008. Residents’ perceptions of the ideal clinical teacher—A qualitative study. Eur. J. Obstet. Gynecol. Reprod. Biol. 140, 152–157. doi:10.1016/j.ejogrb.2008.03.010

Bourne, L.S., 1982. Internal structure of the city: readings on urban form, growth, and policy. Oxford University Press, USA.

Bramer, M., 2013. Principles of Data Mining, Undergraduate Topics in Computer Science. Springer London, London.

Breiman, L., Friedman, J., Stone, C.J., Olshen, R.A., 1984. Classification and regression trees. CRC press.

Cagno, E., Worrell, E., Trianni, A., Pugliese, G., 2013. A novel approach for barriers to industrial energy efficiency. Renew. Sustain. Energy Rev. 19, 290–308. doi:10.1016/j.rser.2012.11.007

Canton, J., 2011. The extreme future of megacities. Significance 8, 53–56.

Caputo, P., Pasetti, G., 2015. Overcoming the inertia of building energy retrofit at municipal level: The Italian challenge. Sustain. Cities Soc. 15, 120–134. doi:10.1016/j.scs.2015.01.001

Cardie, C., 1993. Using decision trees to improve case-based learning. Presented at the Proceedings of the tenth international conference on machine learning, pp. 25–32.

Carley, S., Lawrence, S., Brown, A., Nourafshan, A., Benami, E., 2011. Energy-based economic development. Renew. Sustain. Energy Rev. 15, 282–295.

Carlos, R.M., Khang, D.B., 2008. Characterization of biomass energy projects in Southeast Asia. Biomass Bioenergy 32, 525–532.

Chai, D.S., Wen, J., Nathwani, J., Rowlands, I., 2011. Concept Development For Smart Energy Networks.

Chai, D.S., Wen, J.Z., Nathwani, J., 2013. Simulation of cogeneration within the concept of smart energy networks. Energy Convers. Manag. 75, 453–465. doi:10.1016/j.enconman.2013.06.045

Coe, A., Paquet, G., Roy, J., 2001. E-governance and smart communities a social learning challenge. Soc. Sci. Comput. Rev. 19, 80–93.

CONCERTO, 2015a. Smart Cities Information System [WWW Document]. CONCERTO. URL http://concerto.eu/ (accessed 9.5.15).

CONCERTO, 2015b. CONCERTO Projects [WWW Document]. CONCERTO. URL http://concerto.eu/concerto/concerto-sites-a-projects/sites-con-projects/sites-con-projects-search-by-name.html (accessed 9.5.15).

CONCERTO, 2015c. The CONCERTO initiative [WWW Document]. CONCERTO. URL http://concerto.eu/concerto/about-concerto.html (accessed 9.5.15).

CONCERTO, 2015d. CONCERTO Premium Data Collection Sheets Guide [WWW Document]. URL http://smartcities-infosystem.eu/concerto/concerto-archive/concerto-library/concerto-guidelines (accessed 6.10.15).

Cosgrave, E., Arbuthnot, K., Tryfonas, T., 2013. Living Labs, Innovation Districts and Information Marketplaces: A Systems Approach for Smart Cities. Procedia Comput. Sci. 16, 668–677. doi:10.1016/j.procs.2013.01.070

Dantas, C.R., Murta, L.G., Werner, C.M., 2005. Consistent evolution of UML models by automatic detection of change traces. Presented at the Principles of Software Evolution, Eighth International Workshop on, IEEE, pp. 144–147.

Deakin, M., Al Waer, H., 2011. From intelligent to smart cities. Intell. Build. Int. 3, 133–139. doi:10.1080/17508975.2011.586673

De Groot, J.I., Steg, L., 2007. Value orientations and environmental beliefs in five countries validity of an instrument to measure egoistic, altruistic and biospheric value orientations. J. Cross-Cult. Psychol. 38, 318–332.

Deng, Z., Lin, Y., Zhao, M., Wang, S., 2015. Collaborative planning in the new media age: The Dafo Temple controversy, China. Cities 45, 41–50. doi:10.1016/j.cities.2015.02.006

Dijkstra, L., Poelman, H., 2012. Cities in Europe: the new OECD-EC definition. Reg. Focus 1, 2012.

Di Nucci, M.R., Pol, O., 2009. Nachhaltiger Stadtumbau und Klimaschutz in der CONCERTO-Initiative. Energiewirtschaftliche Tagesfragen 44–46.

Di Nucci, M.R., Ute Gigler, Olivier Pol, Christina Spitzbart, 2010. CONCERTO-PLANNING AND IMPLEMENTATION PROCESS ASSESSMENT REPORT.

Di Nucci, R.M., Spitzbart, C., 2010. Concerto Socio-Economic Impact Assessment Report. Wien.

Dirks, S., Keeling, M., 2009. A vision of smarter cities. IBM Inst. Bus. Value.

Dunkley, E.J.C., Isbister, G.K., Sibbritt, D., Dawson, A.H., Whyte, I.M., 2003. The Hunter Serotonin Toxicity Criteria: simple and accurate diagnostic decision rules for serotonin toxicity. QJM 96, 635–642. doi:10.1093/qjmed/hcg109

Du, P., Zheng, L.-Q., Xie, B.-C., Mahalingam, A., 2014. Barriers to the adoption of energy-saving technologies in the building sector: A survey study of Jing-jin-tang, China. Energy Policy 75, 206–216. doi:10.1016/j.enpol.2014.09.025

Dutton, J., 2007. Seven Challenges Facing The Public Sector Procurement Community. Melbourn, Australia.

EC, 2016. European Initiative on Smart Cities [WWW Document]. Eur. Comm. URL https://setis.ec.europa.eu/set-plan-implementation/technology-roadmaps/european-initiative-smart-cities (accessed 1.17.16).

EC, 2015a. Smart Cities and Communities [WWW Document]. Eur. Comm. URL http://ec.europa.eu/eip/smartcities/ (accessed 9.5.15).

EC, 2015b. What is FP7? The basics [WWW Document]. Eur. Comm. Res. Innov. URL https://ec.europa.eu/research/fp7/understanding/fp7inbrief/what-is_en.html (accessed 11.12.15).

EC, 2015c. Smart Cities & Communities Invitation for Commitments.

EC, 2015d. Paris Agreement [WWW Document]. Eur. Comm. URL http://ec.europa.eu/clima/policies/international/negotiations/future/index_en.htm (accessed 1.3.16).

EC, 2015e. database [WWW Document]. eurostat. URL http://ec.europa.eu/eurostat/data/database?p_p_id=NavTreeportletprod_WAR_NavTreeportletprod_INSTANCE_nPqeVbPXRmWQ&p_p_lifecycle=0&p_p_state=normal&p_p_mode=view&p_p_col_id=column-2&p_p_col_count=1 (accessed 11.12.15).

EC, 2015f. NUTS - NOMENCLATURE OF TERRITORIAL UNITS FOR STATISTICS [WWW Document]. eurostat. URL http://ec.europa.eu/eurostat/web/nuts/overview (accessed 12.11.15).

EC, 2015g. Smart Cities [WWW Document]. Eur. Comm. URL https://ec.europa.eu/digital-agenda/en/smart-cities (accessed 9.5.15).

EC, 2015h. CORDIS [WWW Document]. Eur. Comm. URL http://cordis.europa.eu/ (accessed 9.5.15).

EC, 2014a. Market Place of the European Innovation Partnership on Smart Cities and Communities [WWW Document]. SMART CITIES Initiat. Eur. Comm. URL https://eu-smartcities.eu/

EC, 2014b. About Us [WWW Document]. SMART CITIES Initiat. Eur. Comm. URL https://eu-smartcities.eu/about

EC, 2014c. European Innovation Partnership on Smart Cities and Communities-Operational Implementation Plan.

EC, 2013. European Innovation Partnership on Smart Cities and Communities-Strategic Implementation Plan.

EC, 2008. Action Plan for Energy Efficiency (2007-12).

Egenhofer, C., Saritas, Ö., 2013. 10 Year Rolling Agenda.

Ekasingh, B., Ngamsomsuke, K., Letcher, R.A., Spate, J., 2005. A data mining approach to simulating farmers’ crop choices for integrated water resources management. J. Environ. Manage., Integrative modelling for sustainable water allocation 77, 315–325. doi:10.1016/j.jenvman.2005.06.015

Eleftheriadis, I.M., Anagnostopoulou, E.G., 2015. Identifying barriers in the diffusion of renewable energy sources. Energy Policy 80, 153–164. doi:10.1016/j.enpol.2015.01.039

Ellis, J., OECD, Kamel, S., Unep Risø Centre, 2007. Overcoming Barriers to Clean Development Mechanism Projects.

EURAC, 2016. People [WWW Document]. EURAC Res. URL http://www.eurac.edu/en/aboutus/people/Pages/default.aspx (accessed 1.3.16).

Farzaneh, H., Suwa, A., Dolla, C.N., de Oliveira, J.A.P., 2014. Developing a Tool to Analyze Climate Co-benefits of the Urban Energy System. Procedia Environ. Sci. 20, 97–105.

Ferranto, S., Huntsinger, L., Getz, C., Lahiff, M., Stewart, W., Nakamura, G., Kelly, M., 2013. Management without borders? A survey of landowner practices and attitudes toward cross-boundary cooperation. Soc. Nat. Resour. 26, 1082–1100.

Freeman, R.E., 2010. Strategic management: A stakeholder approach. Cambridge University Press.

French, S., Barchers, C., Zhang, W., 2015. Moving beyond Operations: Leveraging Big Data for Urban Planning Decisions. Presented at the 14th International Conference on Computers in Urban Planning and Urban Management, July 7-10, 2015, Cambridge, MA USA, MIT, Cambridge, MA USA.

Friedl, C., Reichl, J., 2016. Realizing energy infrastructure projects – A qualitative empirical analysis of local practices to address social acceptance. Energy Policy 89, 184–193. doi:10.1016/j.enpol.2015.11.027

Friuli Venezia Giulia Region, 2013. Key to Innovation Integrated Solution- Integrated Urban Energy Governance.

Geerlings, H., Stead, D., 2003. The integration of land use planning, transport and environment in European policy and research. Transp. Policy 10, 187–196.

Giffinger, R., Fertner, C., Kramar, H., Kalasek, R., Pichler-Milanovic, N., Meijers, E., 2007. Smart cities-Ranking of European medium-sized cities. Vienna University of Technology.

Glaeser, E.L., Berry, C.R., 2006. Why are smart places getting smarter. Rappaport InstituteTaubman Cent. Policy Brief 2.

Gray, B., 1985. Conditions facilitating interorganizational collaboration. Hum. Relat. 38, 911–936.

Gui, H., Roantree, M., 2012. A Data Cube Model for Analysis of High Volumes of Ambient Data. Procedia Comput. Sci. 10, 94–101. doi:10.1016/j.procs.2012.06.016

Hall, R.E., 2000. The vision of a smart city. Presented at the The second international life extention technology workshop, Paris, France.

Hargreaves, T., Nye, M., Burgess, J., 2010. Making energy visible: A qualitative field study of how householders interact with feedback from smart energy monitors. Energy Policy, The socio-economic transition towards a hydrogen economy - findings from European research, with regular papers 38, 6111–6119. doi:10.1016/j.enpol.2010.05.068

Harrell, M.C., Bradley, M.A., 2009. Data collection methods. Semi-structured interviews and focus groups. DTIC Document.

Harrison, C., Donnelly, I.A., 2011. A theory of smart cities, in: Proceedings of the 55th Annual Meeting of the ISSS-2011, Hull, UK.

Herrschel, T., 2013. Competitiveness AND Sustainability: Can “Smart City Regionalism” Square the Circle? Urban Stud. 50, 2332–2348. doi:10.1177/0042098013478240

Hirst, E., Brown, M., 1990. Closing the efficiency gap: barriers to the efficient use of energy. Resour. Conserv. Recycl. 3, 267–281. doi:10.1016/0921-3449(90)90023-W

Hollands, R.G., 2008. Will the real smart city please stand up?: Intelligent, progressive or entrepreneurial? City 12, 303–320. doi:10.1080/13604810802479126

IEA, 2014. Capturing the Multiple Benefits of Energy Efficiency.

IEA, 2010. Energy Efficiency Governance, Handbook, 2nd ed. OECD/IEA, Paris, France.

Immendoerfer, A., Bräutigam, K.-R., Jörissen, J., Oertel, M., Stelzer, V., 2012. DP4- Policy Contributions and Recommendations (month 24) (Deliverable DP4 No. ENER/C2/59-1/2010), CONCERTO Premium. Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany.

Immendoerfer, A., Winkelmann, M., Stelzer, V., 2014. Energy Solutions for Smart Cities and Communities Recommendations for Policy Makers. Eur. Union. doi:10.2833/17772

Indira, V., Vasanthakumari, R., Jegadeeshwaran, R., Sugumaran, V., 2015. Determination of minimum sample size for fault diagnosis of automobile hydraulic brake system using power analysis. Eng. Sci. Technol. Int. J. 18, 59–69. doi:10.1016/j.jestch.2014.09.007

Innes, J.E., Booher, D.E., 1999. Consensus building as role playing and bricolage: Toward a theory of collaborative planning. J. Am. Plann. Assoc. 65, 9–26.

Ishizaka, A., Labib, A., 2011. Review of the main developments in the analytic hierarchy process. Expert Syst. Appl. 38, 14336–14345.

Jia, C., Cai, Y., Yu, Y.T., Tse, T., 2015. 5W+ 1H pattern: A perspective of systematic mapping studies and a case study on cloud software testing. J. Syst. Softw.

Kaminker, C., Stewart, F., 2012. The Role of Institutional Investors in Financing Clean Energy.

Kaufmann, V., Bergman, M.M., Joye, D., 2004. Motility: mobility as capital. Int. J. Urban Reg. Res. 28, 745–756.

Kennedy, M., Basu, B., 2013. Overcoming barriers to low carbon technology transfer and deployment: An exploration of the impact of projects in developing and emerging economies. Renew. Sustain. Energy Rev. 26, 685–693. doi:10.1016/j.rser.2013.05.071

Keramati, A., Jafari-Marandi, R., Aliannejadi, M., Ahmadian, I., Mozaffari, M., Abbasi, U., 2014. Improved churn prediction in telecommunication industry using data mining techniques. Appl. Soft Comput. 24, 994–1012. doi:10.1016/j.asoc.2014.08.041

Khansari, N., Mostashari, A., Mansouri, M., 2014. Impacting Sustainable Behavior and Planning in Smart City. Int. J. Sustain. Land Use Urban Plan. IJSLUP 1.

Khatib, T., Monacchi, A., Elmenreich, W., Egarter, D., D’Alessandro, S., Tonello, A.M., 2014.

European end-user’s level of energy consumption and attitude toward smart homes: A case study of residential sectors in austria and italy. Energy Technol. Policy 1, 97–105.

Kitchin, R., 2014. Making sense of smart cities: addressing present shortcomings. Camb. J. Reg. Econ. Soc. rsu027.

Kohavi, R., 1995. A study of cross-validation and bootstrap for accuracy estimation and model selection. Presented at the Ijcai, pp. 1137–1145.

Komninos, N., 2002. Intelligent cities: innovation, knowledge systems, and digital spaces. Taylor & Francis.

Komninos, N., Schaffers, H., Pallot, M., 2011. Developing a policy roadmap for smart cities and the future internet. Presented at the eChallenges e-2011 Conference Proceedings, IIMC International Information Management Corporation, IMC International Information Management Corporation.

Krajačić, G., Duić, N., Zmijarević, Z., Mathiesen, B.V., Vučinić, A.A., da Graça Carvalho, M., 2011. Planning for a 100% independent energy system based on smart energy storage for integration of renewables and CO 2 emissions reduction. Appl. Therm. Eng. 31, 2073–2083.

Kuo, W.-J., Chang, R.-F., Chen, D.-R., Lee, C.C., 2001. Data mining with decision trees for diagnosis of breast tumor in medical ultrasonic images. Breast Cancer Res. Treat. 66, 51–57.

Kylili, A., Fokaides, P.A., 2015. European smart cities: The role of zero energy buildings. Sustain. Cities Soc. 15, 86–95. doi:10.1016/j.scs.2014.12.003

Lazaroiu, G.C., Roscia, M., 2012. Definition methodology for the smart cities model. Energy 47, 326–332. doi:10.1016/j.energy.2012.09.028

Lee, J.H., Phaal, R., Lee, S.-H., 2013. An integrated service-device-technology roadmap for smart city development. Technol. Forecast. Soc. Change 80, 286–306. doi:10.1016/j.techfore.2012.09.020

Leydesdorff, L., Deakin, M., 2011. The triple-helix model of smart cities: a neo-evolutionary perspective. J. Urban Technol. 18, 53–63.

Liu, X., Li, X., Shi, X., Wu, S., Liu, T., 2008. Simulating complex urban development using kernel-based non-linear cellular automata. Ecol. Model. 211, 169–181.

Lombardi, P., Giordano, S., Farouh, H., Yousef, W., 2012. Modelling the smart city performance. Innov. Eur. J. Soc. Sci. Res. 25, 137–149. doi:10.1080/13511610.2012.660325

Lourenco, F., Lobo, V., Bacao, F., 2004. Binary-based similarity measures for categorical data and their application in Self-Organizing Maps.

Lovins, A.B., 2004. Energy efficiency, taxonomic overview. Encycl. Energy 2, 6.

Lund, H., 2014. Renewable energy systems: a smart energy systems approach to the choice and modeling of 100% renewable solutions. Academic Press.

Luthra, S., Kumar, S., Kharb, R., Ansari, M.F., Shimmi, S., 2014. Adoption of smart grid technologies: An analysis of interactions among barriers. Renew. Sustain. Energy Rev. 33, 554–565.

Macharis, C., De Witte, A., Turcksin, L., 2010. The Multi-Actor Multi-Criteria Analysis (MAMCA) application in the Flemish long-term decision making process on mobility and logistics. Transp. Policy 17, 303–311. doi:10.1016/j.tranpol.2010.02.004

Manville, C., Cochrane, G., Cave, J., Millard, J., Pederson, J.K., Thaarup, R.K., Liebe, A., Wissner, M., Massink, R., Kotterink, B., 2014. Mapping smart cities in the EU.

Marle, F., Vidal, L.-A., Bocquet, J.-C., 2013. Interactions-based risk clustering methodologies and algorithms for complex project management. Int. J. Prod. Econ., Anticipation of risks impacts and industrial performance evaluation in distributed organizations life cycles 142, 225–234. doi:10.1016/j.ijpe.2010.11.022

Marsá-Maestre, I., López-Carmona, M.A., Velasco, J.R., Navarro, A., 2008. Mobile agents for service personalization in smart environments. J. Netw. 3, 30–41.

Masser, I., 1990. Special Issue: Urban Innovation for the 21st CenturyCross national learning for urban policy making. Cities 7, 25–30. doi:10.1016/0264-2751(90)90004-Q

Massey, A.P., Wallace, W.A., 1991. Focus groups as a knowledge elicitation technique: an exploratory study. Knowl. Data Eng. IEEE Trans. On 3, 193–200.

McMorran, A.W., Stewart, E.M., Shand, C.M., Rudd, S.E., Taylor, G.A., 2012. Addressing the challenge of data interoperability for off-line analysis of distribution networks in the Smart Grid, in: Transmission and Distribution Conference and Exposition (T D), 2012 IEEE PES. Presented at the Transmission and Distribution Conference and Exposition (T D), 2012 IEEE PES, pp. 1–5. doi:10.1109/TDC.2012.6281555

Montazeri, H., Azizian, R., 2008. Experimental study on natural ventilation performance of one-sided wind catcher. Build. Environ. 43, 2193–2202.

Morgan, J., Daugherty, R., Hilchie, A., Carey, B., 2003. Sample size and modeling accuracy of decision tree based data mining tools. Acad. Inf. Manag. Sci. J. 6, 71–99.

Mosannenzadeh, F., Vettorato, D., 2014. Defining smart city. A conceptual framework based on keyword analysis. Tema J. Land Use Mobil. Environ.

Moss Kanter, R., Litow, S.S., 2009. Informed and interconnected: A manifesto for smarter cities. Harv. Bus. Sch. Gen. Manag. Unit Work. Pap.

Muja, M., Lowe, D.G., 2014. Scalable nearest neighbor algorithms for high dimensional data. Pattern Anal. Mach. Intell. IEEE Trans. On 36, 2227–2240.

Nagesha, N., Balachandra, P., 2006. Barriers to energy efficiency in small industry clusters: Multi-criteria-based prioritization using the analytic hierarchy process. Energy 31, 1969–1983. doi:10.1016/j.energy.2005.07.002

Nam, T., Pardo, T.A., 2011. Conceptualizing smart city with dimensions of technology, people, and institutions, in: Proceedings of the 12th Annual International Digital

Government Research Conference: Digital Government Innovation in Challenging Times. ACM, pp. 282–291.

Neirotti, P., De Marco, A., Cagliano, A.C., Mangano, G., Scorrano, F., 2014. Current trends in Smart City initiatives: Some stylised facts. Cities 38, 25–36. doi:10.1016/j.cities.2013.12.010

Nichols, A.L., 1994. Markets for energy efficiencyDemand-side management Overcoming market barriers or obscuring real costs? Energy Policy 22, 840–847. doi:10.1016/0301-4215(94)90143-0

Nielsen, P.S., Ben Amer, S., Halsn\a es, K., 2013. Definition of Smart Energy City and State of the art of 6 Transform cities using Key Performance Indicators: Deliverable 1.2.

Nijkamp, P., Rietveld, P., Voogd, H., 2013. Multicriteria evaluation in physical planning. Elsevier.

Nijkamp, P., Rodenburg, C.A., Wagtendonk, A.J., 2002. Success factors for sustainable urban brownfield development: A comparative case study approach to polluted sites. Ecol. Econ. 40, 235–252. doi:10.1016/S0921-8009(01)00256-7

Nijkamp, P., Volwahsen, A., 1990. New directions in integrated regional energy planning. Energy Policy 18, 764–773. doi:10.1016/0301-4215(90)90029-4

Odendaal, N., 2003. Information and communication technology and local governance: understanding the difference between cities in developed and emerging economies. Comput. Environ. Urban Syst. 27, 585–607. doi:10.1016/S0198-9715(03)00016-4

Onwuegbuzie, A.J., Leech, N.L., Collins, K.M., 2012. Qualitative analysis techniques for the review of the literature. Qual. Rep. 17, 1.

Oppenheim, A.N., 2000. Questionnaire design, interviewing and attitude measurement. Bloomsbury Publishing.

Painuly, J.P., 2001. Barriers to renewable energy penetration; a framework for analysis. Renew. Energy 24, 73–89. doi:10.1016/S0960-1481(00)00186-5

Palamara, F., Piglione, F., Piccinini, N., 2011. Self-Organizing Map and clustering algorithms for the analysis of occupational accident databases. Saf. Sci. 49, 1215–1230.

Papa, R., Gargiulo, C., Galderisi, A., 2013. Towards an urban planners’ perspective on smart city. TeMA J. Land Use Mobil. Environ. 6, 5–17.

Patel, M.J., Khalaf, A., Aizenstein, H.J., 2016. Studying depression using imaging and machine learning methods. NeuroImage Clin. 10, 115–123. doi:10.1016/j.nicl.2015.11.003

Payne, A., Frow, P., 2005. A strategic framework for customer relationship management. J. Mark. 69, 167–176.

Perboli, G., De Marco, A., Perfetti, F., Marone, M., 2014. A New Taxonomy of Smart City Projects. Transp. Res. Procedia 3, 470–478.

Pezzutto, S., Vaccaro, R., Zambelli, P., Mosannenzadeh, F., Bisello, A., Vettorato, D., 2015.

FP7 SINFONIA project, Deliverable 2.1 SWOT analysis report of the refined concept/baseline (SINFONIA deliverables). European Academy of Bolzano, Bolzano.

Pîrlogea, C., 2011. Barriers to Investment in Energy from Renewable Sources. Econ. Ser. Manag. 14, 132–140.

Piscitello, E.S., Bogach, V.S., 1997. Financial incentives for renewable energy development. World Bank Discuss. Pap. 17–21.

Pol, O., Palensky, P., Kuh, C., Leutgöb, K., Page, J., Zucker, G., 2012. Integration of centralized energy monitoring specifications into the planning process of a new urban development area: a step towards smart cities. E Elektrotechnik Informationstechnik 129, 258–264.

Ponnambalam, K., Saad, Y., Mahootchi, M., Heemink, A., 2010. Comparison of methods for battery capacity design in renewable energy systems for constant demand and uncertain supply. Presented at the Energy Market (EEM), 2010 7th International Conference on the European, IEEE, pp. 1–5.

Price, J., Silbernagel, J., Miller, N., Swaty, R., White, M., Nixon, K., 2012. Eliciting expert knowledge to inform landscape modeling of conservation scenarios. Ecol. Model. 229, 76–87.

Quinlan, J.R., 1986. Induction of decision trees. Mach. Learn. 1, 81–106.

Rasoolimanesh, S.M., Jaafar, M., Badarulzaman, N., 2014. Examining the contributing factors for the successful implementation of city development strategy in Qazvin City, Iran. Cities 41, Part A, 10–19. doi:10.1016/j.cities.2014.05.002

Rasouli, S., Timmermans, H.J., 2014. Using ensembles of decision trees to predict transport mode choice decisions: Effects on predictive success and uncertainty estimates. EJTIR 14, 412–424.

R-Development-Core-Team, 2010. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Reddy, B.S., 2013. Barriers and drivers to energy efficiency–A new taxonomical approach. Energy Convers. Manag. 74, 403–416.

Reddy, S., Painuly, J.P., 2004. Diffusion of renewable energy technologies—barriers and stakeholders’ perspectives. Renew. Energy 29, 1431–1447.

Remm, K., 2004. Case-based predictions for species and habitat mapping. Ecol. Model. 177, 259–281. doi:10.1016/j.ecolmodel.2004.03.004

Ren, J., Tan, S., Goodsite, M.E., Sovacool, B.K., Dong, L., 2015. Sustainability, shale gas, and energy transition in China: Assessing barriers and prioritizing strategic measures. Energy 84, 551–562. doi:10.1016/j.energy.2015.03.020

Richards, G., Palmer, R., 2010. Chapter 11 - Critical Reflections: Keys to Success, in: Palmer, G.R. (Ed.), Eventful Cities. Butterworth-Heinemann, Oxford, pp. 413–434.

Rich, E., Knight, K., 1991. Artificial intelligence. McGraw-Hill New.

Rietbergen, M.G., Blok, K., 2010. Setting SMART targets for industrial energy use and industrial energy efficiency. Energy Policy 38, 4339–4354. doi:10.1016/j.enpol.2010.03.062

Rios, P., 2012. Creating“ The Smart City.”

Rohdin, P., Thollander, P., 2006. Barriers to and driving forces for energy efficiency in the non-energy intensive manufacturing industry in Sweden. Energy 31, 1836–1844.

Roy, P., 2015. Collaborative planning – A neoliberal strategy? A study of the Atlanta BeltLine. Cities 43, 59–68. doi:10.1016/j.cities.2014.11.010

Rupf, G.V., Bahri, P.A., de Boer, K., McHenry, M.P., 2015. Barriers and opportunities of biogas dissemination in Sub-Saharan Africa and lessons learned from Rwanda, Tanzania, China, India, and Nepal. Renew. Sustain. Energy Rev. 52, 468–476. doi:10.1016/j.rser.2015.07.107

Ryan, L., Campbell, N., 2012. Spreading the net: the multiple benefits of energy efficiency improvements.

Sandelowski, M., 2000. Focus on research methods combining qualitative and quantitative sampling, data collection, and analysis techniques. Res. Nurs. Health 23, 246–255.

Sauter, R., Volkery, A., 2013. Review of costs and benefits of energy savings, A report by the Institute for European Environmental Policy (IEEP) for the Coalition of Energy Savings (No. Task 1 Report). Brussels.

Seitz, K., McKenna, R., Fichtner, W., Fath, K., Stengel, J., Schultmann, F., 2013. Information needs for community-level energy investments: some insights from a CONCERTO questionnaire.

Shadbolt, N., Smart, P.R., 2015. Knowledge elicitation: Methods, tools and techniques.

Shepperd, M., Schofield, C., 1997. Estimating software project effort using analogies. Softw. Eng. IEEE Trans. On 23, 736–743.

Shmelev, S.E., Shmeleva, I.A., 2009. Sustainable cities: problems of integrated interdisciplinary research. Int. J. Sustain. Dev. 12, 4–23.

SINFONIA, 2015. Project [WWW Document]. SINFONIA-Smartcities. URL http://www.sinfonia-smartcities.eu/en/project (accessed 9.9.15).

Sizhen, P., Yan, L., Han, S., Ping, Z., 2005. Studies on Barriers for Promotion of Clean Technology in SMEs of China. Chin. J. Popul. Resour. Environ. 3, 9–17. doi:10.1080/10042857.2005.10677398

Söderström, O., Paasche, T., Klauser, F., 2014. Smart cities as corporate storytelling. City 18, 307–320.

Song, C., 2006. Global challenges and strategies for control, conversion and utilization of CO 2 for sustainable development involving energy, catalysis, adsorption and chemical processing. Catal. Today 115, 2–32.

Sorrell, S., Mallett, A., Nye, S., 2011. Barriers to industrial energy efficiency: A literature review (DEVELOPMENT POLICY, STATISTICS AND RESEARCH BRANCH WORKING PAPER 10/2011). UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION, Vienna.

Sorrell, S., Schleich, J., Scott, S., O'malley, E., Trace, F., Boede, E., Ostertag, K., Radgen, P., 2000. Reducing barriers to energy efficiency in public and private organizations. Retrieved Oct. 8, 2007.

Tanner, L., Schreiber, M., Low, J.G., Ong, A., Tolfvenstam, T., Lai, Y.L., Ng, L.C., Leo, Y.S., Puong, L.T., Vasudevan, S.G., 2008. Decision tree algorithms predict the diagnosis and outcome of dengue fever in the early phase of illness. PLoS Negl Trop Dis 2, e196.

Ţăpurică, O.-C., Tache, F., 2014. An empirical analysis of the projects aiming sustainable energy development (SED) in Romania. Renew. Sustain. Energy Rev. 37, 13–20.

Taylor, L., Richter, C., 2015. Big Data and Urban Governance, in: Gupta, J., Pfeffer, K., Verrest, H., Ros-Tonen, M. (Eds.), Geographies of Urban Governance. Springer International Publishing, pp. 175–191.

Thai, K.V., 2008. International handbook of public procurement. CRC Press.

Thai, K.V., Araujo, A., Carter, R.Y., Callender, G., Drabkin, D., Grimm, R., Jensen, K., Lloyd, R.E., McCue, C., Telgen, J., 2005. Challenges in Public Procurement: an international perspective. PrAcademics Press Boca Raton, FL.

Therneau, T., Atkinson, B., Ripley, B., Ripley, M.B., 2015. Package "rpart."

Thollander, P., Palm, J., Rohdin, P., 2010. Categorizing Barriers to Energy Efficiency-an Interdisciplinary Perspective. INTECH Open Access Publisher.

Tjandradewi, B.I., Marcotullio, P.J., 2009. City-to-city networks: Asian perspectives on key elements and areas for success. Habitat Int., City-to-City Co-operation 33, 165–172. doi:10.1016/j.habitatint.2008.10.021

Torija, A.J., Ruiz, D.P., 2016. Automated classification of urban locations for environmental noise impact assessment on the basis of road-traffic content. Expert Syst. Appl. 53, 1–13. doi:10.1016/j.eswa.2016.01.011

Tregua, M., D'Auria, A., Bifulco, F., 2015. Comparing Research Streams on Smart City and Sustainable City. China-USA Bus. Rev. 14, 203–215. doi:10.17265/1537-1514/2015.04.004

Trianni, A., Cagno, E., 2012. Dealing with barriers to energy efficiency and SMEs: Some empirical evidences. Energy, 7th Biennial International Workshop "Advances in Energy Studies" 37, 494–504. doi:10.1016/j.energy.2011.11.005

UN, 2015. ADOPTION OF THE PARIS AGREEMENT, Proposal by the President, Draft decision -/CP.21.

UN, 2014. World Urbanization Prospects [highlights]. ISBN 978-92-1-151517-6

UNDP, 2010. World Energy Assessment, energy and the challenge of sustainability.

UNDP, 2000. World Energy Assessment: Energy and the challenge of sustainability. United

Nations Development Programme, NY.

UN habitat, 2016. Energy [WWW Document]. UN Habitat. URL http://unhabitat.org/urban-themes/energy/ (accessed 2.6.16).

US EPA, 2014. About Smart Growth [WWW Document]. U. S. Environ. Prot. Agency. URL http://www.epa.gov/smartgrowth/about-smart-growth (accessed 3.3.16).

US EPA, 2011. Assessing the Multiple Benefits of Clean Energy. A resource for States.

Vanolo, A., 2014. Smartmentality: The Smart City as Disciplinary Strategy. Urban Stud. 51, 883–898. doi:10.1177/0042098013494427

Veerbeek, W., Pathirana, A., Ashley, R., Zevenbergen, C., 2015. Enhancing the calibration of an urban growth model using a memetic algorithm. Comput. Environ. Urban Syst. 50, 53–65. doi:10.1016/j.compenvurbsys.2014.11.003

Vergragt, P.J., 2009. CCS: the next technological lock-in? a case study from the Netherlands. Presented at the paper to ISA conference, New York, pp. 15–18.

Vettorato, D., 2011. Sustainable energy performances of urban morphologies.

Viitanen, J., Kingston, R., 2014. Smart cities and green growth: outsourcing democratic and environmental resilience to the global technology sector. Environ. Plan. A 46, 803 – 819. doi:10.1068/a46242

Wang, G., Wang, Y., Zhao, T., 2008. Analysis of interactions among the barriers to energy saving in China. Energy Policy 36, 1879–1889. doi:10.1016/j.enpol.2008.02.006

Ward, S., Mohammed, L., 2009. Sustainable Urban Energy Planning–A Handbook for Cities and Towns in Developing Countries. ICLEI E Local Gov. Sustain. UN-Habitat UNEP Nairobi.

Washburn, D., Sindhu, U., Balaouras, S., Dines, R., Hayes, N., Nelson, L., 2009. Helping CIOs understand “smart city” initiatives. Growth 17.

Weber, L., 1997. Some reflections on barriers to the efficient use of energy.

Winters, J.V., 2011. WHY ARE SMART CITIES GROWING? WHO MOVES AND WHO STAYS*. J. Reg. Sci. 51, 253–270.

Wondolleck, J.M., Yaffee, S.L., 2000. Making collaboration work: Lessons from innovation in natural resource managment. Island Press.

Woolery, L.K., Grzymala-Busse, J., 1994. Machine learning for an expert system to predict preterm birth risk. J. Am. Med. Inform. Assoc. 1, 439.

World Energy Council, 2010. Energy and Urban Innovation.

Wright, D.G., Dey, P.K., Brammer, J., 2014. A barrier and techno-economic analysis of small-scale bCHP (biomass combined heat and power) schemes in the UK. Energy 71, 332–345.

Wu, L.-C., Lee, J.-X., Huang, H.-D., Liu, B.-J., Horng, J.-T., 2009. An expert system to predict protein thermostability using decision tree. Expert Syst. Appl. 36, 9007–9014. doi:10.1016/j.eswa.2008.12.020

Xia, D., Chen, B., 2011. A comprehensive decision-making model for risk management of supply chain. Expert Syst. Appl. 38, 4957–4966. doi:10.1016/j.eswa.2010.09.156

Xing, Y., Horner, R.M.W., El-Haram, M.A., Bebbington, J., 2009. A framework model for assessing sustainability impacts of urban development. Presented at the Accounting Forum, Elsevier, pp. 209–224.

Yeh, A.G.O., Shi, X., 1999. Applying Case-Based Reasoning to Urban Planning: A New Planning-Support System Tool. Environ. Plan. B Plan. Des. 26, 101–115. doi:10.1068/b260101

Yeh, A.G.O., Shi, X., 2001. Case-based reasoning (CBR) in development control. Int. J. Appl. Earth Obs. Geoinformation 3, 238–251.

Yovanof, G.S., Hazapis, G.N., 2009. An Architectural Framework and Enabling Wireless Technologies for Digital Cities & Intelligent Urban Environments. Wirel. Pers. Commun. 49, 445–463. doi:10.1007/s11277-009-9693-4

Zhang, X., Chan, S.H., Ho, H.K., Tan, S.-C., Li, M., Li, G., Li, J., Feng, Z., 2015. Towards a smart energy network: The roles of fuel/electrolysis cells and technological perspectives. Int. J. Hydrog. Energy 40, 6866–6919. doi:10.1016/j.ijhydene.2015.03.133

Appendices

The Appendix 1 contains a definition of SEC project and a brief description of CONCERTO projects.

The Appendix 2 includes the questionnaire that was sent to the municipalities of CONCERTO cities and communities. The responces were used in Chapter 6.

Appendix 1

The past experiences: CONCERTO projects

Based on the definition of smart energy city development (provided in Chapter 3), I define smart energy city 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. As the subject of the empirical investigation for this thesis, I distinguished a set of the past SEC experiences that fit the here presented definition of the SEC project. A brief description of these experiences are presented as follows.

I selected a set of projects, involved in a European Union initiative, named CONCERTO. CONCERTO is co-funded with more than 175 Million Euros under the sixth and seventh European Research Framework Programmes (FP6 and FP7) in 58 cities and communities in 23 European countries (CONCERTO, 2015a). It aims to push towards the EU energy targets for 2020 –i.e. 20 % improvement in energy efficiency, 20 % share of renewable energy, 20 % reduction of greenhouse gas emissions (Lützkendorf et al., 2013). The specific aim of CONCERTO is to demonstrate that energy-optimization is more effective at the district and urban scale –as a whole– compared to the single building scale, if collaboration of all relevant stakeholders and integration of different energy solutions are considered (CONCERTO, 2015a). The first generation of CONCERTO projects started in 2005 under EU FP6 (Di Nucci et al., 2010), and the last project was accomplished in 2015 under EU FP7 (EC, 2015a).

The CONCERTO projects are appropriate for the purpose of the here presented thesis because (i) they fit the definition of SEC project mentioned above, providing the legacy for future SEC developments; (ii) the CONCERTO cities and communities are diverse in size and socio-economic, environmental, and political aspects, providing a rich source of information; (iii) CONCERTO projects are all completed and the information for the barriers to implementation of each case is available through several publications of the initiative (CONCERTO, 2015a), specifically in a questionnaire named “CONCERTO policy questionnaire” (accessible through CONCERTO, 2015b). This questionnaire was filled in during the years 2012 and 2013, and gathered, among others, barriers to the implementation of the projects under five categories: legal barriers, administrative barriers, technical barriers, economic barriers, and social barriers. In the here presented thesis, I investigated 43 CONCERTO cities and communities that precisely indicated the barriers to the implementation of their projects in the “CONCERTO policy questionnaire” (Appendix Table 1). In the following, a brief description of the 43 CONCERTO cases is presented.

Appendix Table 1 CONCERTO cities and communities, investigated in the here presented thesis

Project	*City/community*	*Region (NUTS 2*)*	*Country*
ACT2	Hannover	Niedersachsen	Germany
	Nantes	Pays de la Loire	France
CRRESCENDO	Almere	Flevoland	Netherland
	Milton Keynes	Berkshire, Buckinghamshire and Oxfordshire	UK
	Ajaccio	Corse	France
ECOSTILER	Amsterdam	Noord-Holland	Netherland
	Lambeth	Inner London (NUTS 2010)	UK
	Mabjerg	Midtjylland	Denmark
GREEN SOLAR	Salzburg	Salzburg	Austria
CITIES	Valby	Hovedstaden	Denmark
POLYCITY	Ostfildern	Stuttgart	Germany
	Cerdanyola del Vallès	Cataluña	Spain
	Turin	Piemonte	Italy
SEMS	Tulln, AT	Niederösterreich	Austria
	Weilerbach	Rheinland-Pfalz	Germany
	Słubice	Lubuskie	Poland
SOLUTION	Cernier	Espace Mittelland	Switzerland
	Hartberg	Steiermark	Austria
	Lapua	Länsi-Suomi	Finland
TETRAENER	Geneva	Région lémanique	Switzerland
ECO-CITY	Helsingborg	Sydsverige	Sweden
	Tudela	Comunidad Foral de Navarra	Spain
	Trondheim	Trøndelag	Norway
ENERGY IN MINDS!	Weiz / Gleisdorf, AT	Steiermark	Austria
	Zlín	Strední Morava	Czech republic
	Neckarsulm	Stuttgart	Germany
	Falkenberg	Västsverige	Sweden
HOLISTIC	Mödling	Niederösterreich	Austria
SORCER	Hillerød	Hovedstaden	Denmark
ECO-LIFE	Birštonas	Lietuva	Lithuania
	Kortrijk	Prov. West-Vlaanderen	Belgium
	Høje-Taastrup	Hovedstaden	Denmark
GEOCOM	Mórahalom	Dél-Alföld	Hungary
	Galanta	Západné Slovensko	Slovakia
	Montieri	Toscana	Italy
PIME'S	Sandnes	Agder og Rogaland	Norway
	Szentendre	Közép-Magyarország	Hungary
RENAISSANCE	Lyon	Rhône-Alpes	France
	Zaragoza	Aragón	Spain
SESAC	Växjö	Småland med öarna	Sweden
	Delft	Zuid-Holland	Netherland
	Grenoble	Rhône-Alpes	France
STACCATO	Óbuda	Közép-Magyarország	Hungary

* basic regions of a hierarchical system for dividing up the EU economic territories (see EC, 2015b); for complete list of CONCERTO projects and their websites see CONCERTO (2015c)

The selected cities and communities offer concrete innovative strategies and actions to enhance sustainability of urban districts through increasing energy conservation, energy efficiency, and the use of renewable energy sources and innovative technologies (Lützkendorf et al., 2013). These projects integrate localized innovative energy efficiency interventions and local renewable energy sources in mixed renewal and refurbishment districts. A number of these activities, especially those in refurbishment districts, include socio economic research activities, specifically targeted to involve the relevant stakeholders or residents and increase the level of acceptance of the implemented measures.

All of the investigated CONCERTO projects are between three to seven years; they mostly involve three to five types of stakeholders in the project planning and implementation. Most commonly city administration, universities and research and development institutes, housing companies, energy service companies, and social communities are project partners. CONCERTO Projects integrate several smart energy solutions and technologies in buildings and districts, including district heating and/or cooling systems, smart grids, photovoltaics, combined heat and power, and energy management systems (CONCERTO, 2015c). The Appendix Figure 1 shows the distribution of CONCERTO cities and communities.

Appendix Figure 1 Location of the CONCERTO cities and communities, involved in this thesis

Appendix 2

Survey for CONCERTO municipalities

Survey for CONCERTO municipalities

Welcome to our survey

Subject of survey is to gather data on cities involved in CONCERTO initiative to understand how city characteristics have influenced the implementation of CONCERTO projects. The results of this survey will be applied in the PhD research "Smart Energy City: overcoming barriers to the implementation of urban policies and plans".

CONCERTO is a European Commission initiative within the European Research Framework Programme (FP6 and FP7) aiming for energy-optimization of districts and communities.

Contact information (Optional)	
Responsibility	
Email Address (Optional)	

Questions

Please fill in the questions related to your city/town and municipality.

1. 1. Based on your knowledge, was there any long-term (5-10 years) energy plan or policy that concerns your city/town in recent 10 years (2005-2015)?

○ Yes
○ No

1.2. If yes, please name key plans and policies in different levels of planning:

• At municipality level	
• At regional/provincial level	
• At national level	

2. If your municipality has participated in implemention of <u>energy projects</u> (e.g. renewable energy, refurbishment for energy efficiency, energy demand management) in last 10 years:

2.1. Please indicate the type of these projects:

☐ Building/district retrofitting
☐ New building/district construction
☐ Mobility and transportation
☐ Energy networks and infrastructure (smart grid, district heating and cooling, gas networks)
☐ Collaborative planning (e.g. digital platforms to gather information from stakeholders)
☐ Energy data management (e.g. smart points)
☐ Consumer behavior management
☐ Other (please specify)

2.2. Please indicate the technologies used in these projects:

- ☐ District Heating or Cooling
- ☐ Hydro Power Station
- ☐ Optimized Lighting
- ☐ Thermal Collectors
- ☐ Mechanical Ventilation and Heat Recovery
- ☐ Active Thermal Mass Strategies
- ☐ Biomass Boiler
- ☐ Geothermal Plant
- ☐ Photovoltaics
- ☐ Wind Turbine
- ☐ Information Technologies (IT)
- ☐ Natural Ventilation or Passive Cooling
- ☐ Heat Pump
- ☐ Large Scale Storage
- ☐ New Mobility
- ☐ Sorption Cooling
- ☐ Co-/Poly-Generation (CHP)

Other
……………………….

3. Did your municipality have an energy office between 2005 and 2015?

○ Yes (please refer to question 4 and skip question 5)
○ No (please skip question 4 and refer to question 5)

4. Based on your knowledge, approximately, how much was the budget allocated to energy office in your city/town in past 10 years (2005-2015)?

5. Based on your knowledge, approximately, how much was the budget generally allocated to energy service (e.g. renewable energy, refurbishment for energy efficiency, energy demand management) in your city/town in past 10 years (2005-2015)?

6. Based on your knowledge, approximately, which share of your municipality budget (in percentage) was allocated to energy sector/services (renewable energy, refurbishment for energy efficiency, energy demand management), in past 10 years (2005-2015)?

7. Did your municipality have some level of budgetary autonomy between 2005 and 2015? (Budgetary autonomy means degree of independence enjoyed by a public entity in the management of its finances)

○ Yes
○ No

Appendix References

CONCERTO, 2015a. The CONCERTO initiative [WWW Document]. CONCERTO. URL http://concerto.eu/concerto/about-concerto.html (accessed 9.5.15).

CONCERTO, 2015b. CONCERTO Premium Data Collection Sheets Guide [WWW Document]. URL http://smartcities-infosystem.eu/concerto/concerto-archive/concerto-library/concerto-guidelines (accessed 6.10.15).

CONCERTO, 2015c. CONCERTO Projects [WWW Document]. CONCERTO. URL http://concerto.eu/concerto/concerto-sites-a-projects/sites-con-projects/sites-con-projects-search-by-name.html (accessed 9.5.15).

Di Nucci, M.R., Ute Gigler, Olivier Pol, Christina Spitzbart, 2010. CONCERTO-PLANNING AND IMPLEMENTATION PROCESS ASSESSMENT REPORT.

EC, 2015a. ECO-LIFE [WWW Document]. CORDIS. URL http://cordis.europa.eu/project/rcn/94492_en.html (accessed 9.5.15).

EC, 2015b. NUTS - NOMENCLATURE OF TERRITORIAL UNITS FOR STATISTICS [WWW Document]. eurostat. URL http://ec.europa.eu/eurostat/web/nuts/overview (accessed 12.11.15).

Lützkendorf, T., Platt, E., Kleber, M., McKenna, R., Merkel, E., Seitz, K., Stengel, J., 2013. Energy Solutions for Smart Cities and Communities- Evaluation of (Smart) Solutions – Guidebook for Assessment Part II – Final Assessment Report, CONCERTO Premium. Karlsruhe Institute of Technology, Karlsruhe, Germany.