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ENERGY TRANSITION IN ALPINE LOCAL COMMUNITIES.
Public response to changes towards low carbon energy systems

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Contents

Abstract

This research defines the public response to changes towards low carbon energy systems. The findings **support regional and local energy planners** in order to **accelerate the energy transition in the Alpine local communities**, compatibly with their resources and specificities.

Energy transition is a long-term change process of the energy system towards low carbon features (i.e., more energy production from renewable sources, higher energy efficiency). From a technological point of view, energy system is an integrated system including several energy sources, technologies, and products for energy production, distribution, and consumption. From a social point of view, local population's choices and actions determine the time and the features of energy transition at regional and local scales. Indeed, energy system is not only technology matter. **Socio-energy and territorial approaches** underline the importance of **features and relationships between energy, society, and space.**

Based on the interactions between energy, society, and space, this research delineates **an analytical framework and an applied definition of socio-energy system at local and translocal scale.** Through a systematic literature review of 168 scientific publications, this research defines the list of dimensions and key aspects that shape an energy system at regional and local scales by means of local population's choices. This research uses these dimensions to analyse the socio-energy systems and their variation within a regional territory. The transformation of these dimensions into variables is the basis for the cluster analysis applied to the South Tyrol case study (Italy). This analysis defines eight different socio-energy systems within this regional territory.

Each socio-energy system has its own specificities and resources to take into consideration in the energy planning for accelerating the energy transition. With the aim to propose recommendations on how to use social and territorial specificities as levers for wider achievement of energy targets at local scale, this research proposes a Decision Support Tool addressed to regional and local energy planners. The Decision Support Tool also reports potential collaborations between municipalities with similar specificities and needs in order to save, protect, and share resources for a more effective energy planning.

The collaborations proposed by the Decision Support Tool only partially coincide with the actual collaborations in the energy governance of South Tyrol. Through a Bayesian exponential random graph model, this research identifies the network structures and dynamics that are at the basis of the actual energy governance. Further, the analysis identifies some network configurations that might change the actual network towards an energy governance that consider the local and translocal specificities.

Concluding, the methodologies used in this research are replicable to other case studies with small adjustments.

Key words

Energy transition; social science; territory; socio-energy system; governance; renewable energy; local authorities; network analysis; Bayesian statistic

Introduction

Climate change shows its impacts in everyday life: alteration in precipitations, warmer temperatures, increased drought events, rise in sea level, and melting glaciers (Solomon et al., 2009; Pachauri et al., 2014). Climate change is caused by anthropogenic emissions of green houses into the atmosphere i.e., CO_2 (Pachauri et al., 2014). Mitigation initiatives contribute to slow down climate change, while adaptation actions support in dealing with its already existing impacts. These actions require a **strategy of transition to sustainable world** (Sachs, 2015; Keeble, 1988), starting from larger energy production and consumption from renewable energy sources (Jänicke, 2017). Greenhouse gas emissions can be decreased by reducing the use of fossil fuels and achieving 100% renewable energy economies (Droege, 2012).

"A global renewable energy base is the very foundation of sustainable life on this planet" (Droege, 2012, p. 1). But this is not enough. Renewable energy is part of a wider transition towards a sustainable world: *"Only with it [wider renewable energy component], massive afforestation efforts and lifestyle changes to higher quality and dramatically lowered material consumption become the essential elements of hope"* (Droege, 2012, p. 1).

Sustainability addresses persistent environmental and social problems and needs (Geels, 2011). Environmental organizations (i.e., UNEP, National Geographic) reckon that there are two choices: either the choices pursue sustainable world (Sachs, 2015; Keeble, 1988); or the choices return to fossil fuel based economy forgetting sustainability and zero or de-growth development. In the second scenario, pressures on natural and social world will increase (Vandenhole, 2018). Sustainability can be reached through a global system that integrates all scales, sectors, and actors with their own responsibilities, challenges, opportunities and mechanisms (Jänicke, 2017).

The energy transition is pursued by **international and national commitments** in public debate. Countries agreed on a new 2030 framework for climate and energy to achieve a more competitive, secure and sustainable energy system (*The Climate and Energy Framework by Bonn UN Climate Change Conference 2017*) aiming to overcome the Paris Agreement (*COP21*) and the European Renewable energy Directive targets (European Commission, 2010). This research does not focus on competitiveness and security, but on how sustainability can be strongly promoted, *"to leave behind programmes that only superficially 'green' development strategies"* (Droege, 2012, p. 6).

Further strategies supporting the achievement of the 2030 framework targets are needed: at least 40% green house gas emissions decrease, 27% energy consumption decrease, and 27% energy efficiency increase. Around the world, the US government[1] plays an important role in slowing the energy transition and shifting the interest to fossil fuels. EUROSTAT[2] observes that eleven countries in Europe have already achieved and 18 countries are almost achieving the Renewable energy Directive targets for 2020, even if with a slowdown of transition process for the most renewable European countries and a new interest on fossil fuels (Turnheim et al., 2018). From 1990 to 2004, some European countries substantially increased their share of renewable energy, slowing down the rhythms of energy transition in the following period between 2005 - 2016 (Figure 1). Other countries - i.e., Italy - accelerated the transition achieving the 2020 targets in the second period, but generally a brake in the transition of the most renewable countries is observed.

[1] US government withdrawn its signature to Paris agreement.

[2] EUROSTAT is the statistical office of the European Union situated in Luxembourg. It provides high quality statistics for Europe enabling the wide picture of contemporary society and comparisons between countries and regions. For more information: EUROSTAT.

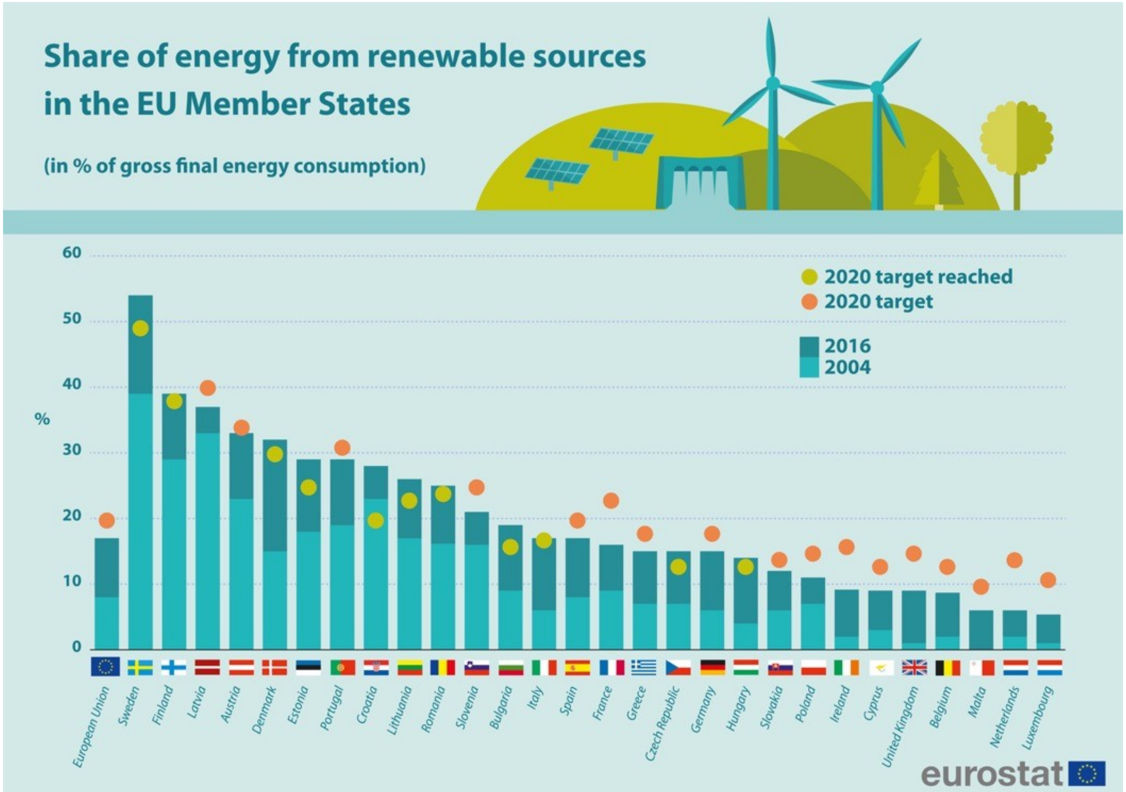


Figure 1: Share of energy from renewable sources in the EU Member States. Source: EUROSTAT.

How much is energy transition slowing down (Turnheim et al., 2018; Osti, 2018)? How social science can contribute to its acceleration (Turnheim et al., 2018; Osti, 2018)?

The goal of this work is to promote a more balanced, inclusive, and equal energy transition, involving all the local territories with their place-based contributions towards low carbon energy systems. Shifting from centralized to decentralized socio-energy system allows to have a wider knowledge and use of the local specificities. At the local scale, there is the potential for a further and accelerated energy transition through local energy planning and management, behind the efforts already made by national and regional scales (individually and in network). A tool supporting regional and local policy-makers and planners is then developed with the aim of effectively contributing to energy transition.

In order to better understand energy transition, the definition of energy system (Section 0.1), the importance of local population's choices (Section 0.2), the role of the public authorities (Section 0.3), the importance of the translocal scale (Section 0.4) and the relevance of the existing governance (Section 0.5) are deepened in the following sections. Finally, the methodology developed in this work is shown in Section 0.6. The contribution of each Chapter of this thesis is clarified in Section 0.7.

0.1 Energy system

Energy transition is a long-term change process of the energy system towards low carbon characteristics (Sovacool, 2016): wider energy production from renewable sources, lower CO_2 emissions, lower energy consumption, and wider energy efficiency. From a technological point of view, energy system is an integrated system including several energy sources, technologies, and products for energy production, distribution and consumption (Mathiesen et al., 2015; Lund and Mathiesen, 2009). An energy system can import and export energy and resources to other energy systems (Bringezu et al., 2012) and can be described through its features of renewability, efficiency, and saving. Energy transition aims to increase all the three features.

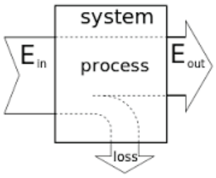
The three features of the energy system are given by different set of factors and follow different dynamics. Renewability concerns resources that can be reused after the energy production. I.e. water can be used for additional energy production or flowed into rivers; or forest biomass availability can be renovated through new plantation. The renewability can be measured through the percentage of renewable energy (RE) (European Commission, 2009):

$$RES_{\%} = (Prod_{REs}/Tot_{Cons}) * 100$$

where:

$REs_{\%}$ is the percentage of renewable thermal and electric energy out of total consumption, $Prod_{REs}$ the total production of renewable energy of the energy system, Tot_{Cons} the total consumption of the energy system.

The second characteristic of an energy system is the efficiency. Energy efficiency is the rate of final energy on initial energy during the considered production, distribution, and consumption processes (UNI CEI EN ISO 50001:2011). Research is improving technological efficiency to reduce the difference between initial and final energy and the losses. A good quality of life can be maintained with lower amount of energy consumption and consumer behaviours can contribute to decrease this difference.



Finally, the third characteristic for describing an energy system is energy saving. It includes consumption decrease beyond the efficient use of energy and it is promoted by a change in people's energy behaviours (DellaValle et al., 2018). Renewability, efficiency, and saving are interrelated one with each other. Efficiency and saving can change the level of consumption that is included in the formula of renewability. Therefore, this research focuses on renewability as a whole.

0.2 Local population's choices

The energy transition path is *"different for each person, community, company, or country"*, (Droege, 2012, p. 2). Characteristics of the energy system are shaped on real and available social, cultural, environmental, and economic resources of the territory (Di Somma et al., 2017). The new interest in **distributed energy systems** (Di Somma et al., 2017) and in **local energy communities** (Dóci and Gotchev, 2016; Van Rijnsoever et al., 2015; Rogers et al., 2012) emphasize these aspects.

Actions of the **local population** determine the level of renewability of local energy systems in the context of energy transition goals (Balest et al., 2018). Local population makes energy choices based on the availability of different territorial resources and limits - i.e. natural, technological, and social ones - and in front of proposals and projects. The energy system is the result of the actions of **individuals, stakeholders, and public actors** in a territory (Sovacool, 2016).

The local population's choices can be either a **reaction** to interventions of other and external actors or an autonomous **action** such as individual or community initiative (Balest et al., 2018) in a territory in which global and over local contexts impose their limits and influences (Geels, 2002). Based on the interaction between all these actors, their actions, their reactions and the energy system, the concept of **socio-energy system** becomes central. **Through this work, the socio-energy system is defined as a system embedded in a territory in which local population makes choices shaping and being shaped by technological energy system. The local population's choices in energy field are embedded in the territory and its territorial systems** (Balest et al., 2018): **natural, legislative, technological, and economic ones**. A community living within a territory is not only touched by the energy transition, but it can be a resource and a key actor in the transition (Batel, 2018; Wolsink, 2018; Miller et al., 2013): *"Rather than seeing communities as a barrier to change [...] several of our contributors note that communities can be valuable partners in renewable energy planning"* (Miller et al., 2013, p. 146).

The research of the I PhD year defines if and which systems, dimensions and aspects of a territory address local population's choices and related socio-energy system changes in terms of increase of RE. The research also defines how the actors, processes, and networks of local population are approached for their analysis in scientific literature through the concepts of *acceptance* and *conflict*. An interesting systematic review is reported in the Chapter 1 and already published in Balest et al. (2018) (Appendix 5). The following parts of the research address more the topics related to energy planners and authorities at local and translocal (Sections 0.3 and 0.4).

0.3 Public and local authorities

The local scale includes the relation between energy and society within a place-based context (Osti, 2010). Public authorities that plan and manage the energy in their territories should be aware of the local population's choices and the related territorial dimensions and aspects. At the local scale, the actors who govern the energy system (i.e., municipalities, associations, citizens, schools) are able to do it in a horizontal and networked way, creating a governance system (Fontaine, 2010) and mobilizing multiple actors, resources, and dynamics (Jänicke, 2017).

At the local scale, public authorities plan and manage their own energy system, i.e. through Sustainable Energy Action Plans (SEAP) or Sustainable Energy and Climate Action Plans (SECAP) in the framework of the Covenant of Mayors initiative[3]. In the development of these plans, public authorities analyse the *status quo* of their territories from a point of view of CO_2 emission, infrastructural, energy supply, demand and efficiency and propose some actions to foster energy transition (Coelho et al., 2017; Balest et al., 2018). However, the territorial and energy planning can not be based only on these analytical aspects. Pinto-Correia et al. (2016) highlight the need to better inform energy planners on territorial peculiarities, differences, and interested actors for developing effective energy plans. The effectiveness of SEAP and SECAP can be strengthened considering also those territorial dimensions and aspects defined in the first part of this research (Chapter 1).

The mere role of the local authorities in planning and management can be strengthened. Local territories have specific needs, preferences, and resources. Municipalities are the closest public authority to local populations recognizing their needs, preferences, and resources. However, this local entity is not always the most effective one in achieving energy transition goals (Kraxner et al., 2015; Novotná et al., 2016). These local authorities sometimes miss resources in terms of money, time, knowledge, and human capital (Kraxner et al., 2015; Novotná et al., 2016).

This research aims to increase the contribution of all territories for a more balanced, inclusive, equal and further energy transition. For this contribution, it is necessary to understand what is **territory**. A territory is a place where there is the relation between society and space (Osti, 2010). In a territory, society organizes the space based on the available resources in order to satisfy needs (Borrelli and Mela, 2018). Territory is never only a natural space, but it is a composition of human actions on spaces (Jackson, 2000).

Through the territory concept, sociology investigates the role played by space in the production of social phenomena (Borrelli and Mela, 2018), through socio-spatial interpretations or socio-ecological aspects. When the focus is on the people's interpretations

[3]The Covenant of Mayors initiative is a movement for local climate and energy actions that involves European municipalities in a voluntary way. Its aims to accelerate the decarbonisation of the territories, to strengthen the capacity of municipalities to adapt to climate change, and to allow citizens to access secure, sustainable and affordable energy. For more information: Covenant of Mayors.

of lines and shapes, sociologists talk about **landscapes**. The landscape is the imagined world (Livingstone, 2002). Instead, if the focus is on the available resources and on their use, beyond the social and cultural interpretations, the object is the **territory**. Territory is still a social construction based on common cultural and social meanings. The territory is the result of continuous interrelations between society and space for the satisfaction of needs (Raffestin, 2012). The representations of this territory makes available 'images' or landscapes (Raffestin, 2012).

Only through the consideration of both territory and landscape, a balanced, inclusive, and equal energy transition will be generated. Both the concrete organization of the space and the people and planners' interpretations of territory are relevant. However, this research focuses on the concept of territory investigating its role in defining local population's energy choices, programming future in-depth analysis about landscape and imageries[4] (Sütterlin and Siegrist, 2017; Stephenson et al., 2010; Calhoun and Sennett, 2007).

0.4 Translocal scale

The empowerment of local actors and authorities can be strengthened by proposing a translocal perspective that supports collaborations between territories. A translocal planning and management of the energy is a strategic tool to save, protect, and share resources (i.e., money, knowledge, environment), increasing the effectiveness of energy plans.

Translocality describes a localized context across borders in which actors develop their own engagement (Greiner and Sakdapolrak, 2013) in planning and management of the territory. Geographical borders are not easily recognizable (Sassen, 2018) and translocality is usually based on spatial closeness (Novotná et al., 2016). The spatial closeness is an interesting resource for saving and sharing some resources (i.e., share a district heating plant in a neighbourhood across municipal borders), but it has risks related to the increase of inequalities and disparities between territories (Osti, 2015; Katsoulakos and Kaliampakos, 2016) that could be reported in the energy transition process. In the definition of translocality of this research, similarities and homogeneities between territories are

[4] **What is next?** My idea for the future is to collect the imageries of regional and local energy planners in order to understand the opportunities and the paths of energy transition.

more important than the spatial closeness (Chapter 2). Collaborations between territories that are similar in terms of resources, needs, and preferences increase balanced and inclusive development according to the territorial cohesion literature (Sánchez-Zamora et al., 2017; European Court of Editors, 2018).

In the translocal definition, local territory is connected with others in two different ways: static or dynamic. The static way is somehow the easiest, even if in this research some aspects are missing (i.e., symbolic and identity aspects). The static translocality is here described through the main dimensions and key aspects of each territory (Table 2.2). The aspects characterizing the dynamic translocality refer to relationships between territories based on mobility and connectivity (Hedberg and Do Carmo, 2012).

The **territorial cohesion** is a concept used in sustainability and development fields of research. This concept is based on environmental, social, economic, geographical, and governance homogeneities and heterogeneities between territories (Medeiros, 2016; Sánchez-Zamora et al., 2017) and it aims to increase sustainable development based on these similarities (European Commission, 2010). This research is looking at a definition of elements of territory as a system that both integrates energy and society in a place-based context and emphasizes **translocal scale**. However, this wide definition is not available in scientific literature yet (Pinto-Correia et al., 2016; Medeiros, 2016; Nosek, 2017; Sánchez-Zamora et al., 2017; Balest et al., 2018). On the one hand, this research defines the elements of territory as socio-energy system on the basis of scientific literature about local population's choices. On the other, this research adds energy aspects to the **territorial cohesion** giving a translocal perspective to the **socio-energy system** (Chapter 2).

One of the main aims of this research is to give the access to the results and the related knowledge to regional and local policy-makers and planners. After emphasizing the methodology, the dimensions, the key aspects, and the data used in this research, the results are showed through maps and tables. This research proposes a **Decision Support Tool** (DST) that integrates socio-demographic, quality of life, socio-economic, cultural, governance and political, geographical and infrastructural, energy and climate dimensions and the linked 41 placed-based variables for the South Tyrol case study (Table 2.2). The map (Figure 2.2) shows the potential collaborations between municipalities for energy planning. The map is matched with the explication of the most relevant territorial and social resources, dimensions, and aspects that can strengthen the collaborations in the energy planning (Table 2.9).

Chapter 2 is the application of the analytical framework of territory as socio-energy system defined in the Chapter 1 at the translocal scale. The application analyses the South Tyrol case study (Italy). The results have been submitted to the Energy Research & Social Science journal through a paper currently under review (Balest et al., 2019). The paper is titled *Territory as socio-energy system at translocal scale: A Decision Support Tool for energy planners*. Co-authors are Laura Secco, Elena Pisani, and Giulia Garegnani.

0.5 Governance of public and local authorities

In a polycentric system where several actors plan and manage the energy systems in the regional and local territories (Ostrom, 2010; Sovacool, 2011), relationships between territories in energy planning and management are already structured. **Aware of this, are the collaborations proposed by the DST realistic? Are they compatible with the actual relational dynamics and with the actual collaborations in energy sector?**

Who and how governs the energy system are relevant topics to promote the change into a more sustainable world (Sachs, 2015). The **governance** is an arena in which multi-actor, multi-sector, and multilevel relationships, power relations, and networking exist (Rametsteiner, 2009; Secco et al., 2014) with the aim to administer a part of the public and social life. The analysis of the governance underlines responsibilities, challenges, opportunities, and mechanisms of different actors and relationships (Jänicke, 2017). In the energy sector, all other sectors, actors, and levels related to energy topics are included in formal and informal networks. Considering the idea to promote the contribution to the energy transition of all local territories through effective collaborations, this research focuses on the **energy governance at translocal scale**.

In the global governance of energy transition, environmental and social problems are addressed (Geels, 2011) thanks to the contribution of the actors at all scales. Governing the energy, actors interact with their territories, technologies, and local populations (Geels and Schot, 2007). With particular reference to local populations, the practice to *governance* of local planners is a continuous interaction between a common understanding by social actors on how to use technologies, how to plan energy, and how to manage territories. Appropriate behaviours and meanings of using, planning, and managing energy, territories, and technologies are recognized and shared (Shove et al., 2012) within a regional territory. The energy governance is the resulting practice of all the involved actors and their relationships: *"those relations can generally be characterized as reflecting societal and organizational structures that reproduce general patterns of behaviour"* (Hedberg and Do Carmo, 2012), such as the governance practice.

The energy governance is sustainable where it is strongly linked to **other practices** such as the **practice of local and careful government of natural resources at the local scale**, and the **practice to collaborate with other actors that share preferences, needs and resources**. The energy governance and the other linked practices are spread through relationships between actors (Shove and Walker, 2010).

In a multi-actor, multi-sector, and multi-level energy governance (Sovacool, 2011; Secco et al., 2014), this research focuses on some scales and actors that have higher potential to effectively plan and manage the energy thanks to their local knowledge (Bulkeley and Kern, 2006; Novotná et al., 2016). Municipalities are the closest public authorities to local territories and their potential to effectively plan and manage the energy is supported by the contribution of actors and tools, such as public utilities (PU). The collaborations between municipalities and PU are not the only existing relationships in the energy sector. However, these collaborations represent an interesting structured network that reports the relational dynamics in the energy sector at regional and local scale (Mejía-Dugand et al., 2017). The relationship between municipality and PU is based on a contract in which the PU supplies an energy service to the municipality (i.e., the management of a RE production plant, or the distribution grid management).

To have a clear picture of **the spread of sustainable energy governance**, this research analyses the energy districts composed by networks of relationships and collaborations between municipalities and PU within the South Tyrol case study. **This research investigates the presence and the opportunities to extend the existing sustainable energy governance through relationships in an energy district**. The social network analysis and the other used analytical tools (Bayesian inference of Exponential

Random Graph Modelling) can not predict the change in the future. However, they can give us reasons on why the spread and the relational dynamics behind sustainable energy governance have the actual shape. This kind of analysis defines some **elements, dynamics, and future addresses of the research that could promote a change towards the collaborations that the DST proposes**.

Summarizing, this research delineates an analytical framework that includes elements of **territory** as **socio-energy system**, focusing on the integration between energy, space, and society at a **translocal scale**. To do this, the following flow of methods is used (Section 0.6 and Figure 2).

0.6 Flow of methods

In the first step of the flow of methods (Figure 2), dimensions and key aspects that explain the local population's choices in front of energy system changes are defined, such as the inclusion of a new RE plant (Balest et al., 2018). Wide literature review search and analysis is reported in the Chapter 1. The focus is on three concepts used in the scientific literature: *acceptance*, *conflict*, and *renewable energy*. The acceptance is analysed in the scientific literature based on three dimensions (Wüstenhagen et al., 2007): socio-political, market, and community. This research is an attempt to look at the acceptance in a wider way, integrating all three dimensions that are usually separately investigated at a translocal scale (Wolsink, 2018; Batel, 2018). The systematic analysis of literature is based on a **territorial analytical framework** and uses a **quantitative and qualitative content analysis** of the entire text of 168 publications, using NVIVO11plus© software. These publications have been selected considering number of citations on a wider group of 1084 scientific papers available in SCOPUS online database. The result of the analysis of these publications is proposed as a list of three dimensions, 15 sub-dimensions and 41 key aspects related to the social system of the territory (Table 1.6). The results also delineate 26 sub-dimensions of the other territorial systems (Table 1.3).

Second, five scientific publications (Abrahams, 2014; Elissalde and Santamaria, 2014; Medeiros, 2016; Dao et al., 2017; Nosek, 2017) and the main European document (European Commission, 2008) about territorial cohesion concept are analysed to identify the main dimensions and factors used in this research field. This list of dimensions and factors is delineate and crossed with the previous list about local population's choices. The final list of eight territorial dimensions, 26 key aspects and 41 factors is the operativization of the analytical framework. This final list of relevant dimensions, factors, and variables analyses the variation of socio-energy systems across territories (Chapter 2 and Table 2.2). This list is not exhaustive because it misses all those information that are not available for all municipalities and, therefore, do not permit the analysis of the variation between municipalities. Other important aspects could be collected through in-depth and future research (i.e., symbolic and identity aspects) in order to give a wider interpretation of the results included in this thesis.

Third, the list of factors is applied to the case study of South Tyrol, collecting data about the 41 factors. This was a quite challenging process for four main reasons: 1) exhaustive databases at municipal scale for South Tyrol province and for all the Italian regions do not exist; 2) single data are available in databases with different formats and shapes; 3) public availability of data is uncertain; and 4) some data are available only for some municipalities and not for all regional territories. All these problems represent the main reason of why this research is not applied to a wider sample of regions in Italy or across the Alpine space[5].

The list of 41 factors is the basis for clustering municipalities and defining potential collaborations for effectively developing actions included in energy plans. This research uses cluster analysis because it divides socio-energy systems according to homogeneities and heterogeneities. In particular, k-means method defines homogeneous groups minimizing the within group dispersion and maximizing the between group dispersion (Novotná et al., 2016). This is an important tool to analyse the variation across territories and the similarities within a common socio-energy system. Each cluster includes municipalities that are homogeneous in terms of 41 dimensions and each cluster has a centroid that is the projection of these 41 dimensions.

The findings are showed through map (Figure 2.2) and table (Table 2.9) permitting the interpretation of the results and the sharing of this knowledge with regional and local energy planners through the DST.

[5] However, during the three years of this PhD, the research has been applied to the Italian regions of Marche and Valle d'Aosta.

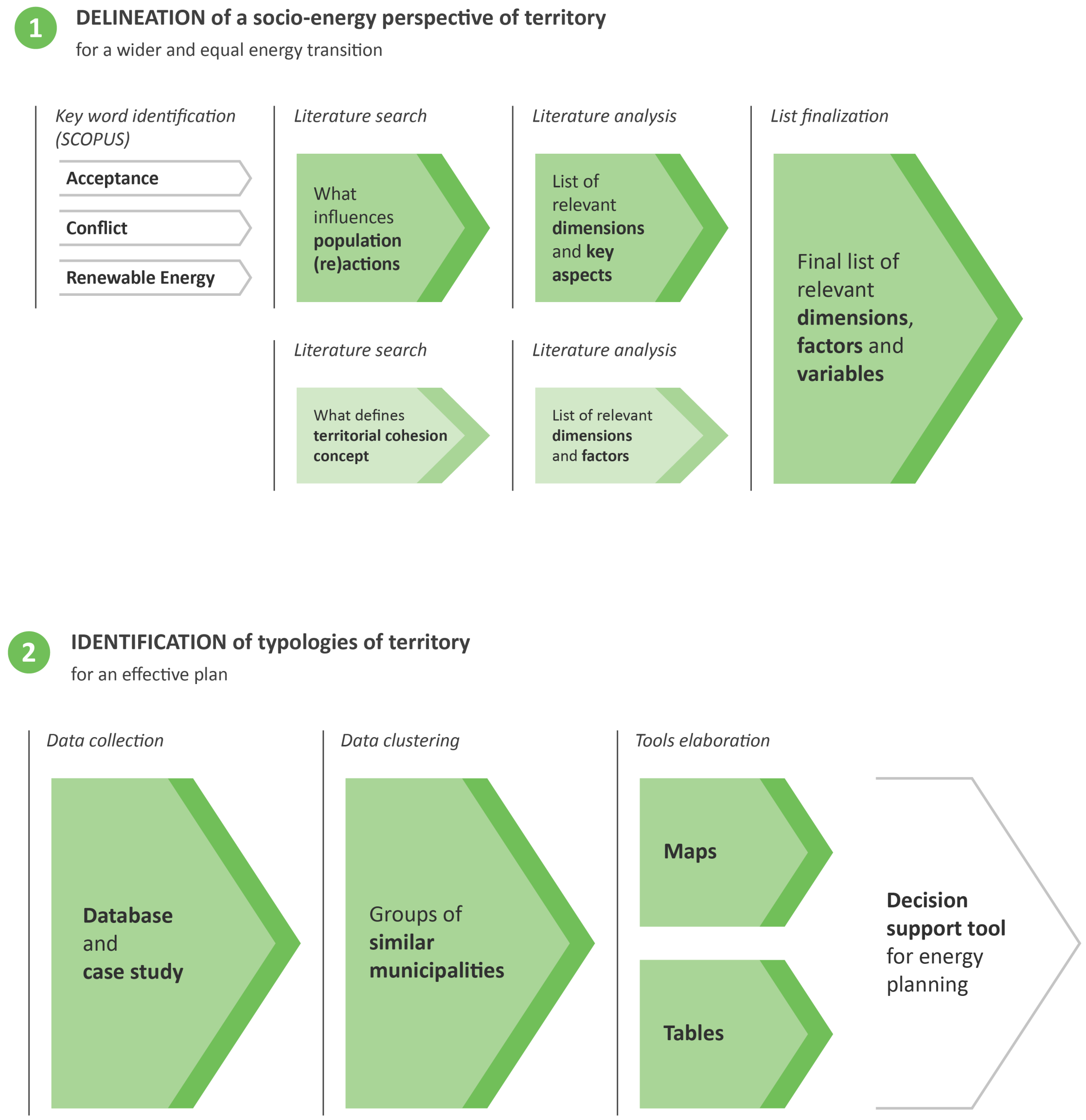


Figure 2: Flow of methods used to define and apply the analytical framework of territory as socio-energy system.

This research defines both the socio-energy systems within the cultural and institutional context of South Tyrol, and the collaborations and resources for developing effective energy plans (Chapters 2 and 4). In order to investigate the realistic opportunity to have or create these collaborations, the relationships between municipalities and PU are analysed through social network analysis. Some hypothesis on the actual relational dynamics are tested through a Bayesian inference for Exponential Random Graph Modelling (BERGM) (Caimo and Friel, 2011). This part is reported in Chapter 3 and a paper has been submitted to the Journal of Cleaner Production with the title *Sustainable energy governance* *practice in South Tyrol (Italy): A probabilistic bipartite network model.* Co-authors are Laura Secco, Elena Pisani, and Alberto Caimo (Balest et al., 2019). The applied methodology will be publicly available in a GITHUB repository after the review of this thesis. The availability of the methodology developed in R language aims to apply it to other case studies and collect feedback from other scientific experts.

0.7 Clarification about how chapters are interrelated

Acceptance is a complex and dynamic process in which the positions of the actors are *"dynamic and continuously being reconsidered and redefined"* (Wolsink, 2018, p. 291). For this reason, this research does not focus only on actors, but also on processes and relationships related to low carbon energy systems. This is the basis for the title of the first chapter: *Local reflections on low-carbon energy systems: A systematic review of actors, processes, and networks of local societies.*

For this dynamic and continuous processes, a new definition of territory that integrates society, space, and energy is needed. This research proposes an analytical framework that investigates the territory as a set of systems, as represented in Figure 1.2: social-cultural, legislative, economic, technological and natural territorial systems. Embedded in these systems and their interactions, several components of the territory exist, such as education system, productive system, or energy system. Considering the socio-energy system as a production of the interaction between society and the other local systems, territory is a core concept for this research. The scheme in the Figure 1.2 is born in an interactive process between the building of the analytical framework of territory (Garegnani et al., 2018) and the analysis of the scientific literature about local population's responses in front of changes in energy systems i.e., new RE plant (Balest et al., 2018). This scheme and the list of dimensions and factors are the links between Chapter 1 and Chapter 2. In Chapter 2, the investigation operativizes the list of dimensions and key aspects of Chapter 1.

Chapter 2 is the application of the analytical framework of territory as socio-energy system in the South Tyrol case study. The analysis based on the 41 factors define eight socio-energy systems in South Tyrol (excluding the ninth group of municipalities characterized by urban specificities). Each socio-energy system has its own resources (Table 2.9) and municipalities within each cluster have potentialities to collaborate one another based on common needs, resources, and actors to involve in the energy planning. The collaborations between municipalities are the link between Chapter 2 and Chapter 3. Chapter 2 investigates the potential collaborations while Chapter 3 analyses the actual collaborations.

This third part of the research investigates if the collaborations proposed by the DST are realistic. Social network analysis and BERGM are applied to the relationships between municipalities and PU. The main results show that translocal collaborations between municipalities exist, even if it is not the prevalent practice. It is more common for municipalities to plan and manage the energy individually. In the case in which translocality exists, it is based on spatial closeness and it is not coherent with my idea of translocal collaborations based on similar territorial and socio-energy system specificities. However, there are some interesting aspects in the actual energy governance that could promote the change towards the proposed collaborations.

Crossing the results of Chapters 1, 2, and 3, this research delineates the recommendations to regional and local energy planners included in Chapter 4. The recommendations are expressed in terms of collaborations and resources to use in order to strengthen the effectiveness of energy plans.

Laura Secco, Elena Pisani, and Giulia Garegnani contributed to this research with their ideas, reviews, and suggestions. Alberto Caimo contributes applying the BERGM in order to answer the research objectives and test the research hypothesis of Chapter 3.

Chapter 1

A systematic review of actors, processes, and networks of local societies and low-carbon energy systems

Published in Balest et al. (2018)

1.1 Abstract

Local population's actions determine the level of renewability of local energy systems in the context of **energy transition goals**. Local population makes energy choices based on the availability of different territorial resources and limits, i.e. natural or environmental, technological, and social ones. The aim of this research is to identify the main dimensions and aspects of territory that can address its change towards energy transition. Indeed, energy system is not only technology matter. Socio-energy and territorial approaches (Jessop et al., 2008; Osti, 2010) underline the importance of features and relationships between the territorial systems: natural, technological, economic, legislative, social, and cultural ones. This research identifies substantial, procedural, and relational dimensions or characteristics of territorial energy systems based on the Conflict Management Triangle

(Solberg and Miina, 1997). 1084 journal papers have been selected based on specific criteria, allowing 168 papers to be analysed using NVIVO11plus©. Following the qualitative and quantitative method applied for the systematized literature review, 15 dimensions and 41 sub-dimensions related to local population's choices about energy transition have been selected. This is a scientific attempt to use a content analysis software (NVIVO11plus©) in this scientific domain.

1.2 Introduction

Climate change effects are apparent in everyday life: alteration in precipitations, higher temperatures, increased drought events, and rise in sea level (Solomon et al., 2009; Pachauri et al., 2014). Climate change is caused by anthropogenic greenhouse gas emissions (e.g. CO2) into the atmosphere (Pachauri et al., 2014). Greenhouse gas emissions can be decreased by reducing the use of fossil fuels towards the long-term process of energy transition (Sovacool, 2016). For example, the European context is based on Directive 2009/28/EC and the Energy Security Strategy (ERS, 2014) which specify three directions to follow: (i) increase of renewable resources rate in energy production, (ii) rise of energy saving and efficiency, and (iii) decrease of CO2 emission. These address energy systems towards energy transition goals in the wider world.

An energy system can be described according to technological and social viewpoints. From the technological viewpoint, an **energy system** is an integrated system including several energy sources, technologies, and products for energy production, distribution and consumption (Lund and Mathiesen, 2009; Mathiesen et al., 2015). An energy system can be described through its characteristics of **renewability** (European Union, 2009), **efficiency** (Union, 2014) and **saving** (European Union, 2009). From the technological viewpoint, energy systems are socio-technological systems that involve not only machines, pipes, mines, refineries, and devices but also the humans who design and make technologies, develop and manage routines, and use and consume energy (Miller et al., 2013, p. 136). As Sovacool (2014) has pointed out the production, distribution and consumption of energy is determined by the interactions between the technical and human components of an energy system. The energy system is the result of the actions of individuals, stakeholders, and public actors in a territory. These actions can be a **reaction** to interventions of other actors or an autonomous **action** such as individual initiative, in a territory in which global and regional contexts impose their limits.

Social and individual reactions to energy interventions, plants, or technologies in a territorial context are often investigated in the scientific literature through the acceptance concept. Upham et al. (2015) consider social acceptance as a "multi-actor phenomenon" or response to energy interventions such as new RE plants. However, acceptance "risks oversimplifying the interactions between societies, communities, collective actors and individuals and energy technologies and further risks perpetuating a normative top-down perspective of these relationships" (Upham et al., 2015, p. 107). This research considers acceptance in wider way. Indeed, other literature does not investigate reactions, but **actions** for low carbon energy systems (Hielscher et al., 2011) such as energy innovations and initiatives.

Selected literature considering reactions and actions of people (from here, the term actions is used for both concepts of actions and reactions) emphasizes the context in which the energy system is inserted and shaped. Sometimes, by observing two or more territories that have a similar availability of natural, technological, economic and legislative resources, different local population actions can be discerned (Ekins, 2004; Zoellner et al., 2008) distinctively shaping the local energy systems. For example, some energy systems focus on the importance for direct links of local resources to the possible actions of the local population. Further, some energy systems consider real social, environmental and economic resources of the territory by looking for an effective use of local resources (Di Somma et al., 2017) and, consequently, they emphasise the energy system concept as both socio-ecological and socio-technological (Hodbod and Adger, 2014). These systems, known as **distributed energy systems**, include small-scale technologies, RE and storage units providing closed energy to end-users (Di Somma et al., 2017) based on a community or other type of ownership and management. The features of this kind of energy system are of specific interest for investigating the possible connections between energy and society within a site-specific context. For this reason, the dimensions and sub-dimensions that influence population's choices linked to local energy systems are investigated in the current literature. However, it is important to mention that theoretical analyses of the linkages between energy and society from a sociological perspective are still in a black box waiting to be opened (Sovacool, 2014). This research aims to define if and which dimensions and aspects of territory address local population choices and related socio-energy system changes towards energy transition, and how the actors, processes, and networks of local population are approached for their analysis in scientific literature. The value of the paper is to improve the research and the theorization on the relationship between energy and local societies, through the consideration of actors, processes, and networks that act for changes towards low carbon and distributed energy systems.

The paper is organized in five sections. After the presentation of the main scope of the research in the Introduction, Section 1.3 presents the theoretical background and analytical framework proposed for the literature analysis. Section 1.4 describes the materials and explains the methods used for the content analysis of the selected literature with the NVIVO11plus© software. Section 1.5 presents the results and discusses the relevant dimensions of energy transition in local territories. Some concluding remarks are then proposed (Section 1.6).

1.3 Conceptual background

From the sociological perspective, an action is a set of deliberated acts made by collective or individual actors. The actors choose between several alternatives for achieving a goal (trade-offs). Moreover the choices are based on and influenced by the context in which actors operate (Weber, 1978). This perspective is also applied in relation to human choices made on energy issues. The **territory** is one of those contexts. Territory is a delimited surface with an active system in which actors act on space and time and in relation to its material environment (Osti, 2010). However, territory usually interacts with actors and resources within wider contexts. Territory is a simply term which implies a great complexity. It involves different scales of interaction and levels of governance. Indeed, a territory can have different geographical extensions, from global to local ones, and they all influence one another.

Within a given territorial extension, five interactive systems make up the territory (Garegnani et al., 2018): natural, technological, economic, legislative and social ones. The natural system describes the natural environment of a specific territory including important resources for producing energy. Plants and technologies constitute the so-called technological system that can give space or not to further technological development or plants diffusion. Producers, distributors, consumers, their roles and interactions make up the economic system (Maruyama et al., 2007). The legislative system is composed of rules, programmes, norms and legislations (Bjelic and Ciric, 2014). The entire system addresses or limits the choices. Lastly, the social-cultural system constitutes the sum of people and institutions, social rules, *habitus*, cognitive values and relationships.

Through the interactions and thanks to the available resources of the five systems, local territories shape their energy systems through local population's choices made in and influenced by territorial context. Territorial context addresses change opportunities through its characteristics and limits and, in this context, local population has the opportunity to make choices about low carbon energy systems. Low carbon energy systems are achieved by improving the production, distribution and consumption of energy based on a sustainable use of local resources and decreasing negative social, environmental and economic impacts by implementing, for example, distributed energy systems.

The actors' knowledge about the five territorial systems can increase the opportunities for low carbon energy systems. Each system in the territory is composed of three types of dimensions (Figure 1.1) that can be summarised using the Conflict Management Triangle (Solberg and Miina, 1997): substantial, procedural and relational. Conflict management triangle is an useful tool to support the literature review identifying different levels of analysis of each territorial system. This research distinguishes between a substantial level of territorial characteristics made by individual and collective dimensions that describe the current features of a system; a procedural level that describes processes driving change; and a relational level that describes interrelationships between components of each system. First, the substantial dimensions include the characteristics that belong to the system in a precise time and space, i.e. socio-demographic characteristics of the population, or the presence of RE plants. Furthermore, the system plays according to some processes, procedures and rules. Indeed, the procedure is a series of actions that are taken in a certain way or order: an established or accepted way of doing something. For example, the energy system is driven by technological innovation that has a certain speed of diffusion, and the social system according to decision-making processes. Finally, actors or components have relationships with one another in the five systems. In this case, the characteristics of relationships (i.e. trust, information sharing, collaboration, integration in networks) between components (actors, plants, etc.) are important. **Low carbon energy system is the result of actors who make choices in territory composed by natural, technological, economic, legislative, social, and cultural systems and their substantial, procedural, and relational characteristics** (Figure 1.1 and Figure 1.2).

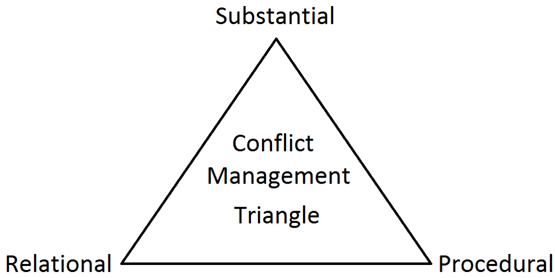


Figure 1.1: Conflict Management Triangle. Source: Solberg and Miina (1997) - modified.

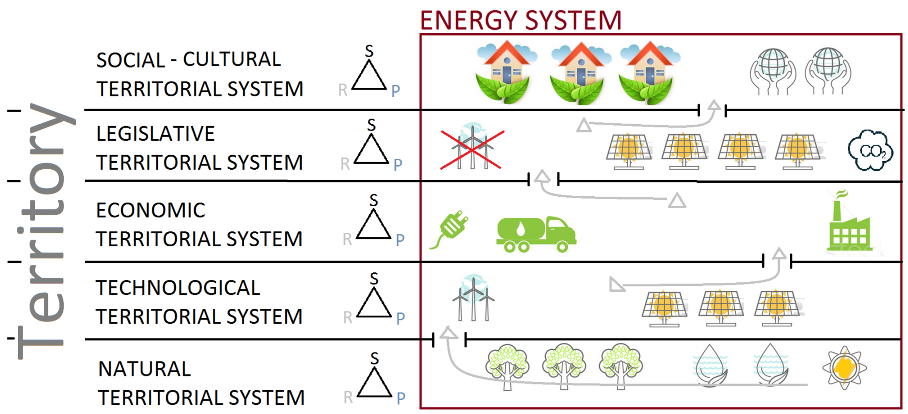


Figure 1.2: Background for analyzing the energy system in a territory. Source: own elaboration.

Actors make energy choices that are low carbon or not, choosing between several alternatives which are limited in the existing territorial context at different scales. When **local actors choose low carbon goals**, local actions shape low carbon energy systems or other local changes (e.g. in supporting policies) towards low carbon energy systems (Michalena and Angeon, 2009; Kasperson and Ram, 2013; Longstaff et al., 2015; Van Rijnsoever et al., 2015). Socio-technical change theories explain that context is made by landscape, regime, and niche levels (Sovacool and Hess, 2017) and people choose based on limited alternatives given by this context that is no easy changeable in the short period. Local population makes choices in this context based on different dimensions (substantial, procedural, and relational) and scales (landscape, regime, and niche) confirming or not the characteristics of socio-energy system, or participating to niche innovation. For example, Magnani and Osti (2016); Gross and Mautz (2015) underline that structural socio-economic and infrastructural features of a country are the landscape that limits people's choices in a local territory. People must make choices in a given landscape and regime (e.g. presence of historical energy companies and monopolies), and push to change them through niche and other forms of change (Geels and Schot, 2007).

1.4 Methods

Within an influential territorial context, the **local population's choices and responses** to energy transition contribute to shape energy systems in the RE production sector. Based on this assumption, this research approaches the systematic literature review by focusing on the most used human and social science terms and concepts (key words in different combinations) in the research field and on the most visible publications according to the number of citations. First, local population's choices and responses address a continuum between support and opposition to energy system changes. In the continuum, two concepts are often used in human and social science scientific literature: *acceptance* and *conflict*. Second, the online database (SCOPUS) was consulted and used to search and collect all the publications related to combinations of the following specific key words:

- *"Acceptance AND 'renewable energy' "*
- *"Conflict AND 'renewable energy' "*.

Acceptance is one of the most used words in publications that concern the interaction between a local population and a low carbon energy system. Moreover, this research focuses on local territories. The literature search should include local, public, community, end-user, or societal acceptance **according to different definitions of actors** who are accepting the energy transition (Devlin, 2005; Devine-Wright, 2005; Wüstenhagen et al., 2007; Zoellner et al., 2008; Musall and Kuik, 2011; Baharoon et al., 2016). However, the results of the first online search showed that these adjectives are not exhaustive in defining all the possible categories of actors. Therefore, the keywords local, public, community,

Search words	Field of research in SCOPUS	Number of publications	Filter to exclude the following subject areas	Number of publications after the subject areas filter	Filter to include only the publications in the following period	Number of publications after the year filter
Acceptance AND "renewable energy"	Title,abstract,key words	602	"Chemical Engineering", "Chemistry", "Biochemistry, Genetics and Molecular Biology", "Immunology and Microbiology", "Pharmacology, Toxicology and Pharmaceutics"	539	1979-2015	493
Conflict AND "renewable energy"	Title,abstract,key words	482	"Chemical Engineering", "Chemistry", "Biochemistry, Genetics and Molecular Biology", "Physics and Astronomy", "Immunology and Microbiology"	446	1979-2015	403

Table 1.1: Online literature search in SCOPUS on 22nd July 2016. The literature includes publications searched in SCOPUS with the following key words: *Acceptance AND renewable energy*, and *Conflict AND renewable energy*. Some filters were adopted to select the publications to include in the literature review (subject areas, year).

end-user, or societal acceptance have been substituted with the wider keyword acceptance. Furthermore, the local population's responses are not always positive (*acceptance*). Thus the key word *conflict* is added. The second focus of this research is energy system renewability even if renewability is only one of the important characteristics of low carbon energy systems. Considering the interaction between conflict-acceptance and **energy system renewability**, the key words *renewable energy* are used.

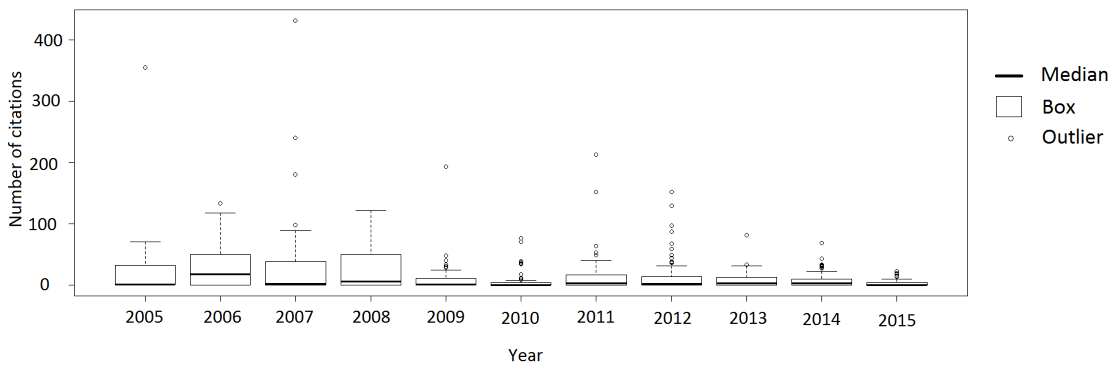


Figure 1.3: Box plot with descriptive analysis of publications in the period 2005-2015. Source: own elaboration based on Statplus for Mac.

In this way, 1084 publications were found in the reference period of 1979-2015. The huge amount of publications can lead to a problem of "coding fatigue" and consequent errors in the analysis (Sovacool, 2014). Authors use systematic literature reviews thanks to a team of coders (Sovacool, 2014), but in this case the resources were limited choosing for the selection of some publications (Table 1.1). Thus the most visible publications were chosen for the analysis according to the **number of citations per publication** in the reference period and selecting the publications with the highest number of total citations (2005-2015). The number of citations is one of indexes that attest to the importance of the specific publication (Wilsdon, 2016) and it underlines the importance in research agenda structure. However, other indices could be used (e.g. SCOPUS publications in the last year, journal impact factor). They are included in the interval between the 3rd quartile (horizontal line at the top of the box) and the maximum value (circle) (Figure 1.3). Consequently, there are 187 most cited publications. Of these 187, nine were twice present in both *"Conflict AND renewable energy"* and *"Acceptance AND renewable energy"* and 10 do not concern my topics. The final dataset included 168 publications that have been analysed quantitatively and qualitatively based on the method proposed by Sovacool (2014).

The quantitative analysis uses R for statistical investigation of the contents. The publications are classified according to several criteria: disciplinary affiliation, analysis unit, investigated technology areas or energy source, and energy goals. First, **disciplinary affiliations** of the selected publications are economics, engineering, environmental science, geography, law, medicine and veterinary medicine, planning, psychology, sociology and communication. Second, selected publications have a different **analysis unit or study object**:

- legislation, e.g. in Rowlands (2005); Rubini (2012); Vaona (2012), and policies in Río (2009)
- individual families or people. This group of publications focuses on energy-related perceptions or actions of people or families that act for individual reasons and aims, e.g. in Kraeusel and Möst (2012); Zhai and Williams (2012)
- single technology or renewable source with main focus on their characteristics and

impacts, e.g. in Margheritini et al. (2012); Khan and el Dessouky (2009)

- stakeholders defined as organized and unorganized groups that are affected by or affect, in the present and future, changes in energy system in terms of rate of RE, efficiency and saving towards energy transition, e.g. Grimble and Wellard (1997); Reed et al. (2009). They act according to group interest, such as representatives of environmental movement
- wider entities such as local, regional, national and transnational territories, e.g. in Bjelic and Ciric (2014); Stoms et al. (2013)

Beyond the analysis unit, publications differ in **investigated technology areas** (i.e. batteries, consumption devices, distribution grids and wider energy systems, transports) **or energy sources** (i.e. biomass, geothermal energy, hydroelectric, hydrogen, PV, solar, wave, wind). Lastly, **energy goals** of papers are energy production, energy saving, efficiency, carbon capture, or integration of energy with other issues.

The second part focuses on the qualitative and quantitative analysis of publication contents giving a measure and a meaning of texts thanks to NVIVO11plus©. In qualitative analysis, the contents are grouped based on the previously presented background (Figure 1.1 and Figure 1.2).

1.5 Results and discussion

1.5.1 Description of the 168 selected publications

The 168 selected and investigated publications belong to different research fields. Selected publications are classified according to disciplinary affiliation and research analysis unit (Figure 1.4). Disciplinary affiliation is categorized in the 11 disciplines of the figure according to the department or institute of affiliation of the authors. Not all authors that collaborate in an institute belong to the main institute discipline, but a cross-check has made according to the main theories and approaches used in each publication to confirm discipline affiliation. The categorization of disciplines investigates how much each discipline contributes to the selected literature, which are the main diffused perspectives that can contribute to research and policy agenda, and how much multidisciplinary research is relevant in energy transition studies. Even if social acceptance is more a social or human concept, engineering is the most relevant research field (Figure 1.4 and Table 1.2). On the one hand, engineers focus on the characteristics of single plants and technologies (i.e. characteristics and impacts). On the other, engineer efforts are on wider territorial potential in the energy sector. The next most important research fields are economics and sociology. While economists treat economic impacts of single technologies and plants and individual choices, sociologists prefer to investigate the social potential of entire territories for low carbon energy choices from wider stakeholder and individual viewpoints. Some publications also tend to mix several research fields combining engineering with sociology or economics with psychology. The results of the literature review shows that multidisciplinary contribution tend to be wider ranging in SCOPUS, except for engineering field. Publications thus confirm the need to combine several research fields and extend viewpoints to achieve important results in the energy research field. Other research fields explore acceptance and conflict in RE issues but with fewer publications: environmental sciences, geography, law, medicine and veterinary medicine, psychology.

Several research fields, especially engineering, consider single energy sources and technologies. In this group of publications, researchers investigate single components, such as biomass as a RE source (Hastik et al., 2016; Van der Horst and Evans, 2010) or a specific technology for energy production. Other engineers focus on the characteristics and potential of territories, i.e. in (Sawangphol and Pharino, 2011; Galparsoro et al., 2012; Scheidel and Sorman, 2012; Kerr et al., 2014; Sun et al., 2014). Sociologists investigate individuals, stakeholders (Späth and Rohracher, 2010), and, partly, entire territories. There is a lack of literature on legislation referred to human and social science concepts of acceptance and conflict in RE research field (Rowlands, 2005; Rubini, 2012; Vaona, 2012).

	Number of publications	Percentage of publications
Batteries	3	1.79
Biomass plants	17	10.12
Consumption advice	4	2.38
Distributional grids	11	6.55
Energy system	40	23.81
Geothermal plants	4	2.38
Hydroelectrict plants	5	2.98
Hydrogen plants	4	2.38
Mix	18	10.71
Other	7	4.17
Photovoltaic plants	14	8.33
Solar plants	8	4.76
Transport	3	1.79
Wave plants	9	5.35
Wind plants	21	12.5
Total	168	100.00

Table 1.2: Selected publications investigate several renewable energy sources and technology areas.

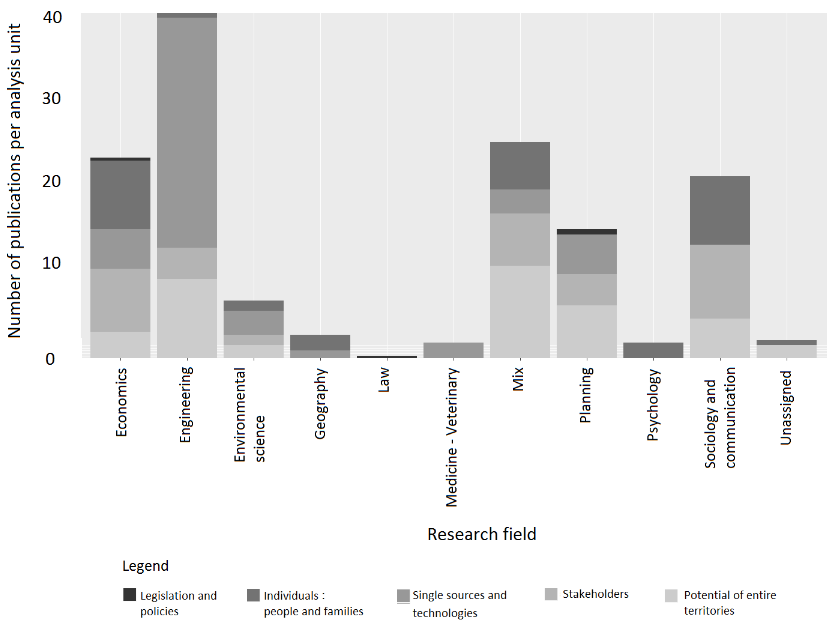


Figure 1.4: Selected publications are classified according to disciplinary affiliation and research analysis unit. Source: own elaboration based on R.

Each publication focuses on one or more energy technology or source (Table 1.2). Most publications consider an entire energy system. Indeed, production is just one of the important energy topics and goals. The category of entire energy system of Table 1.2 includes e.g. interaction between several technologies or sources, interaction between infrastructures or plants, integration between energy production, distribution, and consumption, or water-food-energy nexus. Accordingly, energy changes are related to the increase of energy production, energy saving and efficiency, carbon capture, and integration with other issues (i.e. other economic sectors, environmental protection). Publications about more than one technology or source are relevant as well (Mix) and they concern two or more technologies without investigating integration or interaction between them. Considering publications related to single source, the most relevant are biomass and wind.

1.5.2 Quantitative and qualitative content analysis of the 168 publications

A multi-viewpoint analysis is made of the publication contents. The local population acts through or in the face of energy system modifications of public concern (Michalena and Angeon, 2009; Kasperson and Ram, 2013; Longstaff et al., 2015; Van Rijnsoever et al., 2015): i.e. building of a new RE plant or founding of a RE cooperative. The people and groups usually have two possibilities: (a) react to changes choosing or not choosing between positive, negative, or neutral alternatives (adopt or not adopt, take position for or against, participate in technology ownership or not, participate in the decision-making process or not), or (b) act with innovations for energy transition.

The **local population's actions or reactions** to changes towards low carbon energy systems belong to social actors. The actors can be individuals (e.g. farmers or citizens) (Devine-Wright, 2005; Sauter and Watson, 2007; Dowd et al., 2011; Stigka et al., 2014), stakeholders (Dvarioniene et al., 2015; Wolsink, 2018), or territories (Maruyama et al., 2007) that are included in a local context. As shown in the selected publications, the individual level reacts for example as households that choose their appliances according to individual characteristics and preferences. The stakeholder level includes interactions between local groups who have different interests and react to proposed energy infrastructures or act towards energy transition according to group interest. The territorial level focuses on a wider context that acts with a wider acceptance of RE technologies (Upham et al., 2015).

Content analysis of the 168 selected publications uncovers 585 statements in which the three dimensions of each territorial system are cited (Table 1.3). Especially, the literature analysis shows 322 statements linked to the social system of local territories.

Territorial system	Dimensions	Sources	Statements
A. Social	A.1 S	52	165
	A.2 P	25	82
	A.2 R	29	75
	Total	106	322
Natural	B.1 P	15	24
	B.1 S	0	0
	B.1 R	0	0
	Total	15	24
Technological	C.1 P	55	111
	C.1 S	9	13
	C.1 R	6	13
	Total	70	137
Legislative	D.1 P	17	36
	D.1 S	3	5
	D.1 R	5	6
	Total	25	47
Economic	E.1 P	28	51
	E.1 S	1	1
	E.1 R	3	3
	Total	32	55
Total		248	585

Table 1.3: Number of sources and selected statements (i.e. phrases or paragraphs) per each node that investigate the territorial system and its dimensions in the qualitative analysis. The dimensions are substantial (S), procedural (P) and relational (R).

These statements include **the 41 sub-dimensions of social system that influence the local population's actions shaping energy system** renewability (Table 1.6). Furthermore, the analysis shows that further sub-dimensions of other territorial systems are investigated with social ones (Table 1.3): seven for economic system, four for natural system, seven for legislative system, and eight for technological system.

Dimension	Sub-dimension	Specific aspects
A.1 Substance	A.1.1.Socio-demographic characteristic	Characteristics of population in terms of: • Family income • Family size • Number of families • Population density in a local territory • Distribution of inhabitants in the territory • Variation of inhabitants in selected year of reference • Age structure of the population • Gender structure of the population • Employment • Education • Quality of life or household wealth
	A.1.2 Cultural aspects	Cultural features in terms of: • Symbolic aspects (e.g. traditions, modes of social organizations, and cultures) • Affective aspects (e.g. affective ties between individuals, groups and socio-physical environment) • Socially constructed aspects • Collective identity • Place attachment (emotional connection to location) • Landscape cultural values (e.g. attachment to landscape context or landscape quality) • Land cultural value (e.g. historical and cultural functions of the land) • Environmental attitudes of the population • Safety culture (e.g. attitudes and behaviors that increase development and implementation of safe technologies)
	A.1.3 Habitus	Schemes of thought, perceptions and actions people have in the long period using energy, i.e.: • Local history of renewable energy • Habitus of resilience (or the capacity to group and respond to a crisis) • Habitus of initiative • Habitus of collective ownership
	A.1.4 Preferences and interests	People develop preferences: • Between renewable energy and nuclear or other kinds of energy production sources and technologies • Between different energy appliances • On local distinctiveness • Between several local development choices

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Dimension	Sub-dimension	Specific aspects
A.1 Substance	A.1.5 Perceptions and public beliefs	People develop perceptions, about: • The distribution of risks and benefits • The level of sustainability • The impacts of renewable energies and single technologies • The future of REs, developing optimistic or pessimistic expectations • The risks of climate change • The meaning of energy security • The possibility of power plant accidents • The advantages and disadvantages of REs development • Impacts of REs implementation on local development
	A.1.6 Citizens initiatives	Citizens initiatives are expressed as: • Environmental or other forms of activism • Social movements • Technology- and product-oriented movements • Investments in energy saving measures or other energy interventions • Communication through media and other tools.
	A.1.7 Human capital	Human capital is considered in terms of background information, knowledge and awareness concerning: • Renewable energy technologies (RETs) • Link between energy used and CO2 emissions • Climate change
	A.1.8 Commitment	Commitment is investigated considering • Object of the commitments of several actors • Expressed commitments • Public discussions • Public debate in the media • Shared visions of local actors • Correspondence of activities with group and individual commitments
A.2 Procedure	A.2.1 Institutional and socio-political context	The institutional and socio-political context is characterized by: • Type of decision-making process, i.e. representativeness inter-sectoral process, transparency, time and cost consuming • Public policy framework • Democratic deficit of the planning system • Procedural justice • Top-down or bottom up planning

Continued on next page.

Dimension	Sub-dimension	Specific aspects
	A.2.2 Participation	Participation permits people and stakeholders to be involved in the technological or change process. The participative mechanisms and processes are investigated considering: • Level of participation • Goals of participation • Timeline and accuracy of information • Involved actors • Cooperation mechanisms • Current and past community ownership or engagement • Legitimacy of participative mechanisms and processes • Ability of voice to be heard, adequate information, being treated with respect, and unbiased decision-making • Engagement of the interests of local community • Consideration of local sentiments • Expectations of actors
A.3 Relationship	A.3.1 Habitus	People also develop habitus in terms of relationships with others. Consequently, the existence of a systematic network for public issues and energy topics is important. These habitus-networks are analyzed in terms of involved actors, and network characteristics. Three kinds of relationship are interesting: • one influences the individual choice for individual energy appliances and plants • one influences the individual choice to participate or be involved in a common experience (cooperative, district heating), • one influences the implementation of common plants. However, not all relationships are habitus.
	A.3.2 Source of the relationship	Relationships can be described as bridges between actors that permit the exchange of several resources, i.e. information or discussions with the aim to make decisions.
	A.3.3 Actors in the relationship	Variety of actors, relationships between different levels of actors (citizens, stakeholders, decision-makers).
	A.3.4 Characteristics of the relationship	The characteristics of the relationships are related to: • Trust between actors • Trust in authorities • Informal contacts • Coordination mechanisms • Cooperation versus competition links • Shortness of the communication links • Transparency of relationships • Social capital • Density of relationships
	A.3.5 Object of the relationship	It is possible create a guiding vision and, consequently, the network based on this vision. The vision aims to promote a territory with precise characteristics.

Table 1.6: Dimensions and sub-dimensions of the territorial social system that can influence local population's actions or reactions to energy transition.

A. Social system

A.1 Substantial dimensions

Considering the social system (Table 4), substantial dimensions that influence local population actions include (A.1.1, A.1.8) individual and (A.1.2) cultural characteristics of people and families, their (A.1.3) *habitus*, (A.1.4) preferences, (A.1.5) perceptions, (A.1.6) initiatives, and (A.1.8) commitments. Some of these characteristics are individual, while others belong to the entire social system. Both influence people's choices, actions and reactions. Ertör-Akyazı et al. (2012) explain very well that socio-demographic characteristics have a different influence for each case study:

"Ek (2005), for instance, showed that age and income were negatively related with support for wind power in Sweden, while Greenberg (2009) found that these variables were insignificant correlates of renewable support in the US. Similarly, Ansolabehere and Konisky (2009) demonstrated that income was insignificant in explaining opposition to wind power in the US, but Firestone and Kempton (2007) found that opponents to an offshore wind power project in Nantucket Sound, the US, were likely to be wealthier. With regard to nuclear energy, within the US context, Webber (1982) found that nuclear opposition was positively related to age and education, and negatively to income." (p. 14)

However, some sub-dimensions seem to be universal in influencing local energy system changes (Figure 1.5). On the one hand, the important sub-dimensions are individual characteristics such as quality of life, perceptions, human capital and commitments. On the other, the important contribution to low carbon energy choices is given by social context: local and social identity, *habitus* of resilience, *habitus* of initiative, and *habitus* of collective ownership. Substantial change of **quality of life** creates environmental stress addressing the need to change towards energy transition. Further, the individual is interested in reducing costs and using energy resources that maintain quality of life (Walker et al., 2015). However, people's perceptions are important to explain their choices. Two kind of **perceptions** exist in this issue. On the one hand, perceptions on impacts of plants and technologies (Zografakis et al., 2010). On the other, climate change risk perceptions (Ertör-Akyazı et al., 2012). Negative local population's actions are also due to a lack of or misleading information (Zografakis et al., 2010). Otherwise, a good **human capital** (knowledge, information and awareness) promotes innovation and creativity (Beria et al., 2012), significant behavioural changes and diffusion of more efficient technologies (Rogers et al., 2012) for changes in energy system. **Commitments** such as environmental activism (Ertör-Akyazı et al., 2012) and fight against climate change also depend on knowledge (Dowd et al., 2011; Upham et al., 2015; Wolsink, 2007) and environmental soundness (Wolsink, 2007) of energy issues. Anyway, the local population acts in (A.2.1) an institutional and socio-political context that sometimes includes (A.2.2) participative circumstances.

Considering not only individual aspects, **local and social identity** promotes positive perceptions of energy changes (Devine-Wright, 2005) and local energy initiatives (Wolsink, 2007, p. 126) thanks to "symbolic, affective and socially constructed aspects". The local population sometimes creates a "safety culture" of RE sources placing attention on environmental issues and promoting energy changes (Koh and Ghazoul, 2008). Local safety culture is promoted by the local history of RE, **habitus of resilience** (or the capacity to group and respond to a crisis), **habitus of initiative**, or **habitus of collective ownership**. Indeed, *habitus* are considered schemes of thought, perceptions and actions people have in the long period using energy (Osti, 2010; Upham et al., 2015). Some *habitus* promote energy initiatives that focus on the deliverable of local and collective benefits, i.e. through community RE (Rogers et al., 2012). The concept of *habitus* can be important to increase the understanding of cultures and lifestyles influencing energy issues (Sovacool, 2014). In the analysis of social territorial systems, actors are approached based on two different levels: individual and collective ones. Local population is made by individuals who individually act, and collective entities culturally and socially embedded into the local context.

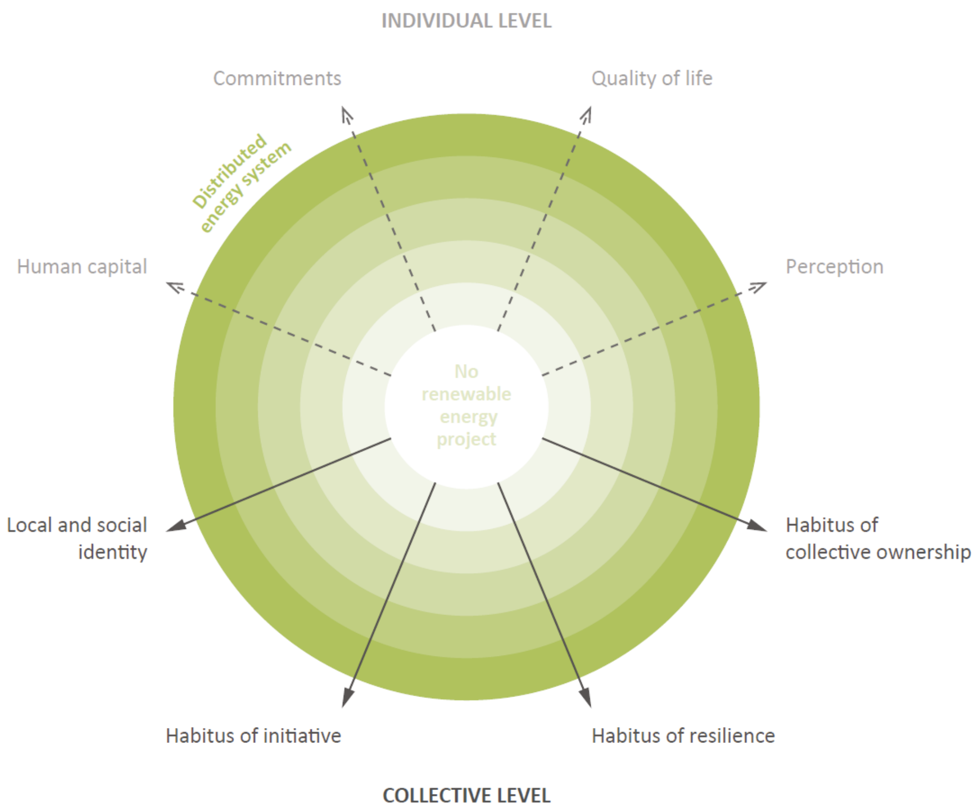

Figure 1.5: Universal substantial dimensions and key aspects of social territorial system (Table 1.6 - A.1).

A.2 Procedural dimensions

The institutional and socio-political context belongs to relevant (A.2) procedural sub-dimensions of the social system. A *"sense of lack of control over development or land use planning processes"* (Devine-Wright, 2005) creates negative perceptions, less acceptance, and fewer initiatives about energy changes. To be legitimated, the decision-making process has to have characteristics, such as **representativeness, inter-sectoral process, transparency, low time and cost consuming** (Figure 1.6). The legitimation fosters positive actions and reactions to energy changes. A lack of participation in the decision-making process also points to a legitimacy problem (Ertör-Akyazı et al., 2012). The interesting concept of **ecological modernization** (Wolsink, 2007) helps to define a positive decision-making process for promoting low carbon energy systems. It includes (Wolsink, 2007, p. 2702):

- *“Open, democratic decision-making, rather than technocratic and corporatist-style decision-making*
- *Participation and involvement, rather than planning and decision-making carried out by scientic, economic and political elites*
- *Open-ended approaches that allow multiple views, rather than the imposition of single, closed-ended proposals*
- *Broad changes in institutions, incorporating environmental concerns, rather than technological solutions to environmental problems”*

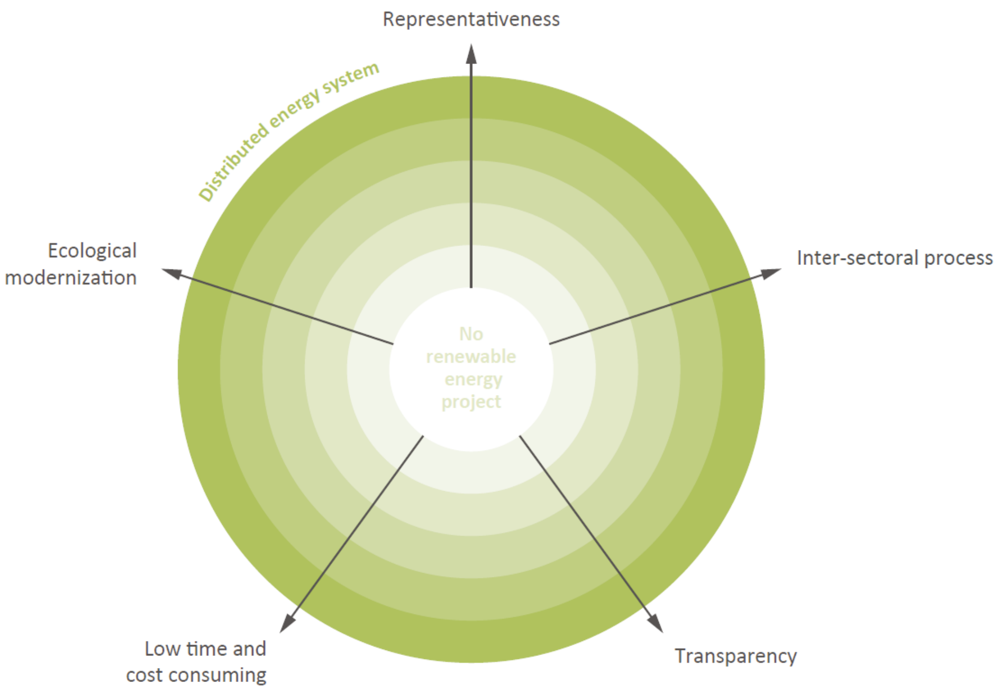

Figure 1.6: Universal procedural dimensions and key aspects of social territorial system (Table 1.6 - A.2).

A.3 Relational dimensions

Institutional, political and social contexts include relationships between actors:

“Social acceptance is not simply a set of static attitudes of individuals; instead it refers

more broadly to social relationships and organizations" (Wolsink, 2010, p. 303).

Sources (A.3.2), actors (A.3.3), characteristics (A.3.4), objects (A.3.5) and habitus (A.3.1) describe social relationships. Relationships are networks or means to exchange sources, as shown by the **social capital concept** (Bowles and Gintis, 2002). One of these sources is information. In this sense, the network is fragile because it causes reactions and opinions and is based on understanding and learning (Dowd et al., 2011). A particularly useful network source is **word of mouth** (Rogers et al., 2012). Information passes through networks more easily if there is trust between actors. Information aspects are related to trust in relationships (Upham et al., 2015). Actors of networks can feel part of a community and stakeholders with access to power and technical knowledge should belong (Dvarioniene et al., 2015). A strong actor network is usually able to promote energy initiatives (Späth and Rohracher, 2010). For example, a higher level of trust between the local population and institutional and promotional actors permits a quicker energy change (Devine-Wright and Batel, 2013; Kontogianni et al., 2014). Furthermore, **predisposition of collaboration** around a common vision (i.e. sound like environmentalists) between actors is fundamental (Wolsink, 2007). A network helps this vision by bringing social pressures (Rogers et al., 2008). Indeed, **social influence processes** and social networks are important in determining public perceptions (Devine-Wright, 2005) and actions, and consequent energy system changes or not changes (Figure 1.7).

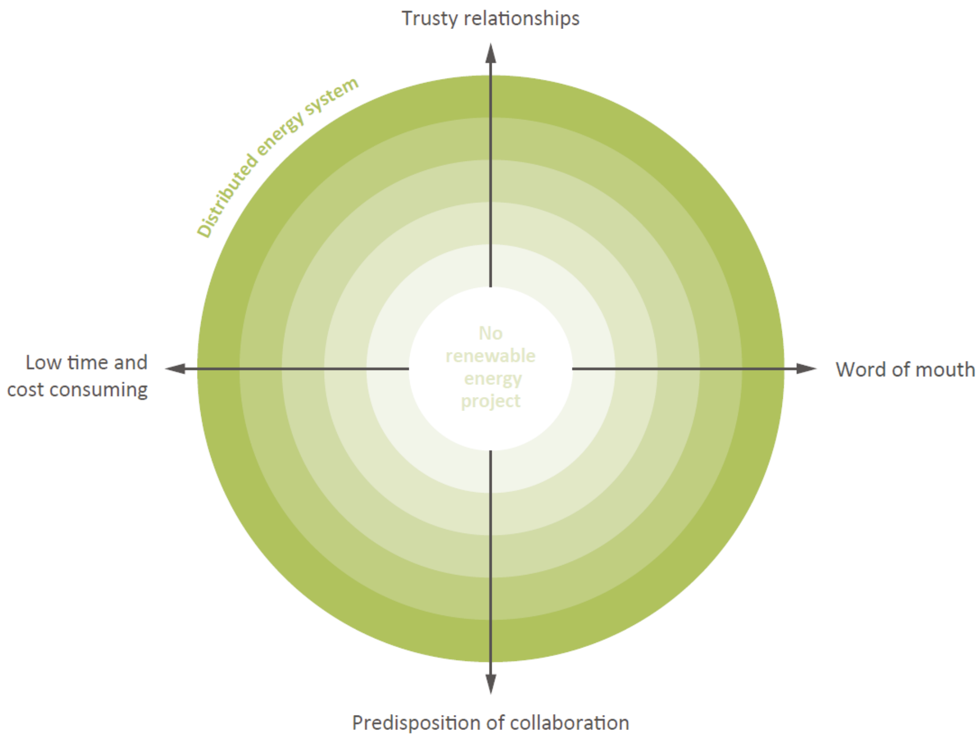

Figure 1.7: Universal relational dimensions and key aspects of social territorial system (Table1.6 - A.2).

Figures 1.5, 1.6, and 1.7 visualize a conflictual arena in the center and an acceptance arena in the outside and darker circles. In the conflictual arena, the key aspects have negative value and the opportunities to increase RE production are fewer. In the acceptance arena, the key aspects have positive value and the opportunities to change towards low carbon and distributed energy systems are higher. The visualized key aspects are universal in the analysed literature. To understand the potentialities of change towards energy transition, all substantial, procedural and relational dimensions must be considered, individually and one another. Actors, processes, and networks are the keys to investigate energy system changes, made by conflictual or acceptance choices of local population. These paragraphs were focused on social territorial system and its actors, processes, and networks, but the research should move to other territorial systems and their interactions with social ones.

System	Dimension	Sub-dimension
B. Natural	B.1. Substance	B.1.1 Natural potential
		B.1.2 Scarcity
	B.2. Procedure	B.2.1 Resilience
	B.3. Relationship	B.3.1 Trade-off
C. Technological	C.1. Substance	C.1.1 Characteristics
		C.1.2 Siting or location
		C.1.3 Ownership
		C.1.4 Decision support tools
		C.1.5 Climate change
	C.2. Procedure	C.2.1 Technological advance
	C.3. Relationship	C.3.1 Distributional grid
		C.3.2 Mix of renewable sources
D. Legislative	D.1. Substance	D.1.1 Legislation and planning on energy issues
		D.1.2 Other legislations
		D.1.3 Institutional capital
	D.2. Procedure	D.2.1 Course of authorization process
		D.2.2 Evolution of legislation
	D.3. Relationship	D.3.1 Network of authorities
		D.3.2 European, national, and local legislation
E. Economic	E.1. Substance	E.1.1 Subsidies, incentives and tax deduction
		E.1.2 Economic attractiveness of investment
		E.1.3 Energy demand and offer or energy market
		E.1.4 Economic sectors
		E.1.5 Land use and resource trade-off
	E.2 Procedure	None
	E.3 Relationship	E.3.1 Economic impacts of energy sector on other sectors
		E.3.2 Relationships between economic actors

Table 1.7: Dimensions and sub-dimensions of other territorial systems related to social system and cited in the literature.

B. Natural system

Some characteristics of other territorial systems are interesting in addressing energy actions of the local population (Table 1.3). First, the social system interacts with the natural system. On the one hand, the social system puts pressure the natural system with population growth, rural-to-urban migrations, global climate change, and increase in renewable sources demand. On the other, social systems develop an attachment to the natural environment based on values and perceptions. Energy interventions should take this double link between social and natural systems into account (Devine-Wright, 2005; Koh and Ghazoul, 2008). Local population's actions and reactions are mainly influenced by natural systems in its characteristics of natural potential, scarcity of natural resources, and trade-offs for resource uses. Furthermore, the social system interacts with technological and research ones.

C. Technological system

Energy plants and renewable sources have their own potential that depends on technological advance, characteristics, plant location and ownership, and network in smart grids and mix of renewable sources. Furthermore, technologies must be active in the energy system. Technologies must thus be inserted in the territory through correct (or not correct) adoption and use. Correct or not correct use depends on e.g. habitus, information on RETs and possibilities to try them, perceptions on impacts and distribution of risks/benefits of the RETs, ownership of RETs. In summary, there is a sort of communication channel between social and technological systems through which they exchange information on uses and needs (Wolsink, 2007; Wüstenhagen et al., 2007; Musall and Kuik, 2011; Rogers et al., 2012; Wolsink, 2018; Carrosio, 2014; Kontogianni et al., 2014). This channel is partly formed by the research system (Madlener et al., 2007; Chen and MacDonald, 2014; Dvarioniene et al., 2015). In fact, the research system is increasingly focusing on energy issues, i.e. with calculations of local RE potential or technological advance. The researchers try to collect information on and spread knowledge within the local population on energy issues. These activities influence such dimensions of social systems that can explain the response of territories (i.e. knowledge, awareness, involvement). Lastly, economic and legislative systems influence actors in energy issues.

D. Legislative system and E. Economic system

The social system is made up of individuals, stakeholders, or groups. These actors can also be described as consumers and/or producers according to the economic perspective (Maruyama et al., 2007). The energy system can be seen as a network between consumers and producers, or investors. The economic system is sometimes linked to legislative ones that confirm some economic mechanisms. The social system anyway functions within a legislative and policy system. Rules, plans, norms, and legislation at local level therefore influence the response of the territory that passes through actions (or no actions) of the local population. The social system can also influence legislation and policies through participatory processes or pressure (Upham and Shackley, 2006; Wüstenhagen et al., 2007; Galparsoro et al., 2012; Bjelic and Ciric, 2014).

Each system is characterized by a set of dimensions that distinguish and interrelate substantial, procedural, and relational characteristics, according to the Conflict Management Triangle. The larger amount of sub-dimensions found in the literature concerns the social system. This research underlines how actors, processes, and networks address the change towards distributed energy systems increasing energy production based on renewable and local resources. Actors, processes, and networks of several territorial systems act together for creating change opportunities. Different research fields investigate these components. The initial choice of key words for the selection of publications in SCOPUS, acceptance and conflict, mainly refer to human and social science concepts. However, engineering research field is getting more and more interested, while law research field is not interested in social science concepts of acceptance and conflict in RE sector. This research lists dimensions and aspects of territory, which influence local population choices and related socio-energy system changes. This research focuses more on social system of territory underlining social actors, processes, and networks that are able to influence the shape of energy system and the energy transition, without missing the other important territorial dimensions.

1.6 Conclusion

For addressing energy system change towards low carbon energy system, deep analysis of dimensions and aspects that address the change is here made from territorial and social perspectives. On the one hand, energy system changes are based on their technological aspects. On the other, territory and its social features address people and group choices in energy terms. Be aware of the importance of social and territorial aspects for energy system change can accelerate and increase energy transition.

The literature shows that the majority of considered publications refer to a wider energy system and not to just **one specific technology or project or one specific decision-phase** (i.e. siting), especially for the electrical part. The complexity of an energy system is recognized (Madlener et al., 2007, p. 6061) considering the interrelation between actors, processes, and networks and a new methodological approach is needed for overcoming it and including social and technological viewpoints. This paper proposes the background for an analysis of the characteristics of a territory and the dimensions and sub-dimensions that address choices, actions, and reactions of people to low carbon energy system features.

The analysis of 168 selected publications shows the set of sub-dimensions that are related to actions and reactions of the local population to low carbon energy choices. One observed trend is the transition from centralized to **distributed energy systems** that produce from local renewable sources and consume the energy produced *in loco*. The investigation of these choices is supported by the set of sub-dimensions. The set is not expected to be exhaustive. Indeed, the literature focuses on the specific concepts of *acceptance* and *conflict* that are usually used in socio-psychological analysis frameworks. However, this research can be the starting point for a deeper case study analysis of local population actions and reactions to energy transition. The results of this research can be also applied to investigate the potential of energy system change in local territory and, specifically, the potential to build distributed energy systems, which focus on the creation of effective connections between energy, society, and resources in site-specific context.

Chapter 2

Territory as socio-energy system at translocal scale

Submitted as Balest et al. (2019)

2.1 Abstract

With the aim to **propose recommendations on how to use social and territorial specificities as levers for wider achievement of energy targets at local scale**, this research proposes a **Decision Support Tool**. Addressed to regional and local energy planners, the Decision Support Tool is based on an **analytical framework** that considers **territory as socio-energy system.** The new definition of the elements of territory as socio-energy system is based on a critical view of the territory underling the interrelations between energy and society. The Decision Support Tool is applied to the South Tyrol **case study** (Italy) and it is a replicable instrument for other regions.

Results show eight different socio-energy systems within the coherent cultural and institutional context of South Tyrol. In particular, the results prove different socio-energy systems in terms of (1) different RE source preferences in the semi-urban and the rural contexts; (2) different links with other local planning, management, and policy needs; (3) different socio-demographic specificities of individuals and families; (4) different kind

of stakeholders and (5) different socio-spatial organizations based on land covers. Each socio-energy system has its own specificities and potentialities that can address a **more balanced, inclusive, equal, and accelerate energy transition at translocal scale.**

2.2 Introduction

European countries have recently agreed on new 2030 framework for **climate and energy** to achieve a more competitive, secure and sustainable energy system (*The Climate and Energy Framework by Bonn UN Climate Change Conference 2017*)[1] with the aim to go beyond the Renewable energy Directive targets (European Commission, 2009).

The **transition** towards a new energy system characterized by larger adoption of RE is already affecting European territories. EUROSTAT observers that 11 European countries have already achieved Renewable energy Directive targets before 2020, even if with a slowdown and a new interest on fossil fuels (Turnheim et al., 2018). In these global and international trends, the meeting of European climate and energy targets through **strategies and planning** is a challenge for researchers and decision makers (Petersen, 2018).

The contexts, actors, relationships, and dynamics at the **local scale** can contribute to an accelerated, more balanced, inclusive, and equal energy transition. At the local scale, public authorities have the opportunity to plan and manage the energy in their territories, i.e. through Sustainable Energy Action Plans (SEAP) or Sustainable Energy and Climate Action Plans (SECAP) of the Covenant of Mayors. In the development of these plans, public authorities analyse the *status quo* of their territories from a CO_2 emission, infrastructural, energy supply, demand and efficiency viewpoints and propose some actions towards energy transition (Coelho et al., 2017; Balest et al., 2018). Pinto-Correia et al. (2016) highlight **the need to better inform energy planners** on territorial peculiarities, differences, and interested actors for developing **effective energy plans**.

Territorial planning is complex and considers several dimensions of the territory, such as space-related processes (Brighenti, 2010), imagined entities (Anderson, 2006), space and resources (Bridge et al., 2013) in an ongoing and interactive process (Jessop et al., 2008;

[1] Energy targets of the Climate and Energy Framework aim to achieve at least 40% green house gas emissions decrease, 27% energy consumption decrease, and 27% energy efficiency increase.

Shove and Walker, 2010; Osti, 2015). The **territory** is a socio-spatial entity in which several actors act (Jessop et al., 2008; Osti, 2010), in the urban and rural environments (European Court of Editors, 2018). Socio-energy systems are embedded in the territory (Balest et al., 2018), involving not only energy supply and demand, technologies and infrastructures (Miller et al., 2015). Socio-energy systems dynamically shape and get shaped by social dynamics in the infrastructural, geographical, social, cultural and political dimensions of the territory.

Defining territory is complex without introducing **dimensions** (Turnhout et al., 2014; Medeiros, 2016). To this purpose, Balest et al. (2018); Garegnani et al. (2018) consider natural, technological, economic, legislative, social and cultural dimensions to analyse the interactions between local populations and territories. Balest et al. (2018) uses socio-technical and socio-ecological perspectives to define the territory as socio-energy system. In a socio-technical perspective, social, technical, and technological dimensions interact with each other (Geels and Schot, 2007), while the socio-ecological perspective places this interaction in a society-space environment (Park, 1915). Accounting for the energy transition, the territory becomes a spatial socio-energy system involving human and local population's choices on technologies and energy uses (Miller et al., 2015; Balest et al., 2018).

Local territories have specific needs, preferences, resources, and different responses to national or international policies and pressures (Geels, 2002; Díaz et al., 2017; Morton et al., 2018). Exploiting natural resources and increasing RE initiatives are decisions taken at municipal scale (Nabielek et al., 2018). This is the closest administrative scale to people, at least in the Italian context. As described by Kraxner et al. (2015); Novotná et al. (2016), it should be noted that the local entity (i.e. the municipality) is not always the most effective one for achieving RE goals. The need to plan at a **translocal scale** is commonly recognized, but different researchers use different scales of translocality (Bridge et al., 2013; Kraxner et al., 2015; Novotná et al., 2016; Nabielek et al., 2018). Many works (Bridge et al., 2013; Nabielek et al., 2018) deal with the regional scale (Nabielek et al., 2018), while this research focuses on **translocal scale emphasizing the role of collaborations between local entities** (Bridge et al., 2013; Rockenbauch and Sakdapolrak, 2017). Indeed, municipalities have the capacity to plan, but the planning effectiveness is weakened by a scarcity of economic and other resources (Kraxner et al., 2015; Novotná et al., 2016). This reason cannot justify the shifting of energy planning to the regional level. This research instead proposes to foster collaborations between municipalities at translocal scale, **with the aim of sharing resources and needs in order to achieve local energy targets effectively.**

Translocality describes a localized context across borders in which actors develop their own engagements (Greiner and Sakdapolrak, 2013) and everyday planning and management practices (Shove and Walker, 2010). The interconnections are possible through networks of mobility and relationships (Greiner and Sakdapolrak, 2013). Today, borders in terms of resources and potentialities are not easily recognizable (Sassen, 2018) and translocal geographies are relevant for energy planning (Sassen, 2018). Translocal geographies are able to connect territories that are closed or faraway in spatial and social terms.

The analysis of the connections between territories is not based on spatial proximity in this research. Cooperation between neighbouring municipalities can be reductive and reduce energy transition opportunities (Sánchez-Zamora et al., 2017), emphasizing **inequalities and disparities** in energy transition process (European Commission, 2008; Sánchez-Zamora et al., 2017). The European Court of Editors, in the technical report *Renewable energy for sustainable rural development*, is enhancing common planning approaches and improving the coordination among territories considering a wider concept of translocality that includes **similarities between territories** (European Court of Editors, 2018).

Linked to the need of a translocal territory planning approach, the European Commission proposes **the concept of territorial cohesion** in the *Green paper* of 2008, addressing both energy transition and local development across Europe (European Commission, 2008). Territorial cohesion is a concept that aims to increase sustainable development thank to territorial specificities and similarities (European Commission, 2010; Walsh, 2012; Aarts and Houwing, 2015; Medeiros, 2016; Alexiadis, 2017) that represent resources of collaboration in a polycentric planning and management system (Ostrom, 2010; Sovacool, 2011; Dao et al., 2017). Territorial cohesion means to share resources and needs for achieving common goals and development through collaborations between localities

(Aarts and Houwing, 2015; Medeiros, 2016), including all territories in development circuits (Walsh, 2012). The homogeneities among local territories *"facilitate more balanced and inclusive territorial development"* of local territories (Sánchez-Zamora et al., 2017, p. 48). The studies on territorial cohesion focus on homogeneities in terms of environmental, social, economic, geographical, and governance resources (Sánchez-Zamora et al., 2017). This concept is an interesting basis for the local and translocal energy planning.

How to define **territorial specificities and similarities** in order to increase effectiveness of energy planning through translocal collaborations? One of the methodologies used for grouping similar territories based on their specificities and similarities is the **cluster analysis** (Yang and Hu, 2008; Pecher et al., 2013). Cluster analysis includes algorithms able to calculate distances based on the homogeneities within the groups and the heterogeneities among the groups (Pecher et al., 2013). Several authors (Yang and Hu, 2008; Pecher et al., 2013; Novotná et al., 2016) analyse typologies of territory through the methodology of clustering, considering socio-economic, and spatial features at national or transnational scale. Even though they provide accurate information, they neglect the integration between social and energy dimensions.

This study uses social science, energy, and planning perspectives emphasizing the importance to include social variables for describing the territory as socio-energy system at translocal scale. This study aims to define an analytical framework for the territory as a socio-energy system, identifying specificities and similarities in translocal homogeneous groups of municipalities. These groups of municipalities have potentialities and resources for collaborative energy planning. This study integrates territorial cohesion concept (Alexiadis, 2017; Sánchez-Zamora et al., 2017) with a definition of territory as socio-energy system.

This research proposes a **Decision Support Tool** (DST) that integrates socio-demographic, quality of life, socio-economic, cultural, governance and political, geographical and infrastructural, energy and climate dimensions and related 41 place-based variables. A map (Figure 2.2) shows the homogeneities and potential collaborations between municipalities in a region, emphasizing common resources and needs.

After defining the relevant territorial and social dimensions of a socio-energy system embedded in a territory (Section 2.4), this research applies the analytical framework to a case study in Northern Italy (Section 2.5): South Tyrol. Results show eight different clusters of municipalities. Each one has its own socio-energy specificities (Section 2.6) and some of these can be used as assets by energy planners (Section 2.6.1).

2.3 Materials and methods

Before grouping similar municipalities by means of cluster analysis, variable choice is an essential step (Ketchen and Shook, 1996). Since irrelevant variables can influence cluster results, a deductive approach (Ketchen and Shook, 1996) is used. Ketchen and Shook (1996) suggest a theoretical foundation when the analysis aims at explaining or predicting relationships. For this reason, variable selection is based on the literature review by defining several dimensions (Section 2.4).

Starting from Balest et al. (2018), the authors look at the relationships between local population and RE projects, identifying the main dimensions affecting the effectiveness of energy plan. Balest et al. (2018) define *"low carbon energy system"* as *"the result of actors who make choices in territory composed by natural, technological, economic, legislative, social, and cultural systems"* (p. 171). These characteristics of territorial energy systems are compared with dimensions coming from the territorial cohesion literature (Figure 2.1). In the scientific literature, the territorial cohesion was firstly defined through the economic dimension by including diversification, competition, entrepreneurship, innovation and actors (Medeiros, 2016; Sánchez-Zamora et al., 2017). More recently (Aarts and Houwing, 2015; Medeiros, 2016), territorial cohesion is composed by socio-economic, environmental sustainability, cooperation governance, and morphologic dimensions at translocal scale (Aarts and Houwing, 2015; Medeiros, 2016).

The crossing of the two lists of dimensions creates a third **list of dimensions and factors that define the elements of territory as socio-energy system at translocal scale**[2]. This list of dimensions includes relevant informations of territory in territorial cohesion terms, and relevant information on how local population interacts with its own

[2] The final list of dimensions and factors aims to cluster all territories within a region. The lack of qualitative data for all municipalities on i.e., symbolic and affective aspects or collective identity (Balest et al., 2018) does not permit to have a complete and exhaustive list. Qualitative aspects will be considered in the steps of a future research.

territory in front of RE projects. A cluster analysis based on this list permits to describe and analyse specificities and similarities between territories useful for developing an effective energy plan (Figure 2.1).

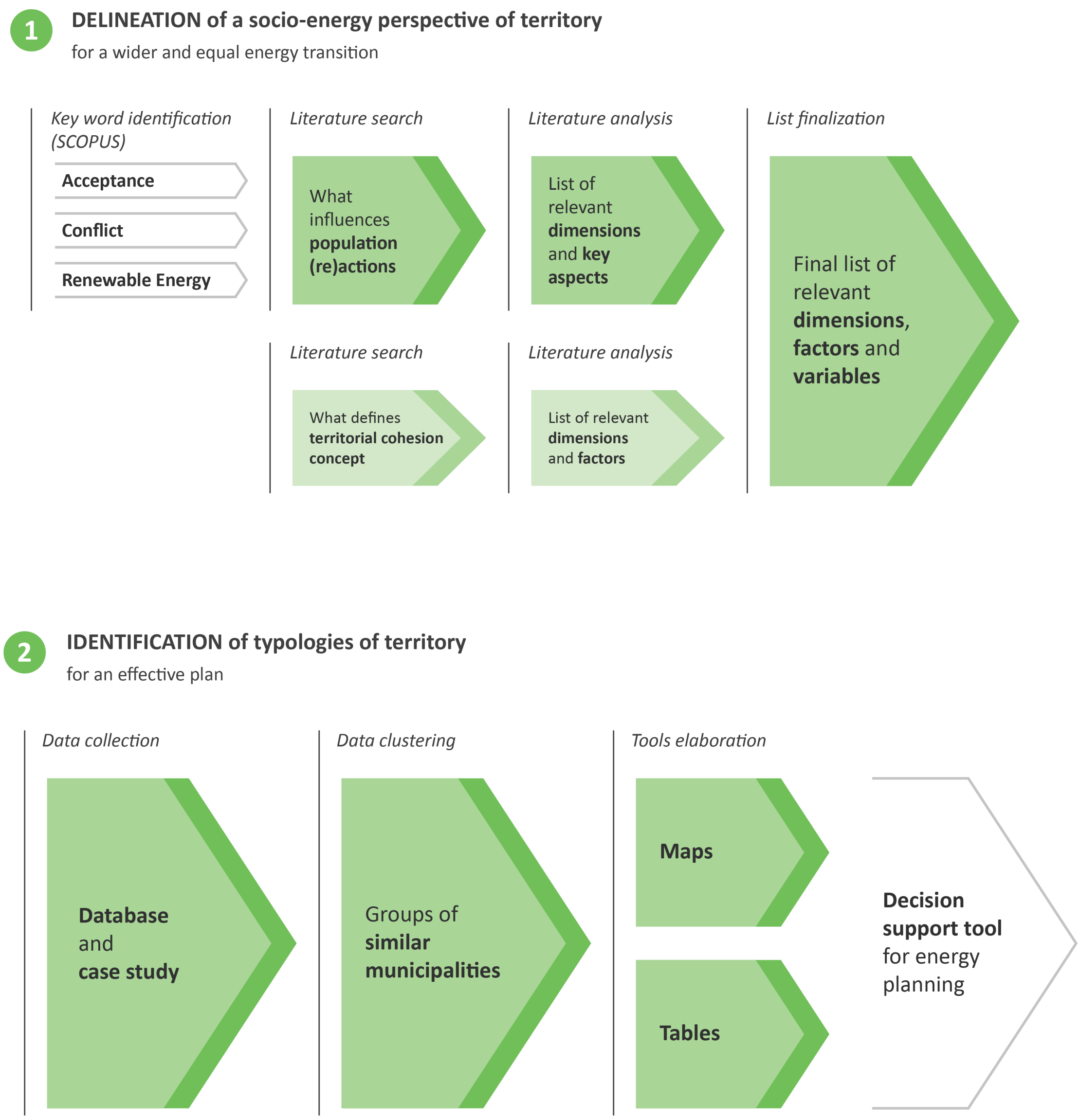

Figure 2.1: Flow of methods used in this research.

Moving these analytical dimensions into values is not easy (Medeiros, 2016). Data collection and harmonization[3] in the South Tyrol case study permit to create a regional database through which municipalities are clustered (Figure 2.1). The spatial coordinates

[3]In the case of spatial data (raster and shape format), the statistical tools of GRASS (Neteler et al., 2012) are used to transform the shape of data from spatial to .csv.

are the only variables not included in the cluster analysis. The goal is indeed to identify potential relationships in a region based on a wider concept of translocality that avoids criteria based on spatial proximity and emphasizes territorial specificities and similarities.

The results are mapped through a Geographic Information System (GIS). The use of maps not only support the communication of results to energy planners but provides a visual interpretation of the clusters.

2.4 Analytical dimensions and key aspects

The following list of dimensions and key aspects derive from the crossing of the relevant dimensions in the two considered literatures: publications on local population's actions and reactions in front of RE projects (Balest et al., 2018) and publications on territorial cohesion, i.e., Medeiros (2016).

2.4.1 The socio-demographic, socio-economic, quality of life, and cultural dimensions

The socio-demographic, socio-economic, quality of life, and cultural dimensions account for local characteristics and resources of individuals, groups, and economies. These dimensions focus on actors - i.e., enterprises and inhabitants - and relationships.

These dimensions can support energy planning in several ways:

Enterprises could be relevant *"actors in energy transition"* (Süsser et al., 2017) and in implementing local and regional energy plans. Different entrepreneurships and **socio-economic structures and features** can explain different potentialities to create RE projects (Süsser et al., 2017). Indeed, enterprises have needs, resources, and goals that can be shared or emphasized in energy planning.

Inhabitants are relevant actors of the social and economic dimension. Firstly, they can be prosumer (Dóci and Gotchev, 2016) since new RE projects integrate production, supply, and demand (Holstead et al., 2017; Wang et al., 2018; Winkler et al., 2018). Secondly, inhabitants can play a role in the implementation phase of RE plans. Their involvement could have different features depending on **civic and political participation** and activity of inhabitants, age (Karytsas and Theodoropoulou, 2014), gender (Kosenius and Ollikainen, 2013), income (Karytsas and Theodoropoulou, 2014), composition and size of families (Stigka et al., 2014), perceptions of injustice (Hyland and Bertsch, 2018), and cultural imageries (Calhoun and Sennett, 2007). For example, income influences the acceptance and the availability to adopt or support RE technologies and energy efficiency measures (Morton et al., 2018; Hyland and Bertsch, 2018). Investments can be done by medium-income people while low-income people have not this potentiality even if RE incentives exist (Yang and Zhao, 2015). However, not all rich people invest on REs and other aspects must be taken into account.

The quality of life and the household wealth are relevant to explain people acceptance or adoption of RE and energy efficiency projects (Balest et al., 2018). For example, individuals have interest to reduce energy-related costs to maintain their quality of life (Walker et al., 2015). A higher quality of life means a higher attention to sustainable goals and actions, because people have already answered to the primary needs. For this reason, the access to services - i.e. schools and libraries - is an important aspect in the analysis of territorial development and cohesion (Medeiros, 2016) and environmental attitudes of people. Activism or soundness of energy topics can contribute to address people choices (Balest et al., 2018).

An example in terms of **socio-demographic features** concerns age. Since RE technologies are easier to use (Prasadh and Suresh, 2016) and youths have knowledge about RE (Halder et al., 2013), youths perceive benefits (Yazdanpanah et al., 2015) in supporting energy projects. *"A typical green consumer is younger, more educated, and wealthier"*, at least when he/she explains a potential will (Paravantis et al., 2018). The spread of green consumer and an equal and similar development in terms of income, quality of life, and environmental activism across translocal scale can contribute to a wider energy transition (Medeiros, 2016).

In the energy planning, involvement processes or dedicated actions to local population need targeted messages for enterprises, inhabitants, and families (Noblet et al., 2015), according to population features and in order to recognize preferences, interests, and knowledge needs (Ouhajjou et al., 2017).

Relationships between actors in local and trans local governance are expression of RE potentialities. Several authors (Rogers et al., 2012; Van Der Schoor and Scholtens, 2015; Dóci and Gotchev, 2016) investigate energy communities as positive networks of producers, consumers, and especially prosumers. Nowadays, local community concept refers to groups of people that live in a common territory (**?**) or have a common interest (Magnani and Osti, 2016). Local communities can become important for achieving energy transition (Miller et al., 2013), thanks to their common identity (Weber, 1978), dense networks, and place attachment. The communities and their networks have been influenced by economic crisis. Sustainable territorial development can be also considered in terms of RE production and it *"requires administrations and civil society actors to initialize and develop projects at the local level, ensure their acceptance and support by the regional population and implement the project in collaboration with relevant actors"* (Müller et al., 2011, p. 5800). The involvement of these actors and relationships is relevant to develop energy planning effectively.

Accordingly, the analysis selects the most relevant dimensions and factors linked to socio-demographic, socio-economic, quality of life-related specificities, and cultural dimensions (Table 2.2). These dimensions observed at translocal scale promote a more equal, balanced, and inclusive development.

2.4.2 The governance and political dimension

Governance is a process for the organization of territory and its resources according to Medeiros (2016). The shape and dynamics of the governance process is given by some local specificities:

Political address. Governance includes horizontal and vertical cooperation between stakeholders who have different **political addresses and opinions** (Engelken et al., 2016). People can be active in political and public life and shape the governance through formal and not formal institutions, such as parties. Different political addresses have different commitments to energy transition and this can be a resource for energy planning, emphasizing the political meaning and commitment of energy transition.

Participation Participation and information can sometimes explain local acceptance or conflict against energy system changes (Zoellner et al., 2008). The social and environmental movements and **civic participation** of people are relevant to understand potentialities of local community initiatives in terms of acceptance or conflict (Argüelles et al., 2017; Becker et al., 2017). The energy planner should understand the relevance of the level of activeness and participation of the local population, in order to build shared projects. At translocal scale, this participation can create a place-based know-how and knowledge (Abrahams, 2014). Good **social network** and knowledge for civic participation are relevant for increasing effectiveness of such kind of initiatives (Becker et al., 2017). Even if it is time and resource consuming and it requires know-how, local actors agree on the importance of an inclusive and democratic decision process (Díaz et al., 2017) in territorial planning, which includes civic and **political participation**.

The governance and political dimension can be described by variables related to population organization (Sánchez-Zamora et al., 2017) in terms of political and civic participation, and cooperation between public institutions (Sánchez-Zamora et al., 2017).

2.4.3 Geographical and infrastructural dimension

Morphology and relationships between infrastructures and actors (Sánchez-Zamora et al., 2017) can influence the spatial-social organization and the attitude of people (Osti, 2015). Territories with different morphological features have different power relationships (Osti, 2015) and territorial cohesion is able to redistribute this power and strengthen collaborations (European Commission, 2008).

Urban and rural territories have different power relationships on different issues (Katsoulakos and Kaliampakos, 2016), different potentialities (Bridge et al., 2013) and needs (Räsänen et al., 2018), and different inhabitant's preferences (Kosenius and Ollikainen, 2013) based on their features i.e, inhabitant density, urban, agriculture, and forest land covers (Osti, 2015), elevation (Katsoulakos and Kaliampakos, 2016), surface of territory, connectivity through highway, street, and railway, and presence of natural parks (Table 2.2). Rural areas are more isolated than urban ones and connectivity from railway, streets, and highways are indicators of territorial connectivity or isolation (Aarts and Houwing, 2015; Medeiros, 2016).

Land covers determine the relationship between society and space and the use that local population makes of their land. Agriculture, forest, and urban covers are resources (i.e, from wastes) (Sacchelli et al., 2013) but also occupy space and create conflicts between actors that share and not share RE aims (Osti, 2016): *"Space must be considered as the prime scarcity factor for renewables infrastructure"* (Wolsink, 2018, p. 289) However, they are also potential RE sources in terms of wastes.

For the territorial cohesion concept, translocal planning and management of land uses is matter of territorial efficiency, quality, and identity (Abrahams, 2014). Resources and land should be effectively managed and preserved, developing the most effective territorial vocations and visions (Abrahams, 2014).

Isolation or connectivity could have an effect on the energy supply (i.e. power lines for transmission and distribution) and on some social aspects. From a social viewpoint, territorial isolation maintains attachment to local **habitus** (Bourdieu, 1990). *Habitus* are schemes of though, perceptions, actions, and practices (Reckwitz, 2002) people have in long period using energy in that local community. In some isolated contexts, communities can easily act towards sustainability through place-based *habitus* and practices (Calhoun and Sennett, 2007) such as community ownership. After economic crisis of 2008, the **isolation** of some territories decreased and the objective of territorial cohesion concept is to develop sustainable transports that do not conflict against sustainable RE production (Abrahams, 2014).

Several works (Mitchell, 2004; De Janvry, 2010; Osti, 2015) observe the **phenomena of counterurbanization**, the consequent attractiveness for tourists (Dalton et al., 2008) and youths, and the higher presence of young people in rural territories. A translocal planning can create clearer tourist and youths vocations (Abrahams, 2014). The presence of young people during the economic crisis in rural areas introduces environmental-related innovative development, i.e. in agriculture sector (De Janvry, 2010).

The geographical and infrastructural dimensions consider surface and elevation of territories, presence of natural parks, land covers, and transport infrastructures (Table 2.2).

2.4.4 Renewable energy and climate dimensions

At European scale, several environmental policies have specific impacts on territories, i.e. Water Framework Directive, Floods Directive, Habitats Directive, Waste Framework Directive and Air Quality Directive. Among these policies, The Climate and Energy Framework plays a relevant role in environmental sustainability (EEA, 2018). RE source exploitation minimizes impacts and secondary waste (Panwar et al., 2011).

The RE and climate dimensions include (Medeiros, 2016; Sánchez-Zamora et al., 2017):

Natural resource availability. It depends on the inherent feature of the territory. Biomass, water, sun, wind and heat from the Earth are the main RE sources. The availability of these natural resources depends on several spatial, socio-economic and planning constraints limiting the exploitation of RE (Sacchelli et al., 2016; Garegnani et al., 2018).

Capacity of local actors to exploit RE. Natural resources have been partly exploited. Past RE initiatives have risen negative or positive *"affective and emotive people imageries"* (Calhoun and Sennett, 2007) related to RE plants, and, consequently, they are addressing future projects (Sütterlin and Siegrist, 2017). Natural resource exploitation for RE production can create conflicts between different uses of the resource and actors (Hastik et al., 2016; Osti, 2016; Sacchelli et al., 2016; Grilli et al., 2017). However, the knowlodge on past RE projects can support energy planning by avoiding further mistakes and potential conflicts (Winkler et al., 2017) through several tools, i.e. participatory process (Hyland and Bertsch, 2018). Similar geomorphological contexts can have similar resources and municipal borders are not the best for effectively answer to planning and management needs.

Considering RE produced and distributed *in loco*, this research proposes and calculates a new index of direct participation of households in production and consumption of RE (Michaels and Parag, 2016; Hecher et al., 2017): the **index of people activity in increase RE share**. This index is not available in the current scientific literature, but it represents an important variable to for the analysis. It is calculated using the number of households covered by the local RE production out of the total number of families. The aim of this index is to understand if the contribution of households can be increased.

Climate. The climate change is perceived by local populations through phenomena i.e., avalanches and flooding. Local populations interact with natural environment (Balest et al., 2018), experiencing and reacting in front of natural hazards. The energy choices are also related to this aspect and climate change adaptation and mitigation activities have potentialities to be integrated in energy planning. Translocal answers to similar natural hazards promote sustainable and efficient risk management (Abrahams, 2014).

According to a place-based choice of variables that considers both local specificities and the availability of secondary data, this analysis is based on 41 factors (Table 2.2) and the South Tyrol case study. This list can include additional variables if applied to other case studies. This research proposes a perspective and a DST that would not only be useful to the South Tyrol case study, but that could be used as a supporting tool for translocal energy planning in other regions and countries.

[H]

Dimensions	**Specific dimensions**	**Variables**
Socio-demographic	Population size	Number of inhabitants
	Household size	Average number of household components
	Population age	Number of inhabitants within 18 years old out of total number of inhabitants
		Number of inhabitants over 65 years old out of total number of inhabitants
	Strangers	Number of strangers out of total number of inhabitants
	Variation of inhabitants	Number of inhabitants moved out or in the municipality out of total number of inhabitants
	Density	Inhabitant density
Quality of life, and household wealth	Services access	Number of kindergarten's pupils in local schools out of total number of inhabitants
		Number of primary school's students in local schools out of total number of inhabitants
		Number of secondary school's students in local schools out of total number of inhabitants
		Number of higher school's students in local schools out of total number of inhabitants
		Number of books in local libraries out of total number of inhabitants
	Quality of life	Number of cars out of number of families
Socio-economic	Income	Number of people with income lower than 10000 euros per year out of total number of inhabitants
		Number of people with income higher than 120000 euros per year out of total number of inhabitants
	Economic development	Number of active enterprises out of total number of inhabitants
	Energy focus	Number of energy enterprises out of total number of inhabitants
	Tourism	Number of tourists overnights in the territory
Cultural	Environmental attitudes of the population	Weight of urban waste out of total number of inhabitants
		Weight of differentiated waste out of total urban waste

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Dimensions	Specific dimensions	Variables
Governance and political	Political participation	Number of voters on total people who have vote rights
	Civic participation	Number of associations on total population
		Number of environmental associations out of total number of associations
	Political address	Number of votes for the most important party in the Region out of total votes
Geographical and infrastructural	Dimension of territory	Surface of municipality (km^2)
	Elevation	Elevation(m a.s.l.)
	Natural parks	Natural park surface out of total surface of municipality
	Land cover	Urban surface out of total surface of municipality
		Agriculture surface out of total surface of municipality
		Forest surface out of total surface of municipality
	Transport infrastructures	Highway surface out of total surface of municipality
		Street surface out of total surface of municipality
		Railway surface out of total surface of municipality
Renewable energy	Hot water production from RE	Surface of solar thermal plants
	Heating produced by RE sources	Power of geothermal plants (kW)
		Power of biogas plants (kW)
		RE production distributed through district heating (kWh)
	Electricity produced by RE sources	PV power (kW)
	People activity in increase RE share	Percentage of individual households who produce and/or consume RE produced *in loco*
Climate	Avalanche and flooding phenomena	Surface in avalanche phenomena out of total surface
		Number of flooding phenomena

Table 2.2: Socio-demographic, quality of life, socio-economic, cultural, governance and political, geographical and infrastructural, renewable energy, and climate dimensions of territorial cohesion, relevant for local energy planning.

2.5 The South Tyrol case study

The Provincial Climate and Energy Plan of South Tyrol (DGP n.940 June 20th 2011) (Autonomous Province of Bolzano, 2011) aims at managing the territory in a sustainable way, by saving and protecting natural resources. In order to achieve the main international targets, the Plan includes actions for energy efficiency optimization, improvements in energy saving, an increase in RE production and supply, the promotion of cultural changes, technological innovations and transnational and research collaborations. Regarding the sustainable approach to energy transition, this Plan focuses on the importance of the presence of a smart grid between production, distribution and consumption, accelerating the energy perspective shift from production and consumption (Holstead et al., 2017; Süsser et al., 2017; Winkler et al., 2018) to the role of the prosumer (Dóci and Gotchev, 2016). In this context, the Provincial Climate and Energy Plan of South Tyrol incentives the role of municipalities and the collaborations they can start with one another on local energy planning, by promoting the creation of tools that allow the comparative analysis of territories. Therefore, the analytical framework and the DST are applied to the South Tyrol case study. The choice to analyse municipalities underlines - just as the South Tyrol Plan - the importance of a comparative analysis tool, also including social resources. This framework aims at strengthening the role of inhabitants and local administrations in the energy transition and planning.

South Tyrol is an autonomous Province in North-East Italy, at the border with Austria, Switzerland, and Italian Regions of Veneto, Trentino, and Lombardia. It has 520891 inhabitants distributed into 114 rural and two urban municipalities (2016). Municipalities are distributed in a total surface of 7398,38 km^2 mainly covered by forest land, in a range of elevation, in average, between 212 and 1568 meters above sea level. Median of inhabitant density is 52,67 inhabitants on squared kilometers with the highest values for Bolzano (2036 in/km^2) and Merano (1498 inh/km^2).

The level of total RE production is medium-high in 2016:

- 212084,50 m^2 of solar thermal plants out of 7398,38 km^2 or 73983810,00 m^2 of

Municipalities surface[4];

- 6232,25 kW of installed geothermal power for heating and cooling and 341 geothermal probes;
- 229136,80 kW of installed photovoltaic (PV) power[5];
- 5951,00 kW of installed power in biogas plants;
- 839040,69 MWh of REs produced *in loco* and distributed through district heating plants;
- 41945 households and users involved in REs production through installation of individual plants (e.g. geothermal, or PV plant) or link to district heating plant[6].

In South Tyrol, solar thermal, geothermal and PV plants are usually individual choices of families and enterprises; biogas plants are usually individual or cooperative choices of agriculture enterprises; district heating is energy distribution plant which is the result of cooperative or collective choices in local territories and cover energy need of groups of units.

This research applies a cluster analysis to the 114 rural municipalities in the South Tyrol, based on the 41 factors included in the Table 2.2.

2.5.1 Cluster analysis

Data collected based on the list of dimensions and factors included in the Table 2.2 turned into percentages (Saarenpää et al., 2013). All the variables affected by surface (e.g. urban surface) or number of inhabitants were turned, except for RE production indicators. RE production indicators are related to real energy consumption data, which do not exist for Italy.

[4]Data is partial because the amount of National tax deduction on solar thermal, and PV plants is still missing in the database.

[5]Data is partial because the amount of National tax deduction on solar thermal, and PV plants is still missing in the database.

[6]Data on district heating, biogas, and solar thermal plants are supplied by Autonomous Province of Bolzano - Energy Saving Office; data on PV and, partly, solar thermal plants are supplied by gse - Atlasole; the list of geothermal plants is supplied by Autonomous Province of Bolzano - Water Resource Management Office.

Variables with large ranges can dominate the solution with respect to those with small ranges (Ketchen and Shook, 1996). For this reason, the analysis uses a standardization that is often used in order to allow an equal contribution of variables to cluster analysis[7] (Becker, 2018).

Cluster analysis is a multivariate method which analyses distances between units based on their features (Pecher et al., 2013; Härdle and Simar, 2007). Through this analysis, the units, i.e. the municipalities, are grouped in natural clusters. Within each group there is a certain level of homogeneity *versus* a certain level of no-homogeneity between groups based on n dimensions.

Since the research focuses on analysing groups of similar municipalities and its within variance, a k-means algorithm is applied. The k-means methodology (Novotná et al., 2016) defines homogeneous groups by minimizing group dispersion and maximizing between group dispersion (Härdle and Simar, 2007). The k-means algorithm focuses on the definition of a local optimum within each group, differently from other algorithms which define global optimum.

The number of clusters is chosen based on statistics of Hopkins (Banerjee and Dave, 2004), NBclust R function (Charrad et al., 2014), and level of explained variance within and between clusters (Saarenpää et al., 2013; Pinto-Correia et al., 2016).

Standardization of variables, k-means algorithm and statistics to verify the number of clusters are implemented by means of R (R Development Core Team, 2008).

[7] The standardization of column is defined as $\sqrt{\sum((x^2)/(n-1))}$, where x is a vector of values in the column and n is the number of values in the column.

2.6 Results and discussion

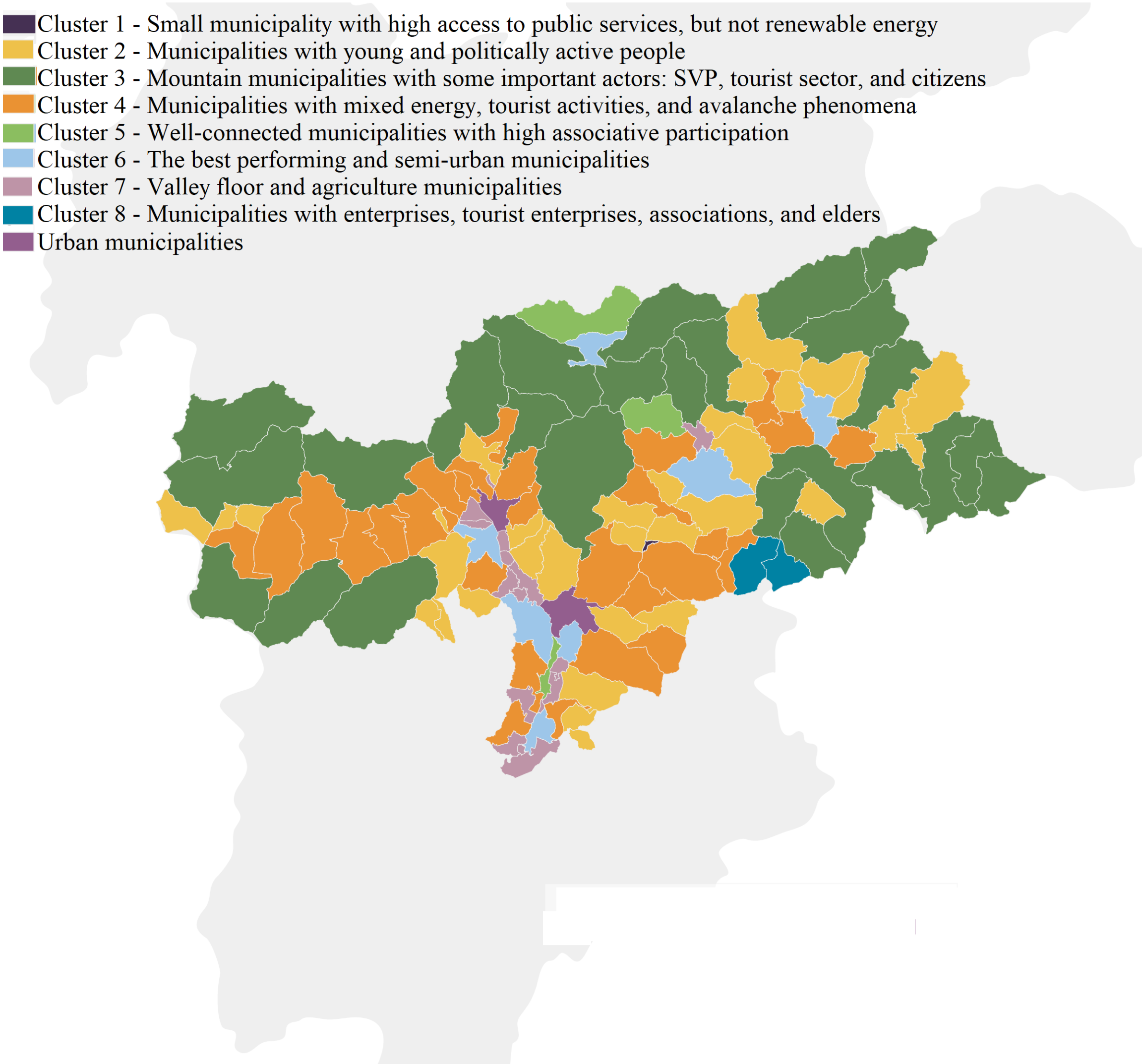


Figure 2.2: The map shows the seven clusters colour shades, in the grey context of EUREGIO Trentino-South Tyrol-Tyrol.

Figure 2.2 maps the eight homogeneous socio-energy systems of South Tyrolean municipalities through different colour shades. According to the NBclust, the best number of clusters for this database is three, but this research aims to go more into detail. The Hopkins statistics recognizes that the best number of clusters is eight, with a value of 0,2213218. Observing the results and excluding the two urban contexts of Bolzano and Merano, the clusters have the following size in terms of number of municipalities involved: 1, 34, 25, 28, 3, 7, 14, 2. The level of explained variance of these results is 38,7%.

Cl.	Description	Level of renewable energy	Relevant variables that local authorities and planners should work on for the increase of RE production	N of municipalities
1 - Small municipality with high access to public services, but not renewable energies	One municipality (Ponte Val Gardena) with low renewable energy production, and high access to kindergarten, primary school, and library services	Low	●●●● Connection through highway and railway ●●● Forest and urban land cover ● Surface ● Number of inhabitants ●●●● Percentage of strangers ●●●● Kindergarten and primary school pupils ●●●● Books in local libraries ● Associative participation ● Enterprises and tourist activities ● Experience of solar thermal, geothermal PV, and district heating plants ● People activity and interest in RE share ● [●][●][●] Differentiated wastes ●●●● Votes for Sdtiroler Volkspartei in National elections (2013) ● Flooding and avalanche phenomena	1

Continued at next page.

Cl.	Description	Level of renewable energy	Relevant variables that local authorities and planners should work on for the increase of RE production	N of municipalities
2 - Little inhabited and biogas municipalities, with young and politically active people	Little inhabited municipalities, with high percentage of youths and related higher average of household components. Political participation and SVP are prevalent. High people interest in renewable energies and experience in biogas sector	Medium	●●●● Young inhabitants ● Presence of elders ● Number of inhabitants ●●● Presence of primary school ● Presence of secondary and high school ● Urban land cover ● Percentage of strangers ●●●● Number of household components ●●●● Political participation ●●●● People activity and interest in RE share ● Enterprises ●●● Experience in biogas energy ●●●● Votes for Sdtiroler Volkspartei in National elections (2013) ●●● High elevation	34

Continued at next page.

Cl.	Description	Level of renewable energy	Relevant variables that local authorities and planners should work on for the increase of RE production	N of municipalities
3 - Mountain municipalities with some important actors: SVP, tourist sector, and citizens	Municipalities with mountain characteristics (wide surface, forest cover, medium-high elevation, sparsely inhabited, low urban and forest cover), experience in district heating plants, and interest of people in RE share and direct involvement in production	Medium	●●●● Mountain municipalities (wide surface, forest cover, medium-high elevation, sparsely inhabited, low urban and forest cover) ●●●● Number of household components ● Percentage of strangers ●●●● Votes for Sdtiroler Volkspartei in National elections (2013) ●●● Tourist activities and energy enterprises ● Associative participation ●●● Experience in district heating plants ●●●● People interest in RE share and direct involvement in production	25
4 - Mixed energy and tourist municipalities and avalanche phenomena	Municipalities with experience in PV, solar thermal, and geothermal plants. They are characterized by some flooding and avalanche phenomena. They have income inequalities, with high average of number of cars per each family.	Medium	●●● Mix of PV, solar thermal, and geothermal plants ●●●● Low and high income with related inequalities ●●●● Number of cars per family ● Associative participation and library services ●●● Tourist activities ●●● Flooding phenomena	28

Continued at next page.

Cl.	Description	Level of renewable energy	Relevant variables that local authorities and planners should work on for the increase of RE production	N of municipalities
5 - Well-connected municipalities with high associative participation	Well-connected municipalities through highway and railway. They have high associative participation and percentage of strangers. They experienced some flooding and avalanche phenomena	Medium-low	●●●● Connection through highway and railway ●●●● Flooding and avalanche phenomena ●●●● Associative participation ●●● Experience in solar thermal plants ● People activity and interest in RE share ● Enterprises ●●●● Percentage of energy enterprises out of total enterprises ● Votes for Sdtiroler Volkspartei in National elections (2013) ● Number of inhabitants and presence of elders ●●●● Percentage of strangers ● Urban land cover and secondary schools	3

Continued at next page.

Cl.	Description	Level of renewable energy	Relevant variables that local authorities and planners should work on for the increase of RE production	N of municipalities
6 - The best performing and semi-urban municipalities	The best performing municipalities with experience in PV, geothermal, solar thermal, and energy district plants. They are semi-urban municipalities in terms of urban land cover, number of inhabitants, inhabitant density, and services access. They have high associative and environmental participation	High	●●●● Connection through main roads ●●●● Income ● Enterprises ●●●● Percentage of energy enterprises out of total enterprises ●●● Tourist activities ●●●● Experience in PV, geothermal, solar thermal, and energy district plants ●●●● Urban land cover and inhabitant density ●●●● Number of inhabitants and presence of medium-aged and aged people ● Forest land cover ●●●● Books in local libraries, secondary and high school students ●●●● Associative and environmental participation ● Votes for Sdtiroler Volkspartei in National elections (2013) ●●● Flooding and avalanche phenomena	7

Continued at next page.

Cl.	Description	Level of renewable energy	Relevant variables that local authorities and planners should work on for the increase of RE production	N of municipalities
7 - Valley floor and agriculture municipalities	Small, valley floor, and agriculture municipalities with experience in PV and geothermal energy plants. They experience inequalities in income and low-medium access to services	Medium	●●●● Low and high income with related inequalities ● Surface ●●●● Agriculture land cover ● Forest land cover ●● Urban land cover ● Elevation above the sea level ●●●● Inhabitant density ● Presence of youths ● Connection through main roads ●●● Political participation ● People activity and interest in RE share ● Experience in district heating plants ●●● Experience in PV and geothermal energy plants ● Secondary school students ●● High school students	14

Continued at next page.

Cl.	Description	Level of renewable energy	Relevant variables that local authorities and planners should work on for the increase of RE production	N of municipalities
8 - Municipalities with enterprises, tourist enterprises, associations, and elders	Municipalities with important actors: enterprises, tourist enterprises, associations, and elders. They experienced avalanche phenomena and they are characterized by forest land cover	Medium-low	●●●● Enterprises ● Number of inhabitants ●●●● Presence of elders ● Presence of youths ● Presence of strangers ● Political participation ●●●● Associative participation ● Kindergarten pupils ●●●● Tourist activities ● Connection through main roads ●●●● Elevation above the sea level ●●●● Forest land cover ●●●● Avalanche phenomena ●●● Experience in geothermal and solar thermal energy plants ● Experience in PV and district heating plants ●●●● Low and especially high income with related inequalities	2

Table 2.9: Synthetic description of all clusters. The relevant variables for each cluster have high[●●●●], medium[●●●], low values[●●], or very low values[●]. In the first column, it is reported a name to the cluster to facilitate the reading rather than for summarizing the cluster characteristics.

2.6.1 The specificities of the eight socio-energy systems in South Tyrol

This research provides evidences of eight socio-energy systems within the South Tyrol context, emphasizing specificities and similarities of municipalities. There are some interesting specificities that belong to the different clusters such as the RE source preferences and difference between rural and semi-urban centres (Section 2.6.2); other planning and management needs linked to energy (Section 2.6.3); the relevance of socio-demographic features of individuals and families (Section 2.6.4); the participation and the engagement of stakeholders (Section 2.6.5); the land cover and use of a landscape (Section 2.6.6).

2.6.2 The renewable energy source preferences and difference between rural and semi-urban centres

Each cluster has its main preferences on a RE source or a mix of RE sources. For example cluster *6 - The best performing and semi-urban municipalities* focuses on a mix of RE production, while cluster *7 - Valley floor and agriculture municipalities* experiences PV and geothermal energy plants. The most performing municipalities should exchange their best practices with the other municipalities that belong to the same socio-energy system. This practice would increase the level of RE production of all municipalities within the cluster.

The produced energy is distributed *in loco* to several households that contribute for a more sustainable and renewable territory. For energy transition goals at local scale, contribution of people is important to make the difference (Van Der Schoor and Scholtens, 2015). According to the results, the semi-urban municipalities produce and distribute more energy than the rural ones. However, observing the level of *pro capite* RE production based on the index of people activity in increase RE share, this is higher in the rural clusters, such as in cluster *3 - Mountain municipalities with some important actors: SVP, tourist sector, and citizens*. The value in this index is also given by the high experience in district heating plants. Semi-urban municipality can strengthen their *pro capite* contribution to a more sustainable and renewable place, i.e. in cluster *6 - The best performing and semi-urban municipalities*.

Focusing on the land covers and uses of a territory, semi-urban or rural characteristics should address different energy planning, because they have different RE potentials

(Bridge et al., 2013) and different stakeholder and inhabitant's preferences (Kosenius and Ollikainen, 2013; Räsänen et al., 2018).

2.6.3 Other planning and management needs linked to energy

Energy planning and management is only one of the components of a wider sustainable perspective included in several policies, such as educational, natural hazard management, and economic development. In the local energy plans, climate change is a very interesting topic and some events (i.e. avalanche and flooding) need to be managed. The local energy plans are documents in which energy and climate topics can be interrelated managed, proposing innovations that can integrate mitigation and adaptation measures. Cluster *4 - Municipalities with mixed energy, tourist activities and avalanche phenomena*, *5 - Well-connected municipalities with high associative participation*, and *8 - Municipalities with enterprises, tourist enterprises, associations, and elders* have all needs to manage avalanche or flooding phenomena. The best way to manage these hazards should be addressed by all the other specificities of the clusters.

This management can be integrated in energy actions as well as other sectors and policies can be linked, i.e. tourist promotion. The South Tyrol is based on tourism activities since the end of the II World War and a development of the sector linked to a message of a more sustainable place could be effective both for energy and tourist sectors.

2.6.4 The relevance of socio-demographic features of individuals and families

Specificities of clusters in terms of socio-demographic features of individuals and families are considered for the effectiveness of energy plans. Energy planning should address or involve in its actions the most relevant components of the local society, i.e. families.

According to the results, families with higher average of components correspond to higher interest and direct-indirect activity in producing and consuming local RE both in cluster *2 - Municipalities with young and politically active people* and cluster *3 - Mountain municipalities with some important actors: SVP, tourist sector, and citizens.* A high interest and activity in producing and consuming local RE is not registered in clusters with lower number of family's components. In other studies, the family size is negatively correlated to the willingness to pay RE projects (Damigos and Kaliampakos, 2003; Zarnikau, 2003; Li et al., 2009; Stigka et al., 2014). With a different kind of analysis and in a different context, the family size seems to be an important factor to increase RE action of families. In these families, young people live.

Planners in cluster *2 - Municipalities with young and politically active people* should interpret youths and politically active people as a resource for a changing and transition world. Indeed, *"a typical green consumer is younger, more educated, and wealthier"* (Paravantis et al., 2018). Re-address or use the political participation towards RE goals is not easy, but it has great potential to increase RE development (Zoellner et al., 2008; Müller et al., 2011). Associations and political groups can be means to increase awareness and information about RE (Rogers et al., 2012), through their relevance as local actors and their networks within and across municipalities.

2.6.5 The participation and the engagement of stakeholders

Stakeholders at local scale are relevant in energy planning. They represent the public of energy planning, beyond the mere citizens and families and they should be involved in the energy planning. Stakeholders are actors and resources that know the territory and that have interest to incentive regional and local development. Cluster *8 - Municipalities with enterprises, tourist enterprises, associations, and elders* has three actors that can contribute with their needs and resources to a more effective energy plan. These actors and their relationships could be included in a participatory process in order to collect local needs and confirm local resources.

Political commitment has also high potential to increase RE development (Sovacool and Ratan, 2012). The relevant presence of SVP political party is a resource that can be used to increase the interest and the political and civic commitment towards energy transition. The cluster *3 - Mountain municipalities with some important actors: SVP, tourist sector, and citizens* is an example of SVP relevance.

2.6.6 The land cover and use of a territory

Land cover specificities define energy production potential based on local resources given by urban, forest, and agriculture wastes and products (Sacchelli et al., 2013). Local planners could consider the opportunities to collaborate with owners of these lands for achieving common goals. Cluster *8 - Municipalities with enterprises, tourist enterprises, associations, and elders* registers a wide forest surface. It could prefers biomass plants more than other clusters (Kosenius and Ollikainen, 2013), because it could use their own resources supplying other services (i.e. forest management). Cluster *7 - Valley floor and agriculture municipalities* has a different energy potential composed by agriculture wastes. However, agriculture land cover is sometimes also an element of competition between the space occupied by agriculture crops or RE production plants (Osti, 2016).

2.7 Conclusion

This research aims to present and test a socio-energy system framework to explore territory. This framework supports regional and local energy planners for the definition of effective plans. The analysis does not want to be exhaustive, but it shows how homogeneous groups of municipalities differ one from another and which are the main specificities for addressing local energy plans to achieve a wider change in terms of RE development.

Local energy planners have the important role of defining the potentialities and future actions to increase local RE production, without weakening natural and social environments. The planning of a territory needs comprehensive information on the local specificities and its relationships with other territories. **This research proposes a Decision Support Tool based on an analytical framework which joins social, energy, and planning sciences perspectives defining territory as socio-energy system at translocal scale.**

The Decision Support Tool provides some recommendations on how to use social, energy, and spatial specificities as levers for wider achievement of climate change and energy targets at translocal scale, promoting important planning implications. The analytical framework and the Decision Support Tool are applied in the South Tyrol case study (Italy) and they are a replicable instrument for other regions.

Chapter 3

Sustainable energy governance practice

Submitted as Balest et al. (2019)

3.1 Abstract

This research aims to analyse with a statistical **network analysis, Bayesian analysis, and exponential random graph model** the **sustainable energy governance practice** set in local contexts, investigating the opportunities to spread it within a region. In this research, the sustainable energy governance is the practice to plan and manage energy resources at local scale and in a collaborative way. The local scale is important to effectively plan and manage energy resources based on local specificities, while the collaborative governance permits to share, save, and protect several kinds of resources.

Energy governance is practised within energy districts. This research defines **sustainable energy district** as territorial district within a region, based on formal or informal relationships, in which municipalities collaborate one another in a sustainable way through contracts with public utilities that supply energy services.

In the South Tyrol case study (Italy), through a Bayesian exponential random graph model, this research identifies the network structures and dynamics that are at the basis of the actual energy governance and identify some elements that might further spread sustainable energy governance.

The results of this research confirm that almost of the collaborations are based on spatial closeness dynamics.

3.2 Introduction

International environmental organizations sustain that there are two choices in the world: on the one hand, the choice for a sustainable world (Keeble, 1988; Sachs, 2015); on the other, the choice to forget a sustainable, zero or de-growth development and increase people's pressures on natural and social world (Vandenhole, 2018). There is a grey zone for intermediate actions, but if the aim is the sustainable development, the choice should commit for cleaner production and energy transition.

Based on **cleaner production** and **energy transition processes**, the sustainability addresses persistent environmental and social problems and needs (Geels, 2011). Sustainability can be reached through a global governance in which each level has its own responsibilities, challenges, opportunities and mechanisms (Jänicke, 2017). Jänicke (2017) states that the *"global system provides a stable opportunity structure for clean-energy innovation, allowing for interactive learning and dynamic action within and between levels"* (Jänicke, 2017, p. 111). The actors who govern the energy (i.e., States, NGOs, municipalities) are currently able to govern in a horizontal and networked way, creating a governance system (Fontaine, 2010) that mobilizes multiple actors, resources, and dynamics (Jänicke, 2017). Indeed, the governance is an arena in which multi-actor, multi-sector, and multi-level relationships, power relations, and networking exist (Rametsteiner, 2009; Secco et al., 2014) with the aim to administer a part of the public and social life.

In relation to the administration of public and social life, energy governance can be described and investigated as a social function (Merton, 1968) or a social practice (Shove and Walker, 2010). Energy governance as a social function plays a role in the social life contributing to its continuity (Merton, 1968). Using the social function approach, energy governance is a recurrent activity that helps the daily social life of groups and individuals to be reproduced. Social function continues responding to social needs (Merton, 1968; Geels and Schot, 2007) - such as energy consumption - and supporting lifestyles and values of political and social actors - such as environmental, sustainable and renewable ones. Unlikely, using the **social practice approach**, this research moves the focus on the opportunities and the conditions to change towards a more sustainable life (Shove and Walker, 2010). As a social practice, energy governance is a way to govern composed by several elements that interact one another (Shove and Walker, 2010). These intertwined elements are the material things (i.e., RE technologies or sources), a common understanding by social actors on how to use them, a recognition of the appropriate behaviours (i.e., competences to use RE technologies), and related meanings (Shove et al., 2012). The governance practice is a collective experience in the sense that there are many co-existing performances (Shove et al., 2012) of doing sustainable energy governance, in a common understanding way, and that impact on everyday life of people. The social function concept is created for investigating what maintain the equilibrium in the society, weakening the role of change (Merton, 1968), while the shift from function to practice better addresses the investigation of the change (Shove and Walker, 2010).

Considering the energy governance as practice according to social practice approach (Shove and Walker, 2010), the change is promoted by its elements and by the change of other related practices. Energy governance is linked to other practices such as local government of natural resources, community and private ownership of natural resources, energy consumptions in houses, and their ongoing interactions. All these elements of practice are **spread through relationships between actors** (Shove and Walker, 2010). If something change in the network and in the dynamics of relationships between the involved actors, all relationships and all elements of social practice will change looking for another equilibrium between practices and elements. The spread of a sustainable energy governance into relationships between actors confirm or deny the existence of a social practice and its importance into the change processes of energy transition (Shove and Walker, 2010). The energy governance practice is linked to other practices and related opportunities to change towards a more sustainable way to answer local population and energy needs.

The **energy governance** interacts with other practices. The practice of sustainability or sustainable actions characterized by careful use of natural resources and RE is globally recognized and represents a common objective (Leal Filho et al., 2016; Jänicke, 2017), even if other economic and financial dynamics can compete (Sassen, 2004). In the cleaner production and energy transition, behind global and international actors, low-carbon energy measures are appropriate when shaped on regional and local specificities, circumstances, needs, and preferences (Union, 2014). **The practice of planning and managing territorial resources and needs at local level** (Jänicke, 2017) is important for its closeness to the local scale and for the recognition of local specificities (i.e., natural energy potential). This practice underlines the peculiar responsibilities, opportunities, challenges, and dynamics (i.e., peer-to-peer learning, competition and cooperation) at the local scale (Jänicke, 2017) in a polycentric system in which multiple authorities govern (Ostrom, 2010; Sovacool, 2011). At the local scale, **the practice to collaborate** between non-state actors (i.e., governance involving municipalities and public utilities (PU)) (Leal Filho et al., 2016; Niesten et al., 2017) mobilizes *"a broad swathe of actors to pursue sustainability"* (Jänicke, 2017). In the practice of collaboration, relationships are build settings where trust and reciprocity can emerge, grow, and be sustained over time. Further, costly and positive actions are frequently taken without waiting for an external authority to impose rules, monitor compliance, and assess penalties (Ostrom, 2010). Trust and reciprocity emerge with actors with whom you have prior experience of collaboration (Nielsen, 2004) that are usually, considering local authorities, between spatially closed and neighboured municipalities. However, the complexity of trust (Nielsen, 2004) and collaborations, stress the need to investigate **the practice to collaborate with similar others** (European Commission, 2008; Medeiros, 2016) for having a more effective energy planning and management. **The practice of planning and managing territorial resources and needs at local scale** recognizing local specificities, and **the practice to collaborate with similar others** are important to define the wider **practice of sustainable energy governance** within a region[1]. For this reason, this research investigates the actual sustainable energy governance practice and the opportunities for its spread.

The sustainability of the energy governance is given by multiple aspects, including its capacity to promote resource efficient uses with the aim to meet existing social and environmental needs (Shove and Walker, 2010). The sustainability of regional and local energy governance is given by the attention of the actors to the regional and local features and needs, in the ongoing interaction between global and local contexts (European Commission, 2008; Medeiros, 2016). In a multi-actor, multi-sector, and multi-level energy governance (Sovacool, 2011; Secco et al., 2014), this research focuses on some scales and

[1]The sustainability concept is huge and it does not include only the meaning considered in this paper (Geels, 2011; Leal Filho et al., 2016).

actors that better represent and understand local specificities (Bulkeley and Kern, 2006; Novotná et al., 2016). Who and how govern the energy are relevant topics to promote the change into a more sustainable world (Sachs, 2015).

Based on its component of closeness to the territorial needs and resources, the local and sustainable governance is matter of a multiple range of actors, such as local authorities (Novotná et al., 2016), and is pursued thanks to local tools (Coelho et al., 2018) and with the support of other actors. Sustainable energy governance is spread through relationships in a space, i.e. energy district. Here, this research defines **sustainable energy district** as territorial district within a region, based on formal or informal relationships, in which municipalities (the closest authority to local specificities) collaborate one another in a sustainable way, also using means as PU. The sustainable energy districts are the space in which energy governance is practised and PU are an important actor that support municipalities in order to achieve international energy targets supplying services and answering to local and energy needs. Municipalities and PU are not the only actor involved in the energy governance: other direct collaborations between municipalities and with no structured actors (i.e. other regional and local stakeholders) exist. However, the collaboration between municipalities and PU is an important and structured relationship that formally supply energy services to local population (Mejía-Dugand et al., 2017).

This paper recognizes the energy governance as practice and focuses on the relational elements to investigate the opportunities to extend sustainable energy governance. **It investigates the presence and the opportunities to extend the existing sustainable energy governance through relationships in an energy district**. Practically, this research investigates the relationships based on contracts between municipalities and PU in the energy governance, their characteristics, the relevant relational dynamics, and the probability to observe new relationships between municipalities and PU. These relationships and these actors, behind the share of an objective, have other characteristics. Collaborations can involve different relational and group dynamics and the actors involved in the collaboration can have different characteristics. Considering the municipalities as actors, studies on natural potential and availability of renewable resources already exist - i.e., Sacchelli et al. (2013); Garegnani et al. (2018) - and the sharing of these kind of resources incentives equal collaborations between similar actors (European Commission, 2008; Medeiros, 2016). Statistical network analysis investigates these actors' relationships and characteristics, exploring if the contracts with PU happen between municipalities that have similar features of energy potential, i.e. forest, agriculture, urban, solar. Statistical network analysis also investigates relational dynamics (or their absence) that shape and spread the actual energy governance network, such as the presence of edges, stars, or other shapes of relation.

Our approach investigates these relational formation of the network by using a Bayesian exponential random graph modelling approach (Caimo and Friel, 2011) for bipartite networks. Exponential random graph models represent an important family of log-linear network models that aim to describe the probability distribution of the edges among pairs of nodes in a network using a set of network configurations.

This paper is a **first application of statistical network analysis approach with the aim to model sustainable energy districts.** A Bayesian exponential random graph modelling has been applied to the South Tyrol case study. South Tyrol case study is interesting for its commitment to energy transition (Autonomous Province of Bolzano, 2011) and its partial freedom form national legislation on energy topics in comparison with other Italian regions. South Tyrol is an autonomous province in the North-East Italy and it has an energy governance based on collaborations between 120 PU and 116 rural municipalities. The results of this research can be used by the provincial and local energy planners and managers of South Tyrol for addressing new collaborations in energy sector and changing the energy governance practice for a wider achievement of international and provincial energy transition goals. This research proposes also a methodology that can be easily applied to other case studies.

3.2.1 Hypothesis

In the analysis of the relational dynamics (defined in terms of small network structures or configurations) behind the spread of sustainable energy governance between municipalities and PU that model the actual sustainable energy districts in South Tyrol, this research proposes some hypothesis.

Hypothesis 1: Municipality uses, plans, and manages the energy through energy services supplied by PU in collaboration with other municipalities

This hypothesis is investigated through the existence of edges, isolated nodes, and degree density.

Hypothesis 2: Contractual relationships among municipalities and PU are more likely to be observed when municipalities belong to the same geomorphological context

This hypothesis is investigated through homophily of municipalities in terms of geomorphological context: if two or more municipalities belong to the same geomorphological valley, they have already collaborated and they have already built a trust (or distrust) that renovate old and new collaborations (Nielsen, 2004).

Hypothesis 3: Contractual relationships among municipalities and PU are more likely to be observed when municipalities are spatially closed

This hypothesis is investigated through homophily of municipalities. As hypothesis 2, the same dynamics are hypothesized here: collaborations are more likely to be observed between spatially closed municipalities.

Hypothesis 4: Contractual relations between municipalities and PU are less likely to be observed when PU supplies equal or similar energy activities

This hypothesis is investigated through homophily of PU, in terms of their main activities (i.e., solar thermal energy production, district heating distribution). PU are means of collaboration for answering to different municipality's and local population's needs: more PU with the same energy activities would be a duplicate.

Hypothesis 5: Contractual relations among municipalities and PU are more likely to be observed when municipalities have similar energy potential (i.e., urban, forest, agriculture land covers and solar radiation)

This hypothesis is investigated through homophily of municipalities about the nature and the similarities of renewable sources. The site-specific nature of renewable sources is described by urban, forest, agriculture land covers and solar radiation (Sacchelli et al., 2013; Garegnani et al., 2018). When two or more municipalities share similar renewable sources, they build shared objectives and projects for an equal development (European Commis-

Data	Description	Year	Case study	Source
Network data	Relationships between municipalities and public utilities in energy sector	2016	South Tyrol	Ministry of Economics and Finance
Geomorphological valley and closeness	Geomorphological valley, longitude and latitude. An index about closeness between municipalities is calculated	2016	South Tyrol	Ancitel open data: own elaboration
Urban, agriculture, and forest land cover	The percentage of each type of land cover out of the total surface. The indices are calculated based on CORINE database and bordering of municipalities	2016	South Tyrol	CORINE Land Cover, Ancitel open data: own elaboration
Solar radiation	Mean of solar radiation	2016	South Tyrol	PVGIS: own elaboration

Table 3.1: Data description and sources used in this research.

sion, 2008; Medeiros, 2016).

Based on these hypothesis, this research applies Bayesian exponential random graph model to the network of collaborations between municipalities and PU in South Tyrol.

3.3 Methods

3.3.1 Energy governance network data in South Tyrol

This research testes the hypothesis and Bayesian inference for ERGMs into the South Tyrol case study. South Tyrol is an area placed in the North-Eastern Italy and composed by 116 municipalities. The municipalities are represented by cycles linked to 120 public utilities that are represented by triangles in the Figure 3.1.

The analysis considers some municipality's characteristics, i.e., geomorphological valley, land cover, and solar radiation (Table 3.1), according to the hypothesis (Section 3.2.1) and **the practice to plan and manage the territorial resources and needs at local scale and the practice to collaborate with similar others** (Section 3.2).

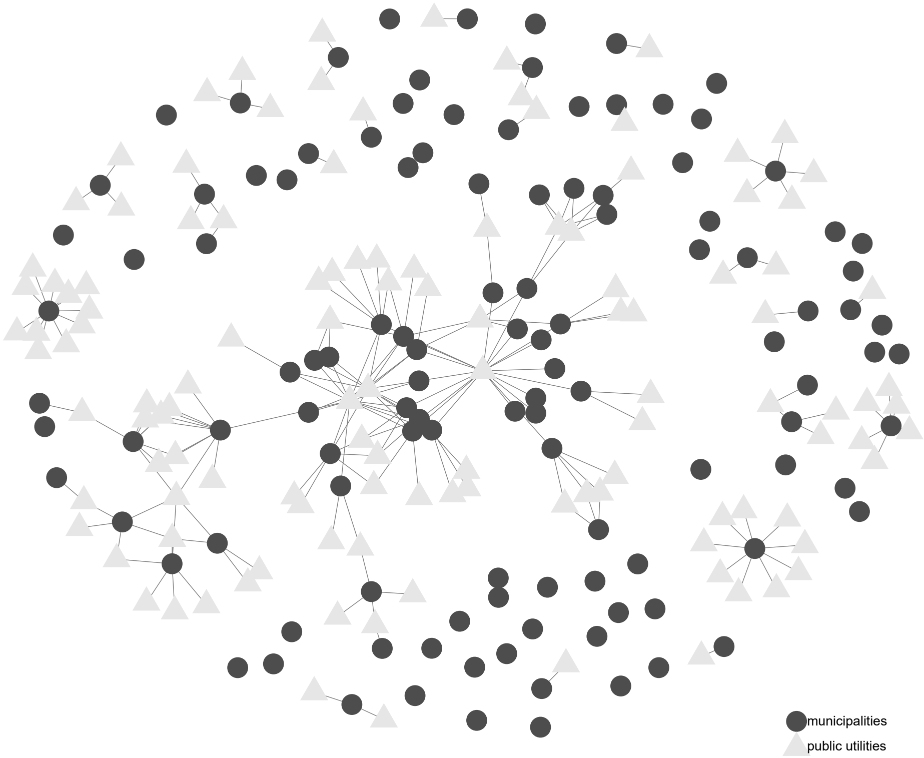


Figure 3.1: The graph represents the municipalities (circles), the public utilities (triangles), and the relationships between them (lines).

3.3.2 Bipartite network data

This is a two mode network composed by the first (municipalities) and the second (PU) modes, with uniplex relations (Figure 3.1). The uniplex is based on relations set on a service contract, in terms of delivery of energy services or goods, and moreover there is an arrow from the municipality to the PU in terms of contractual duties based on the contract. Accordingly, this network is represented as an undirected graph and all the relations among the two modes can be represented without specifying the arrows.

3.3.3 Exponential random graph models (ERGMs)

Typically networks consist of a set of actors and relationships between pairs of them, for example social interactions between individuals. The relational structure or configuration of a network graph is described by a random adjacency matrix Y of a graph on n nodes (actors) and a set of edges (relationships) $\{Y_{ij} : i = 1, \ldots, n; j = 1, \ldots, n\}$ where:

$$Y_{i,j} = \begin{cases} 1, & i \sim j; \\ 0, & i \not\sim j. \end{cases}$$

Exponential random graph models (ERGMs) are a particular class of discrete linear exponential families which represent the probability distribution of network graphs on n nodes as:

$$p(y|\theta) = \frac{\exp\{\theta^t s(y)\}}{z(\theta)},$$

where $s(y)$ is a known vector of sufficient statistics, θ are the associated model parameters, and $z(\theta)$ a normalising constant which is difficult to evaluate for all but trivially small graphs. The dependence hypothesis at the basis of these models (Section 3.2.1) is that edges self organize into small network structures called configurations. There is a wide range of possible network configurations (Robins et al., 2007) which give flexibility to adapt to different contexts. A positive parameter value for θ_i result in a tendency for the certain configuration corresponding to $s_i(y)$ to be observed in the data than would otherwise be expected by chance.

3.3.4 Bayesian inference for ERGMs

The growing interest in Bayesian techniques for the analysis of social networks can be attributed to the development of efficient computational tools and the availability of user-friendly software. Bayesian analysis is a promising approach to statistical network analysis because it yields a rich picture of the uncertain quantities which is essential when dealing with complex statistical network models and heterogeneous relational data. Using a Bayesian framework leads directly to the inclusion of prior information about the network structure into the modelling framework, and provides immediate access to the uncertainties by evaluating the posterior distribution of the parameters.

Bayesian inference for ERGMs is based on the posterior distribution of θ given the data y:

$$p(\theta|y) = \frac{p(y|\theta)\; p(\theta)}{p(y)} = \frac{\exp\{\theta^t s(y)\}}{z(\theta)} \frac{p(\theta)}{p(y)},$$

where $p(\theta)$ is a prior distribution that assigns a probability distribution reflecting prior beliefs about the values of the parameter before analysis the data and $p(y)$ is the evidence or marginal likelihood of y which is typically computationally intractable.

Standard MCMC (Markov Chain Monte Carlo) methods such as the Metropolis-Hastings algorithm, can deal with posterior estimation as long as the target posterior density is known up to the model evidence $p(y)$. Unfortunately in the ERGM context the posterior density $p(\theta|y)$ includes two intractable normalising constants, the model evidence $p(y)$ and $z(\theta)$. For this reason, the ERGM posterior density is computationally 'doubly intractable'.

In order to carry out Bayesian inference for ERGMs, the Bergm package (Caimo and Friel, 2014) for R makes use of a combination of Bayesian algorithms and MCMC techniques including the approximate exchange algorithm which circumvents the problem of computing the normalising constants of the ERGM likelihoods, while the use of multiple chains and efficient adaptive proposal strategies are able to speed up the computations and improve chain mixing quite significantly (Caimo and Friel, 2011, 2013; Caimo and Mira, 2015). This paper makes use of the fast pseudo-posterior correction approach proposed by (Bouranis et al., 2017) to estimate the posterior distribution of the ERGM parameters.

3.3.5 Model specifications

Given hypothesis included in the Section 3.2.1, the main model specifications are listed in the Tables 3.2 and 3.3. The (exogenous) statistics that have an attribute are closely related to the hypothesis (Table 3.3), while the statistics without an attribute (endogenous) (Table 3.2) overlook the characteristics of the network and better fit the goodness of the model (Caimo and Lomi, 2014; Caimo et al., 2017).

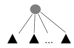
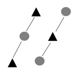
Hypothesis	Statistics name	Attribute	Description	Visualization
Hypothesis 1	edges	None	Number of edges in the network	
Hypothesis 1	gwb1degree	None	Weighted degree distribution for nodes in the first mode (municipality) of the bipartite network. It gives an idea on equal distribution of nodes or distribution around few central nodes in the network	
Hypothesis 1	isolates	None	Number of nodes with degree zero	
Hypothesis 1	b1degree(1)	None	Number of nodes of degree 1 in the first mode (municipality) of the bipartite network. Similar to the edge, degree 1 is represented only by the figure and not the figure included in other configurations	
Hypothesis 1	degree(2)	None	Number of nodes in the network of degree 2, with exactly 2 edges	

Table 3.2: The table lists model specifications in terms of endogenous statistics.

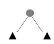
Hypothesis	Statistics name	Attribute	Description	Visualization
Hypothesis 2	b1nodematch	Valley	Nodal valley-based homophily effect for the first mode (municipality) in the bipartite network	
Hypothesis 5	b1nodematch	Urban land cover	Nodal urban land cover-based homophily effect for the first mode (municipality) in the bipartite network	
Hypothesis 5	b1nodematch	Forest land cover	Nodal forest land cover-based homophily effect for the first mode (municipality) in the bipartite network	
Hypothesis 5	b1nodematch	Agriculture land cover	Nodal agriculture land cover-based homophily effect for the first mode (municipality) in the bipartite network	
Hypothesis 3	b1nodematch	Closeness	Nodal closeness-based homophily effect for the first mode (municipality) in the bipartite network	
Hypothesis 5	b1nodematch	Radiation	Nodal radiation-based homophily effect for the first mode (municipality) in the bipartite network	
Hypothesis 4	b2nodematch	Activity	Nodal activity-based homophily effect for the second mode (PU) in the bipartite network	

Table 3.3: The table lists model specifications in terms of covariate statistics.

3.3.6 Software

The R code implementing the methodology proposed in this paper makes use of the Bergm package (Caimo and Friel, 2014) to analyse the bipartite structure of the observed network graph and will be available on GitHub.

3.4 Results and discussion

3.4.1 Posterior estimates

Parameter (statistic)	Mean	Median	2.5%	97.5%
θ_1 (edges)	**-4.7247**	**-4.7364**	**-5.5080**	**-3.9151**
θ_2 (gwb1deg)	**-6.7181**	**-6.6652**	**-9.0727**	**-4.7058**
θ_3 (isolates)	**-6.8594**	**-6.7607**	**-9.9957**	**-4.2771**
θ_4 (b1deg1)	**-2.6944**	**-2.6720**	**-3.9257**	**-1.5968**
θ_5 (degree2)	**-0.9822**	**-0.9859**	**-1.4762**	**-0.4855**
θ_6 (b1nodematch.valley)	**1.1404**	**1.1486**	**0.2605**	**1.9892**
θ_7 (b1nodematch.urban.clc)	0.4278	0.4395	-0.3964	1.2220
θ_8 (b1nodematch.forest.clc)	0.5629	0.5633	-0.4048	1.4964
θ_9 (b1nodematch.agric.clc)	-0.0249	-0.0248	-1.0123	0.9727
θ_{10} (b1nodematch.closeness)	**1.2382**	**1.2267**	**0.5752**	**1.9529**
θ_{11} (b1nodematch.radiation)	**0.8199**	**0.8146**	**0.0770**	**1.5745**
θ_{12} (b2nodematch.PU.nature)	-0.2243	-0.2255	-0.8980	0.4538

Table 3.4: Posterior mean, median and 95% credible intervals.

The analysis uses vague prior distributions for all the parameters, i.e., $\theta_i \sim N_d(\mu, \Sigma)$, where the dimension d corresponds to the number of parameters, μ is mean vector centred at 0 and Σ is a $d \times d$ diagonal covariance matrix whose variances are all set to equals 100.

The posterior estimates of the parameters explain the importance of the corresponding network statistics in explaining the overall connectivity structure of the observed bipartite network. The lines in bold in the Table 3.4 represent the posterior parameter summaries for which 0 does not fall in the credible intervals. This means that the bold posterior parameters are relevant in explaining the actual network, considering the whole used model.

The model investigates the diffusion of energy governance practice based on relationships between municipalities and PU, and underlines the practices below the energy governance in South Tyrol. The actual network (Figure 3.1) has low density characterised by few edges (θ_1, θ_2, θ_4 in Table 3.4) and 53 isolated municipalities (θ_3 in Table 3.4). This means that **the practice of planning and management of territorial resources and needs at local scale through contracts between municipalities and PU** exists but it is not used by almost half of the municipalities. Therefore, the findings partly confirm **Hypothesis 1** of the Section 3.2.1: the values of edges (θ_1), and the network density (θ_2, θ_4) are low (Table 3.4), counting 53 out of 116 municipalities that do not use, plan, and manage the energy through energy services supplied by PU. Further, the presence of PU that supply the services of only one municipality is relevant (θ_5), partly confirming the second part of Hypothesis 1 of the Section 3.2.1: the municipalities that use, plan, and manage the energy through energy services supplied by PU do not always collaborate with other municipalities. **The practice to collaborate between municipalities by means of shared PU** is only partly spread (θ_5) and involve 32 out of 120 PU.

Deepening **the practice to collaborate** including the characteristics of actors - the so called covariate statistics (Table 3.3) - and **the practice to collaborate with similar ones**, this research defines some relevant shared features of municipalities. Looking at the Table 3.4 and its θ_6, θ_{10}, and θ_{11}, the findings show that the municipality attributes of valley, spatial closeness, and solar radiation are relevant to explain the two-star configurations: two municipalities share the same PU when they are closed one each other, belong to the same valley and have similar range of solar radiation. The two-star configurations based on urban, forest, and agriculture land cover of municipalities (Table 3.3) are not relevant to explain the actual network as well as the activities of PU are not relevant to explain the network configuration. **The practice to collaborate with similar others** is only confirmed considering geomorphological context (**Hypothesis 2** of the Section 3.2.1), spatial closeness (**Hypothesis 3** of the Section 3.2.1), and solar radiation characteristics (partially confirming the **Hypothesis 5** of the Section 3.2.1). The **Hypothesis 4** and partially the **Hypothesis 5** are not confirmed in the South Tyrol energy governance. According to the results, the practice of local government just recognises the solar radiation as local resource to use as mean to collaborate with other municipalities for planning and managing the energy. This could be due by a multiplicity of tools in South Tyrol for energy planners that increases the awareness about the solar radiation resource (Rete Civica dell'Alto Adige), while the results in other regions where this awareness is weaker could be different. Several studies on urban, forest, and agriculture land cover and energy potential have been done for the South Tyrol area, but not online results are available. This may mean that energy planners and managers do not have enough information on urban, forest, and agriculture potentialities to build *ad hoc* collaborations. Furthermore, a common range of solar radiation can describe similar morphological characteristics but, in this case, not similar (urban, forest, and agriculture) land cover and natural energy potentials.

3.4.2 Goodness-of-fit diagnostics

A way to examine the fit of the data to the posterior model and the output obtained is to implement a Bayesian goodness-of-fit procedure (Hunter et al., 2008). To do this, network graphs are simulated from independent parameter values randomly drawn from the estimated posterior distribution and compared to the observed network data in terms of high-level characteristics which are not modelled explicitly. In this context, since the research is dealing with a bipartite network, it focuses on the degree distribution.

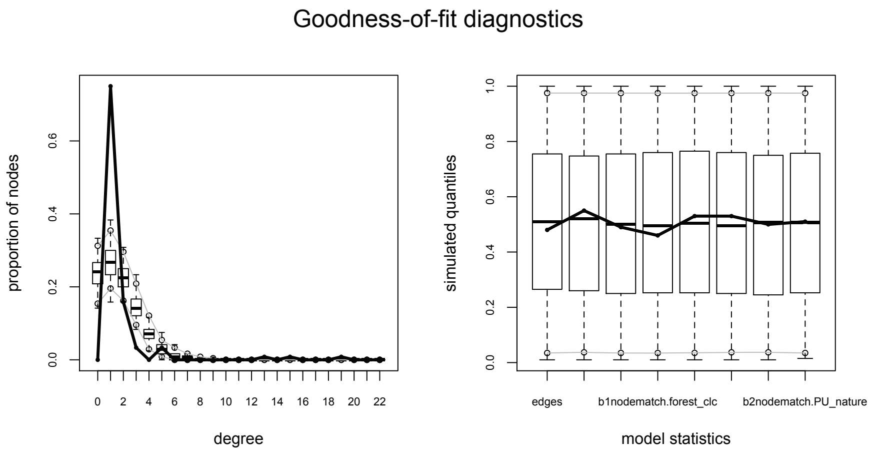


Figure 3.2: Goodness of fit of the first model including only covariate statistics.

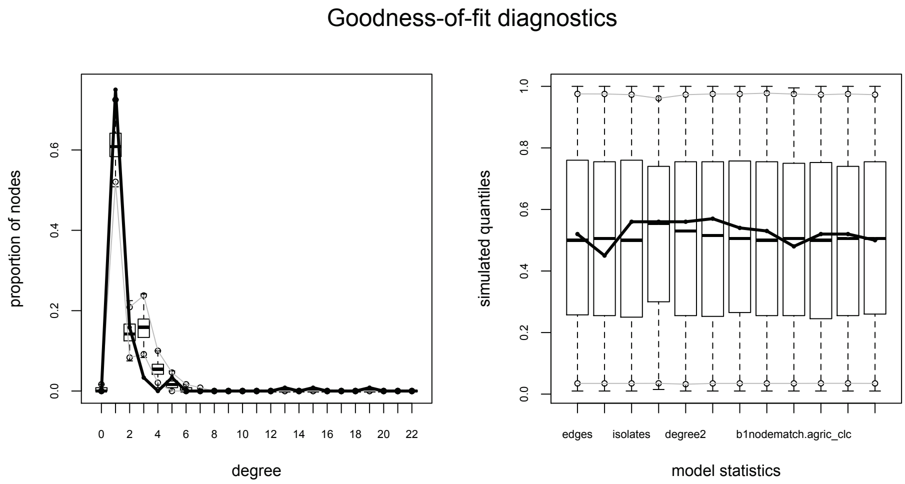


Figure 3.3: Goodness of fit of the second model including endogenous statistics.

The black solid lines represent the distributions of the observed data. The boxplots represent the goodness-of-fit distributions calculated on 100 network graphs simulated from ERGMs based on valued sampled from the estimated posterior distribution. The solid light grey lines mark the 95% intervals. An estimated ERGM is fitting perfectly a certain observed network if the black line falls inside this interval – a result that is very difficult to obtain in practice.

Figures 3.2 and 3.3 show that the model including the extra-dyadic endogenous network statistics[2] better fits the actual network with respect to the model including only covariate statistics.

3.4.3 The relevance of bridges and their probability to exist

The model and its estimates are not only relevant to understand the network dynamics below the actual relationships. Based on model estimates, this research investigates the probability of each edge to be observed compared to not be observed (odds), when it exists and when it does not exist. Once the findings confirm that only 63 out of 116 municipalities use **the practice of planning and managing the territorial resources and needs at local level through contracts with PU**, the research questions the opportunities

[2]Endogenous network statistics are dyadic-based statistics based only and include connectivity information, while exogenous are covariate-based network statistics and contain information on nodal or dyadic attributes.

to spread this practice. The bridges can be mean to spread energy governance practice to the isolated nodes.

In particular, the results underline that some existing edges have low probability to be observed (conditional on the rest of the network structure being fixed), while almost of the not existing edges have low probability to be observed. In the first case, the existing and low likely edges follow dynamics that the model does not consider (i.e., a conflict between municipality and PU). The model is not able to explain why some edges exist. *Vice versa*, the not existing edges are well-explained by the model due by significant presence of isolated municipalities.

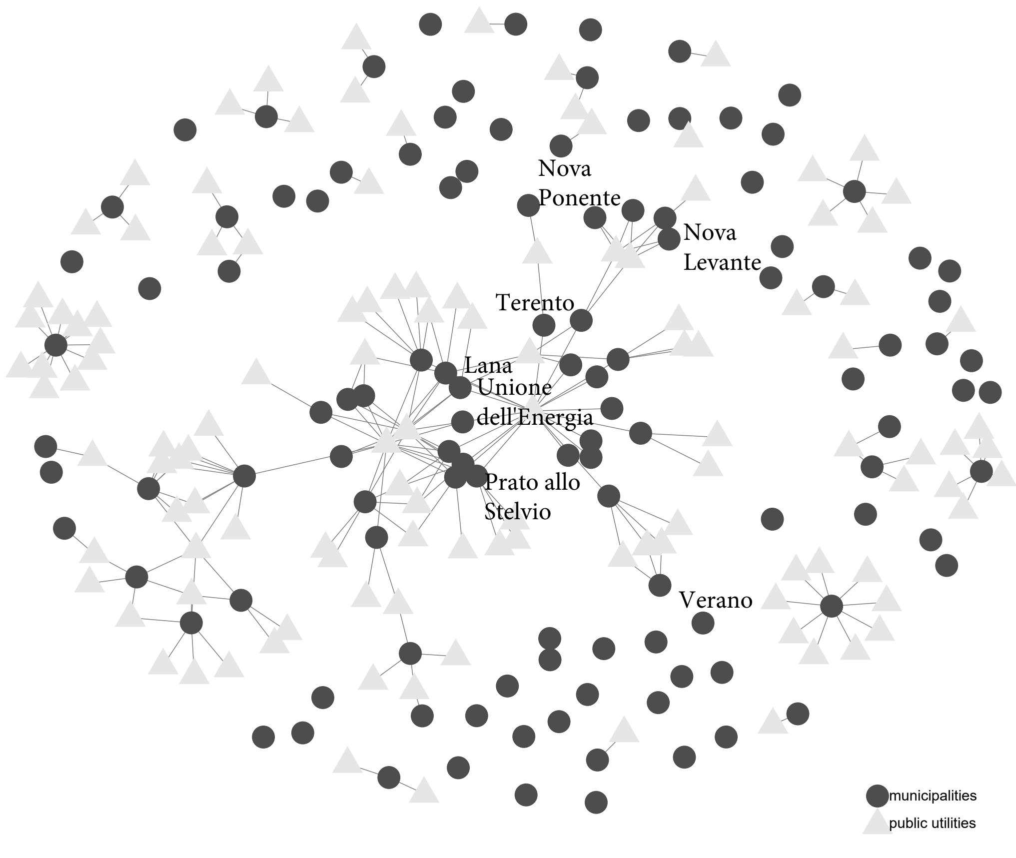


Figure 3.4: The representation of the network shows several bridges, i.e. Unione dell'Energia. Considering as an example, Unione dell'Energia is linked to Terento, Prato allo Stelvio, and Lana and is not linked to Nova Levante, Nova Ponente, and Verano.

The role of bridges may be relevant to spread energy governance and change into wider sustainable energy districts. For this reason, the research investigates the relevance of the main bridges of the network to create new relationships, calculating the probability to have new edges around the main bridges of the network. The Figure 3.4 shows some bridges (i.e., Merano, Prato allo Stelvio, Egna, Bressanone, Unione dell'Energia, Consorzio energetico, Cooperativa energetica) and observes that some existing relationships should not exist according to the model (Figure 3.5). A further investigation on the conditions of their existence may promote a change towards wider energy governance.

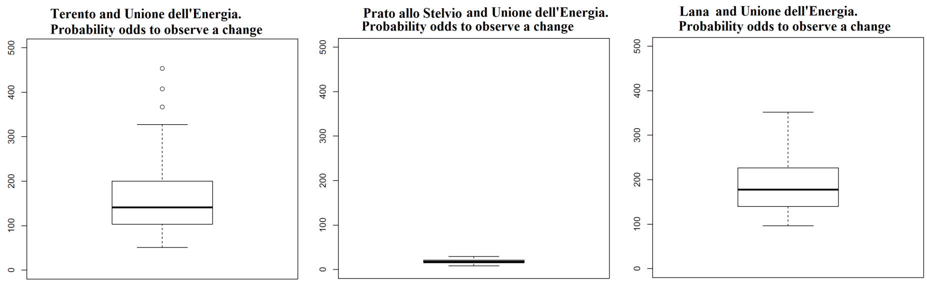


Figure 3.5: The boxplots represent the probability odds to observe three edges that already exist between Unione dell'Energia (PU) and the municipalities of Terento, Prato allo Stelvio, and Lana. Where values are higher than 20, the change from the existent edge to the not existent edge is significantly likely.

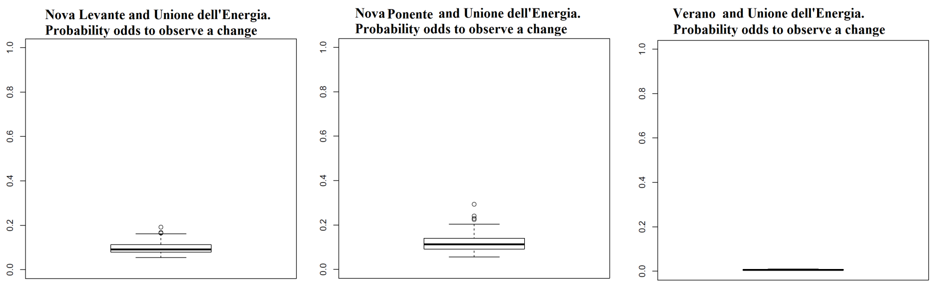


Figure 3.6: The boxplots represent the probability odds to observe the three edges that do not exist between Unione dell'Energia (PU) and the municipalities of Nova Levante, Nova ponente, and Verano. Where values are lower than 0.05, the creation of new edges in those dyads is very low.

As an example, considering Unione dell'Energia (PU) as a bridge that might spread energy governance practice, its relationships with Terento, Prato allo Stelvio, and Lana have low probability to be observed (Figure 3.6). But they still exist. The dynamics beyond these relationships should be deepen investigated (also through qualitative research) looking for dynamics that drive the change. Some relationships that currently exist have low probability to be observed according to the model estimates. These relationships are interesting, because they could involve the conditions of the change that the model is not able to explain.

Summing up, the network will probably change reducing the number of edges (Figure 3.5), but without introducing new ones (Figure 3.6). For supporting some changes in relationships and spreading sustainable energy districts, other dynamics and practices would be introduced. The model recognizes that today **the practice to collaborate with neighbour municipalities** and **the practice to locally govern based on common solar radiation** are relevant in the energy governance network. But they are still not enough to stimulate a spread of the energy governance in South Tyrol through new edges created by the bridges.

3.5 Conclusion

Considering the social practice approaches, things (i.e., technologies and techniques), a common understanding by social actors on how to use them, a recognition of the appropriate behaviours (i.e., competences to use RE technologies), and related meanings constitute the sustainable energy governance practice. This practice is spread in a space composed by relationships between actors within a region.

This research investigates the existence and the opportunities to spread a sustainable energy governance analysing its network of actors and relationships within South Tyrol case study. In particular, it analyses the part of energy governance composed by municipalities and public utilities that practices a **sustainable** energy governance, a **local** planning and management of territorial resources, a **collaboration** with other actors that have **equal and similar resources and needs**. The research investigates this network of actors and relationships thanks to a Bayesian network model for bipartite graphs in order to underline the relational dynamics and structures that created the actual network.

The network of relationships between all 116 municipalities and 120 public utilities confirm that an energy governance is spread only to half municipalities in South Tyrol and, where this kind of relationships is observed, the network is based on relations between spatially closed municipalities. Further, municipalities collaborate when they share common solar radiation resources useful to produce photovoltaic or solar thermal energy. this research partially confirms the governance practice to collaborate with others in the energy sector and it does not confirm the practice to collaborate with other similar municipalities, except for common solar radiation specificities. Given the confirmed practices based on Bayesian exponential random graph model, the likelihood to create new relationships between municipalities and public utilities is low. If energy planners aim to further spread the energy governance practice to other municipalities, they should look at other dynamics that are not included in the model.

The procedure and the open data will be published in a GitHub repository with the aim to replicate this analysis in other case studies and compare different results.

Chapter 4

Recommendations to regional and local energy planners

This research is a first attempt to define socio-energy systems in theoretical and applied research. The findings of this research permit to propose new collaborations between municipalities in order to develop energy plans effectively. These collaborations are based on several resources available in territories, included the social ones.

The climate change can be slowed and dealt through adaptation and mitigation actions. These actions require a **strategy of transition to sustainable world that involves territories and actors at all the scales**, included the local ones.

The **Decision Support Tool (DST)** - that emphasizes **local specificities** and **translocal collaborations** in the **energy planning** based on common resources, needs, and objectives - suggests a strategy for a deepen energy transition that uses and does not waste the available resources.

In the promotion of a more balanced, inclusive, and equal energy transition (Turnhout et al., 2014), this research supports the importance of this DST in increasing the effectiveness of energy planning at regional and local scale (Table 4.1). This DST includes and spreads a wide knowledge about specificities and potentialities of a territory in order to increase RE and promote a sustainable development. The DST stresses the importance of social features and resources of territory for the effective development and implementation of energy plans.

Based on regional and local specificities, this research applies the DST to the South Tyrol case study, proposing collaborations (Figure 4.2) and recommendations on the resources to use in the energy planning (Tables 4.2 and and 4.3). The methodology is developed with the aim to replicate it to other case studies and other topics with small adjustments.

Actually, Chapter 1, 2, and 3 can be read as an autonomous research and each of the three methodologies can be applied to other case studies and topics (i.e., natural hazards protection policies, educational system planning). However, linking the results and the methodologies of the three chapters permits to have an added-value of the research, with wider interpretation and usefulness of the results in the actual energy planning. Chapter 4 explains the most relevant results of this research and then the link between all the results proposing recommendations to energy planners (Tables 4.2 and 4.3).

In particular, Section 4.1 reports the reasons of the importance of the definition of socio-energy systems and their features. Section 4.2 transforms the results of variation of socio-energy systems within South Tyrol in recommendations to regional and local energy planners. Section 4.3 suggests how to achieve an energy governance based on collaborations between municipalities that have similar needs, resources, and preferences.

4.1 The relevance of different resources of socio-energy systems

To realize and be aware of **the existence of different socio-energy systems** within a regional territory are important steps towards the recognition of different territorial and social resources to use in energy planning. **The correct use of these resources** increases the effectiveness of the energy plans using all translocal and local development potentialities.

The critical analysis of the existing scientific knowledge underlines the importance of specificities of each socio-energy system. The deep analysis of literature reports the dimensions and the aspects that promote energy system changes from territorial and social perspectives. The quantitative analysis of 1084 scientific publications found in SCOPUS according to the key words *acceptance*, *conflict*, and *renewable energy* defines

Chapters	Results	Outputs	Figure, map, table
Chapter 1	Systematic review of scientific literature based on actors, processes, and networks related to energy system changes, focusing on *acceptance*, *conflict*, and *renewable energies*	List of dimensions and key aspects for the definition of local population's responses in front or renewable energy changes	Figures 1.2 and 4.1, Tables 1.6 and 1.3
Chapter 2	Applied definition of territory as socio-energy system, emphasizing social and collaborative resources for energy planning	Decision Support Tool including clusters of socio-energy systems and related specificities	Figure 2.2 and Table 2.9
Chapter 3	Definition of relational dynamics that shape the actual energy governance	Results of an Exponential Random Graph Model and probabilities to exist (out of not exist - ODDS) of each relationship between municipality and public utility	Table 3.4 and Figures 3.6 and 3.5
General	Analytical and applied definition of territory as socio-energy system, and recommendations to energy planners about collaborations and other kind of resources available in the territory to use for developing effective energy plans	Recommendations included in the thesis and, in future, in a flyer	Tables 4.2 and 4.3

Table 4.1: Results and outputs of the research.

the most cited 168 publications[1]. The quantitative and qualitative analysis of the 168 selected scientific publications based on a territorial analytical framework (Figure 1.2) defines the dimensions and the key aspects included in the Tables 1.6 and 1.3. These aspects are relevant to increase the achievements of low carbon and distributed energy systems through energy planning (Figure 4.1) and support the analysis of socio-energy systems within a territory (Table 4.1).

At local scale, the society is composed by individual and collective levels. Considering the individual level, actions and reactions of people in front of RE projects are determined by perceptions i.e., on (i) the sustainability of the project, (ii) its risks and benefits distribution, (iii) the impacts of plants and technologies, and (iv) the risks related to climate change (Table 1.6 for a wider list of relevant perceptions).

Acceptance or conflicts of individuals related to RE interventions are also linked to (i) the level of quality of life and household wealth, and to (ii) the individual commitment and its compatibility with the commitment of other individual, social, and political actors. Higher quality of life move the attention of people from primary needs of vulnerable people and communities to other needs, such as climate change mitigation and environmental quality (Wolsink, 2010; Bonte et al., 2011). Today, people satisfy their needs according to environmental and/or economic attitudes. On the one hand, people have environmental

[1]The number of citations is one of indexes that attest the importance of the specific publication (Wilsdon, 2016).

attitudes, particularly strong in the new and young generations (Yazdanpanah et al., 2015; Paravantis et al., 2018). These environmental attitudes are an important resource to underline and use in energy planning i.e., involving young people in participatory planning or in educational programmes that use the word of mouth to spread information to wider population (Rogers et al., 2012). On the other, the people interest is to reduce the costs of energy for maintaining the levels of consumption and the related quality of life (Ekins, 2004). In this case, *ad hoc* economic speeches and incentives have wider impact in people acceptance and promotion of RE interventions.

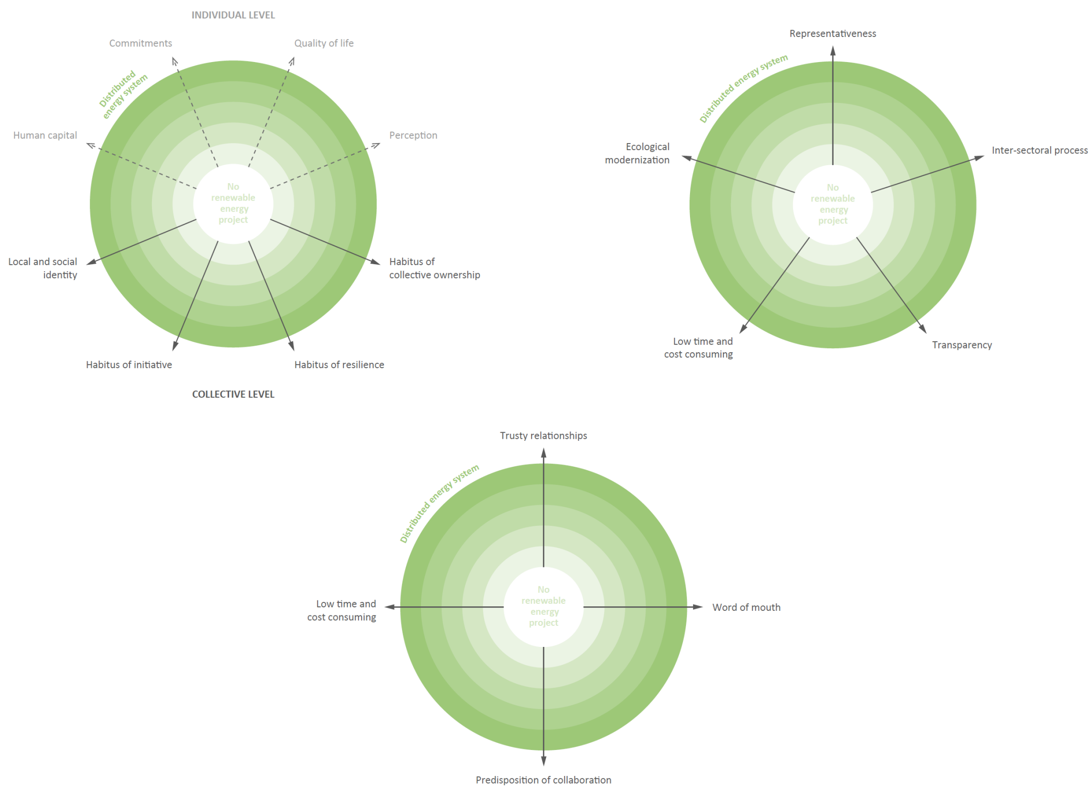


Figure 4.1: The main substantial, procedural, and relational aspects of the local socio-energy systems that support the transition towards low carbon and distributed energy systems. Source: Balest et al. (2018).

The human capital defined in terms of knowledge about (i) RE technologies, (ii) link between energy uses and CO_2 emissions, and (iii) climate change is relevant to shape energy systems with low carbon emissions, and confirms the need to promote educational programmes when these knowledge are missing (Halder et al., 2013). Informative programmes to overlap the lack of understanding new technologies increase their attractiveness (Dowd et al., 2011), the availability to use them and to change energy behaviours (DellaValle et al., 2018).

The collective level of the society at local and translocal scale has other important aspects to consider for achieving low carbon and distributed energy systems. Local and social identity into a common territory emphasizes symbolic and affective aspects (i.e., cultures, traditions, affective ties between inhabitants, place attachment) that are important to define the attachment of people to their local territory and the actions or reactions for its protection and development (Devine-Wright, 2005; Wolsink, 2007, 2010; Musall and Kuik, 2011; Wolsink, 2012; Cohen et al., 2014; Delicado et al., 2016). If local population has high attachment to the local territory (Devine-Wright, 2005) and it perceives a potential damage to the development or the landscape of the territory (Zoellner et al., 2008), conflict against RE project will carry out (Kontogianni et al., 2014). It is important to define the level of attachment of people and their imagery about the local territory they live in, for proposing projects that are coherent with the local population mind and, accordingly, more sustainable from the social viewpoint.

The local population mind can be investigated also considering the historic *habitus*[2] (Balest et al., 2018; Bourdieu, 2018), such as the capacity of the community to group and respond to a crisis (the *habitus* of resilience), the *habitus* of collective ownership of natural resources and common goods, such as forest, or the *habitus* of initiative when no external actors respond to the local needs as in the case of absence of electric grid in some isolated Alpine territories. These aspects are only partly investigated in this research including i.e., through proxies as local population's age, attitudes, and preferences or presence of infrastructures. Deepen investigation should carried on to have a wider interpretation of the results of this research.

The focus of this research is not only to static characteristics of individuals and communities, but also to processes and relationships (Figure 4.1), according to (Wolsink, 2010, p. 303): *"Social acceptance is not simply a set of static attitudes of individuals, instead it refers more broadly to social relationships and organisations, and it is dynamic as it is shaped in learning processes"*. Some characteristics of decision-making processes, such

[2] Habitus are considered schemes of thought, perceptions and actions people have in the long period using energy (Balest et al., 2018; Bourdieu, 2018)

as energy planning and management, are relevant to address local population's energy choices[3] (Wolsink, 2010). For example, transparency and low time and cost consumptions are important (Wüstenhagen et al., 2007; Zoellner et al., 2008) and energy planning should follow the indications of the ecological modernization (Wolsink, 2007):

"

- *Open democratic decision-making, rather than technocratic and corporatist-style decision making.*
- *Participation and involvement, rather than planning and decision-making carried out by scientific, economic and political elites.*
- *Open-ended approaches that allow multiple views, rather than the imposition of single, closed-ended proposals.*
- *Broad changes in institutions, incorporating environmental concerns, rather than technological solutions to environmental problems" (Wolsink, 2007, p. 2702).*

In a concept of ecological modernization, **the processes should represent all the relevant stakeholders and their multiple views about the territory.** Energy planners should work with people and groups who manage public, social, economic, and environmental life of territory i.e., enterprises, forest and agriculture land managers, associations, political parties. Different views also come from different policy and planning sectors, such as climate change adaptation through measures to prevent avalanches and flooding. The relation with other policy and planning sectors creates opportunities for technological, economic, and social innovations, such as new integrated technology that both produces RE and protects from avalanches. With their contribution of local knowledge, the relevant actors from all the sectors are considered as resources (Wolsink, 2010; Hassan et al., 2015) in the Chapter 2 of this thesis.

After the investigation of socio-energy systems and their specificities, this research proposes *ad hoc* participatory processes based on some or all indications of the ecological modernization. Not all the socio-energy systems are suitable of participation or all aspects of ecological modernization and this research contributes to understand where these

[3] More concretely, the perception of these characteristics are relevant.

processes can be finalized. **This process must be adjusted on the specificities of the territorial local context.** For example, a deeper participation and involvement should be asked where the energy plan promotes a change contrasting the most important views of stakeholders (Yazdanpanah et al., 2015). In other cases, the *"broad changes in institutions, incorporating environmental concerns, rather than technological solutions to environmental problems"* should be addressed when the presence of youths - that have typically higher environmental attitudes (Prasadh and Suresh, 2016) - is higher compared to places where aged people - that could prefer economic solutions - are prevalent.

The social relationships between actors and organizations are relevant to explain the local population's choices, the public authorities' choices, and the related shape of the actual energy systems i.e., Walker et al. (2010); Shove and Walker (2010); Müller et al. (2011). According to the Figure 4.1, trust in relationships (Upham et al., 2015), word of mouth exchange of information (Rogers et al., 2012), and predisposition to collaborate for achieving common objectives (Wolsink, 2007) are relevant relational dynamics involved in socio-energy systems. The awareness about these relational dynamics is relevant both to increase the social potentialities towards RE changes and to achieve the collaborations between municipalities towards an effective energy planning. Chapter 3 considers all these dynamics, emphasizing the still not important role of collaborations between municipalities in South Tyrol for energy governance. However, bridges in the network of relationships between municipalities and PU can be tools for transferring important information on energy planning through the word of mouth and the existing trust (Wolsink, 2007; Ertör-Akyazı et al., 2012).

With this important knowledge on how people interact with their territories and RE projects, this research analyses the translocal and local territory in a comprehensive way, defining eight different socio-energy systems in the South Tyrol area. Based on the identification of the different socio-energy systems and the following network analysis of the actual energy governance network, this research proposes to regional and local energy planners the recommendations included in Tables 4.2 and 4.3.

4.2 Specificities of socio-energy systems and recommendations to energy planners for South Tyrol

The Figure 4.2 shows the eight socio-energy systems in the South Tyrol. The energy should be planned based on the resources available within each socio-energy system or cluster as presented in the Table 4.2. Of course, this research is a starting point to have a wider picture of the territory to plan and further investigations should be carried out to deeply interpret the findings. However, some interesting inputs to energy planners are here presented.

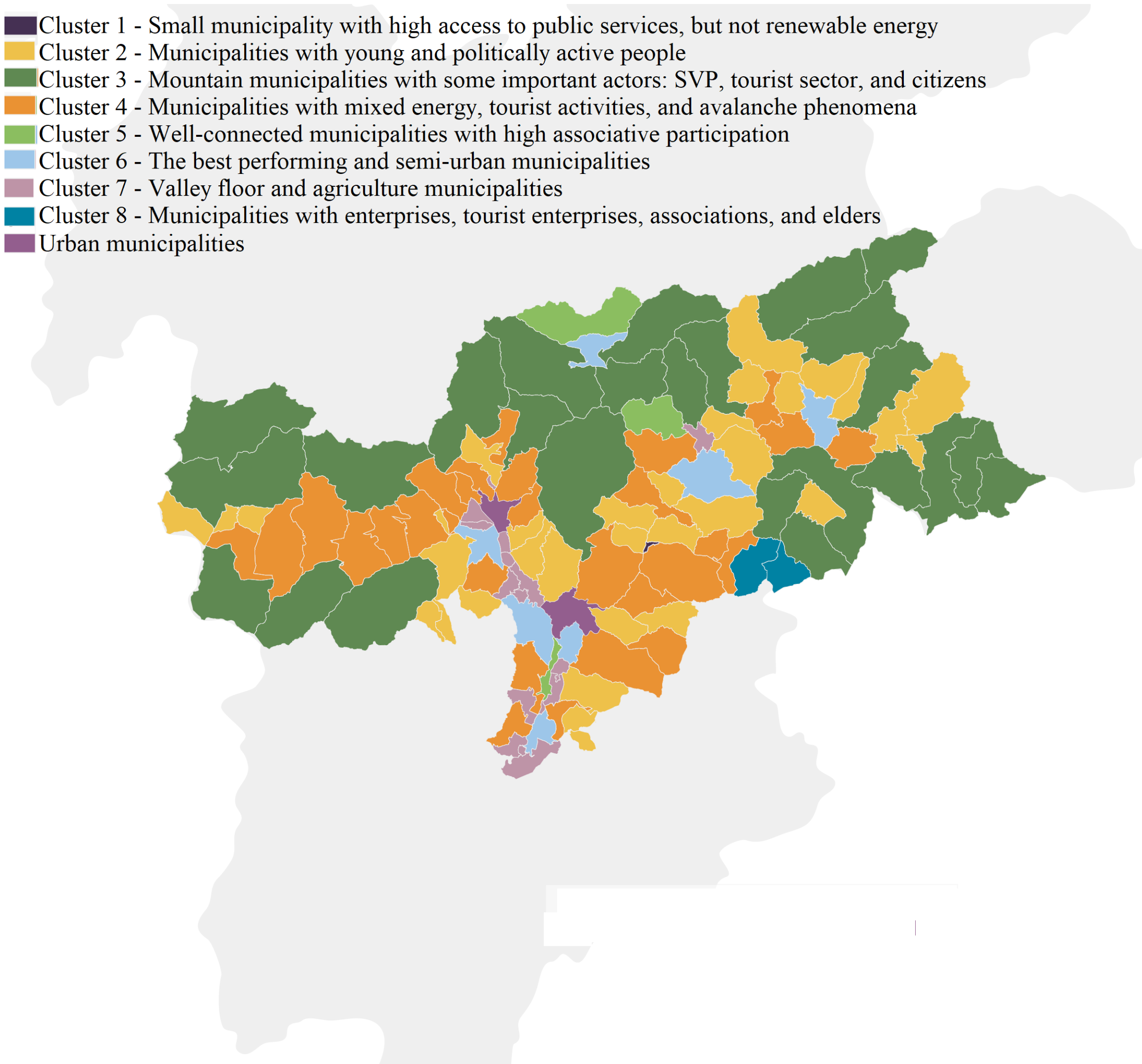


Figure 4.2: The map shows the colour shades of the eight clusters, in the grey context of EUREGIO Trentino-South Tyrol-Tyrol. The ninth colour represents the urban municipalities excluded by the cluster analysis.

Cl.	Description	Recommendations
1	Small municipality with high access to public services, but not renewable energies	• Education programmes in kindergarten and primary school to promote renewable, efficient, and saved energy
2	Municipalities with young and politically active people	• *Ad hoc* education activities starting from the primary school • Discussion with SVP to increase its public commitment to achieve energy transition targets in South Tyrol
3	Mountain municipalities with some important actors: SVP, tourist sector, and citizens	• Participatory energy planning including the tourist sector • Further studies could better address the actions of the plan and the advertisement campaign investigating the preferences of the actual and potential tourists
4	Municipalities with mixed energy, tourist activities, and avalanche phenomena	• Promote technological and social innovations integrating solutions that answer to energy, avalanche, and flooding contrasting needs • Promote electric vehicles with *ad hoc* economic and social incentives dedicated to both low and high income families
5	Well-connected municipalities with high associative participation	• Participatory process for the definition of energy plan involving public authorities and associations • Informative campaign to citizens organized and managed by associations and public authorities • Promote technological and social innovations integrating transport, hazard protection, and energy infrastructures through *ad hoc* action in the energy plan
6	The best performing and semi-urban municipalities	• Participatory process for the definition of energy plan involving public authorities and associations • Informative campaign to citizens that involves associations as bridges to citizens with the aim to increase differentiated wastes, renewable energy production, and energy savings • Education programmes in secondary and high schools in order to promote differentiated wastes, renewable energy production, and energy savings
7	Valley floor and agriculture municipalities	• Participatory process involving agriculture land owners to develop an action in the energy plan • Promote energy action plans in order to decrease inequalities in terms of quality of life
8	Municipalities with enterprises, tourist enterprises, associations, and elders	• Participatory process involving public authorities, enterprises, tourist enterprises, associations, and forest land owners of the two municipalities in order to discuss about a common renewable energy future. The participatory process should be based on techniques that consider the possible conflicts between the two municipalities and between the actors.

Table 4.2: The table reports the recommendations to regional and local energy planners in terms of collaborations and resources to use in the energy planning.

For the interactions between the 41 factors in the cluster analysis (Table 2.2), Ponte Val Gardena is the only municipality in the cluster *1 - Small municipality with high access to public services, but not renewable energy.* This municipality is particularly different from the other clusters for its smallness in terms of surface and number of inhabitants. The tourist sector does not exist, people with high income are not relevant, and the wide presence of highway, streets, and railways out of total surface characterizes this municipality. Kindergarten and primary schools have high number of pupils that probably come from neighbour municipalities. Education programmes in these schools could be a channel to communicate with families and neighbour municipalities in order to collaborate for achieving wider RE, energy efficiency, and saving targets.

As reported in the Section 4.1, the views of the most important actors in the territory must be included in the energy planning especially when stakeholders perceive potential damages to their interests (i.e., economic profit, landscape and environment quality). Several clusters are characterized by importance of some stakeholders, but in different compositions. For example, in the cluster *2 - Municipalities with young and politically active people* youths, families, and SVP are the most relevant actors to involve. Of course, youths and families are involved in different ways compared to SVP for increasing the effectiveness of participation. SVP can be included emphasizing its role in public commitment, while youths and families could be involved through *ad hoc* activities starting from the primary schools and the actual high people involvement in producing and consuming local energy. This people involvement can be strengthen, for example, promoting and sharing a community RE project based on a collective decision.

Moving to cluster *3 - Mountain municipalities with some important actors: SVP, tourist sector, and citizens*, the relevant actors to involve in energy planning are different. The integration between energy and tourist development actions could create a common path that increases the effectiveness of both the sectors. For example, the appeal of tourist sector can increase with the diffusion of RE (Dalton et al., 2008) and a good advertisement campaign to the tourists that desire an environmental quality of the stay. In this way, the share of resources between the two sectors could increase the environmental, social, and economic earnings of both the sectors.

The cluster *8 - Municipalities with enterprises, tourist enterprises, associations, and elders* involves enterprises, tourist enterprises, forest land owners, and associations. A participatory process involving all these actors in the two municipalities of cluster 8 could promote RE actions that are relevant for all the cited sectors. Collaborative planning between two municipalities could be easier than bigger groups of municipalities. However, if the two municipalities do not actually collaborate, it is important to collect the reasons of the possible conflict and the imagery of people and public authorities on the future development of the territory. The imagery can be the first step to discuss about a common RE future in the energy planning and participatory project. The conflict that can exist between the actors and the public authorities should be managed based on specific participatory methods. If the relevant actors in each cluster are not considered as resources, they could become actors of conflict.

In the cluster 8 as in the cluster *5 - Well-connected municipalities with high associative participation* and *6 - The best performing and semi-urban municipalities*, energy planners should involve associations as mean between planners and citizens. In the cluster *6*, the environmental associations are many and this represents a certain kind of attitudes taking care the environment. The involvement of associations can promote the knowledge and the trust between planners and citizens (Zoellner et al., 2008). In such of these associations, local knowledge (also related to other RE projects) can be relevant to address and decrease the environmental and social prints of RE projects (Zoellner et al., 2008).

The knowledge about the characteristics of inhabitants is relevant to address the actions to the specific public and organize the involvement of people and the main civil society actors. In cluster *6 - The best performing and semi-urban municipalities*, the inhabitants do not have environmental attitudes expressed in percentage of differentiated waste. This sector and the RE sector could be object of a common informative campaign that involves associations as bridges to citizens, and schools as bridges to students.

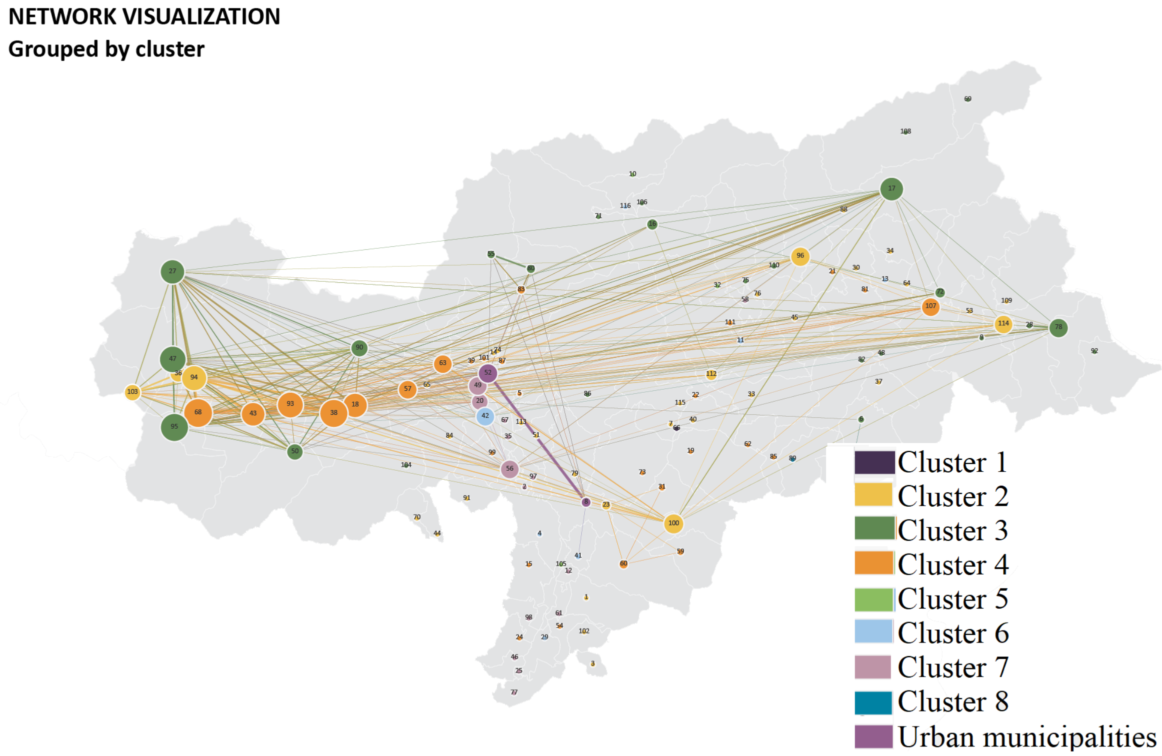
Other interesting aspects are related to inhabitant density. In the cluster *7 - Valley floor and agriculture municipalities*, the inhabitant density is high and this is a resource to promote district heating projects. Linking this potentiality to the high presence of agriculture land cover, the district heating plant could receive the raw material and wastes from the agriculture sector. This is the basis to organize a participatory process with public authorities and agriculture sector in order to save wastes and produce energy in the territory. Other specificities are not relevant for cluster *7*. For example, associations, schools, and youths are not crucial and educational programmes or involvement of associations and youths would not be the most strategic actions. Another interesting aspect on which public authorities could work in the cluster *7* is the decrease of income inequalities. In this valley floor area along the Adige river, the RE sector and incentives dynamics could decrease the inequalities, at least achieving a common quality of life.

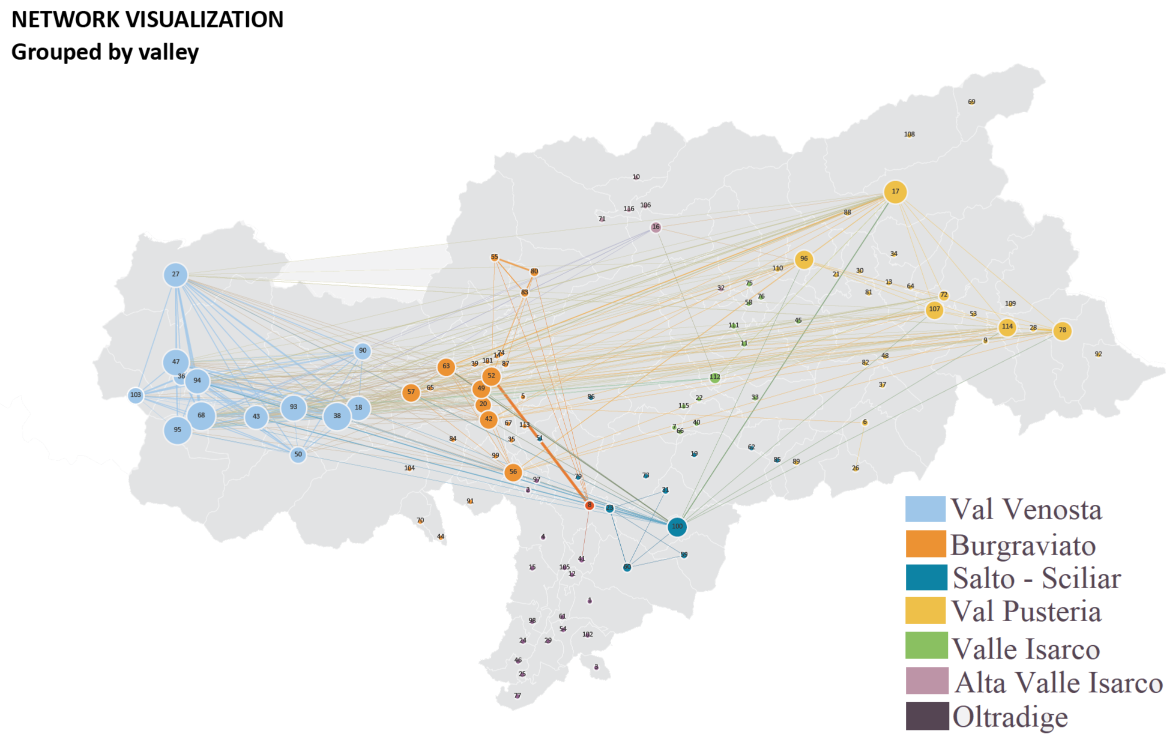
The integration between energy planning and other policy and planning sectors increases the effectiveness looking at the territory in a wider and complete way. It recognizes that territory is complex and the energy is not isolated from the other components. Flooding and avalanche phenomena require protection and prevention measures. These measures can be integrated with energy ones i.e., building an innovative infrastructure that answers to both the energy and the protection needs. The integration between policy and planning sectors involve also transport infrastructures: the integration between highways and railways management, flooding and avalanche prevention, and energy planning is an opportunity for technological innovation. Territory will be also more attractive for residents if its components are well integrated and managed.

The electric vehicle is another sector that can interact with the energy ones. The electricity can be produced at local scale and the cars can be substituted with electric vehicles. Good energy plan actions should consider that the car is a *status* of the family, especially where the number of cars is high, as in the cluster *4 - Municipalities with mixed energy, tourist activities, and avalanche phenomena.*

It is very important to change strategies, address planning actions, and choose participatory approaches according to the specificities of each socio-energy system (Table 4.2). Through this approach, the energy planning can fully use the potentialities of territories. However, the collaborations between municipalities that belong to the same socio-energy system are not obvious.

4.3 Feasibility of new collaborations in energy governance





MUNICIPALITIES

1. Aldino/Aldein
2. Andriano/Andrian
3. Anterivo/Altrei
4. Appiano sulla strada del vino/Eppan an der Weinstraße
5. Avelengo/Hafling
6. Badia/Abtei
7. Barbiano/Barbian
8. Bolzano/Bozen
9. Braies/Prags
10. Brennero/Brenner
11. Bressanone/Brixen
12. Bronzolo/Branzoll
13. Brunico/Bruneck
14. Caines/Kuens
15. Caldaro sulla strada del vino/Kaltern an der Weinstraße
16. Campo di Trens/Freienfeld
17. Campo Tures/Sand in Taufers
18. Castelbello-Ciardes/Kastelbell-Tschars
19. Castelrotto/Kastelruth
20. Cermes/Tscherms
21. Chienes/Kiens
22. Chiusa/Klausen
23. Cornedo all'Isarco/Karneid
24. Cortaccia sulla strada del vino/Kurtatsch an der Weinstraße
25. Cortina sulla strada del vino/Kurtinig an der Weinstraße
26. Corvara in Badia/Corvara
27. Curon Venosta/Graun im Vinschgau
28. Dobbiaco/Toblach
29. Egna/Neumarkt
30. Falzes/Pfalzen
31. Fiè allo Sciliar/Völs am Schlern
32. Fortezza/Franzensfeste
33. Funes/Villnöß
34. Gais/Gais
35. Gargazzone/Gargazon
36. Glorenza/Glurns
37. La Valle/Wengen
38. Laces/Latsch
39. Lagundo/Algund
40. Laion/Lajen
41. Laives/Leifers
42. Lana/Lana
43. Lasa/Laas
44. Lauregno/Laurein
45. Luson/Lüsen
46. Magrè sulla strada del vino/Margreid an der Weinstraße
47. Malles Venosta/Mals
48. Marebbe/Enneberg
49. Marlengo/Marling
50. Martello/Martell
51. Meltina/Mölten
52. Merano/Meran
53. Monguelfo-Tesido/Welsberg-Taisten
54. Montagna/Montan
55. Moso in Passiria/Moos in Passeier
56. Nalles/Nals
57. Naturno/Naturns
58. Naz-Sciaves/Natz-Schabs
59. Nova Levante/Welschnofen
60. Nova Ponente/Deutschnofen
61. Ora/Auer
62. Ortisei/St, Ulrich
63. Parcines/Partschins
64. Perca/Percha
65. Plaus/Plaus
66. Ponte Gardena/Waidbruck
67. Postal/Burgstall
68. Prato allo Stelvio/Prad am Stilfserjoch
69. Predoi/Prettau
70. Proves/Proveis
71. Racines/Ratschings
72. Rasun-Anterselva/Rasen-Antholz
73. Renon/Ritten
74. Rifiano/Riffian
75. Rio di Pusteria/Mühlbach
76. Rodengo/Rodeneck
77. Salorno/Salurn
78. San Candido/Innichen
79. San Genesio Atesino/Jenesien
80. San Leonardo in Passiria/St, Leonhard in Passeier
81. San Lorenzo di Sebato/St, Lorenzen
82. San Martino in Badia/St, Martin in Thurn
83. San Martino in Passiria/St, Martin in Passeier
84. San Pancrazio/St, Pankraz
85. Santa Cristina Valgardena/St, Christina in Gröden
86. Sarentino/Sarntal
87. Scena/Schenna
88. Selva dei Molini/Mühlwald
89. Selva di Val Gardena/Wolkenstein in Gröden
90. Senale-San Felice/Unsere Liebe Frau im Walde-St, Felix
91. Senales/Schnals
92. Sesto/Sexten
93. Silandro/Schlanders
94. Sluderno/Schluderns
95. Stelvio/Stilfs
96. Terento/Terenten
97. Terlano/Terlan
98. Termeno sulla strada del vino/Tramin an der Weinstraße
99. Tesimo/Tisens
100. Tires/Tiers
101. Tirolo/Tirol
102. Trodena nel parco naturale/Truden im Naturpark
103. Tubre/Taufers im Münstertal
104. Ultimo/Ulten
105. Vadena/Pfatten
106. Val di Vizze/Pfitsch
107. Valdaora/Olang
108. Valle Aurina/Ahrntal
109. Valle di Casies/Gsies
110. Vandoies/Vintl
111. Varna/Vahrn
112. Velturno/Feldthurns
113. Verano/Vöran
114. Villabassa/Niederdorf
115. Villandro/Villanders
116. Vipiteno/Sterzing

Figure 4.3: The maps of South Tyrol show the relationships between municipalities through public utilities in energy sector. These maps are a simplification of the relationships because they do not represent the public utilities that are embedded in the edges. The circles are municipalities and their colours represent the clusters or the valleys, and the size shows the number of links with other municipalities.

The network analysis and the ERGM of the actual energy governance underlines some differences between the potential collaborations proposed by the DST (Figure 2.2) and the actual collaborations (Figure 4.3) in energy sector. According to the model (ERGM), the actual energy governance network is not dense and only few relationships exist (Table 3.4). These few existing relationships between municipalities are based on spatial closeness or on similarities of solar radiation. The collaborations based on similarities between municipalities are not spread and **the actual existence of only some clusters is confirmed** by the network analysis and the ERGM of the energy governance. However, this research aims to promote the change towards a more balanced, inclusive, and equal energy transition. This third part of the research underlines some **important dynamics that could change the actual energy governance network** towards the collaborations proposed by the DST.

Crossing the results of the cluster analysis (Chapter 2) and the network analysis (Chapter 3), this research underlines that some main actions should be encouraged (Table 4.3):

- **Promote the practice to collaborate.** The collaborations between municipalities in the energy sector are important to pursue higher RE, energy efficiency, and energy saving targets. Collaborations mean more resources available for the energy planning and management. The shared resources are knowledge, human capital, experience, funding, time. Integrating the actions of the planning, the activities can be organized and funded by more municipalities. These activities can be more effective when they are organized based on more experiences and knowledge.

  Several municipalities do not collaborate with others through PU: some of them use PU for supplying their own individual services, while others do not have contracts with PU. In promoting the collaborations, this information should be considered and **new tools for collaborations in energy sector should be created where PU are not used**, while PU should be deeper used where they are already relevant. The calculation of the odds (Chapter 3) permits to understand the level of probability to create a new relationship based on PU. In general, municipalities that already have contracts with PU are more likely to have a new contract with another PU.

- **Involve PU** in the process to spread the collaborations between municipalities, where PU are already used. Sometimes, PU have important role as bridges to create new collaborations between municipalities. These bridges between actors permit the exchange of several resources, i.e. information, management capabilities, acceptance, and common development visions (Späth and Rohracher, 2010; Müller et al., 2011; Balest et al., 2018). Currently, central PU shape the energy governance not on local and traslocal specificities but with the intention to include all the municipalities. I.e., Unione dell'Energia (SEV) is the result of the merge (2012) of two past utilities, being today an utility that supplies many energy services: Federazione dell'Energia

Raiffeisen and Consorzio Biomassa Alto Adige. Consorzio Biomassa, funded in 1998, managed 44 district heating plants with a huge knowledge of management, while Federazione dell'Energia Raiffeisen suports small and medium energy enterprises. Unione dell'Energia, born in South Tyrol, has a huge knowledge on these kind of energy services that could be integrated with the idea behind this research that aims to promote collaborations in energy planning between municipalities that have similar needs and resources.

This interesting experiment to merge different regional PU can be integrated in another experiment that stresses the consideration of local specificities and similarities for wider energy transition. The PU could integrate their choices in making contracts with municipalities, bordering different contracts according to the DST proposals. However, the effectiveness of this experiment would be higher where municipalities already use PU.

In all the cases where PU are not used by municipalities, regional and local energy planners should create new incentives for a collaborative energy planning, such as participatory, informative, or educational processes according to the recommendations in Table 4.2.

- **Solve the existing conflicts.** The absence of collaborations between municipalities can be result of conflicts in the energy and other sectors. Conflicts between municipalities and between other actors can belong to historical *habitus*, but they can be solved. Today, several conflict management techniques (McCullough and Sarver, 2016; Schaller et al., 2013) exist and the actors can be involved in a process in order to fix past conflicts and promote the change towards new collaborations. Before starting to promote new collaborations, a further research should investigate the existence, the actors, and the reasons of the conflict. These information are fundamental to organize all the other steps of a shared energy planning.

- **Strengthen the network of the actual relationships between municipalities that belong to the same cluster.** Some relationships between municipalities that belong to the same cluster already exist. This network can be confirmed through informative and participatory events in which local energy planners discuss on the real possibility to continue these collaborations in the energy planning.

Cl.	Description	Promoting collaborations
1	Small municipality with high access to public services, but not renewable energies	• Do not focus on collaborations with other municipalities, but on the promotion of relationships between internal actors and citizens
2	Municipalities with young and politically active people	• Tubre, Glorenza, Sluderno, Tires, Terento, and Villabassa have already relationships one another and they are already able to start collaborations in energy planning based on the available resources presented in the Table 4.2 • In order to create new collaborations in this cluster, Tires can promote collaborations with the neighbour municipalities (i.e, San Genesio Atesino, Meltina, and Verano) in the energy sector, but not using PU. Tires can use existing trust relationships, word of mouth opportunities, and solving possible conflicts between municipalities with the support of experts in conflict management. PU could be an important tool to promote other new collaborations, i.e.between Tires and Cornedo all'Isarco.
3	Mountain municipalities with some important actors: SVP, tourist sector, and citizens	• As showed in the Figure 4.3, the majority of municipalities in cluster *3* has already relationships one another. They are already able to start collaborative energy planning based on the available resources presented in the Table 4.2 • Promote new collaborations including i.e., Racines through the spatial closeness with Campo di Trens. In this case, Campo di Trens can use existing trust relationships, word of mouth opportunities, and solving possible conflicts between municipalities with the support of experts in conflict management.
4	Municipalities with mixed energy, tourist activities, and avalanche phenomena	• Start a collective energy planning between municipalities that have already relationships through PU, based on the resources presented in the Table 4.2 • Promote the practice to collaborate in energy sector of the isolated municipalities, understanding why they do not actually collaborate and spreading the collaborative network (i.e., Renon, Castelrotto, Ortisei, Santa Cristina Val Gardena). Informative and participatory events underling the the advantages to collaborate could be the starting point for a collaborative energy planning
5	Well-connected municipalities with high associative participation	• Provincial policy-makers and planners should promote the collaborations between these three municipalities through different tools (preferably not PU). Informative and participatory events for stressing the advantages of a collaboration between these three municipalities could be the starting point of discussion for promoting a collaborative energy planning.
6	The best performing and semi-urban municipalities	• Promote the practice to collaborate in energy sector, understanding why they do not actually collaborate • Incentive the collaborations between the municipalities of this cluster, using the importance of PU as bridge to link Lana and Laives and using other approaches (i.e., participatory process) to link the other municipalities • Promote a different dynamic of collaboration of Lana and Laives in the energy planning, more careful to similar needs and resources between municipalities
7	Valley floor and agriculture municipalities	• Promote the practice to collaborate in energy sector, understanding why they do not actually collaborate and using tools different from PU • Promote collaborations between municipalities that belong to the cluster through informative events to local planners that underline the importance of similarities for an effective energy planning and the advantages of collaborative energy planning and management
8	Municipalities with enterprises, tourist enterprises, associations and elders	• Investigate the reasons of not collaborations between the two municipalities • Propose a participatory process on local and energy development solving the actual conflicts between them (if any) through specific conflict management techniques • Propose a collaborative energy planning to the two municipalities based on the resources presented in the Table 4.2 and stressing the translocal collaboration between the most relevant stakeholders (i.e. enterprises, forest land owners)

Table 4.3: Recommendations on how to promote new collaborations in the energy governance of South Tyrol.

- Once the networks per each cluster are defined, **a participatory process should be carried out to start using in the energy planning the most relevant resources**, based on the results of the DST (Table 4.2). Collaborative energy planning does not mean that the output is only one energy plan, but that the planning process is collaborative.

The Table 4.3 shows some specific recommendations to regional and local energy planners in order to promote relationships between municipalities that belong to the same cluster. However, further findings of this research could be interpreted.

Chapter 5

Conclusion

This research is a first attempt to delineate **an analytical framework and an applied definition** of socio-energy system. These framework and definition investigate the **socio-energy system** as a system embedded in a territory that is composed by a set of layers (social-cultural, legislative, economic, technological and natural). These framework and definition emphasize the roles of the choices of local populations and public authorities. In the socio-energy system, the local population makes choices shaping and being shaped by **the interactions between society and energy in a space-based context.**

This research is based on the idea that all local territories can contribute to the energy transition emphasizing their potentialities and resources. For addressing energy system change towards low carbon and distributed energy system, energy planners are **aware of the importance of social and territorial aspects of an energy system**. This research supports the planners to identify the available resources in the territory, **accelerating the energy transition.**

The findings of this research are included in a **Decision Support Tool** presented through maps and tables that propose recommendations to regional and local energy planners. The recommendations include interesting potential collaborations and other kind of available resources that increase the effective implementation of energy plans.

The results are interesting both for researchers and planners. The researchers observe an application of the proposed analytical framework. While the regional and local planners find recommendations on the resources and collaborations in order to drive an effective energy planning.

The methodologies of the three chapters are replicable to other case studies and other topics. On the one hand, the methodology to systematically analyse the scientific literature can be replicated to other scientific topics (Chapter 1). On the other hand, the data collection for other regions would permit to replicate the methodologies of the Chapters 2 and 3.

In future, the researchers should organize a process involving regional and local planners, and the other proposed actors in order to discuss the results of this research and to apply the recommendations proposed in the Sections 4.2 and 4.3.

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Bibliography

S. Solomon, G. K. Plattner, R. Knutti, P. Friedlingstein, Irreversible climate change due to carbon dioxide emissions, Proceedings of the national academy of sciences 106 (2009) 1704–1709.

R. K. Pachauri, M. R. Allen, V. R. Barros, J. Broome, W. Cramer, R. Christ, J. A. Church, L. Clarke, Q. Dahe, P. Dasgupta, et al., Climate change 2014: Synthesis report. Contribution of Working Groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change, IPCC, 2014.

J. D. Sachs, The age of sustainable development, Columbia University Press, 2015.

B. R. Keeble, The Brundtland report: Our common future, Medicine and War 4 (1988) 17–25.

M. Jänicke, The multi-level system of global climate governance: The model and its current state, Environmental Policy and Governance 27 (2017) 108–121.

P. Droege, 100% renewable: Energy autonomy in action, Routledge, 2012.

F. W. Geels, The multi-level perspective on sustainability transitions: Responses to seven criticisms, Environmental innovation and societal transitions 1 (2011) 24–40.

W. Vandenhole, De-growth and sustainable development: Rethinking human rights law and poverty alleviation, Law and Development Review 11 (2018) 647–675.

European Commission, How to develop a Sustainable Energy Action Plan (SEAP), Technical Report, 2010.

B. Turnheim, J. Wesseling, B. Truffer, H. Rohracher, L. Carvalho, C. Binder, Challenges ahead: Understanding, assessing, anticipating and governing foreseeable societal tensions to support accelerated low-carbon transitions in europe, in: Advancing Energy Policy, Springer, 2018, pp. 145–161.

G. Osti, The uncertain games of energy transition in the island of Sardinia (Italy), Journal of Cleaner Production (2018).

B. K. Sovacool, How long will it take? Conceptualizing the temporal dynamics of energy transitions, Energy Research & Social Science 13 (2016) 202–215.

B. V. Mathiesen, H. Lund, K. Hansen, I. Ridjan, S. R. Djørup, S. Nielsen, P. Sorknæs, J. Z. Thellufsen, L. Grundahl, R. S. Lund, et al., IDA's Energy Vision 2050: A Smart Energy System Strategy for 100% Renewable Denmark (2015).

H. Lund, B. V. Mathiesen, Energy system analysis of 100% renewable energy systemsthe case of denmark in years 2030 and 2050, Energy 34 (2009) 524–531.

S. Bringezu, M. OBrien, H. Schütz, Beyond biofuels: Assessing global land use for domestic consumption of biomass: A conceptual and empirical contribution to sustainable management of global resources, Land Use Policy 29 (2012) 224–232.

European Commission, Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC ("Renewable energy Directive"), Technical Report, 2009.

N. DellaValle, A. Bisello, J. Balest, In search of behavioural and social levers for effective social housing retrofit programs, Energy and Buildings 172 (2018) 517–524.

M. Di Somma, B. Yan, N. Bianco, G. Graditi, P. Luh, L. Mongibello, V. Naso, Multi-objective design optimization of distributed energy systems through cost and exergy assessments, Applied Energy 204 (2017) 1299–1316.

G. Dóci, B. Gotchev, When energy policy meets community: Rethinking risk perceptions of renewable energy in Germany and the Netherlands, Energy Research & Social Science 22 (2016) 26–35.

F. J. Van Rijnsoever, A. Van Mossel, K. P. Broecks, Public acceptance of energy technologies: The effects of labeling, time, and heterogeneity in a discrete choice experiment, Renewable and Sustainable Energy Reviews 45 (2015) 817–829.

J. C. Rogers, E. A. Simmons, I. Convery, A. Weatherall, Social impacts of community renewable energy projects: Findings from a woodfuel case study, Energy Policy 42 (2012) 239–247.

J. Balest, E. Pisani, D. Vettorato, L. Secco, Local reflections on low-carbon energy systems: A systematic review of actors, processes, and networks of local societies, Energy Research & Social Science 42 (2018) 170–181.

F. W. Geels, Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study, Research policy 31 (2002) 1257–1274.

S. Batel, A critical discussion of research on the social acceptance of renewable energy generation and associated infrastructures and an agenda for the future, Journal of Environmental Policy & Planning 20 (2018) 356–369.

M. Wolsink, Social acceptance revisited: Gaps, questionable trends, and an auspicious perspective, Energy Research & Social Science 46 (2018) 287–295.

C. A. Miller, A. Iles, C. F. Jones, The social dimensions of energy transitions, Science as Culture 22 (2013) 135–148.

G. Osti, Sociologia del territorio, Il mulino, 2010.

G. Fontaine, The effects of energy co-governance in Peru, Energy Policy 38 (2010) 2234–2244.

S. Coelho, M. Russo, R. Oliveira, A. Monteiro, M. Lopes, C. Borrego, Sustainable energy action plans at city level: A Portuguese experience and perception, Journal of Cleaner Production (2017).

T. Pinto-Correia, N. Guiomar, C. Guerra, S. Carvalho-Ribeiro, Assessing the ability of rural areas to fulfil multiple societal demands, Land Use Policy 53 (2016) 86–96.

F. Kraxner, S. Leduc, H. Serrano Leon, J. Balest, G. Garegnani, G. Grilli, M. Ciolli, F. Geri, A. Paletto, A. Poljanec, et al., Recommendations and lessons learned for a renewable energy strategy in the Alps (2015).

M. Novotná, M. Šlehoferová, A. Matušková, Evaluation of spatial differentiation in the Pilsen region from a socioeconomic perspective, Bulletin of Geography. Socio-economic Series 34 (2016) 73–90.

N. Borrelli, A. Mela, Food, city and territory: Some reflections from a socio-spatial point of view, City, Territory and Architecture 5 (2018) 7.

J. B. Jackson, Landscape in sight: Looking at America, Yale University Press, 2000.

S. Livingstone, The changing social landscape (2002).

C. Raffestin, Space, territory, and territoriality, Environment and Planning D: Society and Space 30 (2012) 121–141.

B. Sütterlin, M. Siegrist, Public acceptance of renewable energy technologies from an abstract versus concrete perspective and the positive imagery of solar power, Energy Policy 106 (2017) 356–366.

J. Stephenson, B. Barton, G. Carrington, D. Gnoth, R. Lawson, P. Thorsnes, Energy cultures: A framework for understanding energy behaviours, Energy policy 38 (2010) 6120–6129.

C. Calhoun, R. Sennett, Practicing Culture (Taking Culture Seriously), Routledge, 2007.

C. Greiner, P. Sakdapolrak, Translocality: Concepts, applications and emerging research perspectives, Geography Compass 7 (2013) 373–384.

S. Sassen, Embedded borderings: Making new geographies of centrality, Territory, Politics, Governance (2018) 1–11.

G. Osti, Socio-spatial relations: An attempt to move space near society, EUT Edizioni Università di Trieste, 2015.

N. M. Katsoulakos, D. C. Kaliampakos, Mountainous areas and decentralized energy planning: Insights from Greece, Energy Policy 91 (2016) 174–188.

P. Sánchez-Zamora, R. Gallardo-Cobos, C. Romero-Huertas, Assessing the determinants of territorial cohesion: Evidence from Colombian departments, Geoforum 87 (2017) 48–61.

European Court of Editors, Renewable energy for sustainable rural development: Significant potential synergies, but mostly unrealised, Technical Report, 2018.

C. Hedberg, R. M. Do Carmo, Translocal ruralism: Mobility and connectivity in european rural spaces, in: Translocal ruralism, Springer, 2012, pp. 1–9.

E. Medeiros, Territorial cohesion: An EU concept, European Journal of Spatial Development 60 (2016) 1–30.

Š. Nosek, Territorial cohesion storylines in 2014–2020 cohesion policy, European Planning Studies (2017) 1–18.

J. Balest, L. Secco, E. Pisani, G. Garegnani, Territory as socio-energy system at translocal scale: A Decision Support Tool for energy planners, Energy Research & Social Science (2019).

E. Ostrom, Polycentric systems for coping with collective action and global environmental change, Global Environmental Change 20 (2010) 550–557.

B. K. Sovacool, An international comparison of four polycentric approaches to climate and energy governance, Energy Policy 39 (2011) 3832–3844.

E. Rametsteiner, Governance concepts and their application in forest policy initiatives from global to local levels, Small-scale Forestry 8 (2009) 143–158.

L. Secco, R. Da Re, D. M. Pettenella, P. Gatto, Why and how to measure forest governance at local level: A set of indicators, Forest Policy and Economics 49 (2014) 57–71.

F. W. Geels, J. Schot, Typology of sociotechnical transition pathways, Research policy 36 (2007) 399–417.

E. Shove, M. Pantzar, M. Watson, The dynamics of social practice: Everyday life and how it changes, Sage, 2012.

E. Shove, G. Walker, Governing transitions in the sustainability of everyday life, Research policy 39 (2010) 471–476.

H. Bulkeley, K. Kern, Local government and the governing of climate change in Germany and the UK, Urban studies 43 (2006) 2237–2259.

S. Mejía-Dugand, O. Hjelm, L. Baas, Public utility companies in liberalized markets: The impact of management models on local and regional sustainability, Utilities Policy 49 (2017) 137–144.

R. Wüstenhagen, M. Wolsink, M. J. Bürer, Social acceptance of renewable energy innovation: An introduction to the concept, Energy policy 35 (2007) 2683–2691.

G. Abrahams, What is territorial cohesion? what does it do?: Essentialist versus pragmatic approaches to using concepts, European Planning Studies 22 (2014) 2134–2155.

B. Elissalde, F. Santamaria, Territorial cohesion and regional competitiveness: Defining key-notions in the EU's regional policy, Social Sciences 3 (2014) 2014030401–12.

H. Dao, P. Plagnat Cantoreggi, V. Rousseaux, Operationalizing a contested concept: Indicators of territorial cohesion, European Planning Studies 25 (2017) 638–660.

European Commission, Green paper on territorial cohesion: Turning territorial diversity into strength, 2008.

A. Caimo, N. Friel, Bayesian inference for exponential random graph models, Social Networks 33 (2011) 41 – 55.

J. Balest, L. Secco, E. Pisani, A. Caimo, Sustainable energy governance practice in South Tyrol (Italy): A probabilistic bipartite network model, Journal of Cleaner Production (2019).

G. Garegnani, S. Sacchelli, J. Balest, P. Zambelli, GIS-based approach for assessing the energy potential and the financial feasibility of run-off-river hydro-power in Alpine valleys, Applied Energy 216 (2018) 709–723.

B. Jessop, N. Brenner, M. Jones, Theorizing sociospatial relations, Environment and planning D: society and space 26 (2008) 389–401.

B. Solberg, S. Miina, Conflict management and public participation in land management, European Forest Institute, 1997.

How research on acceptance and behaviour can accelerate energy transition, 2014.

European Union, Directive 2009/28/ec of the european parliament and of the council of 23 april 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing directives 2001/77/ec and 2003/30/ec, Official Journal of the European Union 5 (2009) 2009.

I. Union, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, Brussels, 2014.

B. K. Sovacool, What are we doing here? analyzing fifteen years of energy scholarship and proposing a social science research agenda, Energy Research & Social Science 1 (2014) 1–29.

P. Upham, C. Oltra, À. Boso, Towards a cross-paradigmatic framework of the social acceptance of energy systems, Energy Research & Social Science 8 (2015) 100–112.

S. Hielscher, G. Seyfang, A. Smith, Community innovation for sustainable energy, Technical Report, CSERGE Working Paper, 2011.

P. Ekins, Step changes for decarbonising the energy system: Research needs for renewables, energy efficiency and nuclear power, Energy Policy 32 (2004) 1891–1904.

J. Zoellner, P. Schweizer-Ries, C. Wemheuer, Public acceptance of renewable energies: Results from case studies in germany, Energy policy 36 (2008) 4136–4141.

J. Hodbod, W. N. Adger, Integrating social-ecological dynamics and resilience into energy systems research, Energy Research & Social Science 1 (2014) 226–231.

M. Weber, Economy and society: An outline of interpretive sociology, volume 1, Univ of California Press, 1978.

Y. Maruyama, M. Nishikido, T. Iida, The rise of community wind power in japan: Enhanced acceptance through social innovation, Energy Policy 35 (2007) 2761–2769.

I. B. Bjelic, R. M. Ciric, Optimal distributed generation planning at a local level: A review of serbian renewable energy development, Renewable and Sustainable Energy Reviews 39 (2014) 79–86.

E. Michalena, V. Angeon, Local challenges in the promotion of renewable energy sources: The case of crete, Energy Policy 37 (2009) 2018–2026.

R. E. Kasperson, B. J. Ram, The public acceptance of new energy technologies, Daedalus 142 (2013) 90–96.

H. Longstaff, D. M. Secko, G. Capurro, P. Hanney, T. McIntyre, Fostering citizen deliberations on the social acceptability of renewable fuels policy: The case of advanced lignocellulosic biofuels in canada, Biomass and Bioenergy 74 (2015) 103–112.

B. K. Sovacool, D. J. Hess, Ordering theories: Typologies and conceptual frameworks for sociotechnical change, Social studies of science 47 (2017) 703–750.

N. Magnani, G. Osti, Does civil society matter? Challenges and strategies of grassroots initiatives in italys energy transition, Energy Research & Social Science 13 (2016) 148–157.

M. Gross, R. Mautz, Renewable energies, Routledge London, 2015.

E. Devlin, Factors affecting public acceptance of wind turbines in sweden, Wind Engineering 29 (2005) 503–511.

P. Devine-Wright, Beyond NIMBYism: Towards an integrated framework for understanding public perceptions of wind energy, Wind Energy: An International Journal for Progress and Applications in Wind Power Conversion Technology 8 (2005) 125–139.

F. D. Musall, O. Kuik, Local acceptance of renewable energy: A case study from southeast germany, Energy Policy 39 (2011) 3252–3260.

D. A. Baharoon, H. A. Rahman, S. O. Fadhl, Personal and psychological factors affecting the successful development of solar energy use in yemen power sector: A case study, Renewable and Sustainable Energy Reviews 60 (2016) 516–535.

J. Wilsdon, The metric tide: Independent review of the role of metrics in research assessment and management, Sage, 2016.

I. H. Rowlands, The european directive on renewable electricity: Conflicts and compromises, Energy policy 33 (2005) 965–974.

L. Rubini, Aint wastintime no more: Subsidies for renewable energy, the SCM agreement, policy space, and law reform, Journal of International Economic Law 15 (2012) 525–579.

A. Vaona, Granger non-causality tests between (non) renewable energy consumption and output in italy since 1861: The (ir) relevance of structural breaks, Energy Policy 45 (2012) 226–236.

P. D. Río, Interactions between climate and energy policies: The case of spain, Climate Policy 9 (2009) 119–138.

J. Kraeusel, D. Möst, Carbon capture and storage on its way to large-scale deployment: Social acceptance and willingness to pay in germany, Energy Policy 49 (2012) 642–651.

P. Zhai, E. D. Williams, Analyzing consumer acceptance of photovoltaics (PV) using fuzzy logic model, Renewable Energy 41 (2012) 350–357.

L. Margheritini, A. M. Hansen, P. Frigaard, A method for EIA scoping of wave energy convertersbased on classification of the used technology, Environmental Impact Assessment Review 32 (2012) 33–44.

N. A. Khan, H. el Dessouky, Prospect of biodiesel in pakistan, Renewable and Sustainable Energy Reviews 13 (2009) 1576–1583.

R. Grimble, K. Wellard, Stakeholder methodologies in natural resource management: A review of principles, contexts, experiences and opportunities, Agricultural systems 55 (1997) 173–193.

M. S. Reed, A. Graves, N. Dandy, H. Posthumus, K. Hubacek, J. Morris, C. Prell, C. H. Quinn, L. C. Stringer, Who's in and why? A typology of stakeholder analysis methods for natural resource management, Journal of environmental management 90 (2009) 1933–1949.

D. M. Stoms, S. L. Dashiell, F. W. Davis, Siting solar energy development to minimize biological impacts, Renewable Energy 57 (2013) 289–298.

R. Hastik, C. Walzer, C. Haida, G. Garegnani, S. Pezzutto, B. Abegg, C. Geitner, Using the Footprint Approach to Examine the Potentials and Impacts of Renewable Energy Sources in the European Alps, Mountain Research and Development 36 (2016) 130–140.

D. Van der Horst, J. Evans, Carbon claims and energy landscapes: Exploring the political ecology of biomass, Landscape Research 35 (2010) 173–193.

N. Sawangphol, C. Pharino, Status and outlook for thailand's low carbon electricity development, Renewable and Sustainable Energy Reviews 15 (2011) 564–573.

I. Galparsoro, P. Liria, I. Legorburu, J. Bald, G. Chust, P. Ruiz-Minguela, G. Pérez, J. Marqués, Y. Torre-Enciso, M. González, et al., A marine spatial planning approach to select suitable areas for installing wave energy converters (wecs), on the basque continental shelf (bay of biscay), Coastal Management 40 (2012) 1–19.

A. Scheidel, A. H. Sorman, Energy transitions and the global land rush: Ultimate drivers and persistent consequences, Global Environmental Change 22 (2012) 588–595.

S. Kerr, K. Johnson, J. Side, Planning at the edge: Integrating across the land sea divide, Marine Policy 47 (2014) 118–125.

H. Sun, Q. Zhi, Y. Wang, Q. Yao, J. Su, Chinas solar photovoltaic industry development: The status quo, problems and approaches, Applied Energy 118 (2014) 221–230.

P. Späth, H. Rohracher, energy regions: The transformative power of regional discourses on socio-technical futures, Research policy 39 (2010) 449–458.

R. Sauter, J. Watson, Strategies for the deployment of micro-generation: Implications for social acceptance, Energy Policy 35 (2007) 2770–2779.

A.-M. Dowd, N. Boughen, P. Ashworth, S. Carr-Cornish, Geothermal technology in australia: Investigating social acceptance, Energy policy 39 (2011) 6301–6307.

E. K. Stigka, J. A. Paravantis, G. K. Mihalakakou, Social acceptance of renewable energy sources: A review of contingent valuation applications, Renewable and Sustainable Energy Reviews 32 (2014) 100–106.

J. Dvarioniene, I. Gurauskiene, G. Gecevicius, D. R. Trummer, C. Selada, I. Marques, C. Cosmi, Stakeholders involvement for energy conscious communities: The energy labs experience in 10 European communities, Renewable Energy 75 (2015) 512–518.

P. Ertör-Akyazı, F. Adaman, B. Özkaynak, Ü. Zenginobuz, Citizens preferences on nuclear and renewable energy sources: Evidence from turkey, Energy Policy 47 (2012) 309–320.

C. Walker, J. Baxter, D. Ouellette, Adding insult to injury: The development of psychosocial stress in ontario wind turbine communities, Social Science & Medicine 133 (2015) 358–365.

N. Zografakis, E. Sifaki, M. Pagalou, G. Nikitaki, V. Psarakis, K. P. Tsagarakis, Assessment of public acceptance and willingness to pay for renewable energy sources in Crete, Renewable and Sustainable Energy Reviews 14 (2010) 1088–1095.

P. Beria, I. Maltese, I. Mariotti, Multicriteria versus cost benefit analysis: A comparative perspective in the assessment of sustainable mobility, European Transport Research Review 4 (2012) 137.

M. Wolsink, Planning of renewables schemes: Deliberative and fair decision-making on landscape issues instead of reproachful accusations of non-cooperation, Energy policy 35 (2007) 2692–2704.

L. P. Koh, J. Ghazoul, Biofuels, biodiversity, and people: Understanding the conflicts and finding opportunities, Biological conservation 141 (2008) 2450–2460.

M. Wolsink, Contested environmental policy infrastructure: Socio-political acceptance of renewable energy, water, and waste facilities, Environmental Impact Assessment Review 30 (2010) 302–311.

S. Bowles, H. Gintis, Social capital and community governance, The economic journal 112 (2002) F419–F436.

P. Devine-Wright, S. Batel, Explaining public preferences for high voltage pylon designs: An empirical study of perceived fit in a rural landscape, Land Use Policy 31 (2013) 640–649.

A. Kontogianni, C. Tourkolias, M. Skourtos, D. Damigos, Planning globally, protesting locally: Patterns in community perceptions towards the installation of wind farms, Renewable Energy 66 (2014) 170–177.

J. C. Rogers, E. A. Simmons, I. Convery, A. Weatherall, Public perceptions of opportunities for community-based renewable energy projects, Energy Policy 36 (2008) 4217–4226.

G. Carrosio, Energia e scienze sociali: Stato dellarte e prospettive di ricerca, Quaderni di sociologia 66 (2014).

R. Madlener, K. Kowalski, S. Stagl, New ways for the integrated appraisal of national energy scenarios: The case of renewable energy use in Austria, Energy Policy 35 (2007) 6060–6074.

L. Chen, E. MacDonald, A system-level cost-of-energy wind farm layout optimization with landowner modeling, Energy Conversion and Management 77 (2014) 484–494.

P. Upham, S. Shackley, Stakeholder opinion of a proposed 21.5 mwe biomass gasifier in winkleigh, devon: Implications for bioenergy planning and policy, Journal of environmental policy and planning 8 (2006) 45–66.

J. Petersen, The application of municipal renewable energy policies at community level in Denmark: A taxonomy of implementation challenges, Sustainable Cities and Society (2018).

A. M. Brighenti, On territorology: Towards a general science of territory, Theory, culture & society 27 (2010) 52–72.

B. Anderson, Imagined communities: Reflections on the origin and spread of nationalism, Verso Books, 2006.

G. Bridge, S. Bouzarovski, M. Bradshaw, N. Eyre, Geographies of energy transition: Space, place and the low-carbon economy, Energy Policy 53 (2013) 331–340.

B. Jessop, N. Brenner, M. Jones, Theorizing sociospatial relations, Environment and planning D: society and space 26 (2008) 389–401.

European Court of Editors, Renewable energy for sustainable rural development: Significant potential synergies, but mostly unrealised, Technical Report, 2018.

C. A. Miller, J. Richter, J. O'Leary, Socio-energy systems design: A policy framework for energy transitions, Energy Research & Social Science 6 (2015) 29–40.

E. Turnhout, K. Neves, E. de Lijster, measurementalityin biodiversity governance: Knowledge, transparency, and the intergovernmental science-policy platform on biodiversity and ecosystem services (ipbes), Environment and Planning A 46 (2014) 581–597.

R. E. Park, The city: Suggestions for the investigation of human behavior in the city environment, American journal of sociology 20 (1915) 577–612.

P. Díaz, C. Adler, A. Patt, Do stakeholders perspectives on renewable energy infrastructure pose a risk to energy policy implementation? A case of a hydropower plant in Switzerland, Energy Policy 108 (2017) 21–28.

C. Morton, C. Wilson, J. Anable, The diffusion of domestic energy efficiency policies: A spatial perspective, Energy Policy 114 (2018) 77–88.

P. Nabielek, H. Dumke, K. Weninger, Balanced renewable energy scenarios: A method for making spatial decisions despite insufficient data, illustrated by a case study of the vorderland-feldkirch region, vorarlberg, austria, Energy, Sustainability and Society 8 (2018) 5.

T. Rockenbauch, P. Sakdapolrak, Social networks and the resilience of rural communities in the Global South: A critical review and conceptual reflections, Ecology and Society 22 (2017).

C. Walsh, Territorial agenda of the European Union 2020: Towards an inclusive, smart and sustainable europe of diverse regions, 2012.

L. T. Aarts, S. Houwing, Benchmarking road safety performance by grouping local territories: A study in the Netherlands, Transportation research part A: policy and practice 74 (2015) 174–185.

S. Alexiadis, Territorial cohesion and prospects for sustainable development: A co-integration analysis, Habitat International (2017).

Y. Yang, A. Hu, Investigating regional disparities of chinas human development with cluster analysis: A historical perspective, Social Indicators Research 86 (2008) 417–432.

C. Pecher, E. Tasser, J. Walde, U. Tappeiner, Typology of Alpine region using spatial pattern indicators, Ecological indicators 24 (2013) 37–47.

D. J. Ketchen, C. L. Shook, The Application of Cluster Analysis in Strategic Management Research: An Analysis and Critique, Strategic Management Journal 17 (1996) 441–458.

M. Neteler, M. H. Bowman, M. Landa, M. Metz, GRASS GIS: A multi-purpose open source GIS, Environmental Modelling & Software 31 (2012) 124–130.

D. Süsser, M. Döring, B. M. Ratter, Harvesting energy: Place and local entrepreneurship in community-based renewable energy transition, Energy Policy 101 (2017) 332–341.

K. L. Holstead, C. Galán-Díaz, L.-A. Sutherland, Discourses of on-farm wind energy generation in the UK farming press, Journal of Environmental Policy & Planning 19 (2017) 391–407.

Q. Wang, Z. Gao, H. Tang, X. Yuan, J. Zuo, Exploring the direct rebound effect of energy consumption: A case study, Sustainability 10 (2018) 259.

B. Winkler, I. Lewandowski, A. Voss, S. Lemke, Transition towards renewable energy production? Potential in smallholder agricultural systems in West Bengal, India, Sustainability 10 (2018) 801.

S. Karytsas, H. Theodoropoulou, Public awareness and willingness to adopt ground source heat pumps for domestic heating and cooling, Renewable and Sustainable Energy Reviews 34 (2014) 49–57.

A.-K. Kosenius, M. Ollikainen, Valuation of environmental and societal trade-offs of renewable energy sources, Energy Policy 62 (2013) 1148–1156.

M. Hyland, V. Bertsch, The role of community involvement mechanisms in reducing resistance to energy infrastructure development, Ecological Economics 146 (2018) 447–474.

S. Yang, D. Zhao, Do subsidies work better in low-income than in high-income families? Survey on domestic energy-efficient and renewable energy equipment purchase in China, Journal of Cleaner Production 108 (2015) 841–851.

R. R. Prasadh, J. Suresh, Green affinity: Evaluating the perceptions of youth on climate change and renewable energy, Prabandhan: Indian Journal of Management 9 (2016) 11–26.

P. Halder, J. Pietarinen, S. Havu-Nuutinen, P. Pelkonen, C.-Y. Chang, P. Prokop, M. Usak, Knowledge, perceptions, and attitudes as determinants of youths intentions to use bioenergya cross-national perspective, International journal of green energy 10 (2013) 797–813.

M. Yazdanpanah, N. Komendantova, Z. N. Shirazi, J. Linnerooth-Bayer, Green or in between? Examining youth perceptions of renewable energy in Iran, Energy Research & Social Science 8 (2015) 78–85.

J. A. Paravantis, E. Stigka, G. Mihalakakou, E. Michalena, J. M. Hills, V. Dourmas, Social acceptance of renewable energy projects: A contingent valuation investigation in Western Greece, Renewable Energy (2018).

C. L. Noblet, M. F. Teisl, K. Evans, M. W. Anderson, S. McCoy, E. Cervone, Public preferences for investments in renewable energy production and energy efficiency, Energy Policy 87 (2015) 177–186.

N. Ouhajjou, W. Loibl, S. Fenz, A. M. Tjoa, Stakeholder-oriented energy planning support in cities, Sustainable cities and society 28 (2017) 482–492.

T. Van Der Schoor, B. Scholtens, Power to the people: Local community initiatives and the transition to sustainable energy, Renewable and Sustainable Energy Reviews 43 (2015) 666–675.

M. Weber, Economy and society: An outline of interpretive sociology, volume 1, Univ of California Press, 1978.

M. O. Müller, A. Stämpfli, U. Dold, T. Hammer, Energy autarky: A conceptual framework for sustainable regional development, Energy policy 39 (2011) 5800–5810.

M. Engelken, B. Römer, M. Drescher, I. Welpe, Transforming the energy system: Why municipalities strive for energy self-sufficiency, Energy Policy 98 (2016) 365–377.

L. Argüelles, I. Anguelovski, E. Dinnie, Power and privilege in alternative civic practices: Examining imaginaries of change and embedded rationalities in community economies, Geoforum 86 (2017) 30–41.

S. Becker, C. Kunze, M. Vancea, Community energy and social entrepreneurship: Addressing purpose, organisation and embeddedness of renewable energy projects, Journal of Cleaner Production 147 (2017) 25–36.

A. Räsänen, A. Nygren, A. M. Monge, M. Käkönen, M. Kanninen, S. Juhola, From divide to nexus: Interconnected land use and water governance changes shaping risks related to water, Applied Geography 90 (2018) 106–114.

S. Sacchelli, I. De Meo, A. Paletto, Bioenergy production and forest multifunctionality: A trade-off analysis using multiscale GIS model in a case study in Italy, Applied Energy 104 (2013) 10–20.

G. Osti, Renewables, energy saving and welfare in italian fragile rural areas, Sociologia e Politiche Sociali (2016).

P. Bourdieu, The logic of practice, Stanford University Press, 1990.

A. Reckwitz, Toward a theory of social practices: A development in culturalist theorizing, European journal of social theory 5 (2002) 243–263.

C. J. Mitchell, Making sense of counterurbanization, Journal of rural studies 20 (2004) 15–34.

A. De Janvry, Agriculture for development: New paradigm and options for success, Agricultural Economics 41 (2010) 17–36.

G. Dalton, D. Lockington, T. Baldock, A survey of tourist attitudes to renewable energy supply in Australian hotel accommodation, Renewable energy 33 (2008) 2174–2185.

The territorial dimension of environmental sustainability Potential territorial indicators to support the environmental dimension of territorial cohesion, 2018.

N. L. Panwar, S. C. Kaushik, S. Kothari, Role of renewable energy sources in environmental protection: A review, Renewable and Sustainable Energy Reviews 15 (2011) 1513–1524.

S. Sacchelli, G. Garegnani, F. Geri, G. Grilli, A. Paletto, P. Zambelli, M. Ciolli, D. Vettorato, Trade-off between photovoltaic systems installation and agricultural practices on arable lands: An environmental and socio-economic impact analysis for italy, Land Use Policy 56 (2016) 90 – 99.

G. Grilli, M. Ciolli, G. Garegnani, F. Geri, S. Sacchelli, A. Poljanec, D. Vettorato, A. Paletto, A method to assess the economic impacts of forest biomass use on ecosystem services in a national park, Biomass and Bioenergy 98 (2017) 252 – 263.

B. Winkler, S. Lemke, J. Ritter, I. Lewandowski, Integrated assessment of renewable energy potential: Approach and application in rural South Africa, Environmental Innovation and Societal Transitions 24 (2017) 17–31.

L. Michaels, Y. Parag, Motivations and barriers to integrating prosuming services into the future decentralized electricity grid: Findings from Israel, Energy Research & Social Science 21 (2016) 70–83.

M. Hecher, S. Hatzl, C. Knoeri, A. Posch, The trigger matters: The decision-making process for heating systems in the residential building sector, Energy Policy 102 (2017) 288–306.

Autonomous Province of Bolzano, The Provincial Climate and Energy Plan of South Tyrol, Technical Report, 2011.

J. Saarenpää, M. Kolehmainen, H. Niska, Geodemographic analysis and estimation of early plug-in hybrid electric vehicle adoption, Applied energy 107 (2013) 456–464.

R. Becker, The new S language, CRC Press, 2018.

W. Härdle, L. Simar, Applied multivariate statistical analysis, Springer Science & Business Media, 2007.

A. Banerjee, R. N. Dave, Validating clusters using the Hopkins statistic, in: 2004 IEEE International Conference on Fuzzy Systems (IEEE Cat. No.04CH37542), volume 1, pp. 149–153 vol.1.

M. Charrad, N. Ghazzali, V. Boiteau, A. Niknafs, NbClust: An R package for determining the relevant number of clusters in a data set, Journal of Statistical Software 61 (2014) 1–36.

R Development Core Team, R: A Language and Environment for Statistical Computing, R Foundation for Statistical Computing, Vienna, Austria, 2008. ISBN 3-900051-07-0.

D. Damigos, D. Kaliampakos, Assessing the benefits of reclaiming urban quarries: A CVM analysis, Landscape and urban planning 64 (2003) 249–258.

J. Zarnikau, Consumer demand for green powerand energy efficiency, Energy Policy 31 (2003) 1661–1672.

H. Li, H. C. Jenkins-Smith, C. L. Silva, R. P. Berrens, K. G. Herron, Public support for reducing us reliance on fossil fuels: Investigating household willingness-to-pay for energy research and development, Ecological Economics 68 (2009) 731–742.

B. K. Sovacool, P. L. Ratan, Conceptualizing the acceptance of wind and solar electricity, Renewable and Sustainable Energy Reviews 16 (2012) 5268–5279.

R. K. Merton, Social theory and social structure, Simon and Schuster, 1968.

W. Leal Filho, J. Platje, W. Gerstlberger, R. Ciegis, J. Kääriä, M. Klavins, L. Kliucininkas, The role of governance in realising the transition towards sustainable societies, Journal of Cleaner Production 113 (2016) 755–766.

S. Sassen, The global city: Introducing a concept, Brown J. World Aff. 11 (2004) 27.

E. Niesten, A. Jolink, A. B. L. de Sousa Jabbour, M. Chappin, R. Lozano, Sustainable collaboration: The impact of governance and institutions on sustainable performance, Journal of cleaner production 155 (2017) 1–6.

B. B. Nielsen, The role of trust in collaborative relationships: A multi-dimensional approach, M@ n@ gement 7 (2004) 239–256.

S. Coelho, M. Russo, R. Oliveira, A. Monteiro, M. Lopes, C. Borrego, Sustainable energy action plans at city level: A Portuguese experience and perception, Journal of Cleaner Production 176 (2018) 1223–1230.

G. Robins, P. Pattison, Y. Kalish, D. Lusher, An introduction to Exponential Random Graph Models for social networks, Social Networks 29 (2007) 169–348.

A. Caimo, N. Friel, Bergm: Bayesian exponential random graphs in R, Journal of Statistical Software 61 (2014) 1–25.

A. Caimo, N. Friel, Bayesian model selection for exponential random graph models, Social Networks 35 (2013) 11 – 24.

A. Caimo, A. Mira, Efficient computational strategies for doubly intractable problems with applications to Bayesian social networks, Statistics and Computing 25 (2015) 113–125.

L. Bouranis, N. Friel, F. Maire, Efficient Bayesian inference for exponential random graph models by correcting the pseudo-posterior distribution, Social Networks 50 (2017) 98–108.

A. Caimo, A. Lomi, Knowledge sharing in organizations: A Bayesian analysis of the role of reciprocity and formal structure, Journal of Management 41 (2014) 665–691.

A. Caimo, F. Pallotti, A. Lomi, Bayesian exponential random graph modelling of interhospital patient referral networks, Statistics in Medicine 36 (2017) 2902–2920.

D. R. Hunter, S. M. Goodreau, M. S. Handcock, Goodness of fit of social network models, Journal of the American Statistical Association 103 (2008) 248–258.

M. Bonte, P. J. Stuyfzand, A. Hulsmann, P. Van Beelen, Underground thermal energy storage: Environmental risks and policy developments in the netherlands and european union, Ecology and Society 16 (2011).

M. Wolsink, The research agenda on social acceptance of distributed generation in smart grids: Renewable as common pool resources, Renewable and Sustainable Energy Reviews 16 (2012) 822–835.

J. J. Cohen, J. Reichl, M. Schmidthaler, Re-focussing research efforts on the public acceptance of energy infrastructure: A critical review, Energy 76 (2014) 4–9.

A. Delicado, E. Figueiredo, L. Silva, Community perceptions of renewable energies in portugal: Impacts on environment, landscape and local development, Energy Research & Social Science 13 (2016) 84–93.

P. Bourdieu, Structures, habitus, practices, in: Rethinking the Subject, Routledge, 2018, pp. 31–45.

S. Hassan, Y. Sani, A. A. Aziz, N. Sulaiman, W. Daud, Biogasoline: An out-of-the-box solution to the food-for-fuel and land-use competitions, Energy Conversion and Management 89 (2015) 349–367.

G. Walker, P. Devine-Wright, S. Hunter, H. High, B. Evans, Trust and community: Exploring the meanings, contexts and dynamics of community renewable energy, Energy Policy 38 (2010) 2655–2663.

E. McCullough, E. Sarver, Implementing effective conflict management techniques to achieve sustainable development, in: 2016 SME Annual Conference and Expo: The Future for Mining in a Data-Driven World, Society for Mining, Metallurgy and Exploration, 2016, pp. 285–291.

H. Schaller, H. I. Jónasson, T. Aikoh, Managin g conflicting attitudes: National parks in iceland and japan, Tourismos: An International Multidisciplinary Journal of Tourism 8 (2013) 21–38.

M. Asif, T. Muneer, Energy supply, its demand and security issues for developed and emerging economies, Renewable and Sustainable Energy Reviews 11 (2007) 1388–1413.

M. Wolsink, Near-shore wind powerprotected seascapes, environmentalists attitudes, and the technocratic planning perspective, Land Use Policy 27 (2010) 195–203.

F. Ribeiro, P. Ferreira, M. Araújo, The inclusion of social aspects in power planning, Renewable and Sustainable Energy Reviews 15 (2011) 4361–4369.

S. Batel, P. Devine-Wright, T. Tangeland, Social acceptance of low carbon energy and associated infrastructures: A critical discussion, Energy Policy 58 (2013) 1–5.

E. Sardianou, P. Genoudi, Which factors affect the willingness of consumers to adopt renewable energies?, Renewable energy 57 (2013) 1–4.

W. Liu, C. Wang, A. P. Mol, Rural public acceptance of renewable energy deployment: The case of shandong in china, Applied energy 102 (2013) 1187–1196.

C. Zarfl, A. E. Lumsdon, J. Berlekamp, L. Tydecks, K. Tockner, A global boom in hydropower dam construction, Aquatic Sciences 77 (2015) 161–170.

T. Kjellstrom, A. J. McMichael, Climate change threats to population health and well-being: the imperative of protective solutions that will last, Global health action 6 (2013) 20816.

X. Yuan, J. Zuo, D. Huisingh, Social acceptance of wind power: a case study of shandong province, china, Journal of Cleaner Production 92 (2015) 168–178.

D. Van der Horst, Nimby or not? exploring the relevance of location and the politics of voiced opinions in renewable energy siting controversies, Energy policy 35 (2007) 2705–2714.

P. Devine-Wright, Enhancing local distinctiveness fosters public acceptance of tidal energy: a uk case study, Energy Policy 39 (2011) 83–93.

M. A. Cacciatore, D. A. Scheufele, B. R. Shaw, Labeling renewable energies: how the language surrounding biofuels can influence its public acceptance, Energy Policy 51 (2012) 673–682.

N. Hall, P. Ashworth, P. Devine-Wright, Societal acceptance of wind farms: Analysis of four common themes across australian case studies, Energy Policy 58 (2013) 200–208.

Ø. Aas, P. Devine-Wright, T. Tangeland, S. Batel, A. Ruud, Public beliefs about high-voltage powerlines in norway, sweden and the united kingdom: A comparative survey, Energy Research & Social Science 2 (2014) 30–37.

P. A. Bonar, I. G. Bryden, A. G. Borthwick, Social and ecological impacts of marine energy development, Renewable and Sustainable Energy Reviews 47 (2015) 486–495.

J. E. Carlisle, S. L. Kane, D. Solan, M. Bowman, J. C. Joe, Public attitudes regarding large-scale solar energy development in the us, Renewable and Sustainable Energy Reviews 48 (2015) 835–847.

P. Viebahn, D. Vallentin, S. Höller, Prospects of carbon capture and storage (ccs) in indias power sector–an integrated assessment, Applied Energy 117 (2014) 62–75.

B. J. Walker, B. Wiersma, E. Bailey, Community benefits, framing and the social acceptance of offshore wind farms: an experimental study in england, Energy Research & Social Science 3 (2014) 46–54.

J. Woodcock, P. Edwards, C. Tonne, B. G. Armstrong, O. Ashiru, D. Banister, S. Beevers, Z. Chalabi, Z. Chowdhury, A. Cohen, et al., Public health benefits of strategies to reduce greenhouse-gas emissions: urban land transport, The Lancet 374 (2009) 1930–1943.

A. Verbruggen, Renewable and nuclear power: A common future?, Energy Policy 36 (2008) 4036–4047.

E. Savvanidou, E. Zervas, K. P. Tsagarakis, Public acceptance of biofuels, Energy Policy 38 (2010) 3482–3488.

H. Wang, S. L. Brown, G. N. Magesan, A. H. Slade, M. Quintern, P. W. Clinton, T. W. Payn, Technological options for the management of biosolids, Environmental Science and Pollution Research-International 15 (2008) 308–317.

A. Verbruggen, M. Fischedick, W. Moomaw, T. Weir, A. Nadaï, L. J. Nilsson, J. Nyboer, J. Sathaye, Renewable energy costs, potentials, barriers: Conceptual issues, Energy policy 38 (2010) 850–861.

N. C. Bronfman, R. B. Jiménez, P. C. Arévalo, L. A. Cifuentes, Understanding social acceptance of electricity generation sources, Energy Policy 46 (2012) 246–252.

K. Molnarova, P. Sklenicka, J. Stiborek, K. Svobodova, M. Salek, E. Brabec, Visual preferences for wind turbines: Location, numbers and respondent characteristics, Applied Energy 92 (2012) 269–278.

H. Muggenburg, A. Tillmans, P. SchweizerRies, P. Raabe, T. Adelmann, Social acceptance of Pico PV systems as a means of rural electrification: A sociotechnical case study in Ethiopia, Energy for Sustainable Development 16 (2012) 90–97.

E. Dutschke, A. Paetz, Dynamic electricity pricing: Which programs do consumers prefer?, Energy Policy 59 (2013) 226–234.

K. Soma, C. Haggett, Enhancing social acceptance in marine governance in Europe, Ocean & Coastal Management 117 (2015) 61–69.

C. Voigt, L. Lehnert, G. Petersons, F. Adorf, L. L. Bach, Wildlife and renewable energy: German politics cross migratory bats, European Journal of Wildlife Research 61 (2015) 213–219.

D. Hess, Technology and productoriented movements: Approximating social movement studies and science and technology studies 30 (2005) 515–530.

L. Levidou, Eu criteria for sustainable biofuels: Accounting for carbon, depoliticising plunder,, Geoforum 44 (2013) 211–223.

C. Soderberg, K. Eckerberg, Rising policy conflicts in Europe over bioenergy and forestry, Forest Policy and Economics 33 (2013) 112–119.

G. Walker, Renewable energy and the public,, Land Use Policy 12 (1995) 49–59.

K. Patlitzianas, K. Ntotas, H. Doukas, J. Psarras, Assessing the renewable energy producers environment in EU accession member states, Energy Conversion and Management 48 (2007) 890–897.

I. Heras-Saizarbitoria, E. Cilleruelo, I. Zamanillo, Public acceptance of renewables and the media: An analysis of the Spanish PV solar experience, Renewable and Sustainable Energy Reviews 15 (2011) 4685–4696.

E. Moula, M. Maula, J. Hamdy, T. Fang, N. Jung, R. Lahdelma, Researching social acceptability of renewable energy technologies in Finland, International Journal of Sustainable Built Environment 2 (2013) 89–98.

A. Abdilahi, A. Mohd Yatim, M. Mustafa, O. Khalaf, A. Shumran, F. Mohamed Nor, Feasibility study of renewable energybased microgrid system in Somaliland's urban centers, Renewable and Sustainable Energy Reviews 40 (2014) 10481059.

S. Hammami, S. Chtourou, A. Triki, Identifying the determinants of community acceptance of renewable energy technologies: The case study of a wind energy project from Tunisia, Renewable and Sustainable Energy Reviews 54 (2016) 151–160.

S. Agterbosch, R. M. Meertens, W. J. Vermeulen, The relative importance of social and institutional conditions in the planning of wind power projects, Renewable and Sustainable Energy Reviews 13 (2009) 393–405.

A. Petrella, Innovazioni e conflitti nella gestione locale delle energie rinnovabili: Quattro casi italiani a confronto, Stato e mercato (2012) 283321.

I. Maltsoglou, T. Koizumi, E. Felix, The status of bioenergy development in developing countries, Global Food Security 2 (2013) 104–109.

S. Muench, E. Thuss, S. Guenther, What hampers energy system transformations? The case of smart grids, Energy Policy 73 (2014) 80–92.

M. Bonte, P. Stuyfzand, A. Hulsmann, P. van Beelen, Underground thermal energy storage: Environmental risks and policy developments in the netherlands and European Union, Ecology and Society 16 (2011) 22.

A. Battaglini, N. Komendantova, P. Brtnik, A. Patt, Perception of barriers for expansion of electricity grids in the European Union, Energy Policy 47 (2012) 254–259.

F. Hvelplund, Renewable energy and the need for local energy markets, Energy 31 (2006) 1957 1966.

E. Oikonomou, C. Kilias, A. Goumas, A. Rigopoulos, E. Karakatsani, M. Damasiotis, D. Papastefanakis, N. Marini, Renewable energy sources (RES) projects and their barriers on a regional scale: The case study of wind parks in the Dodecanese islands, Greece, Energy Policy 37 (2009) 4874–4883.

A. Shamsuzzoha, A. Grant, J. Clarke, Implementation of renewable energy in scottish rural area: A social study, Renewable and Sustainable Energy Reviews 16 (2012) 185–191.

T. German Energiewende: History, status quo, Hake, j.f. and fischer, w. and venghaus, s. and weckenbrock, c., Energy 92 (2015) 532–546.

Appendices

Appendix I - Detailed results of Chapter 1

The next table includes all relevant dimensions and sub-dimensions of social territorial system for low carbon energy systems according to the systematic literature review included in Balest et al. (2018). The references related to the other territorial systems are available online in Science Direct.

Dimension	Sub-dimension	Specific aspects	References
A.1 Substance	A.1.1.Socio-demographic characteristic	Characteristics of population in terms of: • Family income • Family size • Number of families • Population density in a local territory • Distribution of inhabitants in the territory • Variation of inhabitants in selected year of reference • Age structure of the population • Gender structure of the population • Employment • Education • Quality of life or household wealth	Devine-Wright (2005); Asif and Muneer (2007); Wolsink (2007, 2010); Dalton et al. (2008); Wolsink (2010); Osti (2010); Ribeiro et al. (2011); Ertör-Akyazı et al. (2012); Batel et al. (2013); Sardianou and Genoudi (2013); Liu et al. (2013); Kontogianni et al. (2014); Stigka et al. (2014); Zarfl et al. (2015); Kjellstrom and McMichael (2013); Van Rijnsoever et al. (2015); Yuan et al. (2015)

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Dimension	Sub-dimension	Specific aspects	References
	A.1.2 Cultural aspects	Cultural features in terms of: • Symbolic aspects (e.g. traditions, modes of social organizations, and cultures) • Affective aspects (e.g. affective ties between individuals, groups and socio-physical environment) • Socially constructed aspects • Collective identity • Place attachment (emotional connection to location) • Landscape cultural values (e.g. attachment to landscape context or landscape quality) • Land cultural value (e.g. historical and cultural functions of the land) • Environmental attitudes of the population • Safety culture (e.g. attitudes and behaviors that increase development and implementation of safe technologies)	Devine-Wright (2005); Van der Horst (2007); Osti (2010); Wolsink (2010,?); Devine-Wright (2011); Musall and Kuik (2011); Cacciatore et al. (2012); Ertör-Akyazı et al. (2012); Wolsink (2012); Hall et al. (2013); Aas et al. (2014); Cohen et al. (2014); Delicado et al. (2016); Stigka et al. (2014); Bonar et al. (2015); Carlisle et al. (2015)
	A.1.3 Habitus	Schemes of thought, perceptions and actions people have in the long period using energy, i.e.: • Local history of renewable energy • Habitus of resilience (or the capacity to group and respond to a crisis) • Habitus of initiative • Habitus of collective ownership	Koh and Ghazoul (2008); Kasperson and Ram (2013); Upham et al. (2015)
	A.1.4 Preferences and interests	People develop preferences: • Between renewable energy and nuclear or other kinds of energy production sources and technologies • Between different energy appliances • On local distinctiveness • Between several local development choices	Devine-Wright (2005); Koh and Ghazoul (2008); Rogers et al. (2008); Osti (2010); Devine-Wright (2011); Ertör-Akyazı et al. (2012); Viebahn et al. (2014); Walker et al. (2014)

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Dimension	Sub-dimension	Specific aspects	References
	A.1.5 Perceptions and public beliefs	People develop perceptions, about: • The distribution of risks and benefits • The level of sustainability • The impacts of renewable energies and single technologies • The future of REs, developing optimistic or pessimistic expectations • The risks of climate change • The meaning of energy security • The possibility of power plant accidents • The advantages and disadvantages of REs development • Impacts of REs implementation on local development	Devine-Wright (2005); Solomon et al. (2009); Woodcock et al. (2009); Koh and Ghazoul (2008); Rogers et al. (2008); Verbruggen (2008); Savvanidou et al. (2010); Wang et al. (2008); Verbruggen et al. (2010); Devine-Wright (2011); Sovacool (2011); Bronfman et al. (2012); Ertör-Akyazı et al. (2012); Molnarova et al. (2012); Muggenburg et al. (2012); Zhai and Williams (2012); Devine-Wright and Batel (2013); Dutschke and Paetz (2013); Aas et al. (2014); Secco et al. (2014); Soma and Haggett (2015); Voigt et al. (2015); Walker et al. (2014); Bonar et al. (2015); Hassan et al. (2015); Yuan et al. (2015)
	A.1.6 Citizens initiatives	Citizens initiatives are expressed as: • Environmental or other forms of activism • Social movements • Technology- and product-oriented movements • Investments in energy saving measures or other energy interventions • Communication through media and other tools.	Hess (2005); Maruyama et al. (2007); Koh and Ghazoul (2008); Zoellner et al. (2008); Zografakis et al. (2010); Bronfman et al. (2012); Ertör-Akyazı et al. (2012); Rogers et al. (2012); Levidou (2013); Soderberg and Eckerberg (2013); Soma and Haggett (2015)
	A.1.7 Human capital	Human capital is considered in terms of background information, knowledge and awareness concerning: • Renewable energy technologies (RETs) • Link between energy used and CO2 emissions • Climate change	Walker (1995); Ekins (2004); Patlitzianas et al. (2007); Sauter and Watson (2007); Zoellner et al. (2008); Zografakis et al. (2010); Dowd et al. (2011); Heras-Saizarbitoria et al. (2011); Ertör-Akyazı et al. (2012); Sovacool and Ratan (2012); Moula et al. (2013); Abdilahi et al. (2014); Cohen et al. (2014); Stigka et al. (2014); Hammami et al. (2016)
	A.1.8 Commitment	Commitment is investigated considering • Object of the commitments of several actors • Expressed commitments • Public discussions • Public debate in the media • Shared visions of local actors • Correspondence of activities with group and individual commitments	Zoellner et al. (2008); Agterbosch et al. (2009); Osti (2010); Heras-Saizarbitoria et al. (2011); Petrella (2012); Maltsoglou et al. (2013); Muench and Thuss (2014); Van Der Schoor and Scholtens (2015)

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Dimension	Sub-dimension	Specific aspects	References
A.2 Procedure	A.2.1 Institutional and socio-political context	The institutional and socio-political context is characterized by: • Type of decision-making process, i.e. representativeness inter-sectoral process, transparency, time and cost consuming • Public policy framework • Democratic deficit of the planning system • Procedural justice • Top-down or bottom up planning	Agterbosch et al. (2009); Wolsink (2010); Bonte et al. (2011); Müller et al. (2011); Battaglini et al. (2012); Beria et al. (2012); Sovacool and Ratan (2012); Hall et al. (2013); Aas et al. (2014); Muench and Thuss (2014); Hassan et al. (2015)
	A.2.2 Participation	Participation permits people and stakeholders to be involved in the technological or change process. The participative mechanisms and processes are investigated considering: • Level of participation • Goals of participation • Timeline and accuracy of information • Involved actors • Cooperation mechanisms • Current and past community ownership or engagement • Legitimacy of participative mechanisms and processes • Ability of voice to be heard, adequate information, being treated with respect, and unbiased decision-making • Engagement of the interests of local community • Consideration of "local sentiments" • Expectations of actors	Ekins (2004); Hvelplund (2006); Wüstenhagen et al. (2007); Zoellner et al. (2008); Agterbosch et al. (2009); Oikonomou et al. (2009); Müller et al. (2011); Musall and Kuik (2011); Ribeiro et al. (2011); Ertör-Akyazı et al. (2012); Sovacool and Ratan (2012); Kasperson and Ram (2013); Liu et al. (2013); Miller et al. (2013); Aas et al. (2014); Cohen et al. (2014); Bonar et al. (2015); Longstaff et al. (2015)

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Dimension	Sub-dimension	Specific aspects	References
A.3 Relationship	A.3.1 Habitus	People also develop habitus in terms of relationships with others. Consequently, the existence of a systematic network for public issues and energy topics is important. These habitus-networks are analyzed in terms of involved actors, and network characteristics. Three kinds of relationship are interesting: • one influences the individual choice for individual energy appliances and plants • one influences the individual choice to participate or be involved in a common experience (cooperative, district heating), • one influences the implementation of common plants. However, not all relationships are habitus.	Agterbosch et al. (2009); Walker et al. (2010); Ribeiro et al. (2011); Bronfman et al. (2012); Ertör-Akyazı et al. (2012); Aas et al. (2014); Stigka et al. (2014); Bonar et al. (2015); Upham et al. (2015)
	A.3.2 Source of the relationship	Relationships can be described as bridges between actors that permit the exchange of several resources, i.e. information or discussions with the aim to make decisions.	Späth and Rohracher (2010); Müller et al. (2011); Shamsuzzoha et al. (2012); Aas et al. (2014); Kontogianni et al. (2014)
	A.3.3 Actors in the relationship	Variety of actors, relationships between different levels of actors (citizens, stakeholders, decision-makers).	Agterbosch et al. (2009); Upham et al. (2015)
	A.3.4 Characteristics of the relationship	The characteristics of the relationships are related to: • Trust between actors • Trust in authorities • Informal contacts • Coordination mechanisms • Cooperation versus competition links • Shortness of the communication links • Transparency of relationships • Social capital • Density of relationships	Upham and Shackley (2006); Agterbosch et al. (2009); Michalena and Angeon (2009); Ribeiro et al. (2011); Bronfman et al. (2012); Ertör-Akyazı et al. (2012); Aas et al. (2014); Stigka et al. (2014); Bonar et al. (2015); Hammami et al. (2016)
	A.3.5 Object of the relationship	It is possible create a guiding vision and, consequently, the network based on this vision. The vision aims to promote a territory with precise characteristics.	Späth and Rohracher (2010); German Energiewende: History and status quo (2015)

Table 5.5: Dimensions and sub-dimensions of the territorial social system that can influence local population actions or reactions to energy transition. Source: On line attachment to Balest et al. (2018).

Appendix II - Data sources for Chapters 2 and 3

Data collection has been one of the most challenging aspects of this thesis. This thesis already underlines the main data collection problems and this attachment reports the data sources.

Data	Year	Source
Number and age of inhabitants	2016	ISTAT - National Institute of Statistics
Number of household components (average)	2016	ISTAT - National Institute of Statistics
Citizenship and migrations	2016	ISTAT - National Institute of Statistics
Number of pupils in kindergartens and students in primary, secondary, and higher schools	2016	MIUR - Minister of Education, University, and Research
Number of books in local libraries	2016	MIUR - Minister of Education, University, and Research
Number of cars	2016	MIT - Minister of Infrastructures and Transports
Income	2016	MEF - Minister of Economics and Finance
Enterprises	2016	Local chamber of commerce - Bolzano
Tourists overnight	2016	Local chamber of commerce - Bolzano
Urban and differentiated waste		ISPRA
Votes in election	2013	Italian Government
Associations	2018	Rete Civica
Surface and elevation	2016	ISTAT - National Institute of Statistics
Natural park surface	2017	Autonomous Province of Bolzano
Highway, streets, and railway surfaces	2016	CORINE Land cover and own elaboration
Surface of solar thermal plants	2016	Autonomous Province of Bolzano - Energy Saving Office and gse
Power of geothermal plants	2016	Autonomous Province of Bolzano - Energy Saving Office
Power of biogas plants	2016	Autonomous Province of Bolzano - Energy Saving Office
District heatings	2016	Autonomous Province of Bolzano - Energy Saving Office
PV power	2014	gse
Avalanche and flooding phenomena	2018	Autonomous Province of Bolzano
Contracts between municipalities and public utilities	2016	MEF - Ministry of Economics and Finance
Geomorphological valley and closeness	2016	Ancitel open data: own elaboration
Urban, agriculture, and forest land cover	2016	CORINE Land Cover, Ancitel open data: own elaboration
Solar radiation	2016	PVGIS: own elaboration

Table 5.6: Data description and sources used in this research.