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Stakeholders Involvement in Renewable Energy Communities Co-ownership

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SCORE
Co-own. Prosume. Renew.
Supporting Consumer Ownership in Renewable Energies

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Abstract

The energy transition towards a more sustainable and fossil-free energy system still face several challenges. In fact, the transformation from the current system to a decentralized renewable energy system requires a successful involvement of the communities to remodel the current energy production. As a solution, Renewable Energy Communities (RECs) can involve the stakeholders in an active financial participation labelled Consumer Stock Ownership Plans (CSOPs). By acquiring co-ownership in RE, the model places the stakeholders as producers and consumers of the system, making them "prosumers". Along these lines, an ongoing EU Horizon 2020 project called "Supporting Consumer co-Ownership in Renewable Energies" (SCORE) seeks to overcome the energy usage of fossil sources by promoting the creation of RECs and facilitating co-ownership, focusing on the inclusion of vulnerable groups. Into this framework, this thesis aims to involve stakeholders in RECs co-ownership. This thesis adopts a mixed methodology with an interdisciplinary framework. In this way, based on a stakeholders-oriented approach, the thesis follows three phases: (1) Assessment of different Key Performance Indicators (KPIs) to determine the best refurbishment alternative in terms of energy efficiency, considering a multi-criteria analysis with the PROMETHEE method; (2) Involvement of stakeholders in co-ownership models and evaluation of impacts regarding the creation of RECs, by applying the Storytelling method in two workshops with a WebGIS - Geographic Information system visualization tool; (3) Elaboration of recommendations to enable policies on prosumership at EU and local level. Finally, the thesis provides six interdisciplinary recommendations, going over social, environmental, and economic dimensions of sustainability under the phenomenon of prosumerism. The thesis outcomes can assist energy research and policy making to evaluate best scenarios for urban energy retrofitting; to understand stakeholders' visions about the project scenarios; and to build an effective model to involve the stakeholders in successful energy transitions. The conclusion gives an overall view on how to achieve better interdisciplinary practices when designing RECs with the involvement of stakeholders in co-ownership models by coupling different areas and multi-actors to support decision-making processes in urban energy planning. The proposed methodology has been applied to five pilot case studies of Susa Valley municipalities in Italy. However, the methodology can be applied to other contexts due to its flexibility. This thesis is part of the European H2020 SCORE project (https://www.score-h2020.eu/).

Keywords: renewable energy communities (RECs); stakeholders involvement; consumer co-ownership; interdisciplinary mixed methodology.

Riassunto

La transizione energetica verso un sistema energetico più sostenibile e privo di fossili deve ancora affrontare diverse sfide. La trasformazione del sistema attuale verso un sistema decentralizzato di energia rinnovabile richiede infatti, un più efficace coinvolgimento delle comunità al fine di rimodellare l'attuale produzione di energia. Come soluzione, le Comunità Energetiche Rinnovabili (CER) possono coinvolgere le parti interessate in una partecipazione finanziaria attiva denominata CSOP (Piani di azionariato dei consumatori). Acquistando la co-proprietà di impianti di energia rinnovabile (ER), il modello pone gli stakeholder come produttori e consumatori del sistema, rendendoli "prosumatori". In questo senso, un progetto finanziato dall'UE H2020 denominato SCORE (Supporto alla Co-Proprietà dei Consumatori nelle Energie Rinnovabili) cerca di superare l'uso di energia da fonti fossili promuovendo la creazione di CER e facilitando la co-proprietà, concentrandosi sull'inclusione dei gruppi più vulnerabili. In tale contesto, la tesi mira a coinvolgere le parti interessate nella co-proprietà dei CER. Questa tesi adotta una metodologia mista all'interno di un quadro interdisciplinare. In questo modo, seguendo un approccio che guarda agli stakeholders, la tesi segue tre fasi: (1) Valutazione di diversi Key Performance Indicators (KPIs) per determinare la migliore alternativa di ristrutturazione in termini di efficienza energetica, considerando un'analisi multicriterio con il Metodo PROMETHEE; (2) Coinvolgimento degli stakeholder nei modelli di co-proprietà e valutazione degli impatti riguardanti la creazione di CER, attraverso il metodo Storytelling applicato in due workshop con uno strumento di visualizzazione WebGIS - Sistema d'informazione geografica; (3) Elaborazione di raccomandazioni che consentano politiche sulla prosumership a livello UE e locale. Infine, la tesi fornisce infine sei raccomandazioni interdisciplinari, andando oltre quelle che sono le dimensioni sociali, ambientali ed economiche della sostenibilità sotto il fenomeno del prosumerism. I risultati della tesi possono sostenere la ricerca energetica e l'elaborazione di politiche per la valutazione dei migliori scenari volti all'adeguamento energetico urbano; per comprendere le visioni degli stakeholder sugli scenari del progetto; e per costruire un modello efficace che coinvolga le parti interessate nelle transizioni energetiche di successo. La conclusione fornisce una visione generale su come ottenere migliori pratiche interdisciplinari durante la progettazione di CER con il coinvolgimento delle parti interessate nei modelli di co-proprietà, mettendo in relazione diverse aree e molteplici attori con lo scopo di supportare i processi decisionali nella pianificazione energetica urbana. La metodologia proposta è stata applicata a cinque casi studio pilota dei comuni della Valle di Susa in Italia. Tuttavia, la metodologia utilizzata può essere applicata ad altri contesti grazie alla sua flessibilità. Questa tesi fa parte del progetto europeo H2020 SCORE (https://www.score-h2020.eu/).

Parole chiave: comunità energetiche rinnovabili (CER); coinvolgimento degli stakeholder; co-proprietà dei consumatori; metodologia mista interdisciplinare.

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List of Abbreviations

AMICO	Amico Società Cooperativa Sociale
BDTRE	Base Dati Territoriale di Riferimento degli Enti
CO_2	Carbon Dioxide
CEC	Citizen Energy Community
CFAVS	Consorzio Forestale Alta Valle Susa
CSOP	Consumer Stock Ownership Plans
DH	District Heating
DHW	Domestic Hot Water
EE	Energy Efficiency
EU	European Union
FORESTA	La Foresta Società Cooperativa
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIS	Geographic Information System
IEA	International Energy Agency
IEMD	Internal Electricity Market Directive
ISTAT	Istituto Nazionale di Statistica
KPI	Key Performance Indicator
LHV	Lower Heating Value
LIHS	Low Income Households
MCA	Multi-Criteria Analysis
PBP	Payback Period
PEFC	Program for Endorsement of Forest Certification schemes
PM	Particulate Matter
POLITO	Politecnico di Torino
PROMETHEE	Preference Ranking Organization Method for Enrichment of Evaluations
RE	Renewable Energy
REC	Renewable Energy Community
RED	Renewable Energy Directive
RES	Renewable Energy Source
SCORE	Supporting Consumer co-Ownership in Renewable Energies
SGDs	Sustainable Development Goals
SH	Space Heating
SMEs	Small and Medium-sized Enterprises
STEM	Science, Technology, Engineering and Mathematics
TAA	Thermal Account Access
TFC	Total Final Consumption

1 Introduction

1.1 Background and Problem Statement

The Earth's climate has constantly changed throughout history. The current global average temperature is 0.85°C higher than it was in the late 19th century and the period from 1983 to 2012 was the warmest 30-year period of the last 1400 years in the Northern Hemisphere (*IPCC*, 2014). This increase in temperature has several consequences for the planet earth, as the declining of mountain glaciers and biodiversity hotspots. Approximately half of the causes that promote changes in the global average surface temperature was generated by anthropogenic forcings, such as the anthropogenic increase of Greenhouse Gas (GHG) concentrations (*IPCC*, 2018, 2014)

The continuous growth of the global population increases the relevance of anthropogenic forcings in global warming and GHG emissions. Globally, urban areas are expected to absorb virtually all of the future growth of the world's population, making cities the most important vehicles to fight climate change. With more than half of humankind living in cities, it is estimated that urban areas account for 70 percent of global economic output, and also for half of the current GHG emissions (*UNEP*, 2019). This way, the economic and population growth will continue to be the two most important drivers of increase in carbon dioxide (CO_2) emissions from fossil fuel combustion (*IPCC*, 2014).

Rapid urban growth presents therefore an important challenge to the implementation of the 2030 Agenda for Sustainable Development. In 2015, the world adopted the Agenda, agreeing on a "shared blueprint for peace and prosperity for people and the planet". At the core of it there are 17 Sustainable Development Goals (SDGs) and 169 corresponding targets, which are an urgent call for action by all countries in a global partnership. They recognize that ending poverty and other vulnerabilities must go together with strategies that improve health and education, reduce inequality, and spur economic growth. All while tackling climate change and working to preserve our ecosystems (*Kanuri et al.*, 2016).

Energy is one of the central topics to the achievement of the 2030 Agenda for Sustainable Development. It is inextricably interlinked to many Sustainable Development Goals, including poverty eradication, food security, clean water and sanitation, health, education, prosperity, job creation, sustainable cities and the empowerment of youth and women. However, in order to promote human development, modern energy has to be accessible, affordable, and reliable. A shift towards sustainable energy solutions is essential to the achievement of the Paris Agreement targets adopted under the United Nations Framework Convention on Climate Change (*Kanuri et al.*, 2016).

Energy is central to nearly every big challenge and opportunity the world faces today, since the increase of energy demand and coal share in the global energy matrix were the main contributors to emission growth in the last decades. In the baseline scenarios evaluated by the *IPCC* (2014), direct CO_2 emissions from the energy supply sector are projected to almost double or even triple by 2050 compared to the level in 2010, unless energy intensity improvements are significantly accelerated beyond the historical development.

Nowadays energy accounts for two-thirds of total greenhouse gas emissions around the world. Considering this, efforts to reduce emissions and mitigate climate change ought to include the energy sector for substantial improvements (*International Energy Agency*, 2020). Figure 1.1 shows how the Total Final Consumption (TFC) grew per type of energy source during 1990 and 2018 in the world. Until 2018, the total consumption kept a constant growth rate and *oil products* are the highest share of the total consumption among all the sources (almost 40,64% in 2018). Renewable sources as *wind, solar, etc.* have minimum consumption values (almost 0.49% in 2018), to the point that it becomes hard to see them in Figure 1.1.

On the other hand, when looking for CO_2 emissions growth by sector between 1990 and 2018 in the world, the chart from International Energy Agency (IEA) in Figure 1.2 shows that electricity and heat producers were the biggest contributors (almost 41.71%) to the CO_2 emissions generation.

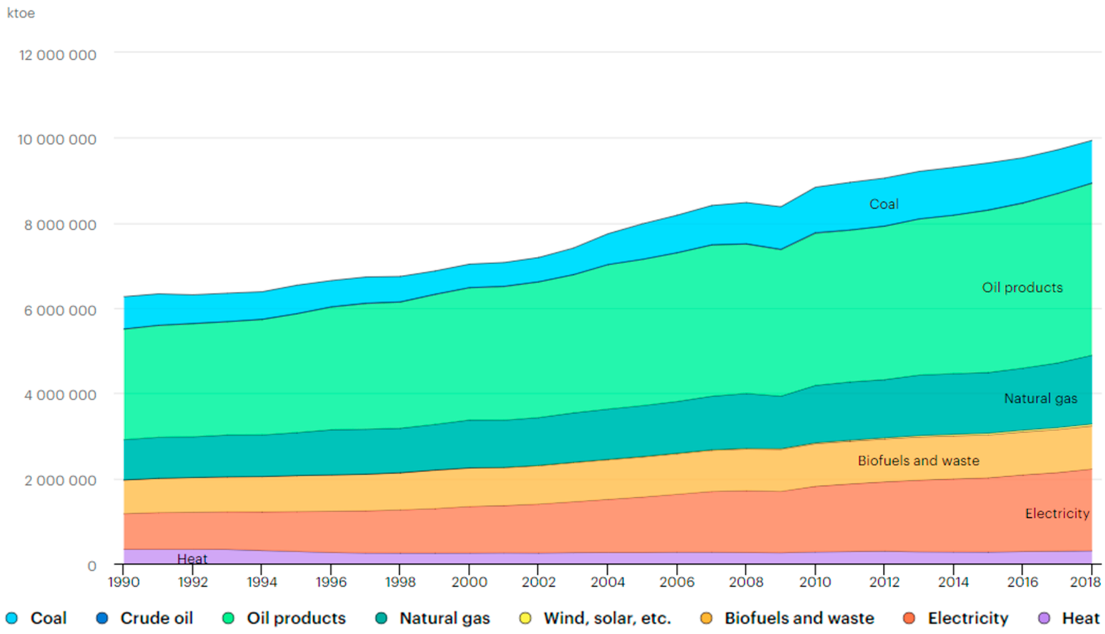


Figure 1.1: *Total final consumption (TFC) in ktoe by source, World 1990-2018.*

Source: IEA - World Energy Balances 2020, https://www.iea.org/data-and-statistics.

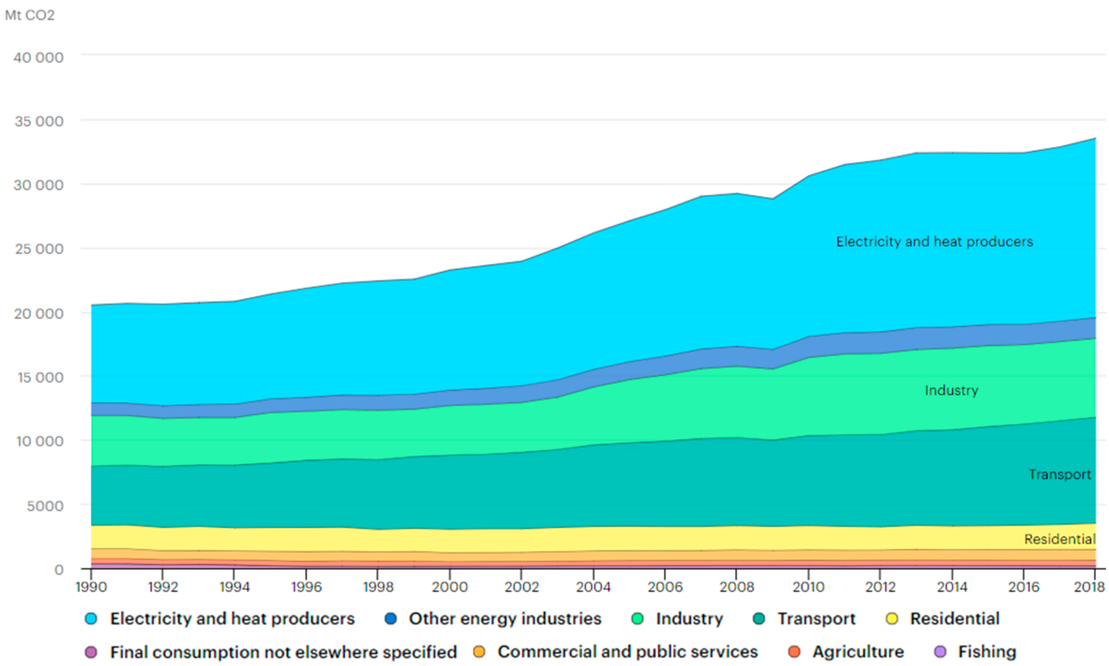


Figure 1.2: CO_2 *emissions in MT by sector, World 1990-2018.*

Source: IEA - World Energy Balances 2020, https://www.iea.org/data-and-statistics.

Despite the EU population growth by 7% between 1990 and 2017, its total energy-related CO_2 emissions decreased by 20%, differently to what has been observed in the rest of the world. This is the result of multiple energy-related policies that contributed to a 39% decrease in the energy intensity of the economy (Total primary energy supply/GDP) and a 19% drop in the CO_2 intensity of the energy supply (CO_2/ Total primary energy supply). It reflects the structural shift of the EU economy, the impact of energy efficiency and the move towards more low-carbon energy sources (*International Energy Agency*, 2020). Therefore, promoting sustainable development and tackling climate change have become integral aspects of energy planning, analysis and policy making, especially at the European level.

In 2019, the EU completed an update of its energy policy framework, called "Clean energy for all Europeans" package. It seeks to improve the transition from fossil fuels to cleaner energy and to facilitate the delivery on the EU's Paris Agreement commitments for reducing GHG emissions. The EU aims to be climate-neutral by 2050 (net-zero GHG emissions) and this objective is at the heart of the European Green Deal. In addition, according to the EU 2030 Climate and Energy framework, there is a binding target of 32% for renewable energy sources (RES) in the EU's energy mix by 2030 (*European Commission*, 2019).

Seidl et al. (2019) mention that to reach the energy transition to RES, it is required: "1) a new energy system logic and architecture, particularly on the electricity distribution grid, and 2) measures to increase social acceptance of system changes across widespread geographies and different types of stakeholders, involving them in the project". In order to meet this challenge, one key element is the implementation of "Renewable Energy Communities" (RECs), stipulated in the Renewable Energy Directive (European Parliament and Council of the European Union 2018), RED II (*European Commission*, 2018). RECs are majority owned by local stakeholders, who are encouraged to share energy within the community. The definition of REC will be better defined later in this thesis.

Additionally, a successful implementation and energy transition requires the coupling of technological solutions with good governance, based on knowledge of engineering, spatial planning, and social science. In this context, the success of decarbonisation depends largely on the effective sustainable development of low carbon, cost-efficient and high-performance solutions, together with their integration into all facets of the European economy and society (*Directorate General for Research and Innovation*, 2018; *Lowitzsch*, 2019a).

1.2 The SCORE Project

Putting decarbonisation at the heart of European main achievements, the EU Framework Program for Research and Innovation 2014-2020, Horizon 2020, is a key point to support the achievement of the Paris Agreement goals (*European Commission*, 2014). Into this framework, the project named SCORE is the main base of this thesis. The project is under the grant agreement N° 784960 and funded with € 1 988 625 EU budget. SCORE (Supporting Consumer co-Ownership in Renewable Energies) has a duration of 36 months, starting on 1st April 2018 and ending on 31st March 2021. It is coordinated by the Stiftung Europa-Universität Viadrina Frankfurt (Oder) in Germany and gathers a consortium of fourteen partners from five EU countries (Bulgaria, Czech Republic, Germany, Italy, Poland), displayed in Figure 1.3 and detailed on Table 1.1.

Figure 1.3: *Logo of SCORE and its fourteen partners in five EU countries.*

Source: Author, 2020.

Partner	Short name	Established in
Center For The Study Of Democracy	CSD	Bulgaria
Město Litoměřice	Litoměřice	Czech Republic
Porsenna O.P.S.	PORSENNA	Czech Republic
Climate Alliance, Klima-Buendnis, Alianza Del Clima e.V.	CA	Germany
Co2online Genuetzige Beratungsgesellschaft MBH	CO2ONLINE	Germany
Deutscher Caritasverband EV	CARITAS	Germany
Stiftung Europa, Universität Viadrina Frankfurt (Oder)	EUV	Germany
Stadt Essen	Essen	Germany
Amico Societa Cooperativa Sociale	AMICO s.c.s.	Italy
Consorzio Forestale Alta Valle Susa	CFAVS	Italy
La Foresta Societa Cooperativa	FORESTA	Italy
Politecnico di Torino	POLITO	Italy
Federacja Konsumentów Stowarzyszenie	FedKon	Poland
Miasto Słupsk	Słupsk	Poland

Table 1.1: *Partners from the SCORE Project.*

Source: Author, 2020.

Considering the framework of the Sustainable Development Goals (SDGs), SCORE is committed to global development and focusing (mainly) on the Goal 11 "Make cities and human settlements inclusive, safe, resilient and sustainable" (*SCORE Consortium*, 2019).

The aim of SCORE is to study and subsequently implement energy communities in three pilot regions in Italy, Czech Republic, and Germany. Looking specifically at (1) overcoming the energy use from fossil sources by adopting energy from renewable sources, (2) increasing energy efficiency of the building systems (e.g., envelope or energy system) and (3) reducing energy consumption related to building/neighbourhood users' behaviour (*Di Nicoli et al.*, 2019).

To achieve these objectives, the project seeks to build new energy infrastructures and motivate consumers to change their consumption habits. The intention is to shift the spotlight from individual to the community, so that the consumers become what is called "prosumers". The prosumer concept is recent in the energy field and denotes a consumer that both consumes and produces energy primarily for their own needs, but that can also sell any excess. This leads to a new and efficient form of producing and distributing energy, decentralizing the market, and spreading the concept of "self-produced energy sharing" (*Torabi Moghadam et al.*, 2020). Considering this point, SCORE aims to encourage the consumers to play an active role, contributing themselves to the production of energy in the community. In a way that they end up acquiring the ownership in RE and becoming prosumers.

However, prosumer models are still not commonly implemented across Europe and the typical prosumer is male, middle aged and has a higher income. The democratic participation model of SCORE thus highlight the importance of including women and low-income households, especially unemployed, through financial empowerment rather than social protection, in order to fight against energy poverty. The project is formulating policy recommendations at the EU and national level to promote "prosumership", with a particular focus on the inclusion of these under-represented groups and the removal of barriers for consumers to become active market players (*Torabi Moghadam et al.*, 2020).

The SCORE project, therefore, seeks to bring together financial, social, and technical innovations to a successful transition from fossil fuels to renewable energies. As mentioned before, the project focus lies on vulnerable groups affected by fuel poverty that are usually excluded from RE investments. The innovations and actions are tailored for their needs and for the local and regional participating authorities. In addition, existing local energy projects receive legal and technical advice for a tailor-made participation model (*Torabi Moghadam et al.*, 2020). These models receive support for engaging with the local stakeholders as well as with the general public, which in turn allow the engagement in a peer-to-peer exchange with other active public authorities. Last of all, the increased visibility by the project can make the models forerunners of Renewable Energy Communities in the EU.

The project approach is to apply Consumer Stock Ownership Plans (CSOPs), using established best practice RE projects updated by inclusive financing techniques. CSOPs are the prototype business model for Renewable Energy Communities (RECs) newly introduced by the Renewable Energy Directive (RED II) which entered into force in December 2018 (*European Commission*, 2018). It enables consumers (especially those without savings or access to capital credit) to acquire an ownership stake in a utility they use and thus to become prosumers in a local and decentralized production. Hence, CSOP enable consumers to participate in a RE project through an intermediary company (i.e., the CSOP LLC). They are represented on the board of directors by a trustee consulting them, moderating the decision-making process amongst them, and safeguarding their interests. Moreover, the consumer investment in a RE installation can be initiated by a group of private energy consumers together with their municipality and/or local small or medium-sized enterprises (*Lowitzsch*, 2019b). The following steps in Figure 1.4 comprises how the consumer-centered investment model of CSOP works.

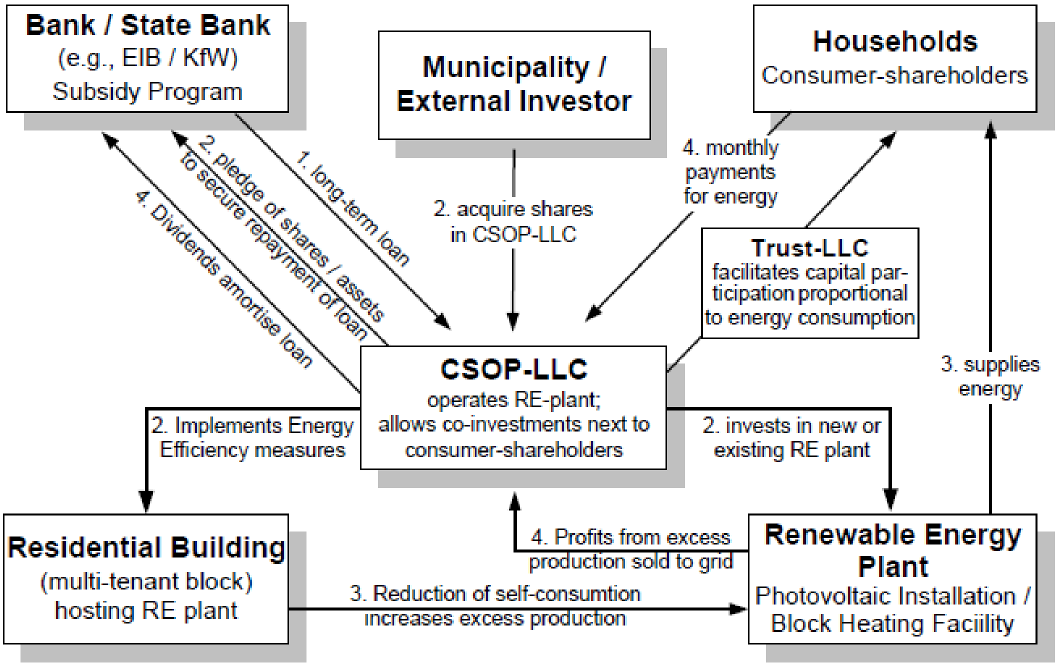


Figure 1.4: *Financing structure of a Consumer Stock Ownership Plans (CSOPs).*

Source: Lowitzsch (2019b).

The SCORE project supports local authorities in the pilots' communities with the expert pool previously shown in Figure 1.3. They conduct a large-scale capacity building program, which addresses and empowers local authorities and stakeholders. The three countries at the focus of the project (Italy, Czech Republic, and Germany) can be seen as representatives for the EU both in old and new member states with distinct political priorities. Besides that, the pilot projects have to demonstrate the practical feasibility of optimized joint prosumer investments with local municipalities in order to be extended to other follower cities across Europe in a near future.

Considering these topics, SCORE implements innovative prosumer renewable energy investments in three European pilot communities, using the following low carbon energy source: Susa Valley (Italy) with Biomass; Essen (Germany) with Photovoltaics; and Litoměřice (Czech Republic) with Photovoltaics. In these pilots, a renewable energy project at community scale will be done to include local consumers and citizens with the active involvement of the local government body through the employment of Consumer Stock Ownership Plans (CSOPs). Within the three pilots of the SCORE Project, the Italian pilot of the Susa Valley (or Valle di Susa) is the study site of this thesis. The pilot cities and their applied renewable energy are shown in Figure 1.5.

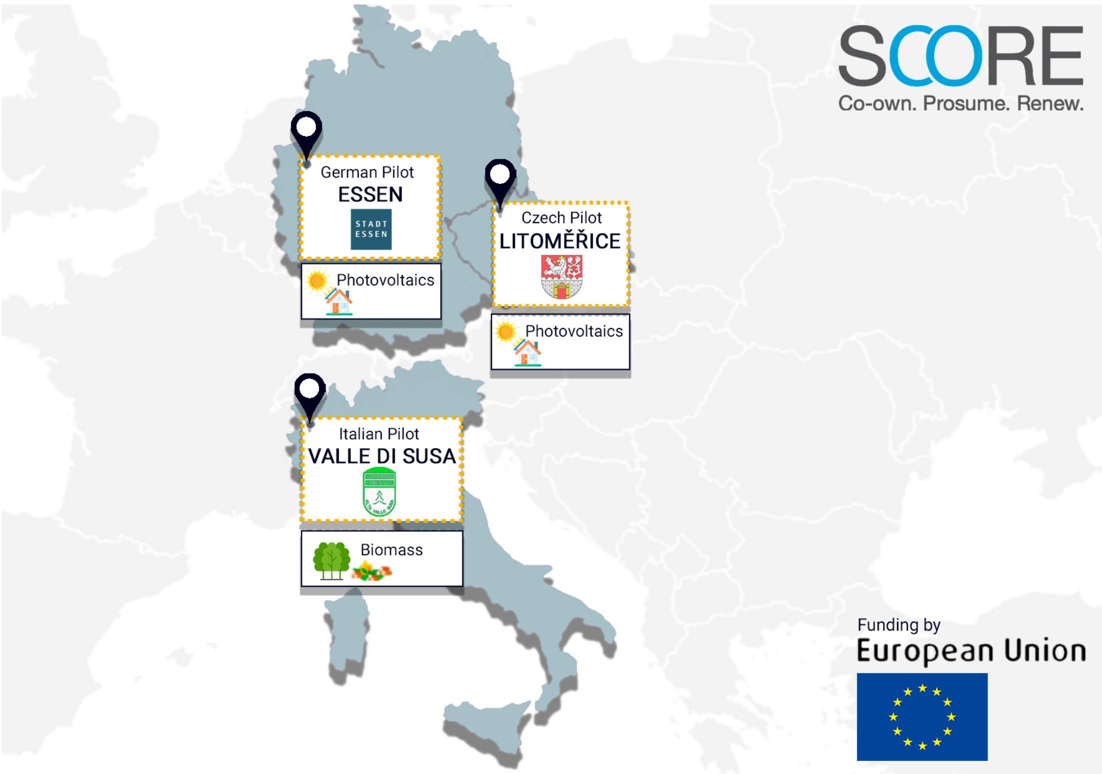


Figure 1.5: *The three pilots and the type of renewable energy sources applied in the project.*

Source: Author, 2020.

1.3 Research objectives

The aim of this study is to involve stakeholders in Renewable Energy Communities (RECs) co-ownership. Based on the learnings of the SCORE project, this thesis seeks to incentive local consumers to become prosumers, playing an active role and involving themselves into the energy production in their community.

Considering multi-actors and multi-criteria aspects to create a sustainable and inclusive decision making, the thesis follows an interdisciplinary mixed methodology. It involves stakeholders in RECs scenarios beyond the Science, Technology, Engineering and Mathematics (STEM) disciplines and applies energy-related social sciences and humanities (energy-SSH). Therefore, to achieve the main objective, the following sub-objectives were an essential path:

1. Assessment of different Key Performance Indicators (KPIs) in order to determine the best refurbishment alternative for the creation of Renewable Energy Communities. Taking into account energy efficiency and includ-

ing social, environmental, technical, and economic aspects;

2. Involvement of the stakeholders in co-ownership models and evaluation of impacts regarding the creation of Renewable Energy Communities;

3. Elaboration of recommendations for consumer co-ownership in Renewable Energy Communities to enable policies on prosumership at EU and local level.

Although the thesis has as a study site the Italian pilot of the SCORE project in the Susa Valley (Italy), it can be also applied for future followers pilots of the project at EU level.

1.4 Thesis Structure

This thesis consists in six chapters and the contents are organized to achieve the objectives discussed in the previous Section.

Chapter 2 describes the literature review on the theme. It starts with an overview of the main problems regarding the energy system nowadays and how community-based models can provide a sustainable transition from the fossil fuels sources. Afterwards, it defines these models, in particular the Renewable Energy Communities (RECs), giving the main legislative framework into this topic and focusing on the Italian study site. Later, overall case studies are reviewed to give a perception about how this topic is being researched these days. Subsequently, the literature reviewed for Energy Communities (EC) are summarized into a Table. After the discussion about EC, the last Section discusses briefly what are the main social challenges for projects like this, and how to involve multiple stakeholders into energy communities initiatives. In the end, different tools used for stakeholders involvement are shown.

Chapter 3 firstly illustrates the proposed methodology, giving a schematic flowchart of the methodological approach, with its phases, objectives, and steps. The three-phases of the thesis follows "a mixed methodology" that combines qualitative and quantitative approaches. The chapter is later divided into the three main phases of the thesis' methodology, in order to explained in detail how each one was accomplished. **Phase 1)** Assessment and Evaluation, with the selection of the best refurbishment alternative for each case study based on a Multi-Criteria Analysis (MCA). The selection was made through the dossiers analysis, evaluation matrix of the case studies and the PROMETHEE method; **Phase 2)** Visualization and participative Workshops, with the involvement of the Stakeholders in the scenarios development through workshops using storytelling methods and WebGIS visualization tools; and **Phase 3)** Recommendations, with the preparation of recommendations for consumer co-ownership through the analysis and post assessment of the previous Phases results.

Chapter 4 provides a comprehensive description of the study site, with the context and the main features of the five case studies of the Italian pilot. After the dossiers documents analysis, it is present the requirements for the project, the main current energy performance indicators, and their critical issues. Following this, it presents refurbishment alternatives for the case studies and it gives the simulation of the energy indicators after each retrofit alternative.

Chapter 5 reports the results obtained. According to the proposed three-phases framework, it first discusses the procedure into the scenario selection based on Multi-Criteria Analysis (MCA) through the PROMETHEE method. It shows the best refurbishment alternative for each Italian case study in the development of RECs. Second, it explains the procedure done for the Workshops organization, and consequently, it evaluates the involvement of the stakeholders in the workshops through the use of the storytelling method, and the impacts regarding their scenarios development for the creation of RECs. Finally, it analyses the previous results and based on a post assessment, some recommendations are elaborate to enable policies in prosumership at EU and local level.

Chapter 6 sums up the conclusions and discussions. It gives a general idea of all the thesis procedure and highlights some limitations and proposals for each Phase of the methodology. In the end, it addresses future developments for further research on the topic.

2

Literature Review

This chapter briefly explores the literature theory of this thesis going through the energy transition process, approaching the Energy Communities (ECs) and Stakeholders Involvement. By giving the definitions and legal framework, and some overall case studies on ECs topic, this chapter further reviews the Stakeholders Involvement in ECs and the benefits and main tools for local communities in this direction.

2.1 Energy Communities

According to the *International Energy Agency* (2020), the European Union is witnessing a continuous shift towards more renewable energy, although fossil fuels still account for 72% of the EU's energy mix, compared with 80% on a global scale. In the International Energy Outlook of 2019, *U.S Energy Information Administration* (2019) made some projections to 2050 regarding primary energy consumption. Worldwide, energy consumption is growing and in the reference case of 2050, renewable energy becomes the leading primary source for energy consumption. Driven by electricity demand growth and economic and policy drivers, renewable energy consumption increases by 3% per year between 2018 and 2050. Although it is the world's fastest growing form of energy, fossil fuels continue to meet much of the world's energy demand as shown in Figure 2.1.

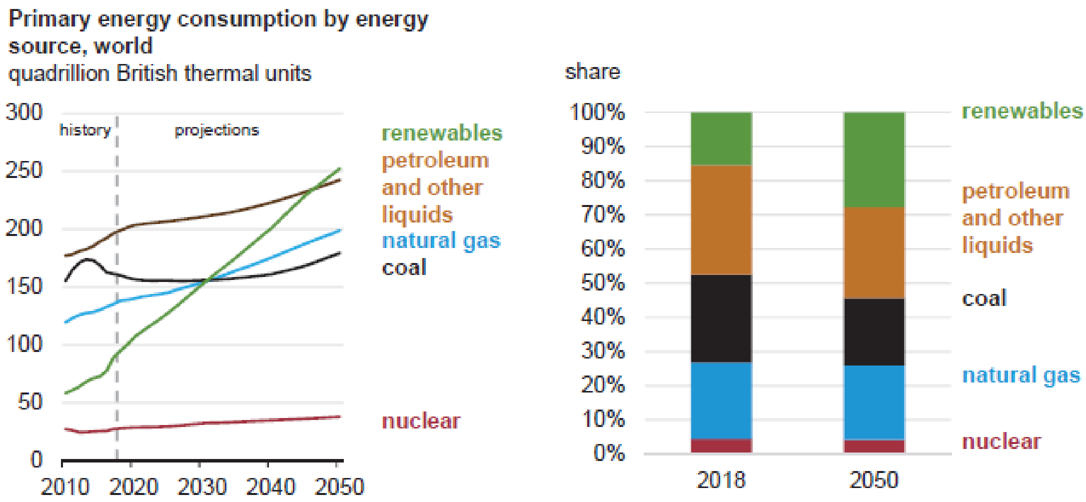


Figure 2.1: *Primary energy consumption by energy source in the world.*

Source: U.S Energy Information Administration (2019).

Along these lines, the energy transition towards a more sustainable and fossil-free energy system still face several challenges. Communities across the world are already feeling the impacts of climate breakdown and energy shortage. And according to *World Energy Council* (2019), the energy transition is a connected policy challenge, which means that its success involves managing three core dimensions of energy systems throughout the transition process (The Trilemma Index):

- The Energy Security, which "reflects a nation's capacity to meet current and future energy demand reliably, withstand and bounce back swiftly from system shocks with minimal disruption to supplies";
- The Energy Equity, which "assesses a country's ability to provide universal access to affordable, fairly priced and abundant energy for domestic and commercial use";
- The Environmental Sustainability, which "represents the transition of a country's energy system towards mitigating and avoiding potential environmental harm and climate change impacts".

The Trilemma Index recognizes Europe's substantial progress on the energy transition pathway, but it has significant variation within the EU region and yet multiple policy challenges remain. Regarding energy security, Europe has a well diversified energy base sources and supplies with a strong Nordic influence in the overall security dimension with the focus on decarbonising.

However, in some European countries the ability to afford sufficient levels of energy is still a real concern, even more in remote and less populous areas. Regarding energy equity, in South Eastern Europe, affordability remains an important issue as energy poverty rates remain high, with growing numbers of households spending more than 10% of their income on their energy bill. As follows, the region carries distinct circumstances that drives inefficient use of energy, increasing energy costs, and unsustainable and unaffordable energy access (*World Energy Council*, 2019).

Looking closer into the Italian energy, the sector still faces issues of supply security, socio-environmental conflicts, along with market concentration and the liberalisation of access to energy supply market by new companies (*SCORE Consortium*, 2018). The Italian sector relies mainly on fossil fuels and it is still highly dependent on gas and oil imports (80% is from abroad) (*Virdis et al.*, 2015). After abandoning nuclear power and replacing it by fossil fuel, the air quality had a negative impact. According to *European Environment Agency* (2018), in 2017 the air quality in Italy was deemed the worst in Europe. Also due to the fact that 74% of residential buildings have autonomous heating systems majority fuelled by coal and natural gas (*Ungaro*, 2014). Therefore, renewable energy (RE) does not play a significant role yet. In 2015, RES covered 33.5 % of electricity consumption, 19.2 % of heating and cooling and 6.4 % of transportation. Considering the ownership structure, six largest energy companies (DSO, A2A, ACEA, IRUDE, DEVAl and HERA) own 90% of the installed capacity of RE for electricity production, while the Independent Power Producers (IPP) remains marginal (*SCORE Consortium*, 2018).

In this way, there is an urgent need to transform this panorama. To further promote a sustainable development and fair transition, policy makers are exploring how to create a modern and optimise infrastructure integrated with renewable source, to raise community awareness about carbon-neutral energy access solutions, energy efficiency and other measures (*World Energy Council*, 2019). It is a long-term undertaking and must embrace all pillars of sustainable development seeking to leave nobody behind and maintain social cohesion. *International Energy Agency* (2020), in particular, stresses the potential of locally sourced energy and community-based models to provide energy and a sustainable transition. The renewable energy community model, in result, could deal with those requests and face the several challenges aforementioned from the energy transition process.

2.1.1 Definitions and Legal Framework

The energy community (EC) represents a new model which considers energy as well economic and social perspectives. In a broad sense, it is a contiguous process of both energy transition and social innovation (*Caramizaru, A. and Uihlein, A.*, 2020). EC reflects, therefore, a growing desire to find alternative ways of organising and governing energy systems (*Van der Schoor et al.*, 2016) . It is a new form of social movement that allows a more participative and democratic energy processes.

To introduce the concept of energy communities and the new legal framework, the *Council of European Energy Regulators* (2019) delineate the difference between individual self-consumption, collective self-consumption and energy communities. Individual self-consumption is not a new concept and it means the consumers that consume energy they produce on site. In a broader scope, collective self-consumption is the direct sharing of electricity between producers or self-consumers and other local final customers, boosted by the increased financial viability of individual self-consumption and the development of a sharing economy. On the other hand, energy communities are entities set up as a legal person, controlled by the shareholders/members, on which the community own the generation assets. Moreover, it covers a bigger geographic scope than the other two previous concepts. Figure 2.2 shows a diagram of these three terms and their meanings.

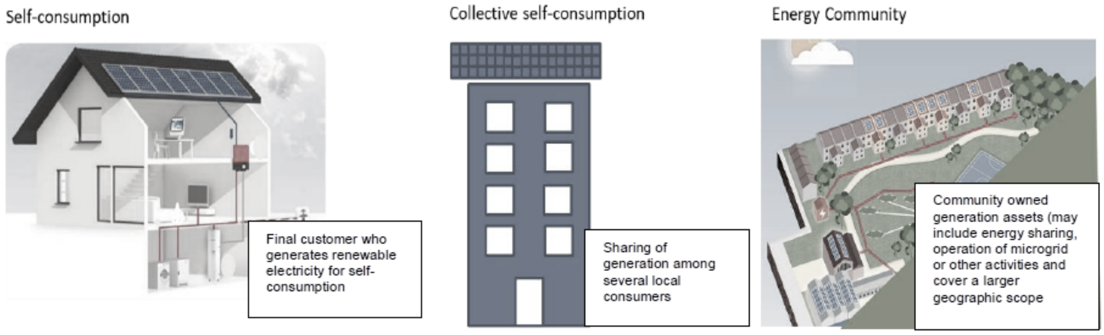


Figure 2.2: *Diagram showing self-consumption, collective self-consumption, and energy community.*

Source: Council of European Energy Regulators (2019).

Until recently, the concept of energy communities lacked a clear status in the EU and national legislation, taking different forms of legal arrangements. Changing this picture, the recent European Commission's package opened a new set for consumers by recognising, for the first time under the EU law, the rights of citizens and communities to engage directly in the energy sector. It formally acknowledges and sets out legal frameworks for certain categories of community energy as 'energy communities' (*Caramizaru, A. and Uihlein, A.*, 2020).

In this context, on 30 November 2016, the European Commission presented the so-called "Clean Energy Package for all Europeans", a set of new rules that address all five dimensions of the Energy Union: energy security; internal energy market; energy efficiency; decarbonisation of the economy; and research, innovation, and competitiveness. It includes the following elements (*European Commission*, 2019):

- **Energy efficiency first:**
  Setting a new and higher target of energy efficiency for 2030 of 32.5%, with a particular emphasis given to improving energy performance in the building sector.

- **More renewables:**
  Setting a new target of at least 32% of renewable energy in energy consumption by 2030, with specific provisions to foster public and private investment, in order to the EU maintain its global leadership on renewables.

- **A better governance of the Energy Union:**
  Requiring an energy rulebook under which each Member State drafts National Energy and Climate Plans (NECPs) for 2021-2030, setting out how to achieve their energy union targets, and in particular the 2030 targets on energy efficiency and renewable energy.

- **More rights for consumers:**
  Making easier for individuals to produce, store or sell their own energy, and strengthen consumer rights with more transparency on bills, and greater choice flexibility.

- **A smarter and more efficient electricity market:**
  Increasing security of supply by helping integrate renewables into the grid and risks, and by improving cross-border cooperation.

According to *Roth et al.* (2018), within this legislative package, some aspects are recurrently emphasized as the better accommodation of the rising share of mostly variable renewables and the empowerment of consumers by offering possibilities to become more active on the energy market. This package of measures, therefore, facilitates the sustainable energy transition, reforms the design and operation of the EU's electricity market, and keeps the EU competitive as the clean energy transition changes global energy markets. The 28 Members States of the EU have until June 2021 to transpose this legislative framework into national Law (*European Commission*, 2016).

Thought the Clean Energy Package, the concept of energy communities is introduced into European legislation and defined in two separate laws. The revised Renewable Energy Directive II (RED II) 2018/2001 sets the framework for 'renewable energy community (REC)' covering renewable energy. And the revised Internal Electricity Market Directive (IEMD) 2019/944 introduces new roles and responsibilities for 'citizen energy community (CEC)' in the energy system covering all types of electricity.

Both types describe energy communities as a possible type of organising collective citizen actions in the energy system, in a non-commercial type of market actor. Besides that, they require a legal entity as a community umbrella and a specific governance (e.g., effective control by certain participants). They must be voluntary and open, and they should be collective actions. Therefore, the energy communities should be primarily value driven rather than focusing on financial profits (*Frieden et al.*, 2019).

Although the two types are similar in their nature, there are differences in the definition of citizen and renewable energy communities. The first one is not limited to specific activities or size and it is limited to the electricity sector. On the other hand, the last one has stringent governance requirements, it is technology-specific around renewable energy sources, and it is rooted in local communities as showed in Figure 2.3.

	Citizen Energy Community	Renewable Energy Community
Membership	Natural persons, local authorities, including municipalities, or small enterprises and microenterprises	Natural persons, local authorities, including municipalities, or small enterprises and microenterprises, provided that for private undertakings their participation does not constitute their primary commercial or professional activity
Geographic limitation	No geographic limitation, MS can choose to allow cross-border Citizen Energy Communities	The shareholders or members must be located in the proximity of the renewable energy projects that are owned and developed by the Renewable Energy Community
Allowed activities	Limited to activities in the electricity sector. Electricity generation, distribution and supply, consumption, aggregation, storage or energy efficiency services, generation of renewable electricity, charging services for electric vehicles or provide other energy services to its shareholders or members	Can be active in all energy sectors. Production, consumption and selling of renewable energy
Technologies	Technology neutral	Limited to renewable energy technologies

Figure 2.3: *Characteristic differences between Citizen Energy Communities and Renewable Energy Communities.*

Source: Council of European Energy Regulators (2019).

Looking more in deep in the Renewable Energy Communities (RECs), the RED II introduces an innovative energy and new governance model for the EU Member States and the possibility of energy sharing within the REC. It provides an "enabling framework", facilitating the development of RECs in an equal footing with other market players and overcoming "mono-directional consumption by passive consumers from energy produced by large-scale industrial producers" (*Torabi Moghadam et al.*, 2020). The consumers will have the right to consume, store or sell RE generated on their premises in two ways according to *Lowitzsch et al.* (2020):

- "individually, that is, households and non-energy small and medium sized enterprises (SMEs) and collectively, for example in tenant electricity projects (Art. 21 RED II), or
- as part of Renewable Energy Communities organised as independent legal entities (Art. 22 RED II)."

Besides that, at the national level in Italy, the Law 221 of *Repubblica Italiana*

(2015) called "Environmental provisions to promote measures of green economy and to contain the excessive use of natural resources" has established the "oil-free zone" within the article 71. It means the possibility to create territorial areas free from fossil fuels dependence and to encourage experiments in this field. Moreover, in 2017 the National Energy Strategy (SEN) recognized energy communities and elaborated a ten-year plan of the Italian Government to conduct a change in the energy system (*Torabi Moghadam et al.*, 2020).

The amendments made during the conversion of the decree-law of 30 December 2019 n.162, contained the Art. 42 bis entitled "Self-consumption from renewable sources". It underlines a transposition of the RED II 2018/2001 (Art. 21 and 22) and allows to activate collective self-consumption from renewable sources or renewable energy communities in the manner and under conditions established by the amendment article 42 bis. According to (*Borroni et al.*, 2020; *Repubblica Italiana*, 2020), the conditions for which the association is allowed are:

1. in the case of self-consumers of renewable energy who act collectively, the individuals besides the households are associated only in the case where participation in the renewable energy community does not constitute the main commercial or professional activity;

2. in the case of energy communities, the shareholders or members are individuals, small and medium-sized enterprises, territorial bodies, or local authorities, including municipalities, and the participation in the renewable energy community cannot constitute the main commercial and industrial activity;

3. the main objective of the association is to provide environmental, economic, or social benefits at the community level to its shareholders or members or to the local areas where the community operates, rather than financial profits;

4. participation in renewable energy communities is open to all consumers involved, including those belonging to low-income or vulnerable families.

The Piedmont Region in Italy, following the new regulatory framework, released in 2018 the Regional Law n.12 called "Promotion of the institution of energy communities" (*Regione Piemonte*, 2018). It encourages the implementation of these communities as non-profit organizations on which private and public stakeholders can participate to produce and exchange energy generated mainly from renewable sources (art. 1.1 and 2.1.). Further, the energy communities acquire and maintain the energy production subject if they annually share between the members not less than 70% of the energy produced (art. 2.2) (*Torabi Moghadam et al.*, 2020).

Furthermore, the Piedmont region has committed to financially support the establishment of energy communities through incentives. By optimizing the management and use of energy networks with agreements with the Italian Regulatory Authority for Energy and Networks (ARERA, Autorita di Regolazione per Energia Reti e Ambiente) or by improving the energy efficiency of buildings through the new released incentive called "Eco-bonus 2020", by "Decreto Rilancio" from 15 may of 2020. This bonus is included in the Italian Law of 27 December 2019 (n. 160), that gives tax deductions envisaged for building interventions that increase the level of energy efficiency of the existing buildings. The family finances the investment itself and receives the five-year tax rebates corresponding to the "110% bonus" (thus including the additional 10%) directly from the state program. This seeks to meet the needs of families and eliminate some of the horizontal problems created by COVID-19. The concession will be valid for works carried out from 1 July 2020 to 31 December 2021 (*Repubblica Italiana*, 2019; *Borroni et al.*, 2020).

In this way, the above-mentioned legislative framework (with some illustrated in Figure 2.4) supports the Italian energy model transition from the current **"one-to-one configuration"** (single energy system to a single end-consumer, e.g., a single family house with photovoltaic system for personal consumption) to a **"one-to-many configuration"** (single energy system to multiple end-consumers, from different buildings and different end-uses) as discussed in *Torabi Moghadam et al.* (2020). Giving a ground base for the elaboration of energy communities in Piedmont, Italy.

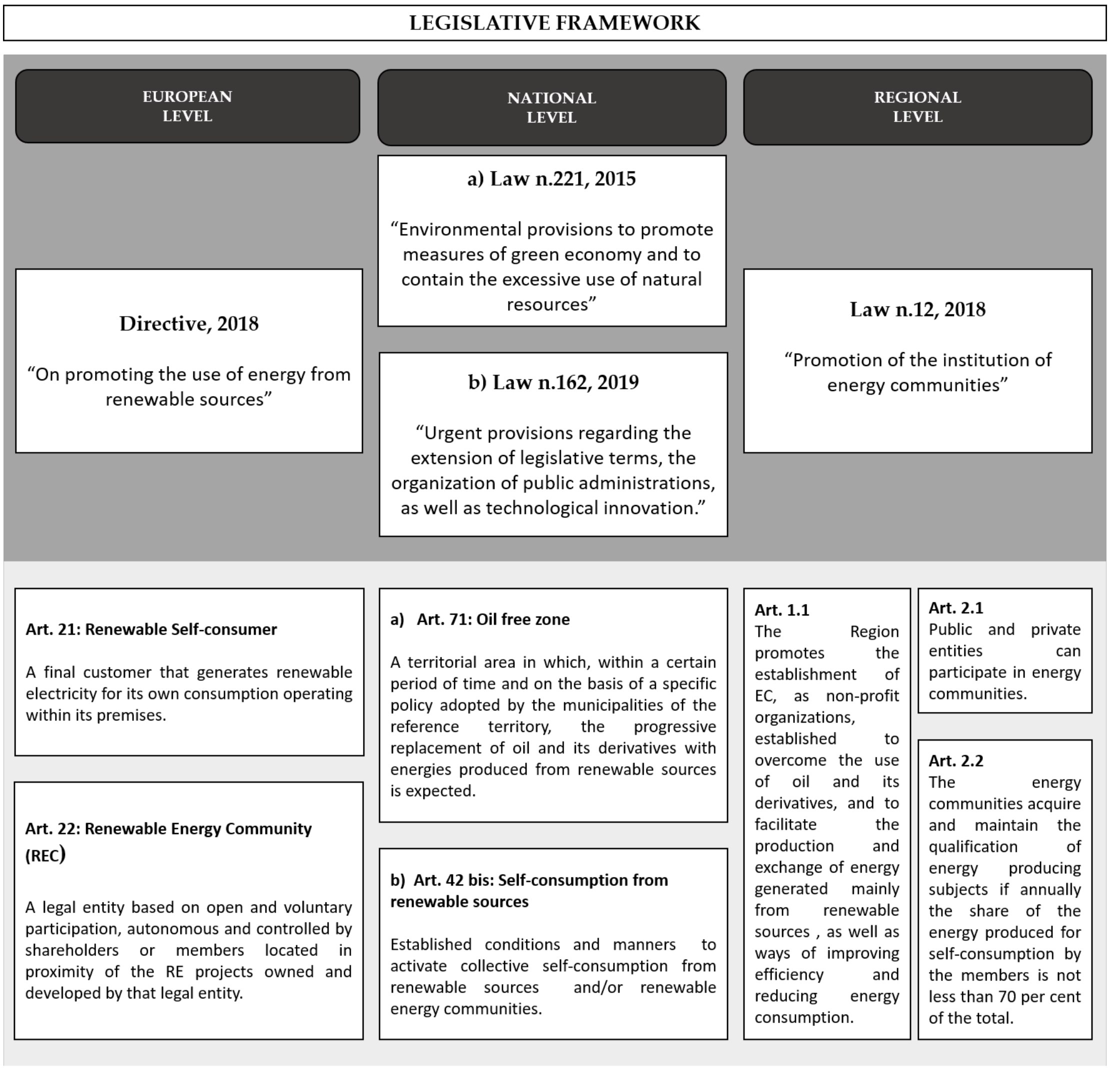


Figure 2.4: *Legislative framework of energy communities regarding the Piedmont region in Italy.*

Source: Torabi Moghadam et al. (2020) modified by Author.

2.1.2 Overall Case Studies

The community initiatives are not a new phenomenon. Following the 1970s oil crisis, Denmark has a rich history of both wind cooperatives and community-based district heating systems. In the Netherlands, wind cooperatives exist since the 1980s and in Germany these even date back a century (*Oteman et al.*, 2014). However, the term Community Energy (CE) has gained increasing reception in literature in the recent years, reflected by rising numbers of peer-reviewed articles related to CE and adjacent topics (*Brummer*, 2018a).

In the comparative literature review made by *Brummer* (2018a) in the UK, Germany, and USA, he focused on the benefits and the barriers community energy projects faced in these countries. To display the social benefits of CE identified in literature, the references have been thematically grouped, leading to seven categories as showed in Figure 2.5. As a small sample of the results, for the UK, the economic benefits were numbered more cited in the articles; in Germany, the education and acceptance benefits; and in the USA, both the community building/ self-realization and the RE generation targets. And similar to the benefits, the barriers impeding CE initiatives has also been identified in six categories as Figure 2.6 shows. For the UK and Germany, the lack of resources/expertise/ resilience were the barriers more cited; and for the USA, the organizational issues/ legal framework/ planning requirements.

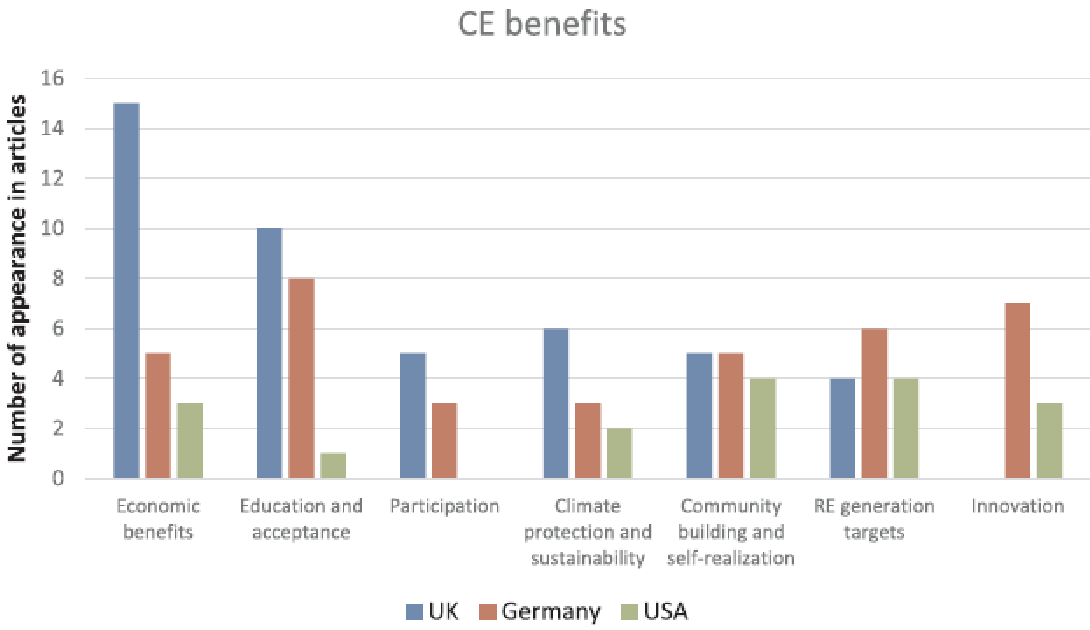


Figure 2.5: *Benefits identified after the literature review of the three cases.*

Source: Brummer (2018a).

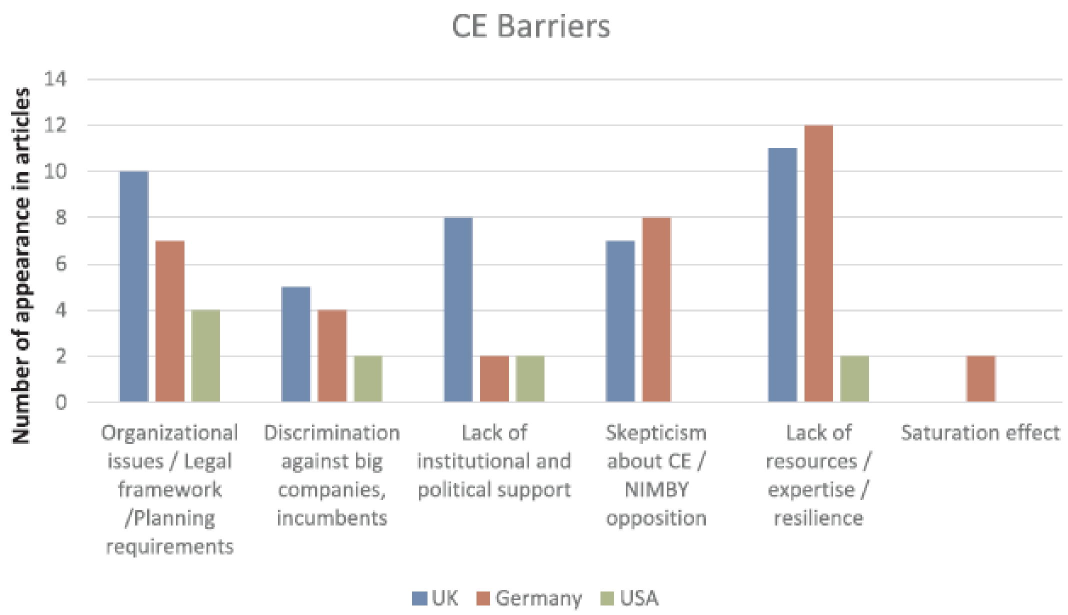


Figure 2.6: *Barriers identified after the literature review of the three cases.*

Source: Brummer (2018a).

Moreover, *Seyfang et al.* (2013) comments that regarding their survey, done with residents of the UK energy communities, almost two thirds of the respondents (65%) are rurally located, while 23% are in urban areas and 12% in suburbs. One of the survey's respondent explained their relation of the energy communities and the rural location: "Our primary purpose is to produce electricity as our community is not on the national grid" and another stated that "Our local geography in Cumbria has great renewable energy potential that has yet to be realised." In this way, they can explain the big potential of investment in energy communities in rural localities. Besides that, their survey also uncovered a wide range of goals from the community energy projects in the UK. The respondents, therefore, had to answer which are the eight goals for their EC showed in Figure 2.7. Most cited saving money on energy bills (83%), followed by reducing carbon dioxide emission (80%) and improving local energy independence (60%).

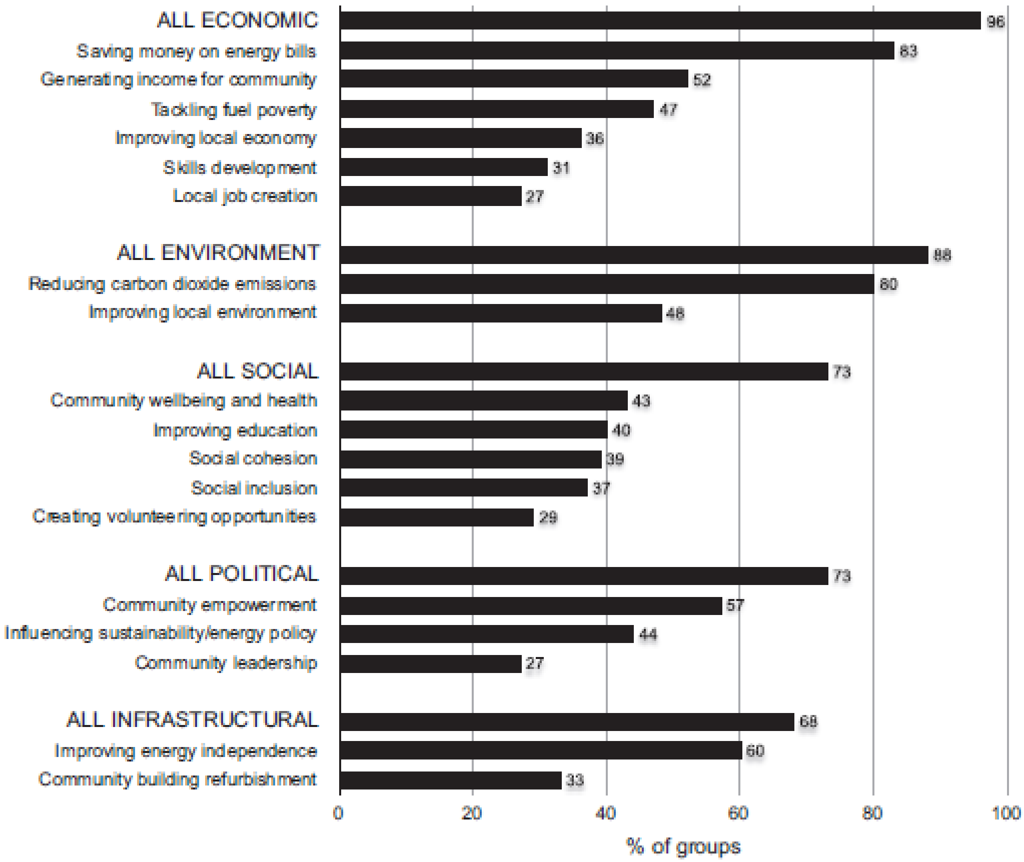


Figure 2.7: *Objectives of UK Community Energy Groups.*

Source: Seyfang et al. (2013).

Looking for the willingness of citizens to participate in an energy community, *Vuichard et al.* (2019) concluded that introducing financial participation models could increase social acceptance for wind energy projects in the research case of a hypothetical project. Also, *Woo et al.* (2019) commented that although people prefer renewable energy, they may be opposed to the construction of renewable energy power plants within their own communities. This situation can be solved if the government provides local residents with adequate levels of incentives. Besides that, a provision of adequate levels of compensation seems to be an important factor in boosting acceptance in the community. On the other hand, *Kalkbrenner and Roosen* (2016) shows that in Germany, social norms, trust, environmental concern, and community identity are important determinants of willingness to participate in community energy. And considering both ownership of a renewable energy system and living in a rural, rather than urban community, increase the likelihood of participation in community-based renewable energy projects.

Besides that, a study about the Samsø Renewable Energy Island project (*Sperling*, 2017) provided a framework of contextual conditions they found important in relation of this specific community energy project's case and how the presence, absence, and type of interplay between the conditions will determine the success or failure of the project. In this way, Table 2.1 gives an overview of those conditions separating they in the national - external context (e.g., governmental support for certain technological solutions, such as subsidies and tax incentives) and in the local - internal context (e.g., sense of locality and responsibility with people in a community feeling some sense of belonging to the place they live in).

External context	**Internal context**
Governmental technology support	Community spirit
Governmental process support	Local traditions and history of cooperative projects
Expert assistance	Sense of locality and responsibility
Guiding visions and plans	Entrepreneurial individuals
	Networks
	Guiding visions and plans

Table 2.1: *Overview of external and internal contextual conditions that determine the success or failure of community energy projects based on Samsø project.*

Source: Sperling (2017).

Thus, bringing overall case studies about ECs helps to give a wider view about how they have been studied worldwide and focused on internal contexts. Consequently, a table summarizes the present findings of the case studies reviewed for this Subsection, as showed in the follow Table 2.2. They are classified by their reference; location of the case studies; topic; methodology used; factors considered; and results given by the study.

	Reference	Location	Topic	Methodology	Factors considered	Results
1	*Brummer* (2018a)	UK, Germany and USA	The benefits and barriers of CE	Literature review, analyzing existing peer-reviewed articles	Definitions, positive effects and difficulties of CE initiatives	Comparison of Community Energy in the UK, Germany and the USA
2	*Eadson et al.* (2019)	Yorkshire and the Humber (UK)	Catalyzing People-powered Energy	Policy analysis, interviews with practitioners and stakeholders, and focused case studies	CE activities, policies, gaps, barriers and challenges	Policy recommendations
3	*Ngar-yin Mah* (2019)	Foshan (China) and Seoul (South Korea)	Socio-technical transition processes of solar communities	Semi-structured interviews, desktop research, and field observations	Networking, Visioning, Reconfiguration of incumbent-newcomer relationships, Institutionalization, Leadership	Conceptualized community-level energy initiatives in two cases studies
4	*Vuichard et al.* (2019)	Switzerland	Community investment, local taxes, and the social acceptance in a hypothetical wind CE	Experimental survey	Financial participation models and the social acceptance	Social acceptance after introducing a financial participation model for wind energy projects
5	*Woo et al.* (2019)	South Korea	Willingness to participate in community-based renewable energy projects	Questionnaires, contingent valuation method (CVM), willingness to accept (WTA)	The level of acceptance of renewable energy among the general public and local residents	The adequate levels of compensation for local residents living near renewable energy power plants
6	*Kalkbrenner and Roosen* (2016)	Germany	Citizens' willingness to participate in local renewable energy projects	Online survey, regression and mediation analyses	Discouragement/Constraints of community: identity, social norms, trust and environmental concern	General attitude toward community energy and the willingness to volunteer and investing money

	Reference	Location	Topic	Methodology	Factors considered	Results
7	*Heaslip and Fahy* (2018)	Aran Islands (Ireland)	Transdisciplinary approaches to community energy transitions	Surveys, focus group, semi-structured interviews, quantitative engineering data collection and reflexive energy planning workshops	Energy practices, policies planning and perceptions of energy within the group dynamic/interviews.	The development of three distinct energy scenarios
8	*Oteman et al.* (2014)	Netherlands, Germany and Denmark	The institutional space of community initiatives for renewable energy	Policy analysis, semi-structured interviews	Relevant legislations, subsidies, grants, tenders and procedures for planning and permits.	Institutional configuration of the energy sector and their influence on the available space for community initiative development
9	*Gorroño Albizuand Karl Sperling and Djørup* (2019)	Denmark	Characteristics of citizen ownership of wind turbines and district heating systems in Denmark	Statistical analysis, literature review and contact to experts	Danish citizen ownership models	Importance of citizen ownership to investment and implementation of decentralized sustainable energy technologies
10	*Schreuer* (2016)	Austria	The establishment of citizen power plants and their empowerment	Semi-structured expert interviews	Perspectives in the field of citizen power plants in Austria	Multi-faceted concept of empowerment in relation to the establishment of citizen power plant
11	*Brummer* (2018b)	Germany	Organizational governance and decision-making in German Renewable Energy Cooperatives (REC).	Interviews, participant observation and Witzel's method of problem-centered interviews based on an outline	Decision-making process in RECs, situations and circumstances where deviations from interventions were visible	The characterization of interactions at work in the governance of small to medium-sized RECs in Germany

	Reference	Location	Topic	Methodology	Factors considered	Results
12	*Seyfang et al.* (2013)	UK	Objectives, origins and development of CE in UK	Web-based survey	CE characteristics and factors influencing the success and growth	CE scope, scale, character, activities and challenges in the UK
13	*Herbes et al.* (2017)	Germany	New business models for renewable energy cooperatives and Barriers perceived by cooperatives' members	Interviews, non-participant observation	Business model elements and Perceptions of risk	Barriers to business models in RECs
14	*Sperling* (2017)	Samsø	Concrete contextual conditions that made the success of the Samsø project possible	Document analysis and semi-structured interviews	External and internal contextual conditions	Most important contextual conditions and interaction points from the project

Table 2.2: *Summary of the literature review from the energy communities case studies.*

Source: Author, 2020.

2.2 Stakeholders Involvement

Energy communities (ECs) are key elements for the Energy Transition success (*Lowitzsch et al.*, 2020). Along with this, the involvement of community in general is considered central to the success of policies regarding climate change, including the shift to green energy (*Lowitzsch*, 2019a). As defined in the Section before, ECs carry the social dimension and community involvement in its core. It is an alternative to organize the energy system, considering a decentralized entity, which the community own the generation assets and it is the main beneficiary. In addition, the adoption of renewable energies in the case of REC further contributes for the fully transition in energy systems. However, the social characteristic of EC, it is also the hardest challenge.

The first challenge is the public acceptance. Many of the barriers for achieving successful projects at the implementation level can be considered as a lack of social acceptance (*Wüstenhagen et al.*, 2007). Consequently, the acceptance and support of the public is essential to manage well energy transitions (*Kalkbrenner and Roosen*, 2016). It is not only limited to the acceptance of one specific energy technology or installation, but also to all administrative and technological elements needed for a local energy system (*Azarova et al.*, 2019). The general level of acceptance concerns the acceptance by local key stakeholders, particularly residents and local authorities, and policy actors in siting decisions and effective policies. The policies need to institutionalize frameworks that effectively foster and enhance market and community acceptance, for example, the establishment of reliable financial procurement systems that create options for new type of investments, and spatial planning systems that stimulate collaborative decision making (*Wüstenhagen et al.*, 2007). Moreover, the benefits of energy communities, beyond counteracting climatic change, as positive regional, economic, and environmental impacts, can be also major drivers of public acceptance (*Cohen et al.*, 2016).

Another meaningful element for the effectiveness of energy communities initiatives is the public engagement (*Radtke*, 2014). According to *Gregg et al.* (2015), the engagement can exist in different ways (from active to passive, as interactive websites) and for different reasons. *Radtke* (2014) combine diverse authors and literature to identify how active member participation in EC is the "key to trust and commitment". As stated by them, such participation depends on: modes of governance, ownership structures, member responsibilities and competences, equal opportunities between communities, trust, social capital, deliberation, and power factors. Besides that, community engagement should seek genuine participation, encouraging empowerment and cooperation, in contrast to "pseudo participation that promotes paternalism and domestication". Community engagement should seek to maintain transparent all aspects of project development (e.g., financial constraints, technical difficulties, and others) as a way to explicitly "expose trade-offs with community members and open up the decision-making process in all its aspects" (*Alvial-Palavicino et al.*, 2011). For this reason, public engagement may range from behavioural change to co-design and implementation.

The third challenge is the creation of positive social impacts, from employment and income to energy justice. The association of aspects as high cost of energy supply, together with the presence of low-income households (LIHs) and inefficient energy performance of buildings (e.g., thermal insulation, heating systems and equipment) are major reasons of energy poverty (*Lowitzsch and Hanke*, 2019; *European Energy Network*, 2019). To give an outline, in Italy, according to an ad hoc indicator of energy poverty from the work of *Faiella and Lavecchia* (2015), in the period between 2005-2016 the proportion of households in energy poverty was, on average, approximately 8% of all households. This percentage has grown in recent years to about 8.6%, (equal to 2.2 million households) in 2016 and it did not unchanged in 2017 (*Italian Government*, 2019). These numbers lead to a concerned problem for REC, since poverty-dynamics in society impact cognition processes and drive into "short-sighted" and poor economic decision-making. And this may lower the willingness to adopt new technologies, as renewables for energy transition (*Lowitzsch and Hanke*, 2019). Thus, to gain positive impacts in energy initiatives and promote energy justice, some potential measures should be taken as follows.

The causes and effects of energy poverty are not only complex but interconnected with economic, technological, and social factors. *Lowitzsch and Hanke* (2019) illustrates the role of renewables in energy poverty through a conceptual map, displayed on Figure 2.8. It shows how the causes and effects of energy poverty are interconnected with potential measures to alleviate it. In a short explanation, RE generation can decrease fuel use and, as RES have reached "grid parity", it comes at a lower cost, reducing the payments for energy use. It has a positive impact in the income of households, having in result a decrease in stress, indebtedness, and social isolation. Besides this, RE generation also increases building efficiency and, therefore, consumption needs decrease in space heating, electricity, and hot water. In turn, it mitigates energy poverty impacts on health and social stigma. Along these lines, measures as Investment support, Grid access and Storage capacity are renewable policy components that help to alleviate energy poverty during a renewable energy generation.

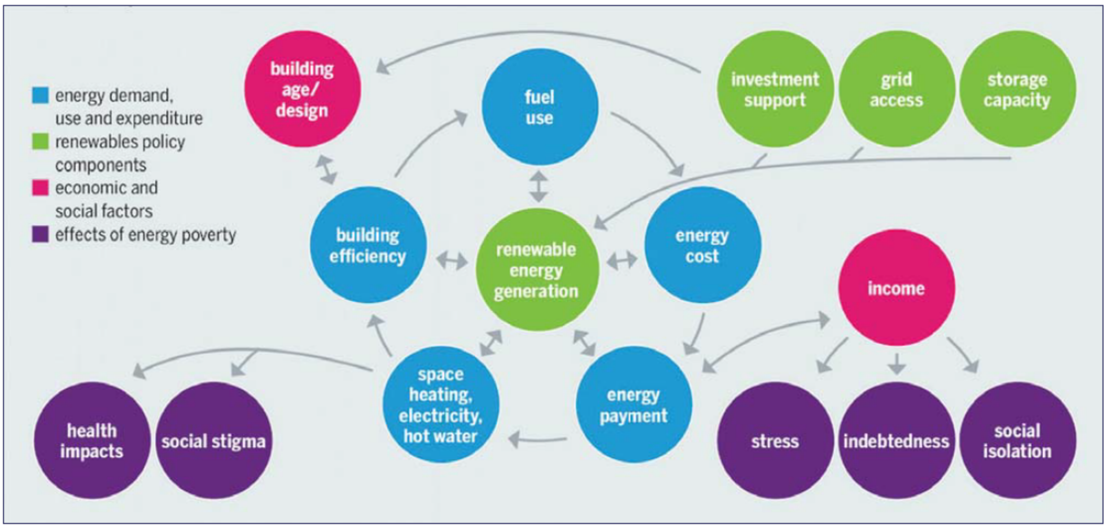


Figure 2.8: *Conceptual map of interconnected causes of energy poverty, its effects, and potential measures to alleviate it.*

Source: Heinrich Böll Foundation et al. (2018); Bartz/Stockmar, CC BY 4.0.

To overcome the challenges briefly discussed, and the current tendency of membership in Energy communities initiatives (i.e., citizens with high levels of income and education) (*Radtke*, 2014), energy policymaking has become a substantial debate at the European level. The 2018 recast of the Renewable Energy Directive (RED II) promotes a comprehensive energy transition, favouring renewable energy (RE) and entailing a more decentralised energy system with consumers becoming producers of the energy they consume (prosumers). In this way, RED II and the European Green Deal promote the protection and empowerment of vulnerable by including them in RECs, seeking to fight the panorama of energy poverty (*Hanke and Lowitzsch*, 2020; *European Commission*, 2018). As consequence, the support of legal policies helps to strengthen the fight against energy exclusion and to mitigate the challenges in RECs. In such a degree that EU has recognized that citizens are active and central players on the energy markets of the future. *European Commission* (2018) adds that "local citizen participation in renewable energy projects through renewable energy communities has resulted in substantial added value in terms of local acceptance of renewable energy [...]". Therefore, involving the community in energy projects has become essential to make ECs more sustainable (*Woo et al.*, 2019).

Stakeholders is the term for the community' groups whom are directly or indirectly affected by a project, as well as those who may have interests in a project and/or the ability to influence its outcome (*Li et al.*, 2017). Moreover, stakeholders can be categorized into different actors such as bureaucratic actors, political actors, special interests, general interests, and experts having a different role such as a promoter, director, ally, mediator, and gatekeeper. Particularly, in the public decision problem, the stakeholders involvement and their identification are significantly important since key representatives can then be invited to participate in brainstorming sessions (*Ferretti*, 2016). They can then be a stake part in decision making in the institutions, programs and environments that affect them (*Kalkbrenner and Roosen*, 2016). According to *Lowitzsch* (2019a), the stakeholders involvement can occur at distinct stages of project implementation and in different forms:

1. "Information about the ongoing development;
2. Participation in decision-making during the planning process;
3. Financial participation in the project" (only for shareholders).

Therefore, the involvement of stakeholders in energy projects are highly beneficial for local communities. It can contribute to local jobs and local wealth creation as the money for energy stays within the community (instead of paying for energy imports). Furthermore, the "democratisation of the energy system" leads to increased social acceptance of renewable and increased energy consciousness, resulting in decreased energy consumption (*Lowitzsch*, 2019a; *Alvial-Palavicino et al.*, 2011).

2.2.1 Tools for Stakeholders Involvement

Several innovative tools exist in order to involve multiple stakeholders and experts in the planning practice. It is possible, for example, to organize collaborative events with a small group of stakeholders (e.g., focus groups, moderated round tables) or with a larger group (e.g., search conferences, world café). Moreover, stakeholders involvement is an ongoing and iterative procedure that occurs during the entire decision-making process of a project. It helps to obtain available existing data, determine relevant sustainable objectives, and propose a common strategic vision (*Torabi Moghadam et al.*, 2017).

In addition to the stakeholders involvement in decision-making during the planning phase (*Devine-Wright*, 2005), they can also be involved into the financial structure, having the right to the investment profits share. The financial involvement can happen in two types of configurations (*Lowitzsch*, 2019a), and while on the **passive participation**, the stakeholders have no role in decision making and the main objective is the investment return, in the **active participation** they have voting rights, providing a role in the utility governance. It may contribute to a greater involvement of the stakeholders into energy projects.

- Passive financial participation (no role in decision-making and investment return is the objective, e.g., loans and silent partnerships);
- Active financial participation (with a role in the utility governance, e.g., coops, limited liability companies and partnerships).

The active financial participation combined with stakeholders who (co-) produce the goods or services they consume ("prosumers"), it is labelled as Consumer Stock Ownership Plans (CSOPs), a prototype business model introduced in RED II (*European Commission*, 2018). The prosumers can be an individual but also a micro enterprise or an SME. Figure 2.9 relates the term Prosumership with Citizen energy and Community energy, to define the consumer co-ownership in RE: "all participation schemes that confer ownership rights in RE projects to consumers in a local or regional area" (*Lowitzsch*, 2019a).

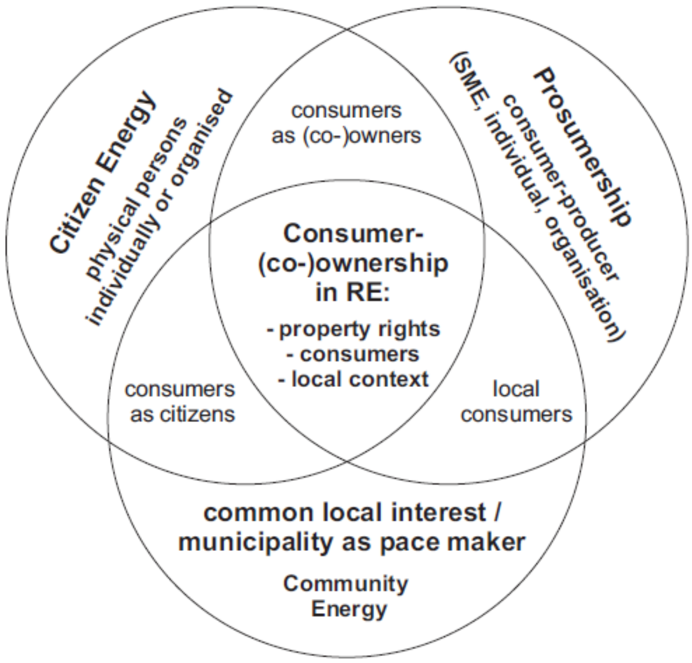


Figure 2.9: *Consumer ownership in RE and its relationship to citizen energy, prosumership and community energy.*

Source: Lowitzsch (2019a).

Consumer co-ownership is the highest level of citizen power as it confers the control over the decision-making process and its outcome (*Gorroño Albizuand*

Karl Sperling and Djørup, 2019). Prosumership can contribute to mitigate two of the major challenges vulnerable energy consumers face on a daily basis: low income and high energy costs. Thus, this financial model can empower vulnerable consumers by providing a second source of income from the sale of excess production to the grid and mitigate energy poverty (*Hanke and Lowitzsch*, 2020; *Lowitzsch and Hanke*, 2019). Besides that, consumer ownership in RE promotes energy efficiency by educating consumers and encouraging emulation ("learning device"). And in the end, by turning consumers into owners, it fosters involvement (*Lowitzsch and Hanke*, 2019).

However, by enabling vulnerable consumers to become (co-)owners of renewables, they can be caught in a "welfare dilemma". The joint ownership may include other owners such as municipalities or conventional investors, that negatively affects the capacity for sound economic decision-making, complicates trade-offs and leads to short-sighted and risk averse assessments. To solve this, calibrated policy action is essential to ensure that the consumer is "at the heart of the energy markets". Consumer Stock Ownership Plans (CSOPs) can, therefore, contribute to meet the challenges of property ownership and avoid the "welfare dilemma" (*Lowitzsch and Hanke*, 2019).

Another important form to involve the stakeholders in energy community initiatives is applying a multi-criteria analysis (MCA) for decision-making. MCA is commonly utilized to address issues of generation, management, and energy policies (*Tegou et al.*, 2012). When different stakeholders are included in the decision making process, MCA can reduce uncertainty in energy development by considering a wide spectrum of social, economic, environmental, and technical indicators. It can increase social acceptance, because it focuses on expectations of different stakeholders in scenario planning and on the construction of a common vision (*Alvial-Palavicino et al.*, 2011).

The process how information is presented for the stakeholders is also crucial and affects its perception. An effective information approach, in consequence, needs to extend beyond consumer choice and include the local community and its decision-making process by framing it around what it is perceived relevant and of interest (*Hanke and Lowitzsch*, 2020). Considering this, a georeferenced supportive web database may help stakeholders to visualize the current urban energy situation and to visualize future scenarios. Therefore, the creation of a georeferenced urban energy inventory can establish the primary step of a strategic planning.

In addition, to involve multiple stakeholders and experts into planning procedure, it is necessary to organize collaborative events, as workshops, focus groups, questionnaires, and/ or interviews. In the work of *Heaslip and Fahy* (2018), for example, some workshops were made using communication tools based on outputs of the technical energy planning phase and the feasibility assessment of energy scenarios. They used a transdisciplinary methodological framework for community energy planning to involve the stakeholders.

Many cities struggle to develop innovative methods to successfully reinforce the collaboration among different research disciplines (*Zanon and Verones*, 2013). One innovative tool that can solve this is Storytelling. Storytelling is an instinctive form of talking or writing which humans have always used for learning purposes. It involves communicating in a way which emphasises plot, characters, and narrative. Considered as a research and collaboration tool, Storytelling is grounded in several social science disciplines, as Anthropology and Sociology (*Mourik et al.*, 2017).

The transdisciplinary characteristic of the Storytelling method can help to face key challenges of "wicked problems". In another words, problems which have a multitude of perspectives, based on values and norms, that needs to have a "democratization" of knowledge inclusion. Storytelling approaches can overcome these challenges by supporting learning and unlearning (e.g., transferring knowledge and understanding); empathy and conflict solving (e.g., when the participants associate themselves with the characters in the story); and inclusion and participation (e.g., inviting multiple voices) (*Mourik et al.*, 2017).

Storytelling can, therefore, be a qualitative method to work with multiple stakeholders taking into account their concerns and expectations, and identifying their visions to construct desirable scenarios (*Alvial-Palavicino et al.*, 2011). During the method application, it is possible to occur visions with different perceptions and narratives of issues, depending on a particular experience of the stakeholder. Despite these differences, visions in the Storytelling should be integrated and never ignored, and treated as equally relevant for the development of the intervention. For these reasons, Storytelling methods engage multi-stakeholders in decision processes by enabling this learning to take place in a non-threatening manner between experts and non-experts.

The "story", different from the "narrative", is more deliberately constructed and not necessarily chronological account. The Storytelling is an active construction or plotting of stories with specific purposes (e.g., to elicit certain emotional reactions) (*Rotmann*, 2017). The story is "explicitly and purposefully emplotted" (following a plot or 'story spine') with a sequence of events and the principle of cause and effect. The story spine is the idea of the plot, which incorporates the purpose and aim of the story. It involves guiding sentences that provide a sequence and causal relationship between paragraphs. This ensures that all elements of a 'goods' story are at least theoretically present. Story spines are a key tool used in Storytelling activities such the SHAPE ENERGY project (*Mourik et al.*, 2017). They are particularly important when collecting stories from an audience not used to telling stories in their professional lives (policy-makers, industry, community, and research participants) (*Rotmann*, 2017).

In general, planning processes in urban energy problems cannot be considered "an innovative approach"; however, its management by means of integrated, cross-sector, multi-criteria and multi-actors approaches is absolutely a "novel" approach to be solved (*Cajot et al.*, 2017). The tools briefly described in this Section can support to overcome these challenges. The Storytelling outcomes, for example, can help energy research and policy making to get the built environment performance story straight(er), develop its characters and, most importantly, engage the audience. Whether the audience is policy makers or the public, people react positively to familiar narratives. These improvements are essential to motivating changes in practice (*Janda and Topouzi*, 2015) and involve stakeholders in the energy transition processes.

3

Methodology

Considering that energy communities are a complex challenge of urban and regional planning (*Brömmelstroet et al.*, 2014), a meaningful involvement of interest stakeholders is essential to achieve a sustainable and integrate urban planning. For this purpose, a stakeholder-oriented approach is fundamental to implement effective strategies for urban and regional adaptation (*Torabi Moghadam et al.*, 2017).

This chapter discusses in detail the design and the methodological set-up of the thesis research. The idea is to solve the problems stated in Chapter 2 by integrating different methodologies and approaches, due to their complementarity in fulfilling varied tasks. The aim is to offer an interdisciplinary integrated methodological framework which is able to support decision-making processes by coupling different areas. This will help in defining and evaluating energy-saving scenarios taking into account the involvement of stakeholders in an interactive way.

Along these lines, the thesis seeks to have a sustainable and integrate urban planning approach from technical (e.g., energy analysis) to social (e.g., multi-stakeholders involvement) elements. The study follows different methodologies combined (statistical, engineering, workshops, storytelling), as "a mixed methodology" (*Dantsiou*, 2017), which combines qualitative and quantitative approaches. Qualitative research refers to semi-structured workshops in which the qualitative data such as stakeholders' opinions and stories are collected through discussions and storytelling methods. Particularly, the stakeholders workshops in this study have the following implications: (i) they answer the second objective of Section 1.3; (ii) they explain the "mixed methodology" choice with the use of qualitative (semi-structured workshops, storytelling) and quantitative data collection and analysis methods (energy data, PROMETHEE, MCA, WebGIS).

3.1 Methodology Framework

The methodology framework consists of three main Phases, in which there are fundamental steps to achieve the objectives previously explained in Section 1.3. The **first Phase (1)** is the "Assessment and Evaluation", which includes two quantitative steps. The study site impact assessment and the Multi-Criteria Analysis (MCA) through the PROMETHEE method. The first Phase seeks to determine the best refurbishment alternative for five Italian case studies of the SCORE project.

The **second Phase (2)** is the "Visualization and the participative Workshops", which uses a mixed methodology. It includes quantitative and qualitative approaches, respectively, in two steps: the data collection and visualization via an interactive WebGIS tool; and the organization of participative Workshops in the Susa Valley with stakeholders, using the method of Storytelling explained in Subsection 2.2.1. The second Phase targets stakeholders involvement, in which citizens and public administration entities will be involved in the co-ownership models and they will create their own scenarios for the Italian energy communities.

After that, the **last Phase (3)** is the "Recommendations". It has a qualitative approach in order to elaborate final recommendations. This Phase gives recommendations of consumer co-ownership in RECs to enable policies on prosumership at EU and local level based on the work done on the previous steps and on the learnings of the SCORE project.

To these means, it is helpful to break the study down into different steps that frame the three Phases of the thesis, in order to understand the research process employed. To this end, in Figure 3.1 is shown a schematic flowchart of the interdisciplinary integrated methodological framework of the research. It first classifies the Phases into quantitative and qualitative approaches. Second, it connects the three Phases with the objectives of Section 1.3. Third, it divides the Phases into main steps, in order to separate well the methodology. These steps are crucial to arrive in the main objective of the thesis: involve stakeholders in (RECs) co-ownership.

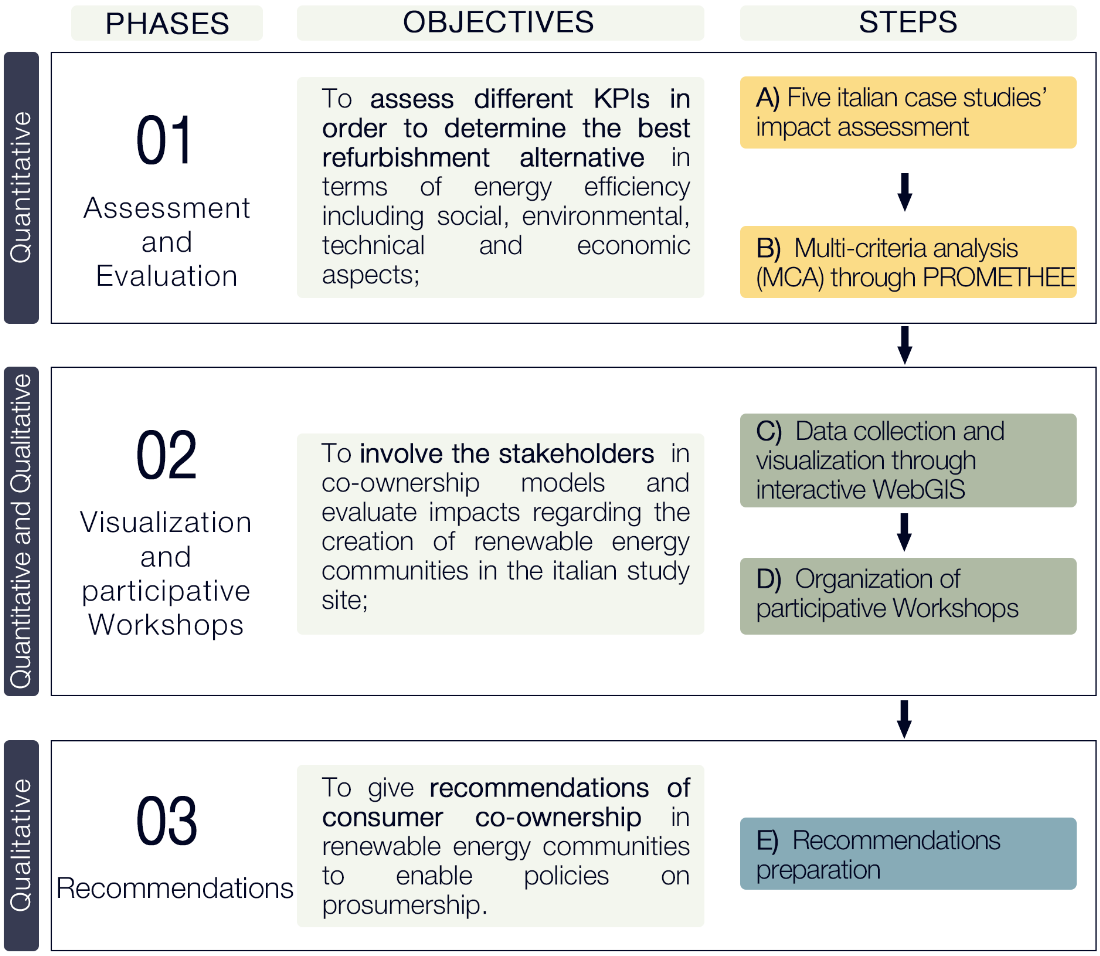


Figure 3.1: *The schematic flowchart of the interdisciplinary integrated methodological framework, with its Phases, objectives, and steps.*

Source: Author, 2020.

3.1.1 First Phase: Assessment and Evaluation

For the first Phase, the aim was to determine the best refurbishment alternative for five cities of the SCORE Italian pilot in the Susa Valley (Almese, Bardonecchia, Bussoleno, San Giorio di Susa and Susa). The methodology was divided into two steps. Firstly, to achieve the goal and select the best alternative, documents called "dossiers" were analysed. They provided the characteristics of the retrofitting alternatives and with them, it was possible to assess the case studies' impacts **(STEP A)**.

Secondly, with the previous information, it was possible to build an evaluation matrix with Key Performance Indicators (KPIs) from the work by *Torabi Moghadam et al.* (2019) and to implement a Multi-Criteria Analysis (MCA) through the PROMETHEE method **(STEP B)**, in order to find the best refurbishment alternative. The schematic procedure for this Phase is illustrated in Figure 3.2, where it shows the output of each step and the methods/tools used.

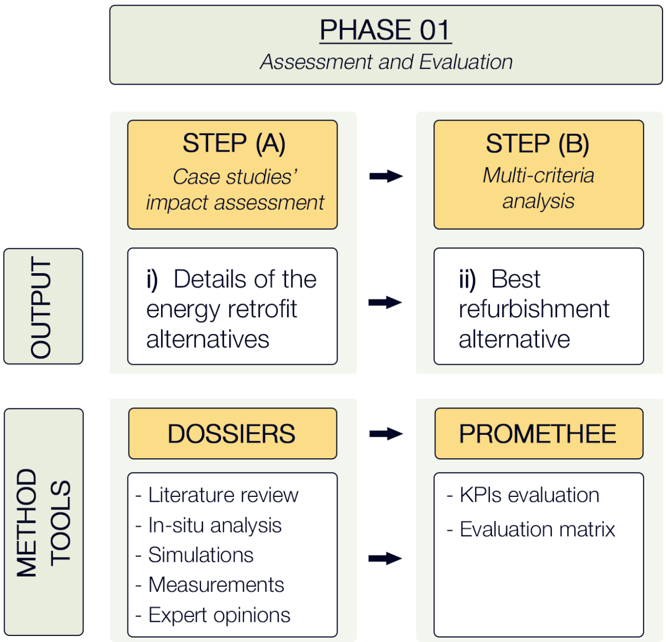


Figure 3.2: *The outputs and methods/tools of the first Phase.*

Source: Author, 2020.

The dossiers are documents in which the project partners identify buildings where the central plants of the RECs will be installed and describe their characteristics. Each dossier illustrates the collected information and data from the pilot buildings, and it is a guideline to improve and increase their energy efficiency. Moreover, it defines different refurbishment measures, which are described using simulation and measurements approaches. The following points are addressed in the detailed dossiers:

1. **Energy impact assessment.** The first is for the current situation of the building, which determines the energy uses and needs for space heating, domestic hot water (DHW), and lighting-equipment through measured data and in-situ analysis. Later, multiple alternative refurbishment options are assessed, determining the future impact in the energy use through energy models. The refurbishment alternatives concern the envelope system, the energy system, or the control system, in order to improve the building energy efficiency.

2. **Environmental impact assessment.** It illustrates how the refurbishment

alternatives will minimize the environmental impact (e.g., reductions of non-renewable source consumption, fuel consumption and CO_2 emissions).

3. **Economic and financial assessment** of the investment costs.

The KPIs, used into the PROMETHEE method in the second step, assess the impacts of the refurbishment alternatives regarding not only the energy aspects but also other sustainable aspects (i.e., environmental, economic, technical and social). According to *Torabi Moghadam et al.* (2020), the final set of seventeen KPIs used in the Italian pilots were selected based on literature review and workshops, where the "Playing Cards" method was employed involving different types of stakeholders. After some adjusts during meetings and workshops, the final framework was detailed and accepted by the SCORE partners. All this selection process of indicators aimed to reduce the number of criteria to obtain a practical but still significant number of KPIs to conduct an effective sustainability assessment. Afterwards, these indicators were classified into four categories: Environmental, Economic, Technical and Social, as shown in Figure 3.3.

Category	Code	Indicator	Type	Data Source	Unit
Environmental	ENV1	Primary energy saving	Quantitative	Estimated or metered data	($kWh_{primary\ energy}$/year)
	ENV2	Global CO_2 emission reduction	Quantitative	Estimated or metered data	(kg/year)
	ENV3	Local NO_X emission reduction	Quantitative	Estimated or metered data	(kg/year)
	ENV4	Local PM_{10} emission reduction	Quantitative	Estimated or metered data	(kg/year)
Economic	EC1	Payback period (PBP)	Quantitative	Calculation	(Years)
	EC2	Investment cost	Quantitative	Calculation	(Euro)
	EC3	Public incentives	Quantitative	Process documentation	(%)
	EC4	Savings on energy expenditure	Quantitative	Calculation	(Euro/year)
	EC5	Labour cost	Quantitative	Estimated or metered data	(Euro/year)
	EC6	Labour cost by a social cooperative	Quantitative	Estimated or metered data	(Euro/year)
	EC7	Material cost	Quantitative	Estimated or metered data	(Euro)
	EC8	Material cost purchased on the territory	Quantitative	Estimated or metered data	(Euro)
	EC9	Running cost	Quantitative	Calculation	(Euro/year)
	EC10	Type thermal account access (TAA) vs. Energy efficiency certificates (EEC)	Qualitative	Process documentation	(TAA/EEC)
Technical	T1	Increase of plant system efficiency	Quantitative	Estimated or metered data	(%)
	T2	Installed power reduction	Quantitative	Estimated or metered data	(kW)
Social	S1	Architectural impact	Qualitative	Process documentation	(Ordinal)

Figure 3.3: *Key Performance Indicators (KPIs) matrix framework.*

Source: Torabi Moghadam et al. (2020).

In order to build the evaluation matrix of the case studies, this thesis used the table of Figure 3.3 to evaluate each refurbishment alternative proposed on the dossiers. The evaluation process provided quantitative and qualitative information giving a support for the retrofitting measurements. In this way, following the classification given by *Torabi Moghadam et al.* (2020), the detailed meaning of the indicators (in relation to their code from the second column of the table) are:

- **ENV1 - Primary energy saving.** Primary energy that would be saved if the new plant is built regarding the renewable nature of the investment and the retrofitting alternatives. The primary energy was calculated through energy models by the SCORE partners and the savings are the comparison between the primary energy values of the current situation and the alternatives.

- **ENV2 - Global CO_2 emission reduction.** The building's energy system CO_2 emissions were calculated comparing the current situation using non-renewable fuels with the different alternatives proposed using renewable fuels. They were calculated by the SCORE partners, using the value of 200,16 g of CO_2 emission per kWh of primary energy used with natural gas fuel (value from Allegato 1 - Requisiti Tecnici per impianti a cippato superiori a 350 kW by Provincia di Torino and the Energy Department of Politecnico di Torino).

- **ENV3 - Local NO_X emission reduction.** The building's energy system NO_X emissions were calculated as the previous indicator ENV2, but regarding the comparison between the current and future NO_X emissions for the different alternatives.

- **ENV4 - Local PM_{10} emissions emission reduction.** The building's energy system PM_{10} emissions were calculated as the previous indicator ENV2, but regarding the comparison between the current and future PM_{10} emissions for the different alternatives.

To assess the local emissions for NO_X (ENV3) and PM_{10} (ENV4), the following values from Table 3.1 were obtained from IREA (Inventario Regionale delle Emisioni in Atmosfera). With those values, it was possible to estimate the quantity of emissions (mg/MWh) emitted per type of boiler fuel.

	NO_X **emissions [mg/MWh]**	PM_{10} **emissions [mg/MWh]**
Diesel oil Boiler	180	13
Natural gas Boiler	107	0.72

Table 3.1: *Quantity of emissions (mg/MWH) emitted per type of Boiler fuel.*

Source: http://www.sistemapiemonte.it/fedwinemar/storedProcess.jsp, 2020.

- **EC1 - Payback period (PBP).** PBP, simple or discounted, provides the amount of time which the expenses are amortized, leading to net gains thereafter. The payback period is assessed by the investments costs of the indicator EC2 (explained below) subtracted by any public incentives (if it exists, as indicator EC3) dividing by the annual savings on energy expenditure (calculated in indicator EC4) as shown in Equation 3.1:

$$Payback\ Period(PBP) = \frac{Investment\ costs\ -\ Public\ incentives}{Annual\ savings\ on\ energy\ expenditure} \tag{3.1}$$

- **EC2 - Investment cost.** The investment cost involves all the costs related to refurbishment of the building and/or the new heating system. It includes the purchase of building material, technological installations, manpower, and the cost for each individual element of the renovation project (building envelope and energy systems). It is the sum of the indicators Labour Cost (EC5) and Material Cost (EC7).

- **EC3 - Public incentives.** This is the percentage of savings linked to the share of investment cost covered by administrative incentives.

- **EC4 - Savings on energy expenditure.** The savings on annual expenditure taking into account the primary energy savings calculated previously (on the indicator ENV1) and the fuel cost of the energy used given by the dossiers as shown in Table 3.2 .

Fuel	**Cost including IVA** [euro/MWh]
Biomass	100
Diesel oil	170
Natural Gas	112,50

Table 3.2: *Fuel costs (euro/MWH).*

Source: Dossiers from SCORE commission (2019).

- **EC5 - Labour cost.** It includes the salary of employees who are directly involved in production activities, services (such as general repairs and maintenance performance), and supervision. It is assumed to be 40% of investment costs, as an expert in the field suggested during an internal meeting.

- **EC6 - Labour cost by a social cooperative.** The part of labour cost that will be covered by the social cooperative. As one of the objectives of the SCORE project is to fight against energy poverty by involving under-represented groups in EC, it is assumed that one of four workers employed in the project, will be part of the social cooperative. Therefore, this criterion is equal a 25% of the labour cost (indicator EC5) and this number may be adjusted whilst the project runs.

- **EC7 - Material cost.** The costs of raw materials or parts that go directly into producing products or providing services. This cost was assumed to be only at the beginning of the project (e.g., aspects like pipelines, central thermal plant and connections).

- **EC8 - Material cost purchased on the territory.** This criterion evaluates the portion of material cost that remains in the territory (the Susa Valley). According to an expert in the field in an internal meeting, most of the materials will be probably provided from other countries. In this way, the total amount of material cost that will be purchased in the territory will be around 10%, according to experts advice.

- **EC9 - Running cost.** This involves the energy costs plus maintenance costs. The energy costs refer to the operational cost for the energy in the buildings (i.e., it is the quantity of fuel that will be used [kWh/year] multiplied for the fuel unit cost [euro/kWh], shown previously in Table 3.2). The maintenance costs are assumed to be 2% of the indicator Investment Cost (EC2), according to *Becchio et al.* (2016).

- **EC10 - Type Thermal Account Access (TAA) vs. Energy Efficiency Certificates (EEC).** This represents the access to the thermal account and energy efficiency certificates, Italian public incentives carried out by energy services management.

- **T1 - Increase of plant system efficiency.** This is the increase in the efficiency of the new system plant compared to the existing one.

- **T2 - Installed power reduction.** This is the reduction of installed power of the new system plant compared to the existing one.
- **S1 - Architectural impact.** This indicator evaluates the visual outcome that may be created by the application of retrofitting measurements for a city. When retrofit measures lead to aesthetic improvement of the city, this criterion has a higher value. Five scores of impact are presented in Table 3.3 according to the study conducted by *Dall 'O' et al.* (2013), with reference to specific measures. This criterion adopts an ordinal scale to rank the strategies, from the best to the worst.

Typology	Description	Value	Description of intervention
Positive	Great positive impact	1	External Thermal Insulation
	Positive impact	2	Windows replacement
Neutral	No impact	3	Roof insulation/Boiler replacement
Negative	Little negative impact	4	Photovoltaic panels
	Negative impact	5	Solar thermal collector

Table 3.3: *Architectural impact criterion evaluation.*

Source: Dall 'O' et al. (2013).

In **STEP A** the evaluation matrix from Figure 3.3 was fulfilled in an EXCEL spreadsheet after the review of the dossiers information and with the help of external experts, as the matrix contained different types of information ranging from environmental to social types. After assessing each KPI, it was possible to compare the retrofitting alternatives proposed in the dossiers with the current situation of the pilot buildings, taking into account the criterion.

The next **STEP B** was to assess the indicators impacts and identify the most feasible and sustainable refurbishment alternative for each pilot case study. It was applied the PROMETHEE method (preference ranking organization method for enrichment evaluation) developed by *Brans et al.* (1986). This method is an outranking Multi-Criteria Analysis. It has been widely applied in the field of energy planning as seen in *Diakoulaki and Karangelis* (2007) and *Dirutigliano et al.* (2017) .

The PROMETHEE method uses the partial aggregation and it is useful to rank a limited number of alternatives, considering conflicting criteria (*De Montis et al.*, 2004). It is based on the pair-wise comparison, checking if one of two alternatives outrank the other or not. In order to implement this method, it is necessary to define two general information (*Torabi Moghadam et al.*, 2020):

i The criteria weight, which is defined based on how much a criterion is important with respect to others. The importance is determined according to the decision makers priorities.

ii The decision-maker's preference function to compare the contribution of the alternatives in terms of each criterion. The preference functions types can be Usual, V-shape, U-shape, Level, Linear or Gaussian (*Vulević and Dragović*, 2017).

Following the methodology applied on previous SCORE case studies by *Torabi Moghadam et al.* (2020), it was used the software available for free called "Visual PROMETHEE". The evaluation matrix made in an EXCEL spreadsheet on **STEP A** was compiled into the software, with all KPIs criteria.

To outrank the alternatives, the software quantifies the degree of preference $\pi(a,b)$ of an alternative "a" compared to "b", by multiplying the weight (W_j) and the preference function P_j (a, b) for each criterion (j) and summing it all afterwards. As calculated in Equation 3.2:

$$\pi(a,b) = \sum_{j=1}^{n} \mathrm{W_j P_j}\ (a,b) \tag{3.2}$$

The preference function P_j (a, b) represents a function of the difference between two alternatives and it is applied to decide how much the alternative "a" is preferred over the alternative "b" as showed in Equation 3.3. The values vary between 0 and 1, where 0 is for no preference or indifference, while 1 is for strict preference, meaning that larger the difference among the alternatives, higher is the value of the preference function.

$$\mathrm{P_j}(a,b) = \mathrm{F_j}\ [\mathrm{d_j}(a,b)],\ 0 \leq\ \mathrm{P_j}(a,b) \leq\ 1 \tag{3.3}$$

The software allows to calculate the net flow through the outgoing flows (φ+) and the incoming flows (φ-) for each alternative. The outgoing flow represents the robustness measure of the analysed alternative and varies between 0 and 1 as calculated in Equation 3.4. The more φ+ approaches 1, the more preferable is the alternative considered in comparison to the others, on the other side, if it is equal to 0, the action in question does not has advantage over the others.

$$\varphi + (a)\ =\ \frac{1}{n-1} \sum_{b \neq a} \pi(a,b)\ \ \varphi + (a)\ \in\ [0,1] \tag{3.4}$$

The incoming flow represents the measure of the weakness of the analysed alternative with respect to the other alternatives. This parameter also varies between 0 and 1, but on the contrary, where φ - = 0 means that the selected alternative has a degree of weakness equal to zero, and therefore represents the best alternative; on the other hand φ - = 1 represents the worst one. Equation 3.5 is used for the calculation:

$$\varphi - (a) = \frac{1}{n-1} \tag{3.5}$$

At this point it is possible to calculate the net flow simply as the difference of the outgoing one and the incoming one. The net flow allows us to directly compare the proposed alternatives and provide the ranking of alternatives as shown in Equation 3.6

$$\varphi\ (a) = \varphi\ +\ (a)\ -\ \varphi\ -\ (a) \tag{3.6}$$

The result of the best alternative is presented after implementing a sensitivity analysis. The sensitivity analysis is proposed by changing different weights with respect to a Baseline alternative, according to stakeholders' interests and opinions. This last part is useful to test the robustness of the model (*Torabi Moghadam et al.*, 2020).

To do this process, it was necessary to define for each criterion the following preferences into the software "Visual PROMETHEE", based on the previous working of *Torabi Moghadam et al.* (2020):

- If the criterion will be minimized or maximized, in order to give worse/-greater preference, respectively, to higher values than the alternative. The criteria for which the maximization choice was made are: primary energy saving (ENVI1), global CO2 emission reduction (ENVI2), local NOx emission reduction (ENVI3), local PM10 emission reduction (ENVI4), public incentives (EC3), savings on energy expenditure (EC4), increase of plant system efficiency (T1), and installed power reduction (T2). On the other hand, the criteria which the minimization function was associated are: PBP (EC1), investment cost (EC2), labour cost (EC5), labour cost by a social cooperative (EC6), material cost (EC7), material cost purchased on the territory (EC8), and running cost (EC9).

- The measurement scale of the quantitative criterion. For the qualitative criterion: EC10 (access to Italian public incentives), the corresponding scale was 'yes' or 'no', and for the S1 (architectural impact) the 5 points ordinal scale, as explained in Table 3.3, was transformed as bellow:

Numerical Value	Corresponding 5-points Visual PROMETHEE
1 - Great positive impact	Very good
2 - Positive impact	Good
3 - No impact	Average
4 - Little negative impact	Bad
5 - Negative impact	Very bad

Table 3.4: *Transformation of the 5 points scale of impact level from Table 3.3 into the corresponding for the software "Visual PROMETHEE"*

- The preference function as the V-shape (i.e., criterion with linear preference) with the threshold as absolute for all criteria.
- The Indifference (Q) and Gaussian (G) as empty (n/a).
- The Preference (P) value as the standard deviation.
- The criteria weight as showed in Table 3.5. Considering three types of weights for the sensitivity analysis: Baseline, Change 01 and Change 02. It was given the Total weight for each indicator and the Single weight for each criterion of the indicators. Environmental has 4 criteria, Economic has 10, Technical 2 and Social 1 based on the previous Table 3.3.
  - The **Baseline** model assigns same weight for each indicator (i.e., environmental, economic, technical, and social), 25% each one, divided equally to the indicators. This means that the weight of each particular indicator will depend on the number of criteria included in that indicator (indicated on parentheses).
  - **Change 1** proposes the same weight for each criterion (e.g., ENV1, EC1, T2), of 0.059 each. This leads to different weights for each category of indicators.
  - **Change 2** focuses on two categories that have more impact in the project, the environmental and economic indicators. Taking into account the relevance of these two, a higher weight was assigned (30 percent each one), leaving the rest to social and technical aspects, divided equally.

	Environmental		Economic		Technical		Social	
	Total (4)	**Single**	**Total (10)**	**Single**	**Total (2)**	**Single**	**Total (1)**	**Single**
Baseline	25%	0,0625	25%	0,025	25%	0,125	25%	0,25
Change 01	23,5%	0,059	58,8%	0,059	11,8%	0,059	5,9%	0,059
Change 02	30%	0,075	30%	0,03	20%	0,1	20%	0,2

Table 3.5: *Three types of weights used for the simulation of sensitivity analysis, classified per total of each indicator and per single criteria of each indicator.*

Source: Author, 2020.

Thus, considering this methodology, the first Phase assessed and evaluated refurbishment alternatives in five case studies, taking into account environmental, economic, technical, and social indicators. Afterwards, the best alternative for each case study was outranked through the program VISUAL PROMETHEE. This information was further used on the workshops, to present the research outputs and involve the stakeholders in future scenarios creation for the RECs.

3.1.2 Second Phase: Visualization and participative Workshops

In the second Phase, the aim was to involve different stakeholders (citizens, public and private sector) in the co-ownership models of the SCORE project in the Italian pilot (focusing on the groups that are the project targets). And in this way, to evaluate impacts regarding the stakeholders scenarios development for the creation of energy communities.

To reach this goal, this Phase collected first all the information developed so far in the SCORE project, together with the outputs of the first Phase of this thesis. With this material, it was built an interactive tool in order to make a clear visualization of the research done so far. The tool was constructed in a Geographic Information System (GIS) called "WebGIS" **(STEP C)**.

WebGIS, or Web-based GIS, is a geographic visualization and analytical functionality expressed within a web browser. It can be assessed using a mobile/desktop and it can be defined as a GIS that uses web technology to communicate between a server and a client as a web mapping/ Internet-based GIS. It does basic things like zoom, pan, and identify but it also is capable of rich data analysis like determining the geographic center of a particular set of data - all at the click of a button. According to *Baker* (2015), the WebGIS can be an effective tool for enhancing learning. The interfaces and data can be tailored to learner need, accounting for developmental level and instructional objectives. Besides that, WebGIS increase capacities for collaboration, analysis, storytelling, sharing, and interactivity. The map scaling and partitioning reduces the cognitive load imposed on the learner and the just-in-time association of maps with non-spatial facts in instruction media facilitates comprehension of the subject matter. Therefore, it is a useful tool to reach different users simultaneously and globally, especially in the online workshops from this thesis.

Second, after the creation of the WebGIS tool, two main participative workshops have been conducted with citizens and the public administration sector. They were meant to outline the current conditions of the Susa Valley regarding energy management and to understand the perceived potentials of an energy community creation. For this purpose, the qualitative method of "Storytelling" was applied together with the online tools "Google forms" and "Zoom Platform", as the workshops were done during the time of COVID-19 restrictions and it had to follow the social distance recommendations in the period of Italian lockdown **(STEP D)**.

The main method used in the workshops, called Storytelling, was explained in the previously Subsection 2.2.1. It is a research and collaboration method grounded in several social disciplines (*Fog et al.*, 2005), since it is able to facilitate productive working in different fields. It can be considered as a communication methodology that consists in telling a story for different purposes: to attract the attention of a specific audience; to convey to an audience the message that the story wants to transfer; to stimulate a specific desire in readers or spectators; or to persuade them to perform a specific action (*Jefferson*, 1978). The Storytelling is a playful and instinctive method of communicating thoughts over language and writing. It allows to explicit life lessons in a narrative form (plot, characters, story), including multiple voices and points of views. The Storytelling has different potentials when focusing on inclusive processes, because it facilitates and stimulates the emergence of stakeholders' opinions and experiences which are conveyed through simple and understandable stories (*Anderson and Wales*, 2012). Following these points, the stories made during the workshops in this Thesis were evaluated later following some methodologies applied in the SHAPE project (*Mourik et al.*, 2017) and in the book of *Kurtz* (2008), as reading the stories multiple times and highlighting important phrases in order to make some correlations and understand their statements.

As for the first Phase in Figure 3.2, the schematic procedure for the second Phase is illustrated in Figure 3.4, where it shows the output of each step, previously discussed here, and the methods/tools used (i.e., the WebGIS and the participative Workshops).

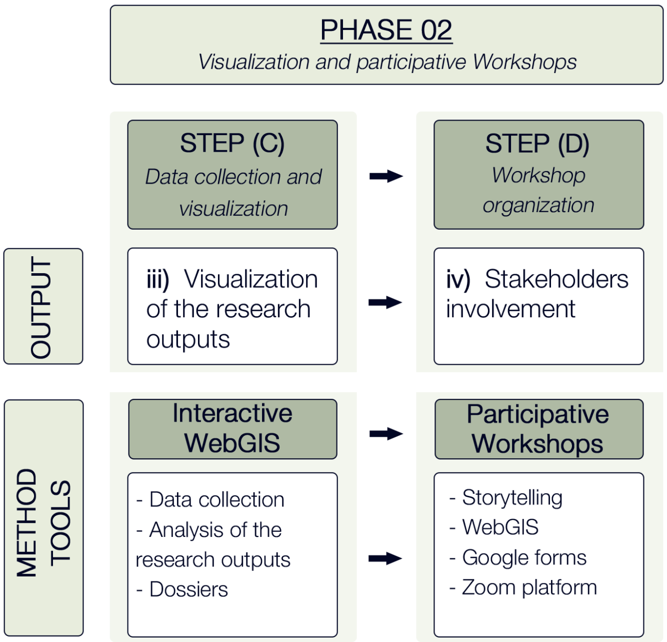


Figure 3.4: *The outputs and methods/tools of the second Phase.*

Source: Author, 2020.

In this second Phase, the Storytelling was a powerful innovative methodology used during the semi-structured workshops that allowed the collaboration and mutual understanding within the inter-disciplinary working group, overcoming the processes of cognitive influence and shyness that often occur in workshops. The built WebGIS tool also supported the workshop and helped to raise awareness among the stakeholders, by sharing the SCORE research activities in an effective way with the Susa Valley community and creating an interactive visualization tool. The conjoint application of those two tools on the workshops was fundamental to stimulate the participation of the stakeholders, helping them to understand the territory and the SCORE project, improving the social inclusion, collaboration, and mutual understanding. The outputs of these workshops contributed to comprehend the stakeholders' scenarios for the RECs in the Susa Valley and to support the elaboration of recommendations in the next Phase of this thesis.

3.1.3 Third Phase: Recommendations

For the last Phase, the aim was to prepare recommendations of consumer co-ownership in Renewable Energy Communities (RECs) at EU and local level.

These recommendations help to consolidate the main objective of the thesis and to incentive the local consumers to become prosumers. By grounding on the learnings and research outputs of the previous Phases.

This Phase is established considering the frame of the 2030 Agenda for Sustainable Development, Goal 11, particularly Goal 11.3 (enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries),and Goal 11.b (increase the number of cities adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change) (*UN-Habitat*, 2016).

Policies with a strong attention to climate change require recommendations and actions to be implementable (*UN-Habitat*, 2016). Recommendations are an important way to address outcomes of projects studies and they give guidance for other programs, based on tested practices and methods. Besides this, they are a crucial stage since they allow generating a long-term vision based on a research (*Alvial-Palavicino et al.*, 2011). While better accuracy and prediction of factual elements is certainly necessary, an evidence-based approach may also enhance built environment performance, increase public understanding, and develop better communication with policymakers. Policy is intimately engaged with rhetoric and language, but also it should be based on both facts and values (*Janda and Topouzi*, 2015).

Under the SCORE project context and the CSOP framework (explained in Section 1.2), the recommendations were formulated to improve the involvement the stakeholders into RECs, over a prosumership of the local energy system **(STEP E)**. In order to incentive local consumers to become owners and producers of the energy, the thesis built some consensus and guidelines that encompass the complexity of multiple visions and objectives that each stakeholder brings to the project. By learning from the inspiring practices and case studies presented, it is hoped that these would empower local stakeholders as key actors in the energy transition effort.

Thus, the recommendations of this thesis propose guidelines that can assist other projects of consumer co-ownership models in renewable energy communities. It was done through a post assessment of the above Phases and research outputs, and the key findings and data from the thesis. In Figure 3.5, the schematic procedure for the third Phase is illustrated, where it shows the output of Step E and the method/tools used.

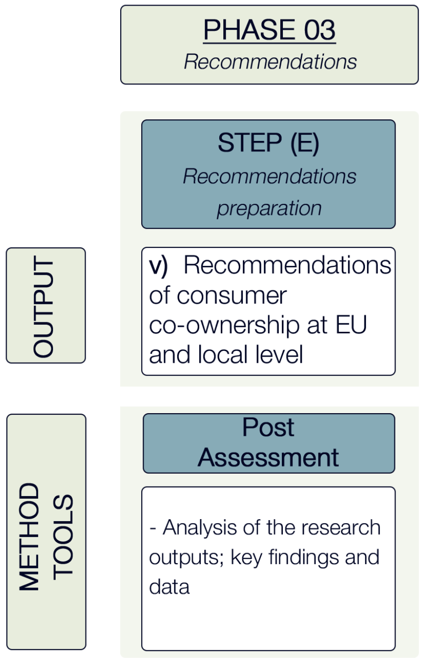


Figure 3.5: *The outputs and methods/tools of the third Phase.*

Source: Author, 2020.

Based on the framework from *CESBA Med Commission* (2019) and *Restrepo Arias et al.* (2020), the recommendations were formulated for policymakers and stakeholders from the public and private sectors. The recommendations focus at promoting the REC as a sustainable choice for energy transitions in Europe based on the case of the Italian Pilot of the SCORE project. In order to fill a framework based on the project of *CESBA Med Commission* (2019), the recommendations are structured in six points as enumerated below:

i Name of the Recommendation;

ii Level of Applicability - EU level and/or Local level - considering Local level as the study site of this thesis (the region of Susa Valley in Italy);

iii Linkage with the 17 Sustainable Development Goals (SDGs) set by the United Nations General Assembly;

iv Background information and justification;

v Description of the Recommendation;

vi Examples and/or references related to the recommendations, to better reflect the idea behind it (if available).

4

Study Site

The Study Site of this thesis is the Italian pilot of the SCORE project in the Susa Valley (or Valle di Susa). It is a region in the northern part of Italy and one of the widest and deepest Italian alpine valleys. It extends from the city of Turin until the western part of Piedmont region, bordering France, with altitudes from 300 to 3 612 meters above sea level. The Susa Valley has 39 municipalities, characterized by different locations, territorial extensions, and demographic sizes. The population is over 90 000, and 30% of the valley's inhabitants live in the main towns Avigliana, Bardonecchia, Bussoleno, and Susa (*Torabi Moghadam et al.*, 2020).

The Italian pilot comprises nine municipalities of the Susa Valley: Almese, Bardonecchia, Bussoleno, Novalesa, Oulx, Rueglio, San Giorio di Susa, Susa and Villar Dora. The energy consumption of these cities nowadays come 75% from fossil fuels sources and the remaining 25% from renewable sources, mostly from biomass. As an initiative from the local administration, eleven public buildings have been already connected to biomass heating systems. However, the biomass sources are not local, but imported from other European and non-European countries, with no certification and unable to be quantified since it is subject to the "grey market" (*Torabi Moghadam et al.*, 2020).

Besides this, the energy poverty, the situation where individuals or households are not able to adequately heat or purchase other energy services at an affordable price (*Dobbins et al.*, 2019), is one of the main issues in the Susa Valley, leading to a decline in living conditions. Groups vulnerable to energy poverty are not located in a particular area in the valley, but they are rather spread over the territory. Their energy behaviour tend to use older, less energy efficient stoves and fossil fuels due to their low prices (*Torabi Moghadam et al.*, 2020).

The project in the Susa Valley therefore focuses in changing this condition by promoting energy communities inside of the SCORE framework. The planned energy community will facilitate the replacement of old utilities and existing heating systems powered by diesel or natural gas fuel with new ones fuelled by biomass, fed by local produced wood chips/blocks.

The choose of the biomass source as a renewable energy is due to the following reasons, according to *SCORE Consortium* (2018):

- It is a renewable resource widely available in Susa Valley;
- It promotes a certified and controlled supply chain, according to sustainable development principles;
- It is a feasible starting point for the creation of REC, since it has low-risk investments;
- It supports a programmable energy generation, as it is a continuous energy source.

The biomass will be provided from local forest, driving positive externalities to a sustainable path in the region as "(1) lower costs for energy, (2) a high share (80%) of energy cost remaining on the territory, and (3) lower CO_2 emissions" due its closed carbon cycle (*Torabi Moghadam et al.*, 2020).

Moreover, the use of biomass in the pilot will be relied on a sustainable forest administration, based on a certificated supply chain of wood. This certification called PEFC (Program for Endorsement of Forest Certification schemes) enables companies to demonstrate legal and sustainable source of forest products to consumers. It is an international non-profit and non-governmental organization committed to promote sustainable forest management through independent third-party certification. It provides a precise and verifiable information about the material. Along with this, it brings a variety of advantages for the environment, people, and the company itself, as access to new markets and a legislation compliance (*Associazione PEFC Italia*, 2020).

The retrofit process is further accompanied by energy efficiency measures for target buildings, as a control system design, envelop system refurbishment design and/or heating plant system design. Besides this, additionally to the direct impacts, SCORE also seeks to involve local stakeholders into Consumer Ownership Plans (CSOPs) previously explained in Section 1.2 and respond to laws and initiatives from Section 2.1.

Among the SCORE Consortium from Figure 1.3, four local partners are in charge of the Italian pilot: the university Politecnico di Torino; the company Consorzio Forestale; the cooperative forestry society La Foresta; and the social cooperative AMICO (*SCORE Consortium*, 2018). Below there is a brief description of their function within the project:

- **Politecnico di Torino (POLITO)**: technical-scientific university and research body. It offers both theoretical and active support, as well as organizational and production process management skills;
- **Consorzio Forestale Alta Valle Susa (CFAVS)**: company from Susa Valley owned by the municipalities of the zone and founded in 1953. It develops the project design, coordinating public authorities and private firms in harvesting the woods;
- **La Foresta Societa Cooperativa (FORESTA)**: cooperative forestry society founded in 1996, recently specialized in installing and managing heat power plants of small and medium size (20-300 kW), operating 0,84 MW in Susa Valley. It has the PEFC7 certification for wood and wood chips and it is the design consultancy and the qualified person in plant;
- **Amico Societa Cooperativa Sociale (AMICO)**: non-profit organization related to Catholic Church, reaching low-income families involving disabled employees. It acts as an intermediary to reach the vulnerable groups of the population, reintegrating marginalized people into the project.

The employment of the participative CSOP model in the renewable energy communities in the Susa Valley is still in elaboration by the consortium partners. With regard to the trusteeship representing the individual consumer co-owners, it is foreseen to involve the social cooperative partner, AMICO. The CSOP operating entity of the renewable energy installation is planning to be a cooperative, in order to benefit from favourable taxation and exemptions from rules for in-house contracting. Foresta will be a member in the CSOP operating cooperative and it will be responsible for the maintenance of the heating systems. The other cooperative members and thus co-owners will be citizens, the municipality, and local actors (e.g., CFAVS). The set-up also requires dealing with administrative and legal procedures which are still in elaboration with La Foresta, CFAVS and two Italian experts.

Furthermore, the involvement of the citizens is a principal feature of the participative CSOP model. In this way, the action plan of the project focuses specifically on low-income households (LIH) and women to become co-owners and co-investors, as well as other residents, SMEs, and municipalities. Approximately 2 200 households will benefit from the Italian project and due to the foreseen behavioural changes related to co-ownership of the new installations, the overall energy consumption is expected to be reduced by 14% per year (*SCORE Consortium*, 2018).

Regarding the consumers that will benefit from the project and the energy served by a district-heating network powered with a biomass plant, they can be distinguish between (a) direct consumers, mostly residents that use the energy supplied to a building and (b) indirect consumers, which are estimated consumers indirectly involved in the use of services within public buildings (e.g., schools, town hall, gym). The consumers of the study site can be considered mostly direct consumers because the majority of the project design is for private residential buildings that will be connected to a District Heating (DH) network. These consumers and the main stakeholders who are involved in the Susa Valley project can be defined as:

- Citizens and vulnerable citizens (they will be aggregated as an organisation in the CSOP model);
- ESCOs and private entities (e.g., La Foresta, CFAVS, SMEs);
- Public entities (e.g., municipalities, Unione Montana Valle Susa).

In a way to be concise, this thesis evaluated the first Phase of the methodology (the best refurbishment alternative for each REC, explained in Subsection 3.1.1), just for five municipalities of the project: Almese, Bardonecchia, Bussoleno, San Giorio di Susa and Susa, illustrated in Figure 4.1 and further detailed in this Chapter.

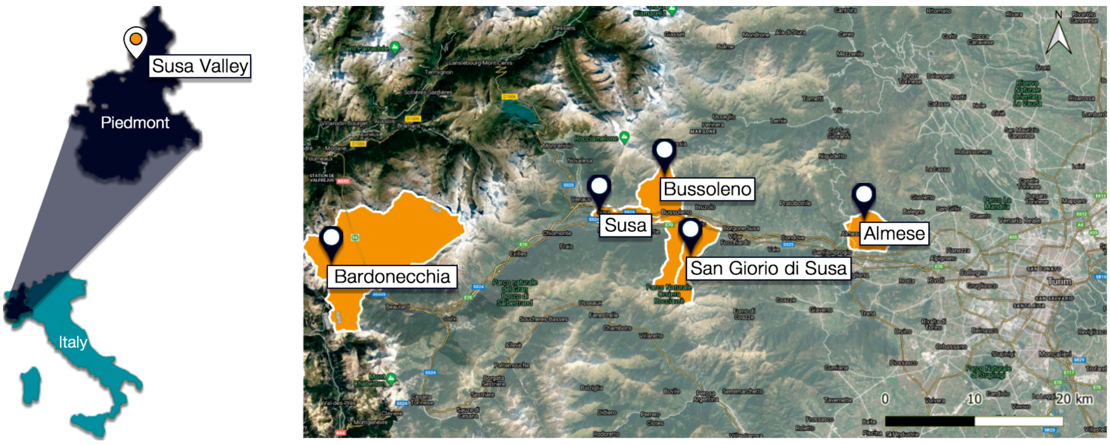


Figure 4.1: *Location of the study site: five municipalities of the Susa Valley (Italy).*

Source: Author, 2020.

Table 4.1 estimated the number of consumers in the five cases studies of the study site. It gives to each municipality: the estimated inhabitants based on *ISTAT* (2020); the Households directly benefiting from the project; and the Households of the focus groups (women and LIH) through an estimation based on the SCORE consortium research and Caritas' services (*Caritas*, 2020). The city with the highest number of inhabitants of the study site is Almese, being San Giorio di Susa with the lowest. The city with more households directly benefiting from the project is Bardonecchia, since the project will be connected with the existing DH network of the whole city.

#	**Municipality**	**# Inhabitants** (*ISTAT*, 2020)	**# Households directly benefiting**	**# Households in focus groups - Women and LIH**
1.	Almese	6 375	365	N.d.
2.	Bardonecchia	3 159	> 1000	50
3.	Bussoleno	5 824	> 200	20
4.	San Giorio di Susa	971	150	50
5.	Susa	6 173	>500	50

Table 4.1: *Information regarding the municipalities of the study site and the estimation of consumers who will benefit from the project.*

Source: Author, 2020.

A feasibility study was conducted for each city of the Susa Valley pilot presenting project actions to identify buildings for the installation of the RE heating system. Table 4.2 shows the study site municipalities and their relative buildings, where the new plant for the heating system will be installed. While some buildings selected for the project are public (i.e., existing DH network in a city scale, sport facilities or middle school), and provides economic security, for other municipalities the buildings are private and residential. By incorporating residential buildings, the citizen involvement has a crucial importance as it leads to involving them directly in the project. Besides that, Table 4.2 indicates the existing energy heating sources used in these buildings nowadays (i.e., natural gas boilers) and the planned heating systems for the future REC. Apart from the substitution of the old boilers with fossil fuels sources (natural gas) to biomass, a DH network will be also developed or, for the case of Bardonecchia, improved as there is already a DH network in this city.

#	Municipality	Building	Existing heating sources	Planned heating systems
1.	Almese	Private residential buildings	Natural gas boiler (individual generators)	DH network (biomass)
2.	Bardonecchia	Municipal buildings; Private buildings; DH network	Natural gas boiler	Retrofit of the existing DH network (biomass)
3.	Bussoleno	Middle school; Kindergarten; Municipal gym	Natural gas boiler (individual generators)	DH network (biomass)
4.	San Giorio di Susa	Private residential buildings	Natural gas boiler (individual generators)	DH network (biomass)
5.	Susa	Private residential buildings	Natural gas boiler (individual generators)	DH network (biomass)

Table 4.2: *Municipalities of the study site and their main building information regarding existing and planned energy systems (DH: district heating).*

Source: Author, 2020.

The feasibility study was carried out for each building of Table 4.2. This study is reported on the "dossiers" (explained in Subsection 3.1.1) and it is a comprehensive description of the study site, with the context and the main features for the project. It provides a diagnosis of the buildings, through an energy modelling to quantify the actual consumption. This helped to identify later different energy retrofitting options. Therefore, to choose the best refurbishment alternative further in the Section 5.1, the following Sections summarizes for each study site municipality the following characteristics:

- The main energy indicators of the existing energy system fuelled with fossil fuels sources;
- The list of the refurbishment alternatives for the creation of renewable energy communities;
- The energy indicators simulation after each refurbishment alternative.

4.1 Pilot 01: Almese

In the Almese pilot the target is to construct a District Heating (DH) network fuelled by biomass source, in private residential buildings from ten sections of the municipality. The project consists of 218 dwellings with a gross volume higher than 1.000 m^3. The dossiers estimated the net heated volumes (m^3) and calculated the thermal energy needs for each dwelling (kWh/year). The information about the urban sections, with the number of dwellings and their annual thermal energy needs (kWh) are shown in Figure 4.2.

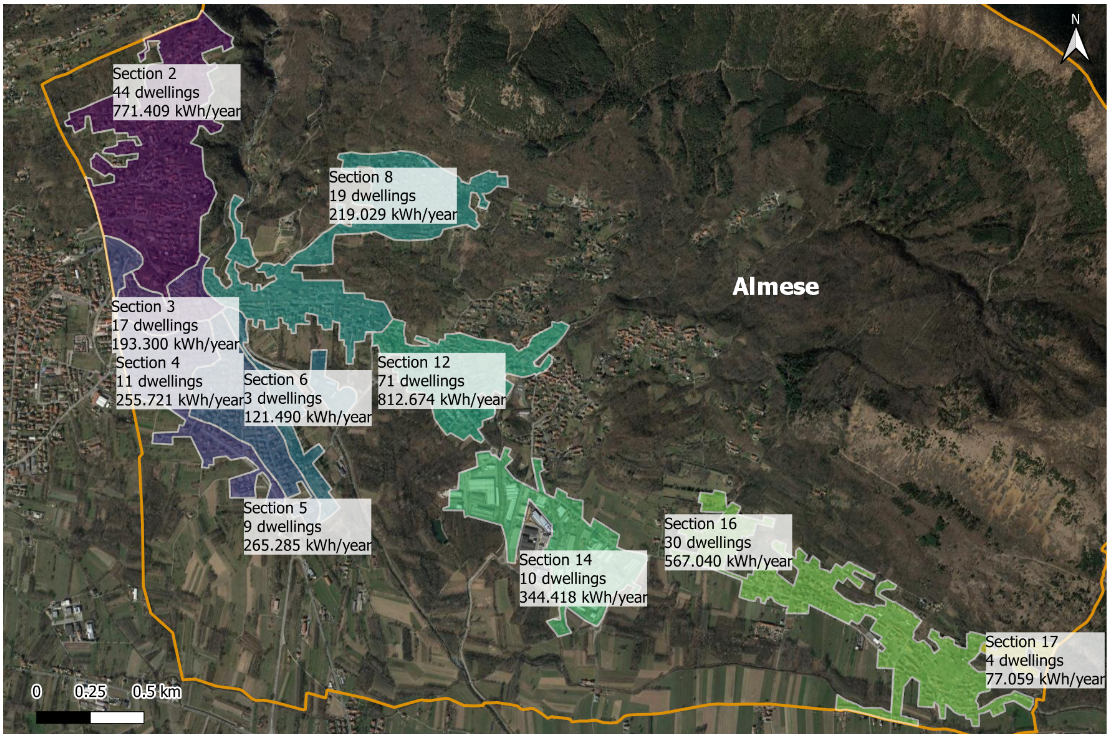


Figure 4.2: *The characteristics of the urban sections of the Almese project.*

Source: Author, 2020.

In Almese there are no previous DH networks. So, besides the requirement of dwellings with gross volume higher than 1.000 m^3, there are other requirements:

i The buildings have to be close together to be easily connected to a future DH network;

ii The heating plant of each building need to have its own centralized generators;

iii Heat generation must come from natural gas, delivered by the municipal network;

iv The efficiency of the boilers currently installed will be considered as 95%;

v The technical water distribution circuits in the dwellings are not considered in the analysis: the data refer to the needs of the buildings at the output of the generators.

The energy performance of the buildings were deducted from the RENERFOR project data (Territorial Cooperation ALCOTRA 2007-2013 of Piedmont Region) about the number of dwellings, heated volumes and energy needs for space heating (SH). The thermal needs for domestic hot water (DHW) were calculated according the method from the regulation UNI TS 11300-2:2014. The estimation of primary energy consumption has been calculated using a medium generation efficiency of 0,95 and the natural gas consumption was estimated with a Lower Heating Value (LHV) of 9,79 kWh/m^3 (given by the Ministero dell'Ambiente, average from 2015-2017). The emission of $C0_2$ has been calculated with a factor of 200,16 g/kWh (given by Allegato 1 - Requisiti Tecnici per impianti a cippato superiori a 350 kW by Provincia di Torino and the Energy Department of Politecnico di Torino). Table 4.3 shows a summary of Almese's energy indicators.

	Energy needs (kWh/year)	**Primary energy consumption** (kWh/year)	**Natural gas fuel consumption** (m^3/year)	$C0_2$ **Emission** (kg/year)
Space Heating (SH)	3.318.053	3.492.687	356.761	699.096
Domestic Hot Water (DWH)	309.371	325.654	33.264	65.183
Total	3.627.424	3.818.341	390.025	764.279

Table 4.3: *Energy indicators for Space Heating and Domestic Heating Water in Almese.*

Source: Author, 2020.

Taking into account that the Almese pilot does not use any renewable energy resource as thermal energy supply, the critical issue for this pilot is the high $C0_2$ emission level , mainly done by natural gas fuel. For this reason, the alternatives were designed to have an energy transition with primary consumption of local resources, in order to obtain a lower impact of $C0_2$ emission for the thermal needs of the identified buildings.

To elaborate alternatives for the supply change from fossil fuels to a renewable source, the dossiers estimated the annual thermal request for the DH in Almese, during 2019. The energy model with the energy load and the contribution of different generators in supplying heat, has been constructed following the method suggested by the Allegato 1 - Requisiti Tecnici per impianti a cippato superiori a 350 kW by Provincia di Torino and the Energy Department of Politecnico di Torino.

In Figure 4.3, it is possible to see in blue the constant amount of energy needed to meet the demand of the DHW and losses for distribution, estimated to be constant all year and around 76,73 kWh. The amount of energy that meets the space heating needs is represented in red and it depends on the external temperature. The demand of the space heating is considered only from before 15^{th} of April and after 15^{th} of October, defined from the DPR 412/93. The sum of these hourly values is 3.381.094 kWh/y (estimated).

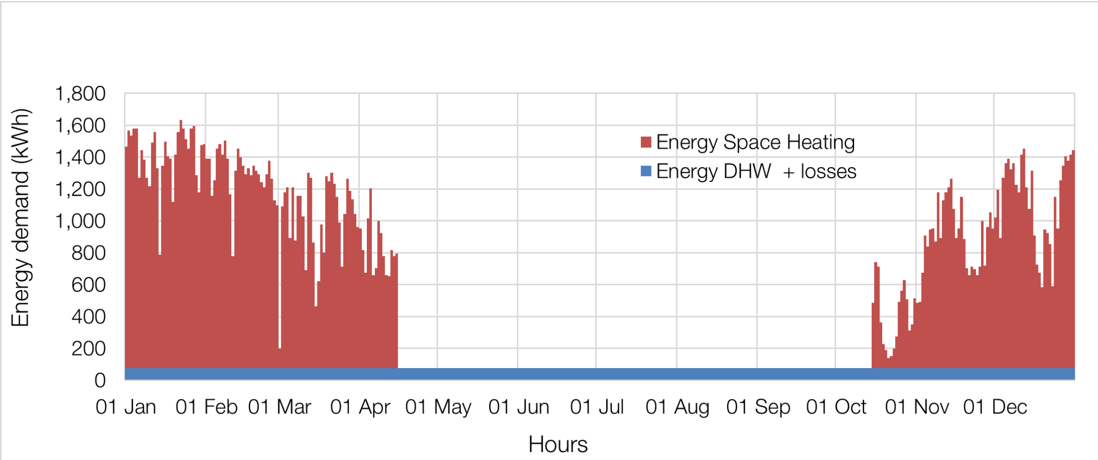


Figure 4.3: *Estimated hourly thermal energy demand for the District Heating in Almese for space heating and DHW+losses in 2019.*

Source: SCORE commission, 2019.

Considering these values, the solution designed is a retrofit of the power plants with the installation of a new District Heating system in the city of Almese, delivering heat to the buildings. The project foresees the installation of a wood chip-fired boiler, fed with biomass from the surrounding forests, in the centralized thermal plant with the integration of a natural gas fired condensing boiler. It is planned also the installation of a solar plant, in order to improve efficiency and brake down emission levels and environmental impact.

The designed setup for the control system is related to guarantee the priority to the solar plant and to the biomass boiler, secondarily the gas fuelled system turns on to fulfil the heat request of the total District Heating network. The criteria to set the priority of activation between the different generators have been designed as follows:

i The solar thermal plant works every day at its maximum productivity, in order to minimize emissions.

ii The primary generator, fired with woodchips is the first generator that switches on; the role of principal generator is ideal for the biomass boiler, because its combustion technology performs at its best with a load as constant as possible.

iii The secondary generator, fired with natural gas is used to supply heat during the peak of load that will exceed the power of the solar collectors and the primary boiler.

The project elaborated two alternatives for Almese refurbishment, summarized in Table 4.4:

Case	Alternatives
0.0)	As built
1)	The solar plant meets the annual average demand of thermal energy for DHW and losses in the distribution (76,73 kW) **only in the hour of maximum solar radiation**. It is a conservative condition in which there is no storage available and the production of solar collectors never exceed demand. The optimal size of the biomass generator was calculated as 500 kW.
2)	The solar plant could meet **50% of the total annual demand** of thermal energy for DHW and for losses in the distribution of the DH network. It is a condition in which the solar plant surplus of energy can be conserved in a proper storage tank or in the DH tubes circuit itself. The optimal size of the biomass generator was calculated as 500 kW.

Table 4.4: *List of the refurbishment alternatives in Almese.*

Source: Author, 2020.

Firstly, the solar plant meets the **annual average demand** for DHW+losses only in the hour of maximum solar radiation, without storage and never exceeding demand, with a calculated area of 235 m^2 for the solar collectors. Table 4.5 details the first case alternative, given the installed size of each system, the operating hour, energy produced, efficiency of the boilers and primary energy of the fuels.

Case 1	Installed size	Operating hours	Energy Produced	Contribution on energy production	Generation Efficiency (boilers)	Primary Energy (fuels)
	(m^2) kW	h/y	MWh/y	-	-	MWh/y
Solar collectors	(235)	4.180	129	3,83%	N/A	N/A
Biomass generator	500	8.759	2.014	59,57%	94%	2.143
Gas generator	1.500	2.823	1.238	36,60%	98%	1.263
Total	2.000	8.760	3.381	100,00%	95,52%	3.406

Table 4.5: *Contribution on thermal energy production for the first case alternative of Almese.*

Source: Author, 2020.

Secondly, the solar plant meets 50% of the total annual demand for DHW and losses, with storage of the energy surplus. For both alternatives, the generators size will be 500 kW for the biomass and 1500 kW for the gas. As the previous Table, Table 4.6 details some information for the second case alternative of Almese.

Case 2	Installed size	Operating hours	Energy Produced	Contribution on energy production	Generation Efficiency (boilers)	Primary Energy (fuels)
	(m^2) kW	h/y	MWh/y	-	-	MWh/y
Solar collectors	(611)	4.180	392	11,59%	N/A	N/A
Biomass generator	500	7.019	1.769	52,32%	94%	1.882
Gas generator	1.500	2.772	1.220	36,09%	98%	1.245
Total	2.000	8.760	3.381	100,00%	95,63%	3.127

Table 4.6: *Contribution on thermal energy production for the second case alternative of Almese.*

Source: Author, 2020.

The project simulated each alternative in relation of the primary energy consumption, considering the SH and DWH + losses, separating it in renewable or now renewable sources. After, it calculated the fuel consumption values from gas and wood. In the end, it showed the CO_2 emissions for each alternative. A summary of the principal indicators is shown in Table 4.7. The meaning of the table indicators is explained below.

- Q_p, tot: the total primary energy consumption of the buildings and systems (kWh/year);
- Q_p, ren: the renewable primary energy consumption of the buildings and systems (kWh/year);
- Q_p, nren: the not renewable primary energy consumption of the buildings and systems; (kWh/year)
- **Fuel consumption**: linked to the previous values with the LHV factor of the fuel, (m^3 for gaseous fuels and kg for solid fuels);
- **Emissions of** $C0_2$: consequent to fuel consumption, according to the emission factors (200,16 $kgC0_2/m^3$ of natural gas and 0 $kgC0_2/kg$ of wood).

Case	Q_p, tot [kWh/year]	Q_p, ren [kWh/year]	Q_p, nren [kWh/year]	**Gas consumption** [m^3_{gas}/year]	**Wood consumption** [kg_{wood}/year]	CO_2 **emissions** [kg/year]
0.0)	3.818.341	- -	3.818.341	390.025	- -	764.279
1)	3.405.570	2.142.756	1.262.815	128.990	630.222	252.765
2)	3.127.004	1.881.997	1.245.006	127.171	553.529	249.200

Table 4.7: *Energy indicators simulation for the current situation and the alternatives in Almese.*

Source: Author, 2020.

4.2 Pilot 02: Bardonecchia

In the Bardonecchia pilot the target is to retrofit the power plants with installation of biomass boiler. The project consists in supplying a great part of primary energy from a local renewable resource, in order to reach a lower impact on carbon dioxide emissions for heating some municipal buildings. The intervention deals with the following municipal buildings:

i The Town Hall and the middle school (together in a unique building);

ii The Palace of Festivities;

iii The Elementary School;

iv The Pharmacy;

v The Sports Hall;

vi The Croce Rossa headquarters;

vii The Municipal Warehouse.

Figure 4.4 illustrated these buildings in Bardonecchia and it gives the average annual consumption (kWh/year) for them. The thermal energy demand was calculated as the average amount of heat exchanged with the existing DH network at the points of delivery to the users. The values were collected from the supplier company bills available from 2017 to 2018 for the Pharmacy, Croce Rossa and Warehouse buildings. For the rest of the buildings, the data collection period was from 2013 to 2018.

Figure 4.4: *The municipal buildings of the Bardonecchia project and their average annual consumption.*

Source: Author, 2020.

In Bardonecchia there is already a DH network and the current situation was modelled with the following assumptions:

i The heating plant of each building have its own heat exchanger linked to the DH network that feed the city of Bardonecchia; these components take heat for both space heating (SH) and domestic hot water (DHW) needs;

ii In the power plant the thermal energy is generated by heat recovery from gas-fired internal combustion engines in a co-generation set up and from gas-fired boilers;

iii At least one circuit for the distribution of technical water in each building;

iv The district heating total efficiency is 70%.

The dossiers were elaborated with district heating data from *A.I.R.U.* (2018); the heat exchangers power and the average annual consumption data from supplier bills details; and efficiency data from PAESC Annex 2. Table 4.8 shows the energy indicators for the Bardonecchia pilot (the municipal buildings and the DH total), considering that the consumption of primary energy has been estimated using a medium generation efficiency for the DH of 0,70 and the consumption of natural gas was estimated with a Lower Heating Value (LHV) of 9,73 kWh/m^3. The emission of $C0_2$ has been calculated with a factor of 200,16 g/kWh (given by Allegato 1 - Requisiti Tecnici per impianti a cippato superiori a 350 kW by Provincia di Torino and the Energy Department of Politecnico di Torino).

	Average annual consumption (kWh/year)	**Primary energy consumption** (kWh/year)	**Natural gas fuel consumption** (m^3/year)	$C0_2$ **Emission** (kg/year)
Municipal Buildings	1.778.366	2.540.523	261.102	508.511
Total (*A.I.R.U.* (2018))	55.953.800	79.934.000	8.215.211	15.999.589

Table 4.8: *Energy indicators for the municipal buildings and DH in Bardonecchia.*

Source: Author, 2020.

The principal critical issue for this pilot is that the buildings are supplied with an energy resource (natural gas fuel) that is not renewable and it has high emission level of $C0_2$. The environmental impact of the energy supply chain could be much more positive if the municipality changes the supply to a local renewable energy. For this reason, it was proposed the installation in the centralized thermal plant of a wood chip-fired boiler, fed with biomass from the surrounding forests. In order to improve efficiency and brake down emission levels and environmental impact.

The project foresees the usage of the actual district heating network to supply heat to the municipal buildings. Moreover, the designed setup for the control system is related to guarantee the priority to the biomass boiler utilization, and secondarily to turn on the existing gas fuelled system, to fulfil the heat request of the total DH network. The project gives three different refurbishment alternatives for Bardonecchia, summarized in Table 4.9.

Case	Alternatives
0.0)	As built
1)	The primary supply will be from wood chips fuel and the generation will only match the load of the municipal buildings considered. The biomass boiler size is designed to satisfy the **peak load of this group of buildings**.
2)	As the case 1, but the utilization of the biomass boiler will be for the **whole year**, at the nominal power. The biomass boiler size is the one considered in case 1.
3)	As for the case 2, but considering a different size of the biomass boiler that optimizes the production from this renewable resource for **all the users of the district heating in Bardonecchia**.

Table 4.9: *List of the refurbishment alternatives in Bardonecchia.*

Source: Author, 2020.

In the first case, the biomass generator is supposed to be installed in the power plant where currently is generated the whole heat that circulate in the DH of Bardonecchia. However, the new boiler will supply heat only to the identified municipal buildings. The running time is as requested by their heating needs and the size of the biomass will be 2.000 kW. Table 4.10 shows the thermal energy production for this case.

Case 1	Installed size	Operating hours	Energy Produced	Contribution on energy production	Generation Efficiency (boilers)	Primary Energy (fuels)
	kW	h/y	kWh/y	-	-	kWh/y
Biomass generator	2.000	Requested by their heating needs	1.998.165	100%	93%	2.148.565

Table 4.10: *Thermal energy production for the first case alternative of Bardonecchia.*

Source: Author, 2020.

In the second case, the boiler size is the same as before (2.000 kW), but the running time will be during all year (8.600 hours). It will provide heating not only to the municipal buildings, but the remaining heating (not used by them) will be delivery to other private buildings (around 88% of the delivered energy), as shown by Table 4.11 through the thermal energy production.

Case 2	Installed size	Operating hours	Energy Produced	Contribution on energy production	Generation Efficiency (boilers)	Primary Energy (fuels)
	kW	h/y	MWh/y	-	-	MWh/y
Biomass generator	2.000	8.600	17.200	27,27%	93%	18.500
Gas generator	N/A	N/A	45.865	72,73%	78,9%	58.130
Total	N/A	N/A	63.065	100 %	82,3%	76.630

Table 4.11: *Thermal energy production for the second case alternative of Bardonecchia.*

Source: Author, 2020.

In the last case, the boiler size is made to provide renewable heat to all buildings connected to the DH of the municipality. In this way, the project calculated the thermal energy demand for the DH in order to assess the optimal size for the biomass boiler (7.000 kW). The criteria to set the priority of activation between the gas and biomass generators have been designed as: First, the primary generator fired with wood-chips switches on (the constant load is ideal for this type of boiler); and second, the natural gas boiler turns on, when the peak of load exceed the power of the primary boiler.

Case 3	Installed size	Operating hours	Energy Produced	Contribution on energy production	Generation Efficiency (boilers)	Primary Energy (fuels)
	kW	h/y	MWh/y	-	-	MWh/y
Biomass generator	7.000	8.760	40.698	64,5%	93%	43.761
Gas generator	42.296	4.117	22.367	35,5%	79%	28.312
Total	49.296	8.760	63.065	100 %	87,5%	72.074

Table 4.12: *Thermal energy production for the third case alternative of Bardonecchia.*

Source: Author, 2020.

The project simulated each alternative in relation of the primary energy consumption, separating it in renewable or now renewable sources. After, it calculated the fuel consumption values from gas and wood sources. In the end, it showed the CO_2 emissions for each alternative. The summary of the principal indicators is separated in two Tables 4.13 and 4.14, because they have different scales and therefore need to have a different comparison. The first is the comparison between the first alternative and the current energy situation of the municipal buildings. While the second table is the comparison between the other two alternatives and the current situation of the whole DH in Bardonecchia from *A.I.R.U.* (2018).

The meaning of the tables indicators is explained below.

- Q_p, tot: the total primary energy consumption of the buildings and systems (kWh/year);
- Q_p, ren: the renewable primary energy consumption of the buildings and systems (kWh/year);
- Q_p, nren: the not renewable primary energy consumption of the buildings and systems; (kWh/year)
- **Fuel consumption**: linked to the previous values with the LHV factor of the fuel, (m^3 for gaseous fuels and kg for solid fuels);
- **Emissions of** $C0_2$: consequent to fuel consumption, according to the emission factors (200,16 $kgC0_2/m^3$ of natural gas and 0 $kgC0_2/kg$ of wood).

Case	Q_p, tot	Q_p, ren	Q_p, nren	**Gas consumption**	**Wood consumption**	CO_2 **emissions**
	[kWh/year]	[kWh/year]	[kWh/year]	[m^3_{gas}/year]	[kg_{wood}/year]	[kg/year]
0.0)	2.540.523	–	2.540.523	261.102	- -	508.511
1)	2.148.565	2.148.565	–	–	631.931	–

Table 4.13: *Energy indicators simulation for the current situation in the municipal buildings and the first alternative in Bardonecchia.*

Source: Author, 2020.

Case	Q_p, tot	Q_p, ren	Q_p, nren	**Gas consumption**	**Wood consumption**	CO_2 **emissions**
	[MWh/year]	[MWh/year]	[MWh/year]	[m^3_{gas}/year]	[t_{wood}/year]	[kg/year]
***A.I.R.U.* (2018)**	79.934	–	79.934	8.215.211	- -	15.999.589
2)	76.630	18.500	58.130	5.974.306	5.441	11.635.301
3)	72.074	43.761	28.312	2.909.764	12.871	5.666.930

Table 4.14: *Energy indicators simulation for the current DH heating and other two alternatives in Bardonecchia.*

Source: Author, 2020.

4.3 Pilot 03: Bussoleno

In the Bussoleno pilot the target is to retrofit the power plants in order to connect three buildings to a unique biomass boiler with a small district heating (DH) network. The project consists in supplying a great part of primary energy from a local renewable resource, in order to reach a lower impact on emissions of carbon dioxide for heating some buildings. The intervention deals with the following identified buildings, illustrated in Figure 4.5:

i The middle school;

ii The kindergarten "Tetti verdi", which is located 80 meters far from building 1;

iii The municipal gym, located in front of the middle school.

Figure 4.5: *Buildings of the Bussoleno project and their annual thermal generation.*

Source: Author, 2020.

In Bussoleno the current situation was modelled with the following assumptions:

i There is a boiler room into each building with gas-fired boilers;

ii There is least one circuit for the distribution of technical water in each building;

iii There is no information available about the type of heaters installed, geometry and materials of the building structures;

iv The total installed power for the buildings are 260 kW.

Through the regulation UNI/TS 11300-2:2019 and some experts suggestions, it was given for the gas fired generators a thermal efficiency of 0,84. The energy indicators were estimated from municipality data, in relation of the annual fuel consumption (in m^3 of gas acquired) and heated volumes (using the estimation of the efficiency of the generation system of 0,84). For primary energy, it was taking into account the trend of utilization of the buildings (i.e., the week operating timetables). Besides that, the energy model was calculated following the methodology of Allegato 1 - Requisiti Tecnici per impianti a cippato superiori a 350 kW by Provincia di Torino and the Energy Department of Politecnico di Torino.

Table 4.15 shows the energy indicators for the Bussoleno pilot, considering that the consumption of natural gas was estimated with a Lower Heating Value (LHV) of 9,73 kWh/m^3, as suggested from MATTM and MiSE "Deliberazione n. 14/2009" Annex 1 Appendix 1. The emission of $C0_2$ has been calculated with a factor of 200,16 g/kWh (Allegato 1 - Requisiti Tecnici per impianti a cippato superiori a 350 kW).

	Annual thermal generation (kWh/year)	**Primary energy consumption** (kWh/year)	**Natural gas fuel consumption** (m^3/year)	$C0_2$ **Emission** (kg/year)
Middle School	335.236	399.091	41.017	79.882
Kindergarten	200.852	239.110	24.574	47.860
Municipal Gym	149.815	178.351	18.330	35.699
Total	685.903	816.551	83.921	163.441

Table 4.15: *Energy indicators for the pilot buildings in Bussoleno.*

Source: Author, 2020.

The critical issues for this pilot are the obsolete heat generation technology in the buildings (gas boilers with more than 20 years old and without condensation) with a low level of efficiency (0,84) and multiple generators without integration with each other. Besides this, the energy supply is from a non renewable energy resource (natural gas fuel) that has high emission level of $C0_2$. For this reason, it was proposed the replacement of the installed boilers with a unique wood chip-fired boiler, using biomass from the surrounding forests, to improve efficiency and brake down emission levels and environmental impact.

The project foresees the installation of a small district heating network in order to serve the three buildings with a new biomass boiler with an estimated size of 350kW. This value guarantees a production from a renewable resource for about a half of the total hours of generation. Moreover, it is planned an installation of thermostatic valves for each emission system, climatic and internal air sensors to improve regulation of the heating plant; a review of balance and flow settings to reach and follow the better working point of the distribution system; and an implementation of the control systems to reduce energy losses, improve remote regulations and take historical data for monitoring the operative phase and supporting any following in-depth analysis.

Moreover, the designed setup for the control system is related to guarantee the priority to the biomass boiler utilization, and secondarily to turn on the existing natural gas fuelled system, to fulfil the heat request during the peak of load (power demand higher than 350 kW). The project gives three different refurbishment alternatives for Bussoleno, summarized in Table 4.16.

Case	Alternatives
0.0)	As built
1)	There is a replacement of the boilers with a unique biomass-fired one; a regulation retrofit; and a construction of a small district heating network.
2)	As the case 1, but there will be also an installation of a thermal storage system of 7.000 dm^3.
3)	As the case 1, but there will be also an installation of a thermal storage system of 20.000 dm^3 .

Table 4.16: *List of the refurbishment alternatives in Bussoleno.*

Source: Author, 2020.

In the first case there is no thermal storage. So, a part of the thermal energy produced from combustion of solid biomass fuel could be wasted during modulation and shutdown phases and in this way, the regulation and the generation efficiencies would be lower than expected. Table 4.17 shows the thermal energy production for this case.

Case 1	**Installed size**	**Operating hours**	**Energy Produced**	**Contribution on energy production**	**Generation Efficiency (boilers)**	**Primary Energy (fuels)**
	kW	h/y	kWh/y	-	-	kWh/y
Biomass generator	350	2.261	603.159	87,7%	93%	648.558
Gas generator	>366	966	84.229	12,3%	84%	100.273
Total	>716	2.261	687.388	100%	91,9%	748.832

Table 4.17: *Thermal energy production for the first case alternative of Bussoleno.*

Source: Author, 2020.

In the second case, starts from the case 1 and includes the minimum thermal storage volume useful to obtain the financial contribution of Conto Termico (D.M. 16 febbraio 2016). This volume is quantifiable as 20 dm^3 per kW installed in the biomass boiler, which corresponds to 7.000 dm^3. The stored energy is considered produced by the biomass generator and it can be charged in less than 15 minutes, with 0,95 of efficiency. Figure 4.6 illustrated how this storage will work in the energy system and Table 4.18 summarized the thermal energy production for this case.

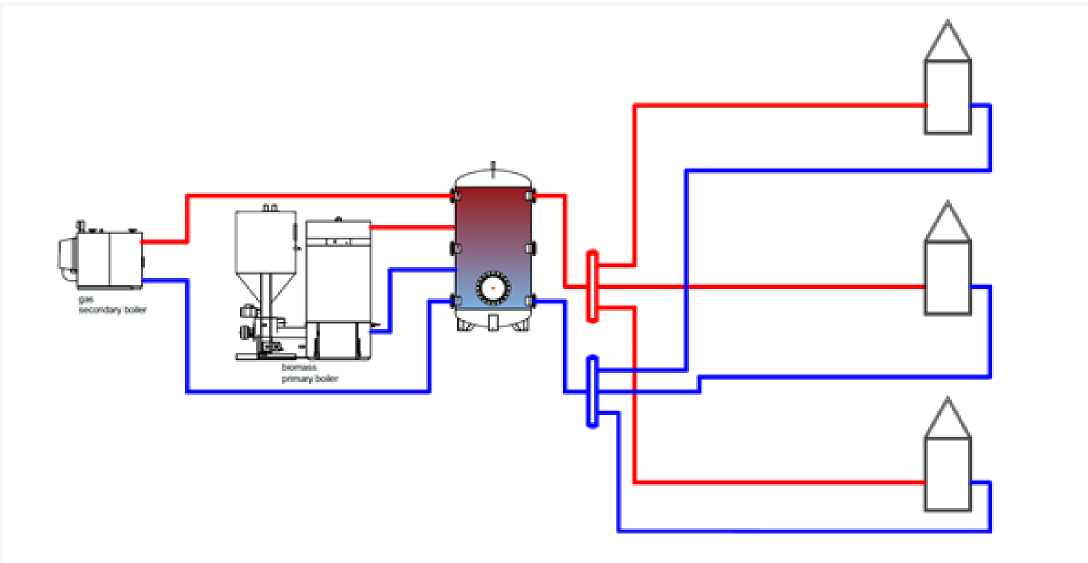


Figure 4.6: *Storage system (7.000* dm^3*) for the second case alternative in Bussoleno.*

Source: SCORE commission, 2019.

Case 2	Installed size kW	Operating hours h/y	Energy Produced kWh/y	Contribution on energy production -	Generation Efficiency (boilers) -	Primary Energy (fuels) kWh/y
Biomass generator	350	2.261	608.318	88,5%	93%	654.106
Gas generator	>366	951	79.125	11,5%	84%	94.197
Total	>716	2.261	687.443	100%	91,9%	748.303

Table 4.18: *Thermal energy production for the second case alternative of Bussoleno.*

Source: Author, 2020.

The third case starts from the case 1 and includes three thermal storages, each located in the power plant of a single building. In order to use the gas boiler to the least possible extent, the total volume identified is 20.000 dm^3. The stored energy is considered produced by the biomass generator and it can be charged in less than 45 minutes, with 0,95 of efficiency. Figure 4.7 illustrated how this storage will work in the energy system and Table 4.19 summarized the thermal energy production for this case.

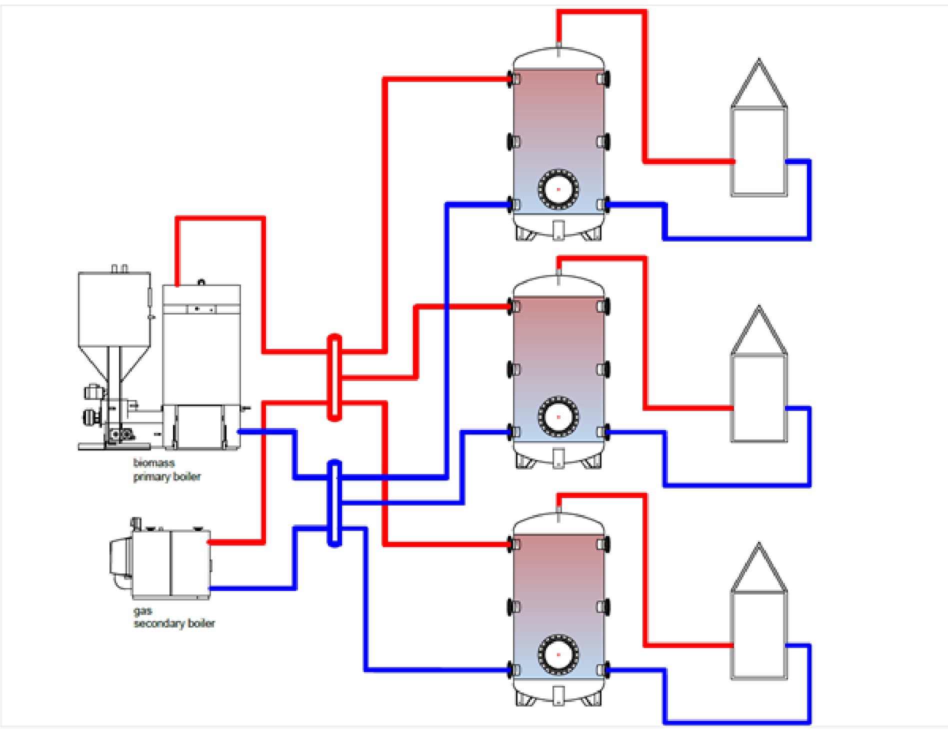


Figure 4.7: *Storage system (20.000* dm^3*) for the third case alternative in Bussoleno.*

Source: SCORE commission, 2019.

Case 3	Installed size kW	Operating hours h/y	Energy Produced kWh/y	Contribution on energy production -	Generation Efficiency (boilers) -	Primary Energy (fuels) kWh/y
Biomass generator	350	2.261	617.966	89,8%	93%	664.480
Gas generator	>366	894	69.904	10,2%	84%	83.219
Total	>716	2.261	687.870	100%	91,9%	747.699

Table 4.19: *Thermal energy production for the third case alternative of Bussoleno.*

Source: Author, 2020.

The project simulated each alternative in relation of the primary energy consumption, separating it in renewable or now renewable sources. After, it calculated the fuel consumption values from gas and wood. In the end, it showed the CO_2 emissions for each alternative. A summary of the principal indicators is shown in Table 4.20. The meaning of the table indicators is explained below.

- Q_p, tot: the total primary energy consumption of the buildings and systems (kWh/year);
- Q_p, ren: the renewable primary energy consumption of the buildings and systems (kWh/year);
- Q_p, nren: the not renewable primary energy consumption of the buildings and systems; (kWh/year)
- **Fuel consumption**: linked to the previous values with the LHV factor of the fuel, (m^3 for gaseous fuels and kg for solid fuels);
- **Emissions of** $C0_2$: consequent to fuel consumption, according to the emission factors (200,16 $kgC0_2/m^3$ of natural gas and 0 $kgC0_2/kg$ of wood).

Case	Q_p, tot [kWh/year]	Q_p, ren [kWh/year]	Q_p, nren [kWh/year]	**Gas consumption** [m^3_{gas}/year]	**Wood consumption** [kg_{wood}/year]	CO_2 **emissions** [kg/year]
0.0)	816.551	- -	816.551	83.921	- -	163.441
1)	748.832	648.558	100.273	10.306	66.665	20.071
2)	748.303	654.106	94.197	9.681	192.384	18.854
3)	747.699	664.480	83.219	8.553	195.435	16.657

Table 4.20: *Energy indicators simulation for the current situation and the alternatives in Bussoleno.*

Source: Author, 2020.

Notes:

- The annual energy demand remains the same in the simulations;
- The total primary energy consumption decreases because of the contribution in generation of the biomass boiler, whose efficiency is higher than the gas generators one;
- In the simulation, the stored energy is produced from the biomass boiler, so its contribution is only assigned to renewable energy.

4.4 Pilot 04: San Giorio di Susa

In the San Giorio di Susa pilot the target is to construct a District Heating (DH) network fuelled by biomass source in private residential buildings from one section of the municipality (Section 1). The project consists of 29 dwellings with a gross volume higher than 1.000 m^3. The dossiers estimated the net heated volumes (m^3) and calculated the thermal energy needs for each dwelling (kWh/year). The information about the urban section, with the number of dwellings and the annual thermal energy needs (kWh) are shown in Figure 4.8.

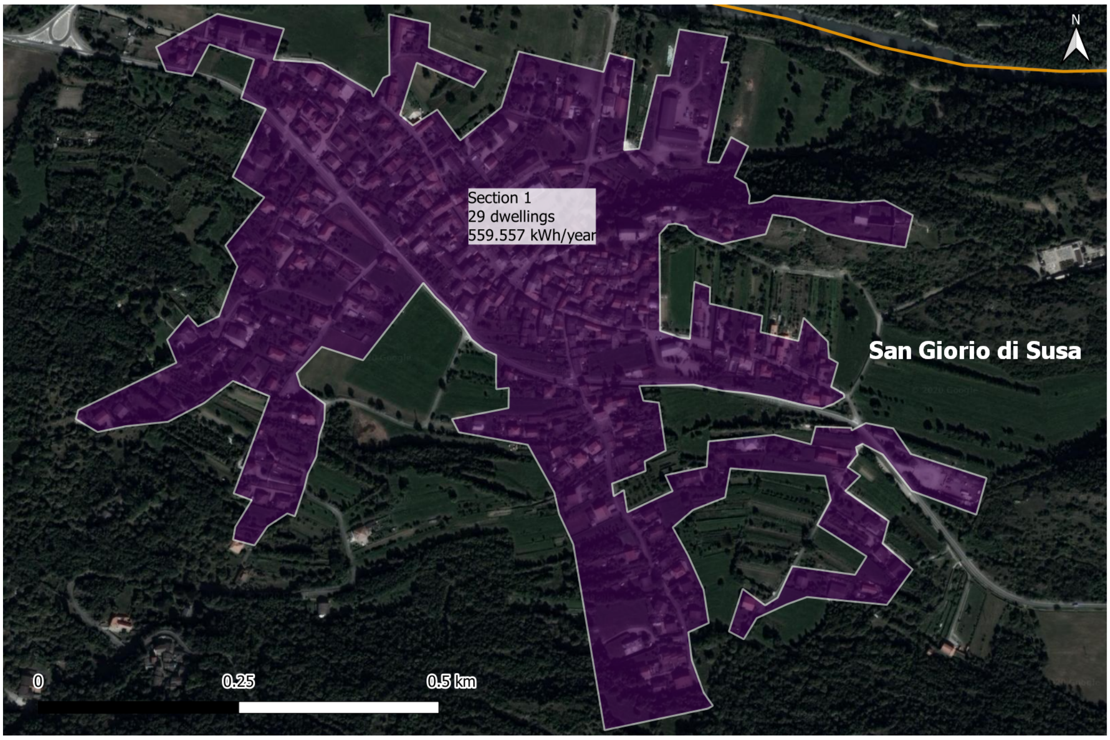


Figure 4.8: *The characteristics of the urban sections of the San Giorio di Susa project.*

Source: Author,2020.

In San Giorio di Susa there are no previous DH networks. So, besides the requirement of residencies with gross volume higher than 1.000 m^3, there are another requirements:

i The buildings have to be close together to be easily connected to a future DH network;

ii The heating plant of each building need to have its own centralized generators;

iii The heat generation must come from natural gas, delivered by the municipal network;

iv The efficiency of the boilers currently installed will be considered as 95%;

v The technical water distribution circuits in the dwellings are not considered in the analysis: the data refer to the needs of the buildings at the output of the generators.

The energy performance of the buildings were deducted from the RENERFOR project data (Territorial Cooperation ALCOTRA 2007-2013 of Piedmont Region) about the number of dwellings, heated volumes and energy needs for space heating (SH). The thermal needs for domestic hot water (DHW) were calculated according the method from the regulation UNI TS 11300-2:2014. The estimation of primary energy consumption has been calculated using a medium generation efficiency of 0,95 and the natural gas consumption was estimated with a Lower Heating Value (LHV) of 9,79 kWh/m^3 (given by the Ministero dell'Ambiente, average from 2015-2017). The emission of $C0_2$ has been calculated with a factor of 200,16 g/kWh (given by Allegato 1 - Requisiti Tecnici per impianti a cippato superiori a 350 kW by Provincia di Torino and the Energy Department of Politecnico di Torino). Table 4.21 shows a summary of San Giorio di Susa's energy indicators.

	Energy needs (kWh/year)	**Primary energy consumption** (kWh/year)	**Natural gas fuel consumption** (m^3/year)	$C0_2$ **Emission** (kg/year)
Space Heating (SH)	508.734	535.509	54.700	107.187
Domestic Hot Water (DWH)	50.826	53.501	5.465	10.709
Total	559.560	589.010	60.165	117.896

Table 4.21: *Energy indicators for Space Heating and Domestic Heating Water in San Giorio di Susa.*

Source: Author, 2020.

Taking into account that the San Giorio di Susa pilot does not use any renewable energy resource as thermal energy supply, the critical issue for this pilot is the high $C0_2$ emission level , mainly done by natural gas fuel. For this reason, the alternatives were designed to have an energy transition with primary consumption of local resources, in order to obtain a lower impact of $C0_2$ emission for the thermal needs of the identified buildings.

To elaborate alternatives for the supply change from fossil fuels to a renewable source, the dossiers estimated the annual thermal request for the DH in San Giorio di Susa, during 2019. The energy model with the energy load and the contribution of different generators in supplying heat, has been constructed following the method suggested by the Allegato 1 - Requisiti Tecnici per impianti a cippato superiori a 350 kW by Provincia di Torino and the Energy Department of Politecnico di Torino.

In Figure 4.9, it is possible to see in blue the constant amount of energy needed to meet the demand of the DHW and losses for distribution, estimated to be constant all year and around 12,19 kWh. The amount of energy that meets the space heating needs is represented in red and it depends on the external temperature. The demand of the space heating is considered only from before 15^{th} of April and after 15^{th} of October, defined from the DPR 412/93. The sum of these hourly values is 548.000 kWh/y (estimated).

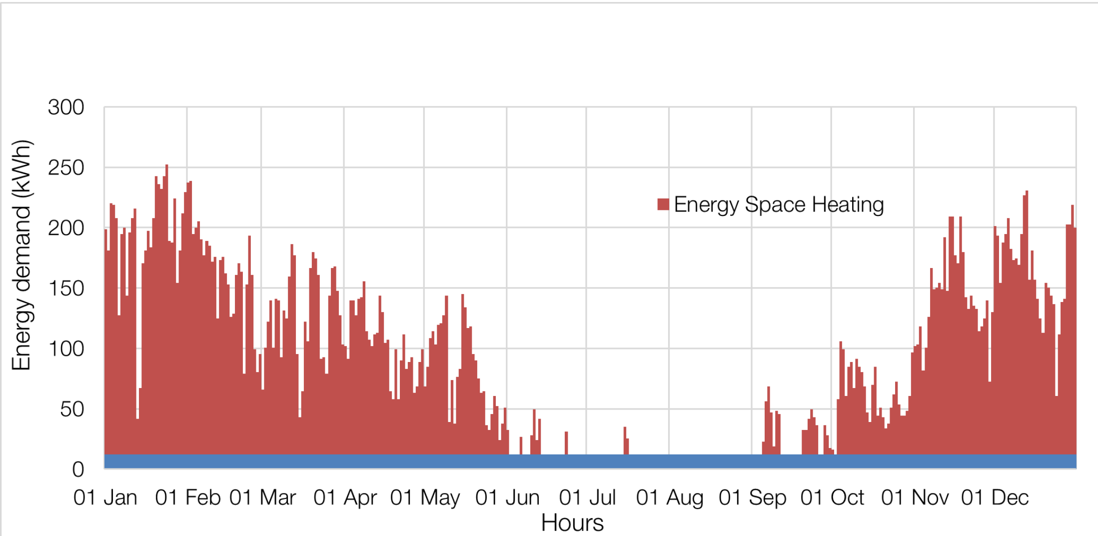


Figure 4.9: *Estimated hourly thermal energy demand for the District Heating in San Giorio di Susa for space heating and DHW+losses in 2019.*

Source: SCORE commission, 2019.

Considering these values, the solution designed is a retrofit of the power plants with the installation of a new District Heating system in the city of San Giorio di Susa, delivering heat to the buildings. The project foresees the installation of a wood chip-fired boiler, fed with biomass from the surrounding forests, in the centralized thermal plant with the integration of a natural gas fired condensing boiler. It is planned also the installation of a solar plant, in order to improve efficiency and brake down emission levels and environmental impact.

The designed setup for the control system is related to guarantee the priority to the solar plant and to the biomass boiler, secondarily the gas fuelled system turns on to fulfil the heat request of the total District Heating network. The criteria to set the priority of activation between the different generators have been designed as follows:

i The solar thermal plant works every day at its maximum productivity, in order to minimize emissions.

ii The primary generator, fired with woodchips is the first generator that switches on; the role of principal generator is ideal for the biomass boiler, because its combustion technology performs at its best with a load as constant as possible.

iii The secondary generator, fired with natural gas is used to supply heat during the peak of load that will exceed the power of the solar collectors and the primary boiler.

The project elaborated two alternatives for San Giorio di Susa refurbishment, summarized in Table 4.22:

Case	Alternatives
0.0)	As built
1)	The solar plant meets the annual average demand of thermal energy for DHW and losses in the distribution (12,2 kW) **only in the hour of maximum solar radiation**. It is a conservative condition in which there is no storage available and the production of solar collectors never exceed demand. The optimal size of the biomass generator was calculated as 75 kW.
2)	The solar plant could meet **50% of the total annual demand** of thermal energy for DHW and for losses in the distribution of the DH network. It is a condition in which the solar plant surplus of energy can be conserved in a proper storage tank or in the DH tubes circuit itself. The optimal size of the biomass generator was calculated as 75 kW.

Table 4.22: *List of the refurbishment alternatives in San Giorio di Susa.*

Source: Author, 2020.

Firstly, the solar plant meets the **annual average demand** for DHW+losses only in the hour of maximum solar radiation, without storage and never exceeding demand, with a calculated area of 37 m^2 for the solar collectors. Table 4.23 details the first Case alternative, given the installed size of each system, the operating hour, energy produced, efficiency of the boilers and primary energy of the fuels.

Case 1	Installed size	Operating hours	Energy Produced	Contribution on energy production	Generation Efficiency (boilers)	Primary Energy (fuels)
	(m^2) kW	h/y	kWh/y	-	-	kWh/y
Solar collectors	(37)	4.180	20.549	3,75%	N/A	N/A
Biomass generator	75	8.759	343.550	62,69%	94%	365.479
Gas generator	275	3.082	183.902	33,56%	98%	187.655
Total	350	8.760	548.001	100,00%	95,39%	553.134

Table 4.23: *Contribution on thermal energy production for the first case alternative of San Giorio di Susa.*

Source: Author, 2020.

Secondly, the solar plant meets 50% of the total annual demand for DHW and losses, with storage of the energy surplus. The generators size will be 75 kW for the biomass and 275 kW for the gas. As the previous table, Table 4.24 details some information for the second case alternative of San Giorio di Susa.

Case 2	Installed size	Operating hours	Energy Produced	Contribution on energy production	Generation Efficiency (boilers)	Primary Energy (fuels)
	(m^2) kW	h/y	kWh/y	-	-	kWh/y
Solar collectors	(97)	4.180	62.236	11,36%	N/A	N/A
Biomass generator	75	7.259	306.217	55,88%	94%	325.763
Gas generator	275	3.000	179.521	32,76%	98%	183.185
Total	350	8.760	548.001	100,00%	95,48%	508.948

Table 4.24: *Contribution on thermal energy production for the second case alternative of San Giorio di Susa.*

Source: Author, 2020.

The project simulated each alternative in relation of the primary energy consumption, considering the SH and DWH + losses, separating it in renewable or now renewable sources. After, it calculated the fuel consumption values from gas and wood. In the end, it showed the CO_2 emissions for each alternative. A summary of the principal indicators is shown in Table 4.25. The meaning of the table indicators is explained below.

- Q_p, tot: the total primary energy consumption of the buildings and systems (kWh/year);
- Q_p, ren: the renewable primary energy consumption of the buildings and systems (kWh/year);
- Q_p, nren: the not renewable primary energy consumption of the buildings and systems; (kWh/year)
- **Fuel consumption**: linked to the previous values with the LHV factor of the fuel, (m^3 for gaseous fuels and kg for solid fuels);
- **Emissions of** $C0_2$: consequent to fuel consumption, according to the emission factors (200,16 kg$C0_2/m^3$ of natural gas and 0 kg$C0_2$/kg of wood).

Case	Q_p, tot	Q_p, ren	Q_p, nren	**Gas consumption**	**Wood consumption**	CO_2 **emissions**
	[kWh/year]	[kWh/year]	[kWh/year]	[m^3_{gas}/year]	[kg_{wood}/year]	[kg/year]
0.0)	589.010	- -	589.010	60.165	- -	117.896
1)	553.134	365.479	187.655	19.168	107.494	37.561
2)	508.948	325.763	183.185	18.711	95.813	36.666

Table 4.25: *Energy indicators simulation for the current situation and the alternatives in San Giorio di Susa.*

Source: Author, 2020.

4.5 Pilot 05: Susa

In the Susa pilot the target is to construct a District Heating (DH) network fuelled by biomass source in private residential buildings from eleven sections of the municipality. The project consists of 1.062 dwellings with a gross volume higher than 1.000 m^3. The dossiers estimated the net heated volumes (m^3) and calculated the thermal energy needs for each dwelling (kWh/year). The information about the urban sections, with the number of dwellings and their annual thermal energy needs (kWh) are shown in Figure 4.10.

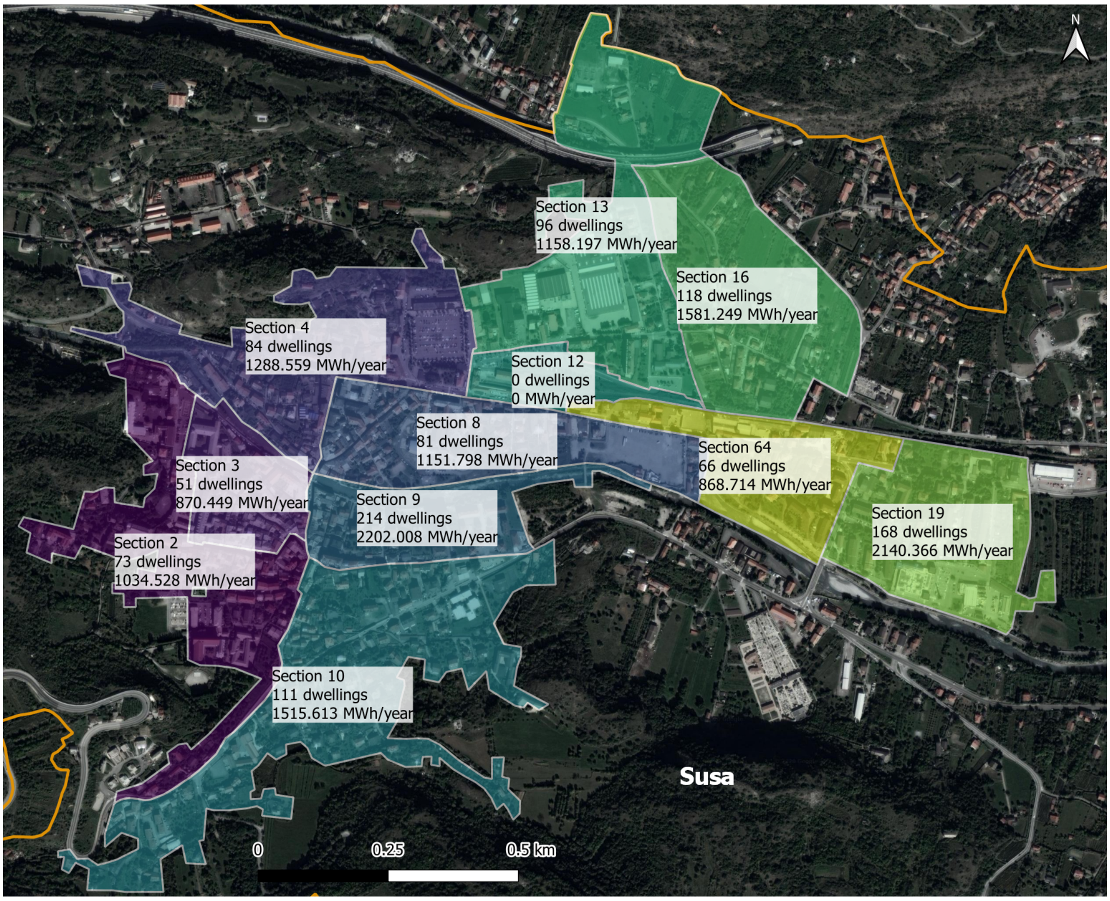


Figure 4.10: *The characteristics of the urban sections of the Susa project.*

Source: Author,2020.

In Susa there are no previous DH networks. So, besides the requirement of residencies with gross volume higher than 1.000 m^3, there are another requirements:

i The buildings have to be close together to be easily connected to a future DH network;

ii The heating plant of each building need to have its own centralized generators;

iii The heat generation must come from natural gas, delivered from a network in the whole city centre;

iv The efficiency of the boilers currently installed will be considered as 95%;

v The technical water distribution circuits in the dwellings are not considered in the analysis: the data refer to the needs of the buildings at the output of the generators.

The energy performance of the buildings could be deducted from the RENERFOR project data (Territorial Cooperation ALCOTRA 2007-2013 of Piedmont Region) about the number of dwellings, heated volumes and energy needs for space heating (SH). The thermal needs for domestic hot water (DHW) were calculated according the method from the regulation UNI TS 11300-2:2014. The estimation of primary energy consumption has been calculated using a medium generation efficiency of 0,95 and the natural gas consumption was estimated with a Lower Heating Value (LHV) of 9,79 kWh/m^3 (given by the Ministero dell'Ambiente, average from 2015-2017). The emission of $C0_2$ has been calculated with a factor of 200,16 g/kWh (given by Allegato 1 - Requisiti Tecnici per impianti a cippato superiori a 350 kW by Provincia di Torino and the Energy Department of Politecnico di Torino). Table 4.26 shows a summary of Susa's energy indicators.

	Energy needs (kWh/year)	**Primary energy consumption** (kWh/year)	**Natural gas fuel consumption** (m^3/year)	$C0_2$ **Emission** (kg/year)
Space Heating (SH)	12.164.742	12.804.992	1.307.966	2.563.000
Domestic Hot Water (DWH)	1.646.739	1.733.409	177.059	347.000
Total	13.811.481	14.538.401	1.485.025	2.910.000

Table 4.26: *Energy indicators for Space Heating and Domestic Heating Water in Susa.*

Source: Author, 2020.

Taking into account that the Susa pilot does not use any renewable energy resource as thermal energy supply, the critical issue for this pilot is the high $C0_2$ emission level , mainly done by natural gas fuel. For this reason, the alternatives were designed to have an energy transition with primary consumption of local resources, in order to obtain a lower impact of $C0_2$ emission for the thermal needs of the identified buildings.

To elaborate alternatives for the supply change from fossil fuels to a renewable source, the dossiers estimated the annual thermal request for the DH in Susa, during 2019. The energy model with the energy load and the contribution of different generators in supplying heat, has been constructed following the method suggested by the Allegato 1 - Requisiti Tecnici per impianti a cippato superiori a 350 kW by Provincia di Torino and the Energy Department of

Politecnico di Torino.

In Figure 4.11, it is possible to see in blue the constant amount of energy needed to meet the demand of the DHW and losses for distribution, estimated to be constant all year and around 345,65 kWh. The amount of energy that meets the space heating needs is represented in red and it depends on the external temperature. The demand of the space heating is considered only from before 15th of April and after 15th of October, defined from the DPR 412/93. The sum of these hourly values is 13.255.814 kWh/y (estimated).

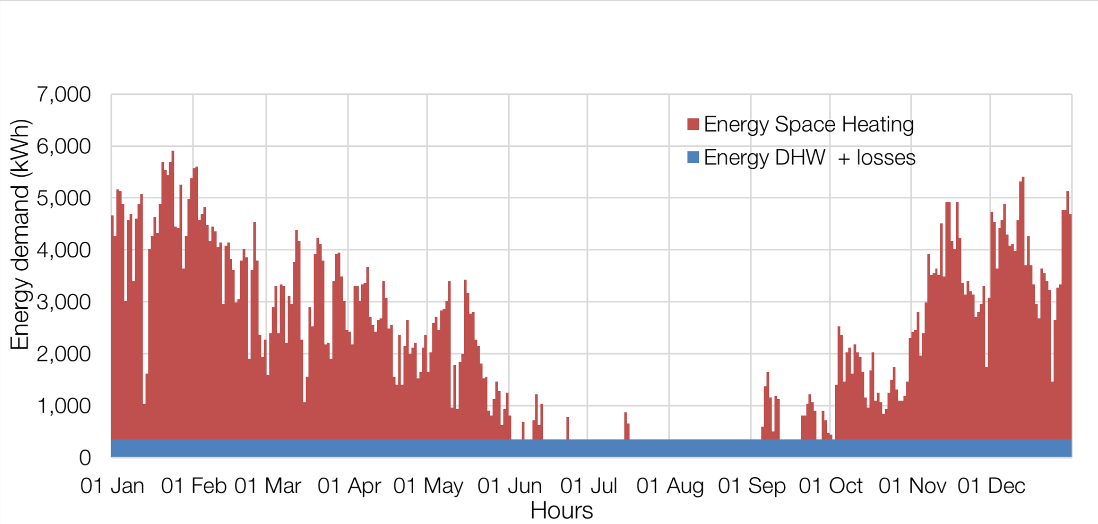


Figure 4.11: *Estimated hourly thermal energy demand for the District Heating in Susa for space heating and DHW+losses in 2019.*

Source: SCORE commission, 2019.

Considering these values, the solution designed is a retrofit of the power plants with the installation of a new District Heating system in the city of Susa, delivering heat to the buildings. The project foresees the installation of a wood chip-fired boiler, fed with biomass from the surrounding forests, in the centralized thermal plant with the integration of a natural gas fired condensing boiler. It is planned also the installation of a solar plant, in order to improve efficiency and brake down emission levels and environmental impact.

The designed setup for the control system is related to guarantee the priority to the solar plant and to the biomass boiler, secondarily the gas fuelled system turns on to fulfil the heat request of the total District Heating network. The criteria to set the priority of activation between the different generators have been designed as follows:

i The solar thermal plant works every day at its maximum productivity, in order to minimize emissions.

ii The primary generator, fired with woodchips is the first generator that switches on; the role of principal generator is ideal for the biomass boiler, because its combustion technology performs at its best with a load as constant as possible.

iii The secondary generator, fired with natural gas is used to supply heat during the peak of load that will exceed the power of the solar collectors and the primary boiler.

The project elaborated two alternatives for Susa refurbishment, summarized in Table 4.27:

Case	Alternatives
0.0)	As built
1)	The solar plant meets the annual average demand of thermal energy for DHW and losses in the distribution (345,65 kW) **only in the hour of maximum solar radiation**. It is a conservative condition in which there is no storage available and the production of solar collectors never exceed demand. The optimal size of the biomass generator was calculated as 1.750 kW.
2)	The solar plant could meet **50% of the total annual demand** of thermal energy for DHW and for losses in the distribution of the DH network. It is a condition in which the solar plant surplus of energy can be conserved in a proper storage tank or in the DH tubes circuit itself. The optimal size of the biomass generator was calculated as 1.750 kW.

Table 4.27: *List of the refurbishment alternatives in Susa.*

Source: Author, 2020.

Firstly, the solar plant meets the **annual average demand** for DHW+losses only in the hour of maximum solar radiation, without storage and never exceeding demand, with a calculated area of 1.060 m^2 for the solar collectors. Table 4.28 details the first Case alternative, given the installed size of each system, the operating hour, energy produced, efficiency of the boilers and primary energy of the fuels.

Case 1	Installed size	Operating hours	Energy Produced	Contribution on energy production	Generation Efficiency (boilers)	Primary Energy (fuels)
	(m^2) kW	h/y	MWh/y	-	-	MWh/y
Solar collectors	(1.060)	4.180	583	4,40%	N/A	N/A
Biomass generator	1.750	8.759	8.263	62,33%	94%	8.790
Gas generator	6.250	3.113	4.410	33,27%	98%	4.500
Total	8.000	8.760	13.256	100,00%	95,39%	13.291

Table 4.28: *Contribution on thermal energy production for the first case alternative of Susa. Source: Author, 2020.*

Secondly, the solar plant meets 50% of the total annual demand for DHW and losses, with storage of the energy surplus. For both alternatives, the generators size will be 1.750 kW for the biomass and 6.250 kW for the gas. As the previous Table, Table 4.29 details some information for the second case alternative of Susa.

Case 2	Installed size	Operating hours	Energy Produced	Contribution on energy production	Generation Efficiency (boilers)	Primary Energy (fuels)
	(m^2) kW	h/y	MWh/y	-	-	MWh/y
Solar collectors	(2.573)	4.180	1.766	13,32%	N/A	N/A
Biomass generator	1.750	7.241	7.203	54,34%	94%	7.662
Gas generator	6.250	3.019	4.288	32,34%	98%	4.375
Total	8.000	8.760	13.256	100,00%	95,49%	12.037

Table 4.29: *Contribution on thermal energy production for the second case alternative of Susa. Source: Author, 2020.*

The project simulated each alternative in relation of the primary energy consumption, considering the SH and DWH + losses, separating it in renewable or now renewable sources. After, it calculated the fuel consumption values from gas and wood. In the end, it showed the CO_2 emissions for each alternative. A summary of the principal indicators is shown in Table 4.30. The meaning of the table indicators is explained below.

- Q_p, tot: the total primary energy consumption of the buildings and systems (kWh/year);
- Q_p, ren: the renewable primary energy consumption of the buildings and systems (kWh/year);
- Q_p, nren: the not renewable primary energy consumption of the buildings and systems; (kWh/year)
- **Fuel consumption**: linked to the previous values with the LHV factor of the fuel, (m^3 for gaseous fuels and kg for solid fuels);
- **Emissions of** $C0_2$: consequent to fuel consumption, according to the emission factors (200,16 $kgC0_2/m^3$ of natural gas and 0 $kgC0_2/kg$ of wood).

Case	Q_p, tot	Q_p, ren	Q_p, nren	Gas consumption	Wood consumption	CO_2 emissions
	[kWh/year]	[kWh/year]	[kWh/year]	[m^3_{gas}/year]	[kg_{wood}/year]	[kg/year]
0.0)	14.538.401	- -	14.538.401	1.485.026	- -	2.910.000
1)	13.290.536	8.790.311	4.500.224	459.676	2.585.000	901.000
2)	12.037.497	7.662.418	4.375.079	446.893	2.254.000	876.000

Table 4.30: *Energy indicators simulation for the current situation and the alternatives in Susa. Source: Author, 2020.*

5

Results

The results are presented in this chapter following the three main Phases of the methodology illustrated in Chapter 3, namely Assessment and Evaluation; Visualisation and participative Workshops; and Recommendations.

5.1 Best refurbishment alternative selection

Starting from the dossiers' information of the study site, this Section serves the purpose of determining the best refurbishment alternative for five cities of the SCORE Italian pilot in the Susa Valley (Almese, Bardonecchia, Bussoleno, San Giorio di Susa and Susa). This Section is divided into two Subsections, the first being a screening of the case studies, while the second runs a Multi-Criteria Analysis (MCA) to determine the best scenario for each city.

5.1.1 Case studies' impact assessment

This step consists in assessing each municipality of the study site. The data from the documents dossiers, regarding the refurbishment alternatives and the energy indicators, were summarized in the previous Chapter 4. With those data, together with experts advice and surveys, it was possible to fill the matrix of Key Performance Indicators (KPIs) previously explained on Figure 3.3. Some indicators were estimated, metered, or calculated, while others were obtained through process documentation. The establishment of an evaluation matrix is fundamental to reach the best scenario in the end. It allows the comparison of each refurbishment alternative proposed with the current situation, taking into account the selected KPIs. As follows, the evaluation matrix for each city alternative is built in relation of the current situation.

Pilot 01: Almese

In Almese, it is expected to build a DH network within ten sections of the city consisting in 218 private residential residences. The energy indicators of the current situation were shown previously in Table 4.3. Considering the requirements and the constraints of the pilot city, the project elaborated two refurbishment alternatives (detailed in Table 4.4). It considers together with the construction of the DH network, a centralized thermal plant with a biomass boiler and solar panels collectors to improve the efficiency of the plant. The retrofit therefore relies on the way the solar panels collectors will be estimated to meet the DHW (plus losses) demand. In the first alternative (**A1**), it will only meet the demand in the hour of maximum solar radiation, while in the second (**A2**), it will meet 50% of the total demand, needing a storage for the energy surplus. Afterwards, the project simulated again the energy indicators but now considering those scenarios, as shown already in Table 4.7.

The KPIs were calculated following the methodology and procedure of Subsection 3.1.1. As commented before, the evaluation matrix is a comparison with the current situation, showing the savings and reductions in correlation of the energy indicators from the current situation (Table 4.3) and from the interventions simulation (Table 4.7).

The indicator "Public Incentives" (**EC3**) was given by the experts in the field and SCORE partners. Through process documentation and their advice, for Almese it was established the value of 30% of savings in relation to the investment cost covered by administrative incentives. It will help to motivate the adherence of the pilot municipalities in the project, encouraging them financially. This public incentive is taken from *Titoli di Efficienza Energetica (TEE)* and, therefore, the indicator (**EC10**) will not be applied for this case.

The indicator "Material Cost" (**EC7**) was also given by the SCORE experts. For Almese, the construction of the DH network and the central plant consider the follow values (Table 5.1):

Material/services	**Unit**	**Price** [euro/unit]	**Quantity** [unit]	**Total Cost** [euro]
Pipeline	m^2	500	600	300.000
Central thermal plant	-	500.000	1	500.000
Connections-pipes	m^2	10.000	10	100.000

Table 5.1: *Material and services costs for Almese.*

Source: Experts advice from SCORE commission (2020).

The indicator "Increase of Plant Efficiency" (**T1**) is the subtraction of the efficiency from the current non renewable boiler in Almese (i.e., 95%, as stated in the dossiers) and the efficiency from the new renewable boilers. According to Tables 4.5 and 4.6, for the first alternative the new efficiency would be 95,52%, while for the second alternative 95,63%. On the other hand, for the indicator "Installed power reduction" (**T2**), it would be no difference as the project in Almese do not focused on reduce the power of the boilers.

The indicator "Architectural Impact" (**S1**) takes into account the classification of Table 3.3. As the retrofit interventions have the installation of solar thermal collectors, both alternatives have the Value "5", as they have negative visual impact for the city. The final evaluation matrix for Almese is shown in Figure 5.1.

Category	Code	Indicator	A1	A2
Environmental	ENV1	Primary energy saving [kWh/y]	2.555.526	2.573.335
	ENV2	Global emissions CO2 reduction [kgCO2eq/y]	511.514,00	515.079,00
	ENV3	Local emissions NOX reduction [kg/y]	273,44	275,35
	ENV4	Local emissions PM10 reduction [kg/y]	1,84	1,85
Economic	EC1	Payback period (PBP) [years]	2,85	2,83
	EC2	Investment cost [euro]	1.170.000,00	1.170.000,00
	EC3	Public incentives [%]	30%	30%
	EC4	Savings on energy expenditure [euro/year]	287.496,68	289.500,19
	EC5	Labor cost [euro]	270.000,00	270.000,00
	EC6	Labor cost by a social cooperative [euro]	67.500,00	67.500,00
	EC7	Material cost [euro]	900.000,00	900.000,00
	EC8	Material cost purchased on the territory [euro]	90.000,00	90.000,00
	EC9	Running cost [euro/year]	379.742,29	351.662,88
	EC10	Type Thermal Account Access (TAA) vs. Energy Efficiency Certificates (EEC) [TAA/EEC	N/A	N/A
Technical	T1	Increase of plant system efficiency [%]	0,52%	0,63%
	T2	Installed power reduction [kW]	0,0	0,0
Social	S1	Architectural impact [-]	5	5

Figure 5.1: *Almese evaluation matrix.*

Source: Author, 2020.

Pilot 02: Bardonecchia

Bardonecchia already has one DH network. Hence, the target is to retrofit the power plants with the installation of a new renewable energy boiler. The project proposes to attend two demand scales: first, only for seven municipal buildings; second, for all users of the District Heating. The current energy indicators for Bardonecchia were shown in Table 4.8. Considering the requirements and the constraints of the pilot city, the project elaborated three refurbishment alternatives (detailed in Table 4.9). For the first alternative (**A1**), the biomass boiler will satisfy only the seven municipality buildings demand; for the second alternative (**A2**), the biomass boiler will produce energy during the whole year at nominal power and it will satisfy the seven municipality buildings demand (the surplus will be turn to the city district heating); for the third alternative (**A3**), the biomass boiler will be designed to attend all users of the district heating in Bardonecchia. Afterwards, the project simulated again the energy indicators but now considering those scenarios, as shown already in Tables 4.13 and 4.14.

The KPIs were calculated following the methodology and procedure of Subsection 3.1.1. As commented before, the evaluation matrix is a comparison with the current situation, showing the savings and reductions in correlation of the energy indicators from the current situation (Table 4.8) and from the interventions simulations (Tables 4.13 and 4.14).

The indicator "Public Incentives" (**EC3**) was given by the experts in the field and SCORE partners. Through process documentation and their advice, for Bardonecchia it was established the value of 30% of savings in relation to the investment cost covered by administrative incentives. It will help to motivate the adherence of the pilot municipalities in the project, encouraging them financially. This public incentive is taken from *Titoli di Efficienza Energetica (TEE)* and, therefore, the indicator (**EC10**) will not be applied for this case.

The indicator "Material Cost" (**EC7**) was also given by the SCORE experts. For Bardonecchia, the retrofit of the central plant with biomass boiler and the existing DH, considered the follow values (Table 5.2):

Material/services	**Unit**	**Price** [euro/unit]	**Quantity** [unit]	**Total Cost** [euro]
Central thermal plant	-	500.000	2	1.000.000
Connections-pipes	m^2	10.000	20	200.000

Table 5.2: *Material and services costs for Bardonecchia.*

Source: Experts advice from SCORE commission (2020).

The indicator "Increase of Plant Efficiency" (**T1**) is the subtraction of the efficiency from the current non renewable boiler in Bardonecchia (i.e., 78,9% as stated in the dossiers) and the efficiency from the new renewable boilers. According to Tables 4.10,4.11 and 4.12, for the first alternative the new efficiency would be 93%; for the second alternative 82,3%; and for the third alternative

87,50%. On the other hand, for the indicator "Installed power reduction" (**T2**), it would not make any difference for the municipal buildings in the cases **A1** and **A2**; and considering for the whole city, the installation will reduce the installed power from 49.400 kW (*A.I.R.U.* (2018)) to 49.296 kW in the case **A3**.

The indicator "Architectural Impact" (**S1**) takes into account the classification of Table 3.3. As the interventions have only the replacement of boilers, they will have the Value "3", as they have no visual impact on the city. The final evaluation matrix for Bardonecchia is shown in Figure 5.2.

Category	Code	Indicator	A1	A2 (AIRU 2018)	A3 (AIRU 2018)
Environmental	ENV1	Primary energy saving [kWh/y]	2.540.523	21.804.000	51.622.000
	ENV2	Global emissions CO2 reduction [kgCO2eq/y]	508.511,00	4.364.288,00	10.332.659,00
	ENV3	Local emissions NOX reduction [kg/y]	271,84	2.333,03	5.523,55
	ENV4	Local emissions PM10 reduction [kg/y]	1,83	15,70	37,17
Economic	EC1	Payback period (PBP) [years]	3,82	0,45	0,19
	EC2	Investment cost [euro]	1.560.000,00	1.560.000,00	1.560.000,00
	EC3	Public incentives [%]	30%	30%	30%
	EC4	Savings on energy expenditure [euro/year]	285.808,84	2.452.950,00	5.807.475,00
	EC5	Labor cost [euro]	360.000,00	360.000,00	360.000,00
	EC6	Labor cost by a social cooperative [euro]	90.000,00	90.000,00	90.000,00
	EC7	Material cost [euro]	1.200.000,00	1.200.000,00	1.200.000,00
	EC8	Material cost purchased on the territory [euro]	120.000,00	120.000,00	120.000,00
	EC9	Running cost [euro/year]	246.056,50	8.420.825,00	7.592.400,00
	EC10	Type Thermal Account Access (TAA) vs. Energy Efficiency Certificates (EEC) [TAA/EEC	N/A	N/A	N/A
Technical	T1	Increase of plant system efficiency [%]	14,10%	3,40%	8,60%
	T2	Installed power reduction [kW]	0,0	0,0	104,0
Social	S1	Architectural impact [-]	3	3	3

Figure 5.2: *Bardonecchia evaluation matrix.*

Source: Author, 2020.

Pilot 03: Bussoleno

In Bussoleno, it is expected to build a small DH network connecting three buildings. The energy indicators of the current situation were shown previously in Table 4.15. Considering the requirements and the constraints of the pilot city, the project elaborated three refurbishment alternatives (detailed in Table 4.16). Together with the DH network, a centralized thermal plant with a biomass boiler will be installed for the first alternative (**A1**). Besides this, the second (**A2**) and third (**A3**) alternatives will have also thermal storage systems (different sizes for each alternative). Afterwards, the project simulated again the energy indicators but now considering those scenarios, as shown already in Table 4.20.

The KPIs were calculated following the methodology and procedure of Subsection 3.1.1. As commented before, the evaluation matrix is a comparison with the current situation, showing the savings and reductions in correlation of the energy indicators from the current situation (Table 4.15) and from the interventions simulation (Table 4.20).

The indicator "Public Incentives" (**EC3**) was given by the experts in the field and SCORE partners. Through process documentation and their advice, for Bussoleno it was established the value of 30% of savings in relation to the investment cost covered by administrative incentives. It will help to motivate the adherence of the pilot municipalities in the project, encouraging them financially. This public incentive is taken from *Titoli di Efficienza Energetica (TEE)* and, therefore, the indicator (**EC10**) will not be applied for this case.

The indicator "Material Cost" (**EC7**) was also given by the SCORE experts. For Bussoleno, the construction of the DH network and the central plant consider the follow values (Table 5.3):

Material/services	**Unit**	**Price** [euro/unit]	**Quantity** [unit]	**Total Cost** [euro]
Pipeline	m^2	500	450	225.000
Central thermal plant	-	500.000	1	500.000
Connections-pipes	m^2	10.000	10	100.000

Table 5.3: *Material and services costs for Bussoleno.*

Source: Experts advice from SCORE commission (2020).

The indicator "Increase of Plant Efficiency" (**T1**) is the subtraction of the efficiency from the current non renewable boiler in Bussoleno (i.e., 84%, as stated in the dossiers) and the efficiency from the new renewable boilers. According to Tables 4.17, 4.18 and 4.19, the new efficiency would be 91,90% for all alternatives. On the other hand, for the indicator "Installed power reduction" (**T2**), there will be a power reduction from 716 kW to 350 kW for the new boilers.

The indicator "Architectural Impact" (**S1**) takes into account the classification of Table 3.3. As the interventions have only the replacement of boilers, they will have the Value "3", as they have no visual impact on the city. The final evaluation matrix for Bussoleno is shown in Figure 5.3.

Category	Code	Indicator	A1	A2	A3
Environmental	ENV1	Primary energy saving [kWh/y]	716.278	722.354	733.332
	ENV2	Global emissions CO2 reduction [kgCO2eq/y]	143.370,00	144.587,00	146.784,00
	ENV3	Local emissions NOX reduction [kg/y]	76,64	77,29	78,47
	ENV4	Local emissions PM10 reduction [kg/y]	0,52	0,52	0,53
Economic	EC1	Payback period (PBP) [years]	9,32	9,24	9,10
	EC2	Investment cost [euro]	1.072.500,00	1.072.500,00	1.072.500,00
	EC3	Public incentives [%]	30%	30%	30%
	EC4	Savings on energy expenditure [euro/year]	80.581,28	81.264,83	82.499,85
	EC5	Labor cost [euro]	247.500,00	247.500,00	247.500,00
	EC6	Labor cost by a social cooperative [euro]	61.875,00	61.875,00	61.875,00
	EC7	Material cost [euro]	825.000,00	825.000,00	825.000,00
	EC8	Material cost purchased on the territory [euro]	82.500,00	82.500,00	82.500,00
	EC9	Running cost [euro/year]	97.586,51	97.457,76	97.260,14
	EC10	Type Thermal Account Access (TAA) vs. Energy Efficiency Certificates (EEC) [TAA/EEC]	N/A	N/A	N/A
Technical	T1	Increase of plant system efficiency [%]	7,90%	7,90%	7,90%
	T2	Installed power reduction [kW]	366,0	366,0	366,0
Social	S1	Architectural impact [-]	3	3	3

Figure 5.3: *Bussoleno evaluation matrix.*

Source: Author, 2020.

Pilot 04: San Giorio di Susa

For San Giorio di Susa, the procedure was the same for Almese, as their interventions have similar approach. It is also expected to build a DH network, but it will be within only one section of the city that has in total 29 private residential residences. The energy indicators of the current situation were shown previously in Table 4.21. Considering the requirements and the constraints of the pilot city, the project elaborated two refurbishment alternatives (detailed in Table 4.22). The interventions are similar to the proposals for Almese. It considers together with the construction of the DH network, a centralized thermal plant with a biomass boiler and solar panels collectors to improve the efficiency of the plant. The retrofit therefore relies on the way the solar panel collectors will be estimated to meet the DHW (plus losses) demand. In the first alternative (**A1**), it will only meet the demand in the hour of maximum solar radiation, while in the second (**A2**), it will meet 50% of the total demand, needing in this way a storage for the energy surplus. Afterwards, the project simulated the energy indicators considering those scenarios, as shown in Table 4.25.

The indicator "Public Incentives" (**EC3**) was given by the experts in the field and SCORE partners. Through process documentation and their advice, for San Giorio di Susa it was established the value of 30% of savings in relation to the investment cost covered by administrative incentives. It will help to motivate the adherence of the pilot municipalities in the project, encouraging them financially. This public incentive is taken from *Titoli di Efficienza Energetica (TEE)* and, therefore, the indicator (**EC10**) will not be applied for this case.

The indicator "Material Cost" (**EC7**) was also given by the SCORE experts. For San Giorio di Susa, the construction of the DH network and the central plant consider the follow values (Table 5.4):

Material/services	**Unit**	**Price** [euro/unit]	**Quantity** [unit]	**Total Cost** [euro]
Pipeline	m^2	500	600	300.000
Central thermal plant	-	300.000	1	300.000
Connections-pipes	m^2	10.000	20	200.000

Table 5.4: *Material and services costs for San Giorio di Susa.*

Source: Experts advice from SCORE commission (2020).

The indicator "Increase of Plant Efficiency" (**T1**) is the subtraction of the efficiency from the current non renewable boiler in San Giorio di Susa (i.e., 95%, as stated in the dossiers) and the efficiency from the new renewable boilers. According to Tables 4.23 and 4.24, for the first alternative the new efficiency would be 95,39%, while for the second alternative 95,48%. On the other hand, for the indicator "Installed power reduction" (**T2**), it would be no difference as the project in San Giorio di Susa do not focused on reduce the power of the boilers.

The indicator "Architectural Impact" (**S1**) takes into account the classification of Table 3.3. As the retrofit interventions have the installation of solar thermal collectors, both have the Value "5", as they have negative visual impact for the city. The final evaluation matrix for San Giorio di Susa is shown in Figure 5.4.

Category	Code	Indicator	A1	A2
Environmental	ENV1	Primary energy saving [kWh/y]	401.355	405.825
	ENV2	Global emissions CO2 reduction [kgCO2eq/y]	80.335,00	81.230,00
	ENV3	Local emissions NOX reduction [kg/y]	42,94	43,42
	ENV4	Local emissions PM10 reduction [kg/y]	0,29	0,29
Economic	EC1	Payback period (PBP) [years]	16,12	15,95
	EC2	Investment cost [euro]	1.040.000,00	1.040.000,00
	EC3	Public incentives [%]	30%	30%
	EC4	Savings on energy expenditure [euro/year]	45.152,44	45.655,31
	EC5	Labor cost [euro]	240.000,00	240.000,00
	EC6	Labor cost by a social cooperative [euro]	60.000,00	60.000,00
	EC7	Material cost [euro]	800.000,00	800.000,00
	EC8	Material cost purchased on the territory [euro]	80.000,00	80.000,00
	EC9	Running cost [euro/year]	78.459,09	73.984,61
	EC10	Type Thermal Account Access (TAA) vs. Energy Efficiency Certificates (EEC) [TAA/EEC]	N/A	N/A
Technical	T1	Increase of plant system efficiency [%]	0,39%	0,48%
	T2	Installed power reduction [kW]	0,0	0,0
Social	S1	Architectural impact [-]	5	5

Figure 5.4: *San Giorio di Susa evaluation matrix.*

Source: Author, 2020.

Pilot 05: Susa

For Susa, the procedure was the same for Almese and San Giorio di Susa, as their interventions have similar approach. It is also expected to build a DH network, but it will be within eleven sections of the city that have in total 1.062 private residential residences. The energy indicators of the current situation were shown previously in Table 4.26. Considering the requirements and the constraints of the pilot city, the project elaborated two refurbishment alternatives (detailed in Table 4.27). The interventions are similar to the proposals for Almese. It considers together with the construction of the DH network, a centralized thermal plant with a biomass boiler and solar panels collectors to improve the efficiency of the plant. The retrofit therefore relies on the way the solar panels collectors will be estimated to meet the DHW (plus losses) demand. In the first alternative (**A1**), it will only meet the demand in the hour of maximum solar radiation, while in the second (**A2**), it will meet 50% of the total demand, needing in this way a storage for the energy surplus. Afterwards, the project simulated the energy indicators considering those scenarios, as shown in Table 4.30.

The indicator "Public Incentives" (**EC3**) was given by the experts in the field and SCORE partners. Through process documentation and their advice, for Susa it was established the value of 30% of savings in relation to the investment cost covered by administrative incentives. It will help to motivate the adherence of the pilot municipalities in the project, encouraging them financially. This public incentive is taken from *Titoli di Efficienza Energetica (TEE)* and, therefore, the indicator (**EC10**) will not be applied for this case.

The indicator "Material Cost" (**EC7**) was also given by the SCORE experts. For Susa, the construction of the DH network and the central plant consider the follow values (Table 5.5):

Material/services	**Unit**	**Price** [euro/unit]	**Quantity** [unit]	**Total Cost** [euro]
Pipeline	m^2	500	1.500	750.000
Central thermal plant	-	500.000	2	1.000.000
Connections-pipes	m^2	10.000	50	500.000

Table 5.5: *Material and services costs for Susa.*

Source: Experts advice from SCORE commission (2020).

The indicator "Increase of Plant Efficiency" (**T1**) is the subtraction of the efficiency from the current non renewable boiler in Susa (i.e., 95%, as stated in the dossiers) and the efficiency from the new renewable boilers. According to

Tables 4.28 and 4.29, for the first alternative the new efficiency would be 95,39% and for the second alternative 95,49%. On the other hand, for the indicator "Installed power reduction" (**T2**), it would be no difference as the project in Susa do not focused on reduce the power of the boilers.

The indicator "Architectural Impact" (**S1**) takes into account the classification of Table 3.3. As the retrofit interventions have the installation of solar thermal collectors, both alternatives have the Value "5", as they have negative visual impact for the city. The final evaluation matrix for Susa is shown in Figure 5.5.

Category	Code	Indicator	A1	A2
Environmental	ENV1	Primary energy saving [kWh/y]	10.038.177	10.163.322
	ENV2	Global emissions CO2 reduction [kgCO2eq/y]	2.009.000,00	2.034.000,00
	ENV3	Local emissions NOX reduction [kg/y]	1.074,08	1.087,48
	ENV4	Local emissions PM10 reduction [kg/y]	7,23	7,32
Economic	EC1	Payback period (PBP) [years]	1,81	1,79
	EC2	Investment cost [euro]	2.925.000,00	2.925.000,00
	EC3	Public incentives [%]	30%	30%
	EC4	Savings on energy expenditure [euro/year]	1.129.294,91	1.143.373,73
	EC5	Labor cost [euro]	675.000,00	675.000,00
	EC6	Labor cost by a social cooperative [euro]	168.750,00	168.750,00
	EC7	Material cost [euro]	2.250.000,00	2.250.000,00
	EC8	Material cost purchased on the territory [euro]	225.000,00	225.000,00
	EC9	Running cost [euro/year]	1.443.806,30	1.316.938,19
	EC10	Type Thermal Account Access (TAA) vs. Energy Efficiency Certificates (EEC) [TAA/EEC	N/A	N/A
Technical	T1	Increase of plant system efficiency [%]	0,39%	0,49%
	T2	Installed power reduction [kW]	0,0	0,0
Social	S1	Architectural impact [-]	5	5

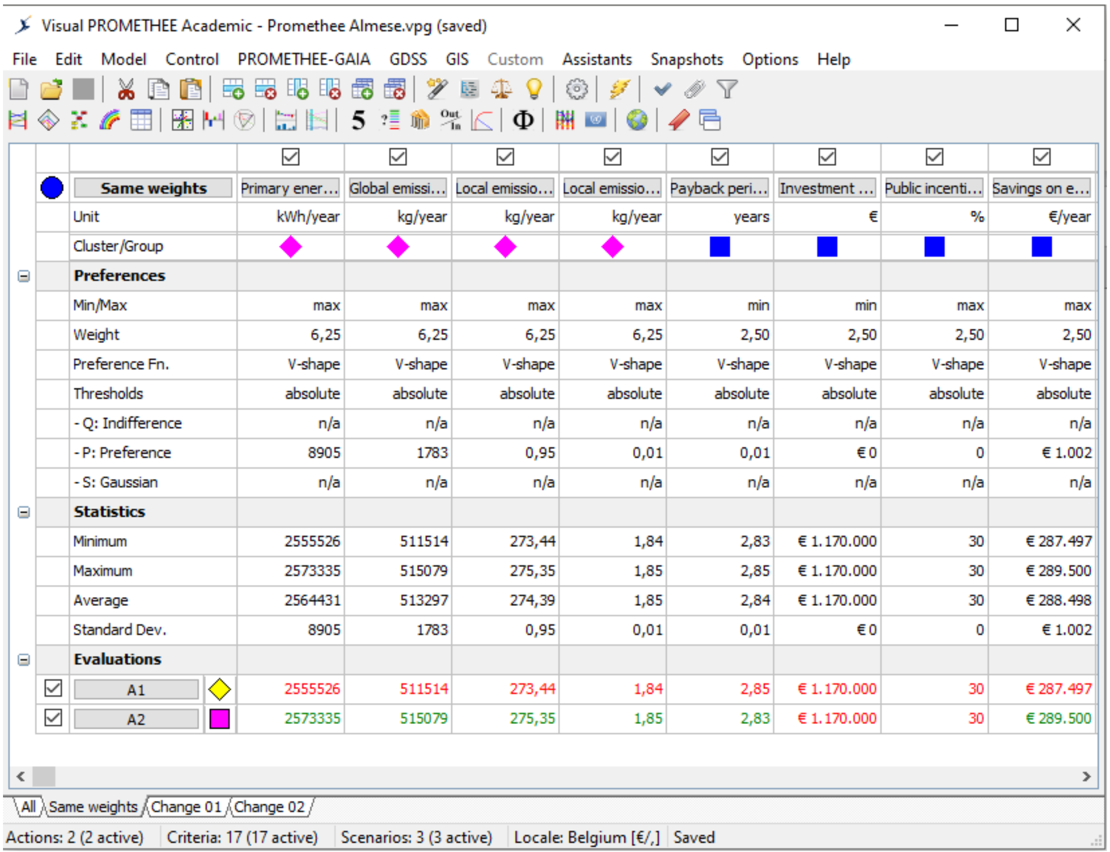
Figure 5.5: *Susa evaluation matrix.*

Source: Author, 2020.

5.1.2 Multi-Criteria Analysis (MCA)

Secondly, with the previous evaluation matrices, it was possible to implement a Multi-Criteria Analysis (MCA) applying the PROMETHEE method, explained in Subsection 3.1.1. It helped to assess the different KPIs and to find the best refurbishment alternative for the Italian cases studies through a pair-wise comparison.

Using the "Visual PROMETHEE" software, the set of criteria (KPIs) defined on the evaluation matrices were added by grouping it on clusters of environmental, economic, technical, and social categories. Besides this, it was necessary to give each criteria some preferences, previously explained in Subsection 3.1.1. A screenshot of the software is shown in Figure 5.6.


Visual PROMETHEE Academic - Promethee Almese.vpg (saved)

File Edit Model Control PROMETHEE-GAIA GDSS GIS Custom Assistants Snapshots Options Help

Same weights	Primary ener…	Global emissi…	Local emissio…	Local emissio…	Payback peri…	Investment …	Public incenti…	Savings on e…
Unit	kWh/year	kg/year	kg/year	kg/year	years	€	%	€/year
Cluster/Group								
Preferences								
Min/Max	max	max	max	max	min	min	max	max
Weight	6,25	6,25	6,25	6,25	2,50	2,50	2,50	2,50
Preference Fn.	V-shape	V-shape	V-shape	V-shape	V-shape	V-shape	V-shape	V-shape
Thresholds	absolute	absolute	absolute	absolute	absolute	absolute	absolute	absolute
- Q: Indifference	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
- P: Preference	8905	1783	0,95	0,01	0,01	€ 0	0	€ 1.002
- S: Gaussian	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Statistics								
Minimum	2555526	511514	273,44	1,84	2,83	€ 1.170.000	30	€ 287.497
Maximum	2573335	515079	275,35	1,85	2,85	€ 1.170.000	30	€ 289.500
Average	2564431	513297	274,39	1,85	2,84	€ 1.170.000	30	€ 288.498
Standard Dev.	8905	1783	0,95	0,01	0,01	€ 0	0	€ 1.002
Evaluations								
A1	2555526	511514	273,44	1,84	2,85	€ 1.170.000	30	€ 287.497
A2	2573335	515079	275,35	1,85	2,83	€ 1.170.000	30	€ 289.500

All | Same weights | Change 01 | Change 02

Actions: 2 (2 active) | Criteria: 17 (17 active) | Scenarios: 3 (3 active) | Locale: Belgium [€/,] | Saved

Figure 5.6: *Screenshot of the software Visual PROMETHEE.*

Source: Author, 2020.

Furthermore, a sensitivity analysis is proposed by changing different weights for different scenarios with respect to the Baseline scenario, according to previous stakeholders' interests and opinions (Table 3.5). This is useful to test the robustness of the model. According to Table 3.5, the **Baseline model** assigns the same weight for each category (25% each one), divided equally to the indicators. The **Change 1** proposes the same weight for each indicator (5,9% each one). This leads into different weight for each category: 23,5% for Environmental, 58,8% for Economic, 11,8% for Technical, and 5,9% for Social. On the other hand, **Change 2** focuses on the two categories that have more impact in the project: Environmental and Economic. By giving these categories a greater relevance and assigning a higher weight (30% each one), leaving the rest to Social and Technical, divided equally (20% each one). Table 5.6 summarizes the weight for each category in each scenario for the sensitive analysis.

Scenario	Environmental	Economic	Technical	Social
Baseline	25%	25%	25%	25%
Change 01	23,5%	58,8%	11,8%	5,9%
Change 02	30%	30%	20%	20%

Table 5.6: *Category weight applying sensitive analysis in three scenarios.*

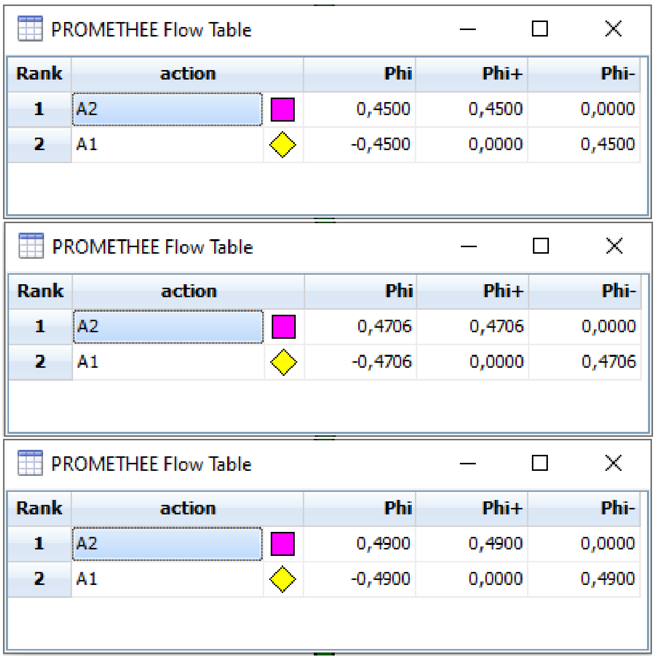
Source: Author, 2020.

The results of the best alternative for each case study of the Italian study site are presented below, considering the three scenarios.

Pilot 01: Almese

Considering the previous PROMETHEE methodology of Subsection 3.1.1 and the Evaluation Matrix of Almese (Figure 5.1), the software Visual PROMETHEE was filled with the 17 criteria, 2 retrofit alternatives and 3 scenarios with different weights based on Table 5.6 (**Baseline**, **Change 01** and **Change 02**). The software gives one result for each scenario and there are several ways to show the results. For this thesis, two types of layout were chosen: PROMETHEE Table and Scenario Comparison.

The PROMETHEE Table, illustrated in Figure 5.7, shows the results by ranking the alternatives and giving values of Phi, Phi + and Phi - in each scenario. Higher and closer to 1 the values of Phi and Phi + are, best it is the alternative. On the other hand, higher the value of Phi -, worse it is the alternative. Another way to show the results is through the Scenario Comparison, illustrated in Figure 5.8. The three scenarios are represented by bars centered on the value 0 and ranging from -1 to 1 on the Phi scale. The alternatives are then classified in each bar scenario, placing their PHI value in each situation (same values from the PROMETHEE Table). By doing this, it is possible to visualize the difference between the Phi values during each scenario.



PROMETHEE Flow Table

Rank	action	Phi	Phi+	Phi-
1	A2	0,4500	0,4500	0,0000
2	A1	-0,4500	0,0000	0,4500

PROMETHEE Flow Table

Rank	action	Phi	Phi+	Phi-
1	A2	0,4706	0,4706	0,0000
2	A1	-0,4706	0,0000	0,4706

PROMETHEE Flow Table

Rank	action	Phi	Phi+	Phi-
1	A2	0,4900	0,4900	0,0000
2	A1	-0,4900	0,0000	0,4900

Figure 5.7: *The scenarios results (respectively Baseline, Change 01 and Change 02) for Almese in Visual PROMETHEE.*

Source: Author, 2020.

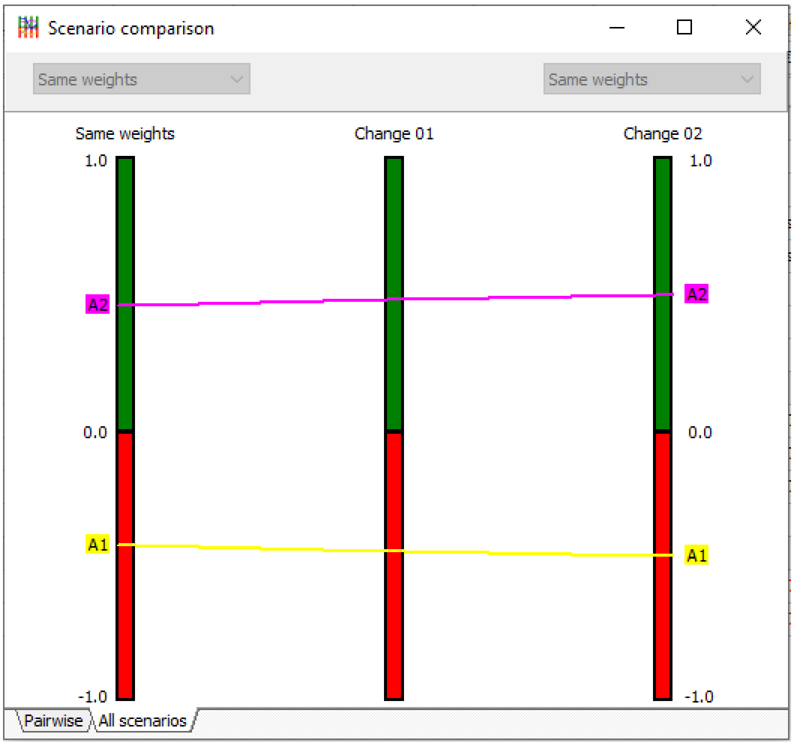


Figure 5.8: *Three scenarios comparison for Almese in Visual PROMETHEE.*

Source: Author, 2020.

Looking into the results, in all three scenarios the best outranked alternative is Alternative 2 (A2). In these scenarios, the rank position is not affected by the sensitivity analysis, even if Phi values varies for each retrofitting situation. However, considering that the Phi values are increasing for each scenario, it means that in Change 02 scenario, Alternative 02 was the most preferred alternative as it has the biggest Phi value. The chosen Alternative 2 (A2) is the construction of the DH and the solar plant, where the solar panels will be calculated to meet 50% of the total annual demand of thermal energy for DHW (the interventions are explained in Table 4.4).

Pilot 02: Bardonecchia

Considering the Evaluation Matrix of Bardonecchia (Figure 5.2), the software Visual PROMETHEE was filled with the 17 criteria, 3 retrofit alternatives and 3 scenarios with different weights based on Table 5.6 (**Baseline**, **Change 01** and **Change 02**). The software gives one result for each scenario and there are several ways to show the results. For this thesis, two types of layout were chosen: PROMETHEE Table and Scenario Comparison.

The PROMETHEE Table, illustrated in Figure 5.9, shows the results by ranking the alternatives and giving values of Phi, Phi + and Phi - in each scenario. Higher and closer to 1 the values of Phi and Phi + are, best it is the alternative. On the other hand, higher the value of Phi -, worse it is the alternative. Another way to show the results is through the Scenario Comparison, illustrated in Figure 5.10. The three scenarios are represented by bars centered on the value 0 and ranging from -1 to 1 on the Phi scale. The alternatives are then classified in each bar scenario, placing their PHI value in each situation (same values from the PROMETHEE Table). By doing this, it is possible to visualize the difference between the Phi values during each scenario.

PROMETHEE Flow Table

Rank	action	Phi	Phi+	Phi-
1	A3	0,4048	0,4798	0,0750
2	A2	-0,1986	0,1437	0,3423
3	A1	-0,2062	0,1500	0,3562

PROMETHEE Flow Table

Rank	action	Phi	Phi+	Phi-
1	A3	0,3641	0,4230	0,0588
2	A2	-0,1062	0,1697	0,2759
3	A1	-0,2580	0,1176	0,3756

PROMETHEE Flow Table

Rank	action	Phi	Phi+	Phi-
1	A3	0,4357	0,5007	0,0650
2	A2	-0,1633	0,1725	0,3357
3	A1	-0,2725	0,1300	0,4025

Figure 5.9: *The scenarios results (respectively Baseline, Change 01 and Change 02) for Bardonecchia in Visual PROMETHEE.*

Source: Author, 2020.

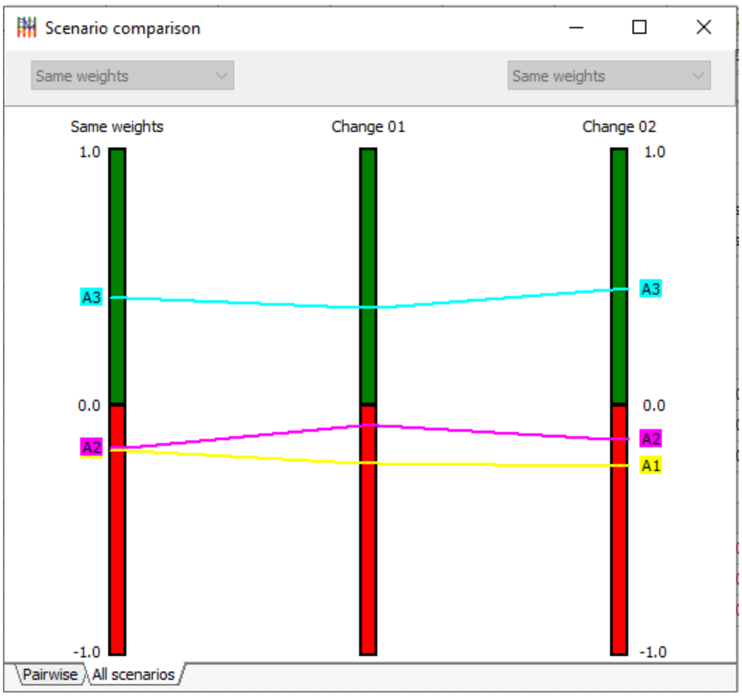


Figure 5.10: *Comparison of the three scenarios for Bardonecchia in Visual PROMETHEE.*

Source: Author, 2020.

Looking into the results, in all three scenarios the best outranked alternative is Alternative 3 (A3). In these scenarios, the rank position is not affected by the sensitivity analysis, even if Phi values varies for each retrofitting situation. However, considering that the values of Phi differs for each scenario, in Change 02 scenario, Alternative 03 was the most preferred alternative as it has the biggest Phi value. The chosen Alternative 3 (A3) is the installation of a 7.000 kW biomass boiler size, to provide renewable energy heating to all buildings connected to Bardonecchia District Heating (the interventions were previously explained in Table 4.9).

Pilot 03: Bussoleno

Considering the Evaluation Matrix of Bussoleno (Figure 5.3), the software Visual PROMETHEE was filled with the 17 criteria, 3 retrofit alternatives and 3 scenarios with different weights based on Table 5.6 (**Baseline**, **Change 01** and **Change 02**).The software gives one result for each scenario and there are several ways to show the results. For this thesis, two types of layout were chosen: PROMETHEE Table and Scenario Comparison.

The PROMETHEE Table, illustrated in Figure 5.11, shows the results by ranking the alternatives and giving values of Phi, Phi + and Phi - in each scenario. Higher and closer to 1 the values of Phi and Phi + are, best it is the alternative. On the other hand, higher the value of Phi -, worse it is the alternative. Another way to show the results is through the Scenario Comparison, illustrated in Figure 5.12. The three scenarios are represented by bars centered on the value 0 and ranging from -1 to 1 on the Phi scale. The alternatives are then classified in each bar scenario, placing their PHI value in each situation (same values from the PROMETHEE Table). By doing this, it is possible to visualize the difference between the Phi values during each scenario.

Looking into the results, in all three scenarios the best outranked alternative is Alternative 3 (A3). In these scenarios, the rank position is not affected by the sensitivity analysis, even if Phi values varies for each retrofitting situation. However, considering that the values of Phi differs for each scenario, in Change 02 scenario, Alternative 03 was the most preferred alternative as it has the biggest Phi value. The chosen Alternative 3 (A3) is the installation of a thermal storage system of 20.000 dm^3 (the interventions were previously explained in Table 4.16).

PROMETHEE Flow Table

Rank	action	Phi	Phi+	Phi-
1	A3	0,4185	0,4185	0,0000
2	A2	-0,1169	0,0890	0,2060
3	A1	-0,3015	0,0000	0,3015

PROMETHEE Flow Table

Rank	action	Phi	Phi+	Phi-
1	A3	0,4056	0,4056	0,0000
2	A2	-0,0853	0,1144	0,1997
3	A1	-0,3203	0,0000	0,3203

PROMETHEE Flow Table

Rank	action	Phi	Phi+	Phi-
1	A3	0,4521	0,4521	0,0000
2	A2	-0,1153	0,1068	0,2221
3	A1	-0,3368	0,0000	0,3368

Figure 5.11: *The scenarios results (respectively Baseline, Change 01 and Change 02) for Bussoleno in Visual PROMETHEE.*

Source: Author, 2020.

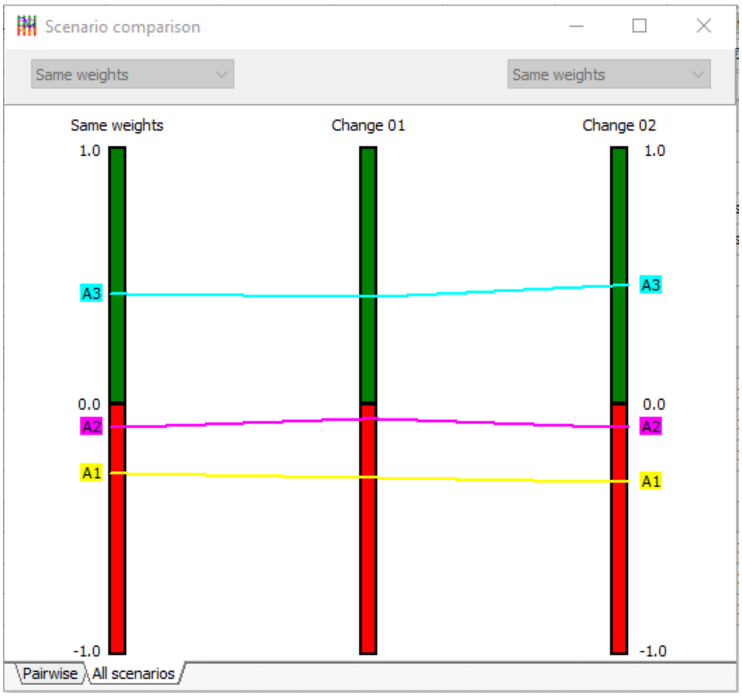


Figure 5.12: *Three scenarios comparison for Bussoleno in Visual PROMETHEE.*

Source: Author, 2020.

Pilot 04: San Giorio di Susa and Pilot 05: Susa

Considering the Evaluation Matrix of San Giorio di Susa and Susa (Figure 5.4 and Figure 5.5, respectively), the software Visual PROMETHEE was filled for both cities, inserting the 17 criteria, 2 retrofit alternatives and 3 scenarios with different weights based on Table 5.6. The software gives one result for each scenario and for this thesis, two types of layout were chosen: PROMETHEE Table and Scenario Comparison.

The results for San Giorio di Susa and Susa are the same as for Almese. They have similar interventions proposals for refurbishment and the same behaviour in the evaluation matrix. In this way, the alternatives behave equally in the PROMETHEE Table and the Scenario Comparison, as previously shown in Figure 5.7 and Figure 5.8, respectively. Thus, in all three scenarios the best outranked alternative for them is Alternative 2 (A2). The chosen Alternative 2 (A2) is the construction of the DH and the solar plant, where the solar panels will be calculated to meet 50% of the total annual demand of thermal energy for DHW (+losses). And the surplus of energy will be conserved in a proper storage tank or in the DH tubes circuit itself. The interventions were explained in Table 4.22 for San Giorio di Susa and in Table 4.27 for Susa.

5.1.3 Discussion of Phase 01 results

Looking into the results of Table 5.7, for each case study it is possible to say that the weights approach was not effective. The best refurbishment alternative for each city did not change when the weight changed. Normally, the weights are crucial for Multi-Criteria Analysis as they can influence the results. This was not the case because the best alternative results did not vary during the different scenarios, showing that the model implemented was robust.

Scenario	Almese	Bardonecchia	Bussoleno	San Giorio di Susa	Susa
Baseline	A2	A3	A3	A2	A2
Change 01	A2	A3	A3	A2	A2
Change 02	A2	A3	A3	A2	A2

Table 5.7: *Best refurbishment alternative for each case study, considering the PROMETHEE sensitive analysis.*

Source: Author, 2020.

The scenarios here were based on two-macro families defined by *Wang et al.* (2009): first (Change 01), with the same weight to each indicator; while the second (Change 02), ordering the criteria by importance. *Franceschini et al.*

(2007) says that the performance indicators have to be chosen to represent a scenario without omission or redundancy. To this extend, in order to verify the MCA with these properties, given by the authors as "exhaustiveness and non-redundancy", it was applied for this thesis an extra scenario for the case studies: Withdrawing the indicators that were redundant for them (EC2, EC3, EC5, EC6, EC7, EC8, EC10 and S1). Therefore, diving the weight equally with the remaining indicators, the weights shifted to 11% for each indicator, and the categories changed to Environmental (44%), Economic (33%), Technical (22%) and Social (0%).

The new proposed scenario results shown that even taking the redundant indicators out, the result was the same as in Table 5.7. This can reaffirm the robustness of the model, as it gave the same results as the other scenarios. Moreover, the Social category was redundant for all case studies, as it did not change for the different alternatives. Additionally, the Environmental category seems to be the most sensitive for all the cases, having the higher weight value in the new proposed scenario.

Making a different analysis, Figure 5.13 puts together the best retrofit alternatives and the respective KPIs for each case study in a Table. It also adds the information about the households directly benefiting from the project, with the focus groups in parenthesis (LIH and women). By doing this, it was possible to evaluate the retrofit alternatives between the cities and give a "preference ranking" to investment. The city Bardonecchia was the most preferred, followed by Susa, Bussoleno, Almese and San Giorio di Susa.

Bardonecchia is the case study with higher number of households benefiting, because the alternative will retrofit the existing DH and it covers all the city. For this reason, the city has the best performance in general due to the size of the DH and to its already built infrastructure. It explains the lower value of payback period and higher savings in energy expenditure. However, because of this, the running cost of Bardonecchia is also the highest one. This should be considered when implementing the project to assess the investment feasibility.

On the other hand, although San Giorio di Susa is the cheapest city to invest and to running the project, it is the city that has the worst performance in the environmental aspect (numerically). Besides this, it has a higher value of payback period. These can be explained due to the project's size, it is the smallest city of the study site and therefore it has the smallest different between the current and future scenario. Its retrofit alternatives are similar with the alternatives from the cities Almese and Susa. But their population are really different. Almese and Susa are the two most populated cities in the study site, respectively. This makes a great difference in the primary energy saving, on which San Giorio di Susa has the lowest value. In this way, San Giorio di Susa can be considered the most complex city to invest in the study site, needing more adjustments and detailed investment calculations.

Susa is the most expensive city for the investment. As cited before, it is one the most populated and the project will also benefit more than 1062 residences. These points explain the high value of investment, since the project has to be built from zero and benefit a large number of households. Notwithstanding these points, Susa has a good payback period, savings in energy expenditure and perform well in the environmental aspects, making it a great investment for the project despite the high value of investment. Bussoleno is the case study that will only benefit public buildings, in a total of three buildings. The project seeks to construct a small DH only for these buildings. It is a small project, which can explain the low investment cost and labor cost.

				Almese	Bardonecchia	Bussoleno	San Giorio di Susa	Susa
Best Refurbishment Alternative				A2	A3	A3	A2	A2
Households directly benefiting (focus groups)				365 (n.d.)	>1000 (50)	>200 (20)	150 (50)	>500 (50)
Environmental	ENV1	**Primary energy saving**	*[kWh/y]*	2.573.335	51.622.000	733.332	405.825	10.163.322
	ENV2	**Global emissions CO2 reduction**	*[kgCO2eq/y]*	515.079,00	10.332.659,00	146.784,00	81.230,00	2.034.000,00
	ENV3	**Local emissions NOX reduction**	*[kg/y]*	275,35	5.523,55	78,47	43,42	1.087,48
	ENV4	**Local emissions PM10 reduction**	*[kg/y]*	1,85	37,17	0,53	0,292	7,32
Economic	EC1	**PBP**	*[years]*	2,83	0,19	9,10	15,95	1,79
	EC2	**Investment cost**	*[euro]*	1.170.000,00	1.560.000,00	1.072.500,00	1.040.000,00	2.925.000,00
	EC3	**Public incentives**	*[%]*	30%	30%	30%	30%	30%
	EC4	**Savings on energy expenditure**	*[euro/year]*	289.500,19	5.807.475,00	82.499,85	45.655,31	1.143.373,73
	EC5	**Labor cost**	*[euro]*	270.000,00	360.000,00	247.500,00	240.000,00	675.000,00
	EC6	**Labor cost by a social cooperative**	*[euro]*	67.500,00	90.000,00	61.875,00	60.000,00	168.750,00
	EC7	**Material cost**	*[euro]*	900.000,00	1.200.000,00	825.000,00	800.000,00	2.250.000,00
	EC8	**Material cost purchased on the territory**	*[euro]*	90.000,00	120.000,00	82.500,00	80.000,00	225.000,00
	EC9	**Running cost**	*[euro/year]*	351.662,88	7.592.400,00	97.260,14	73.984,61	1.316.938,19
	EC10	**Certificates**	*[TAA/EEC]*	N/A	N/A	N/A	N/A	N/A
Technical	T1	**Increase of plant system efficiency**	*[%]*	0,63%	8,60%	7,90%	0,48%	0,49%
	T2	**Installed power reduction**	*[kW]*	0,0	104,0	366,0	0,0	0,0
Social	S1	**Architectural impact**	*[-]*	5	3	3	5	5

Figure 5.13: *Best refurbishment alternative for each case study and their KPIs, adding the households directly benefiting and (focus groups).*

Source: Author, 2020.

To conclude this Phase, the Multi-Criteria Analysis carried out showed that the best refurbishment alternative for each case study was always the last one proposed. This can be explained by taking a deeper look on the details of each alternative. Analysing the proposals, it can be observed that the main costs are constant, and it does not depend on the characteristic of the alternatives. They normally only changed the size of boiler, size of storage tank or capacity of the solar plant, but the built infrastructure cost remains the same for all the alternatives. Besides this, the alternatives increased the capacity of the boiler/storage/solar plant, and these can only have positive consequences, as the rising of the plant system efficiency.

It would be interesting in the future to analyse the case studies again, after a more detailed investment cost assessment and business plan with energy subsidies. This would change the values and refine the alternatives' indicators, giving a more reliable analysis of the best refurbishment alternative. Moreover, in the future, it would also be more precise to analyse the indicators per capita of the households that will be directly benefiting. The numbers in this Phase of the project are estimated, but a feasible number would help to understand the benefits and cost for each stakeholder.

5.2 Stakeholders involvement

The next Phase was to involve different stakeholders into the project. To this mean, it was conducted two workshops in collaboration with the SCORE partners Politecnico di Torino (PoliTo), La Foresta Soc. Coop., Consorzio Forestale Alta Valle Di Susa, Unione Montana Valle Susa and the Cooperativa Sociale AMICO. These workshops in the Susa Valley had the following objectives:

- Sharing the research activities and results of the SCORE project with the Susa Valley community, including the outputs of the **1st Phase** of this thesis;
- Raising awareness among stakeholders about the possible benefits of energy communities;
- Co-creating of scenarios for the definition of an energy community in the Susa Valley shared by all stakeholders.

These objectives led to engaging the stakeholders into the project with the aim at fostering co-ownership in renewable energy sources and boosting commitment. Besides that, the co-creation of scenarios provided information to evaluate impacts regarding the participants acceptance for the creation of the RECs. The workshops took into consideration that the energy communities promoted by the SCORE project seeks to involve and benefit all local stakeholders (citizens and public bodies) through democratic participation, highlighting the inclusion of women and low-income households.

Along these lines, a **preliminary workshop** was carried out on 07^{th} February 2020 in Almese, together with the social cooperative AMICO. The meeting was proposed as a preliminary stage, to identify stakeholders (especially vulnerable citizens, e.g., low income, unemployment, and single mothers) and invite them to participate later in the workshops. Within a semi-structured debate, the aim of this preliminary stage was, therefore, to give them some fundamental notions about the project topic and create a constructive debate. It was possible to understand some of the citizens' energy habits and problems that they are currently facing as the low efficiency of the building envelope and a high energy expenditure (for heating). This information supported the construction of the story spine and the schemes of the workshops subsequently.

Afterwards, on beginning of February 2020, the workshops organization was previously configured as a single physical meeting in a municipality facility in Bussoleno, in the Susa Valley. It was designed as a workshop with all stakeholders, in order to present the SCORE project and to make work groups using the Storytelling methodology. However, due to the social distancing COVID-19 restrictions during that period, the physical version of workshop was switched to the virtual one.

In order to increase the organization efficiency, the workshop was divided in two days involving different focus groups of stakeholders from Susa Valley municipalities:

- The **1^{st} Workshop** was held on **17^{th} April 2020** involving public administration members (e.g., mayors, public entities, SMEs);
- The **2^{nd} Workshop** was on **23^{rd} April 2020** engaging citizens.

Figure 5.14 describes the procedure to construct the workshops, going from the collection of research data to the construction of the main tools (i.e., WebGIS, Story spine, Zoom platform links, Google Forms).

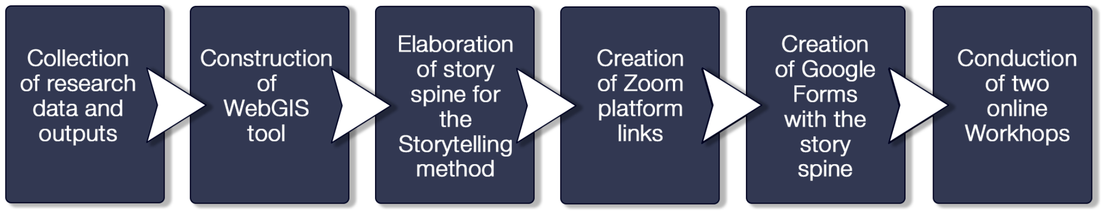


Figure 5.14: *The stages made to organize the workshops.*

Source: Author, 2020.

The participants were initially contacted and enrolled by local intermediaries (e.g., the social cooperative AMICO) through phone calls and e-mails. During the workshops, it was implemented a specific Research Design (RD) to aid the participants to create scenarios by providing a guide, which was flexible for different end users and types of action. Additionally, the WebGIS visualization and the Storytelling methodology were employed during the workshops with the aim at facilitating the participant engagement into the definition of current and future scenarios regarding the energy communities in the valley.

5.2.1 Data collection and WebGIS Visualization

For the first Step of the second Phase, all the data from the SCORE project and the study site were collected. The previous reports from the consortium and the results obtained in the first Phase of this thesis helped to elaborate the participative and inclusive workshops. Additionally, to help the end users and, essentially, the participants of the workshops, a visual tool was done to support the identification of the preferred energy efficiency solutions. The interactive WebGIS tool for the pilot of Susa Valley was developed by giving the impact estimation on buildings' energy efficiency in the pilot projects and the main information about them.

To create the WebGIS tool, three main stages were executed. They are summarized below in Figure 5.15, which identifies each stage and their main contents carried out to construct the interactive tool.

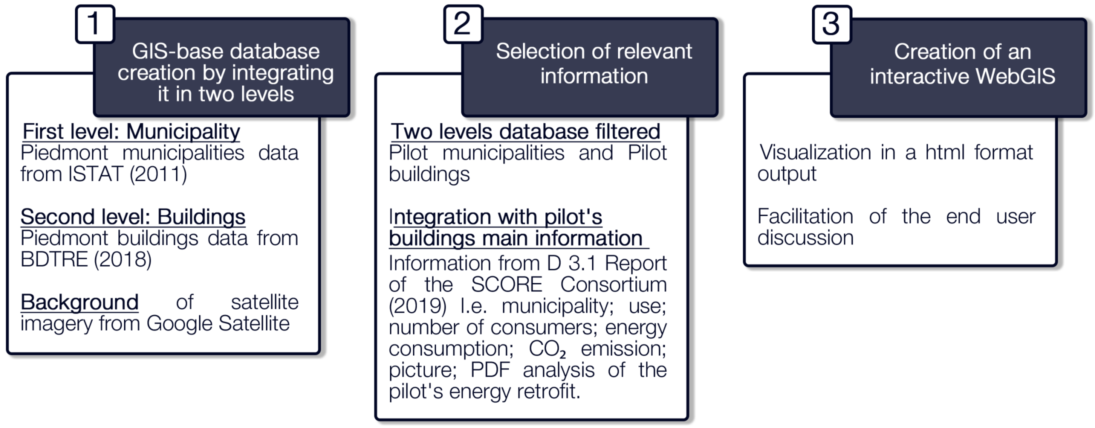


Figure 5.15: *The three stages of the WebGIS development and its contents.*

Source: Author, 2020.

Firstly, the essential database was collected through the Geographic information System (GIS) free open-source QGIS (3.4. version). The input data for the development of the database were composed in two levels: (a) the municipality level (e.g., municipality perimeter) from the ISTAT (Italian National Institute of Statistics) 2011 national Census database; and (b) the buildings level (e.g., building geometrical information, first floor typology) from BDTRE (Base Dati Territoriale di Riferimento degli Enti) 2018 regional cartographic database. The background of satellite imagery was obtained from the QGIS plugin Google Satellite.

Secondly, among those data, it was filtered only those data related to the project's pilots, as the municipalities and the buildings. It was created just one spatial layer (shapefile) with all those filtered merged data. All other main information about them were successively integrated into the pilot case studies with the information retrieved from the technical dossiers, i.e., *SCORE Consortium* (2019). Figure 5.16 illustrates these two stages through the data collection and the GIS data framework, which overlapped the filtered data and the information from the dossiers.

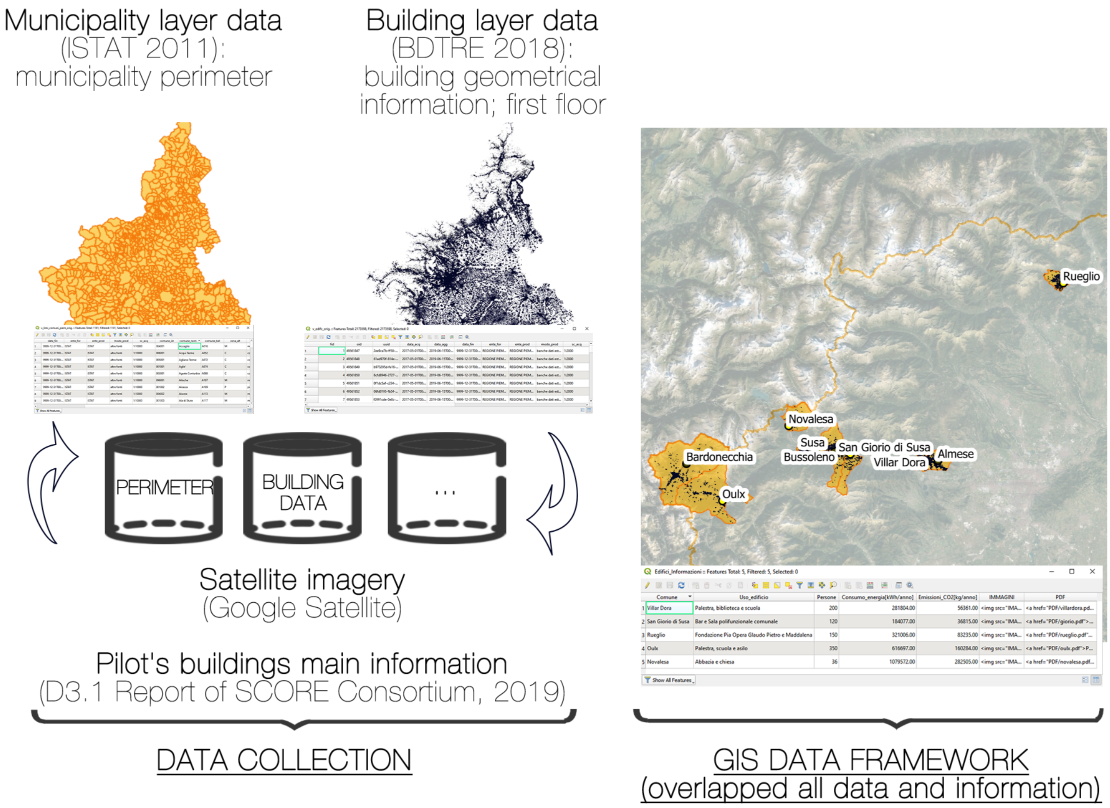


Figure 5.16: *The first two stages of the WebGIS visualization tool creation.*

Source: Author, 2020.

Thirdly, the interactive WebGIS was created utilizing the "qgis2web" plugin tool. It was configured for a better comprehension through a HTML format output, to facilitate the end user discussion. It can be access for everyone and simultaneously. In relation of the previous information added on the file from the dossiers, it was highlighted for pilot only the main information. It gives in a "pop-up" form an overview of the building plan for each city (e.g., use, consumers) and a current estimation of the pilot's energy efficiency (e.g., CO_2 emissions). In the annex PDF, it gives an energy impact estimation after the refurbishment. Figure 5.17 shows in details the tool (on the left) and the main information (on the right) gathered after an analysis of the dossiers/deliveries of the project.

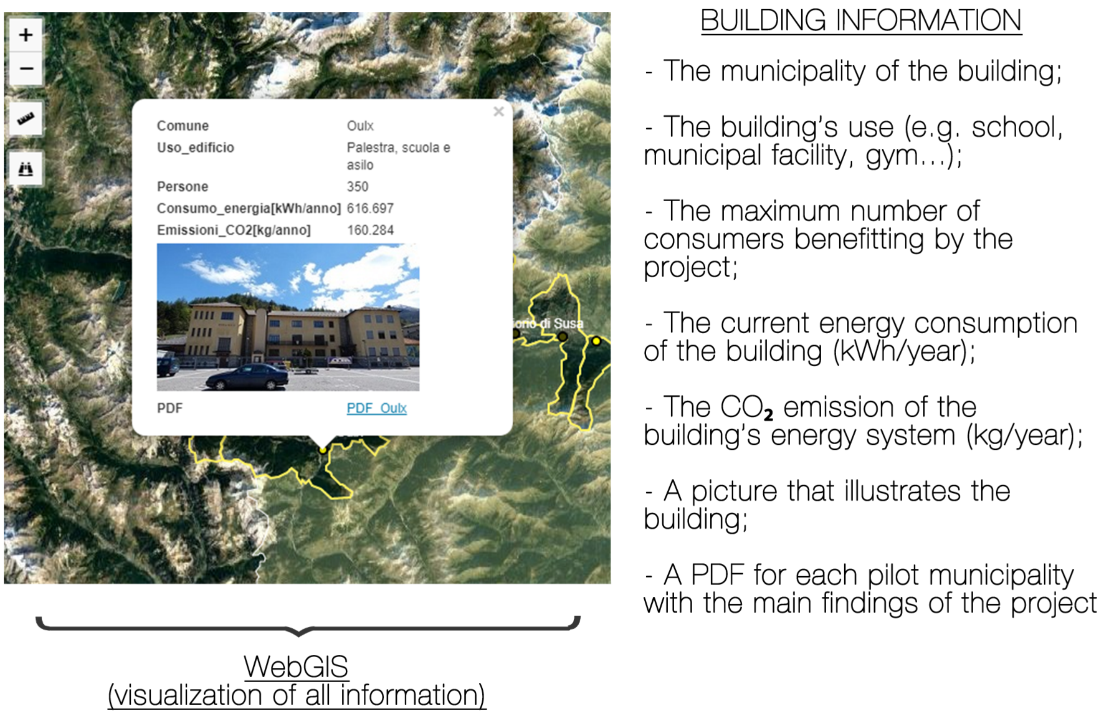


Figure 5.17: *The WebGIS visualization tool (on the left) and the main information added for each municipality (on the right).*

Source: Author, 2020.

Figure 5.18 shows the use of this visualization tool during the online workshop for the citizens. It helped the participants to visualize the research activities and the SCORE project results. So that they could visualize the current and future energy scenario, after the installation of RECs in their community. Therefore, it was a simple way to share with the stakeholders what has been done so far and to boost their perception of the possible benefits of the project.

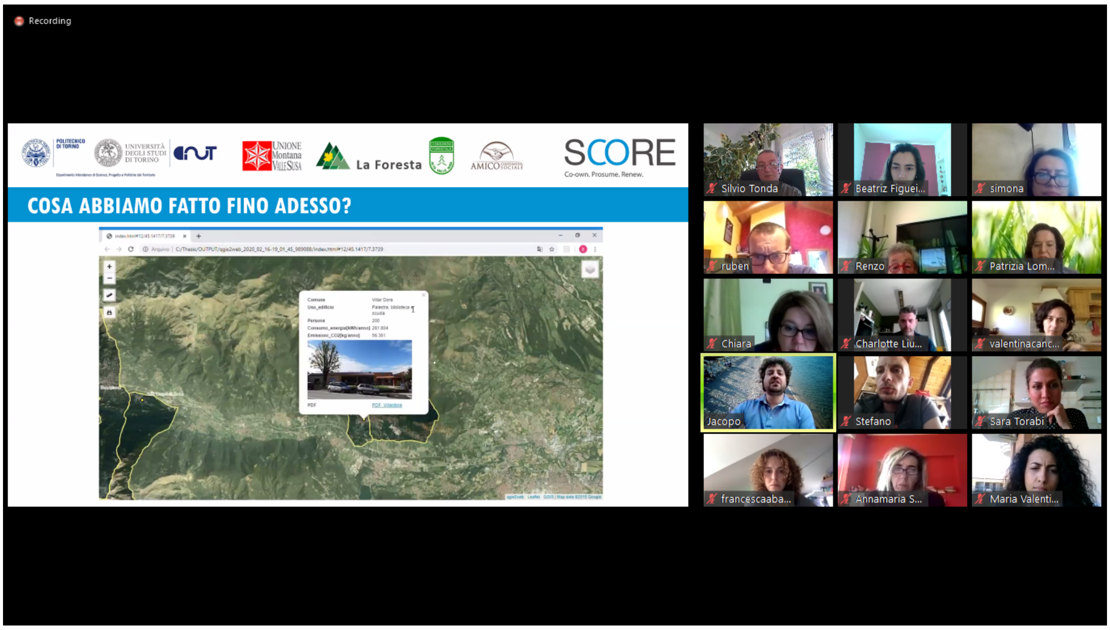


Figure 5.18: *The WebGIS visualization tool during the workshop for the citizens.*

Source: Author, 2020.

The PDF documents for each pilot municipality were elaborated following the dossiers' assessment and the results evaluation through the PROMETHEE method. It contains the following information, divided in three columns:

- The main current problems regarding the energy efficiency and retrofitting of the pilot (e.g., emission of fossil fuels combustion for energy generation, obsolete heat generation technology, loss of energy due to opaque housing materials...).
- Suitable retrofit proposals for the pilot (e.g., replacement of the boilers with a unique biomass-fired one, regulation retrofitting, insulation of walls/ slabs and re-placement of windows) and the selected retrofit for the project.
- The main benefits of the selected retrofit in relation of: decrease of the primary energy consumption (kWh/year); decrease of the global emission of CO_2 (kgCO_2eq); and finance benefits such as payback, public incentives, investment costs, material costs, labour cost, and labour cost by a social cooperative (these benefits were obtained using the methodology of the first Phase of this thesis, where the evaluation matrix and the application of the PROMETHEE method were made).

Figure 5.19 illustrates the PDF made for Oulx, one of the Italian pilots. The PDFs for other municipalities are further shown in Appendix A.

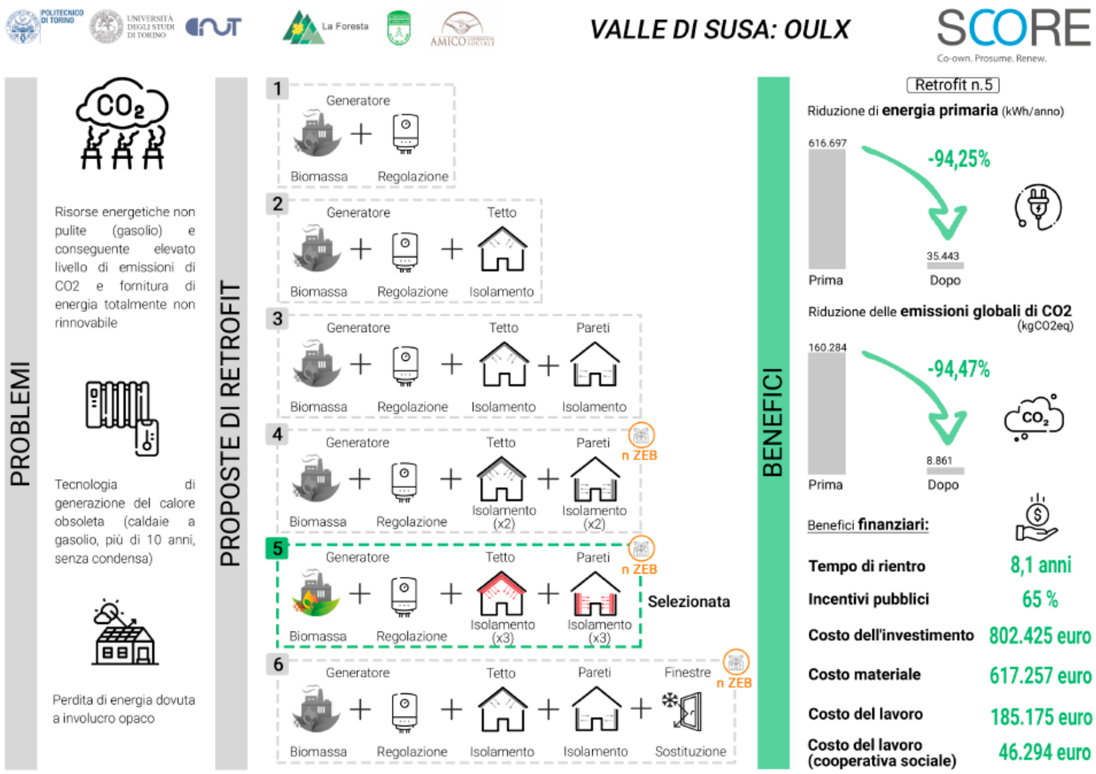


Figure 5.19: *PDF document containing the main research findings of the Oulx municipality (in Italian).*

Source: Author, 2020.

Thus, the WebGIS tool conveyed all the project data in a location-based information in a way that the participants could absorb and leverage the insights for a greater decision making. It was used on the municipalities of the Italian pilot, showing the building's main data and the refurbishment alternatives proposes. Moreover, the tool permitted presenting the information in a way to keep it simple and to initiate a good foundation for the storytelling methodology afterwards.

5.2.2 Workshops Set-Up

To start organizing the Workshops, it was defined the Story spine of the Storytelling method and how it was going to be applied on the workshops. It was decided to ask questions for the participants and request them to write via a web-based tool, because the workshops were made online and it needed to be interactive and effective. The story spine of the questions started demanding questions about the current situation of the energy in the Susa Valley and later, about how they think would be a future scenario when the Renewable Energy Communities were installed in their region. Considering these answers, the last question asked the participants to point strengths and weaknesses of this project, based on the stories before. Figure 5.20 illustrates the story spine adopted on the workshops.

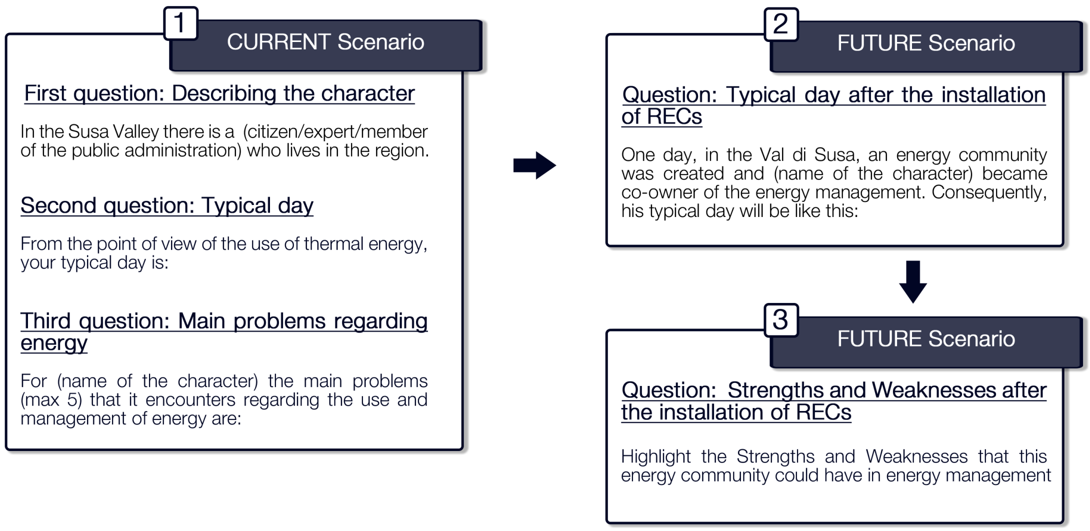


Figure 5.20: *Story spine adopted on the workshops, which is part of the storytelling method.*

Source: Author, 2020.

The two online workshops were made through the ZOOM Video Conferencing platform. Along with it, the online survey Google Forms was used to compile on time responses from the participants and to make the workshops more active and participative. Figure 5.21 shows the first survey that was shared with them to compile in the introduction, in order to know them better and understand their demands, whilst other Google Forms templates are shown in Appendix B.

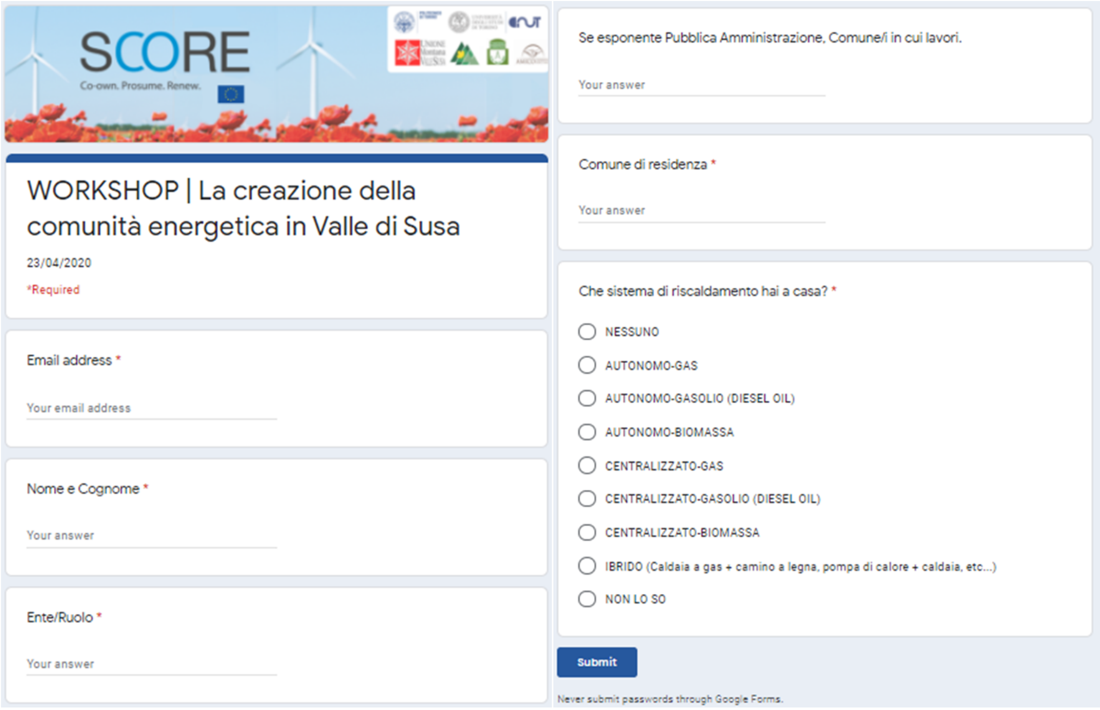


Figure 5.21: *The Google Forms template used during the workshop introduction.*

Source: Author, 2020.

In this way, the workshops were divided into four main parts and the Google Forms surveys were used each time as a tool to interact better with the participants:

i to familiarize with them, to collect personal information and their residence heating system.

ii in the first working group section, during the application of the Storytelling methodology about the current scenario in the Susa Valley. It asked them to briefly create a character and describe their typical day regarding the thermal energy habits. Later, to list five main problems about the use and management of energy.

iii in the second working group section, during the Storytelling of the future scenario. Participants were asked to imagine their characters in an eventual scenario after the installation of energy communities in the Susa Valley and after they became co-owners of the energy management.

iv on a plenary session to discuss and define collectively some strengths and weaknesses of the energy communities' project.

For the second workshop (citizens type) a small modification was made: while the creation of the future scenario through Storytelling was collective for the public administration, for the citizens it was changed to an individual Storytelling. Collective here means that, through the coordination of the workshop's mediators, the public administration participants elaborated together their future scenario along some discussions. Instead, in respect of the second workshop, the citizens elaborated separately their own story, submitted through the Google Forms survey and after it the discussion happened regarding each story. This change provided a better interactivity between the participants in the plenary session in respect to the illustration of the stories. Furthermore, in the elaboration of the weaknesses and strengths afterwards, the discussion was more enriched.

These tools proved to be an easy way to foresee the implementation of the energy communities and demonstrate the research developed so far. The Google Forms surveys were essential to interact with the participants in the online workshop model, aggregating their stories and answers on the same time they could look at other participants answers. It enabled us to use the Storytelling methodology and to still carried out the workshops during the unprecedented situation of COVID-19.

5.2.3 Participative Workshops outputs

Public administration Workshop

The first workshop was on 17^{th} April 2020 with six participants from the public administration of the Susa Valley. Members of the SCORE project supported and moderated the workshop during all the time, making sure that everyone had a voice and could participate equally. The participants were contacted through the known local authorities via e-mail or personal contact. Following an agenda, the workshop lasted four hours with three main sections: the introduction and the application of the Storytelling methodology for the current and future scenario.

In the introduction, it was briefly explained the project topics and the main research done so far. The workshop started asking the participants to answer the first Google Forms survey about their heating system (Figure 5.21). The public administration participants were from different entities/roles (mainly municipalities employees, technicians, and SMEs) and municipalities of the Susa Valley: Susa, Gravere, Oulx, San Giorio di Susa, Almese, Avigliana and Venaus.

Besides that, the participants answered about the source of heating system on their residence among autonomous biomass, diesel oil, gas or an hybrid system that combines more than one type (Gas boiler + wood fireplace, heat pump + boiler, etc.). Most of the participants have an autonomous gas system or an autonomous biomass system. Figure 5.22 shows the participants on the public administration workshop at the ZOOM Platform (online).

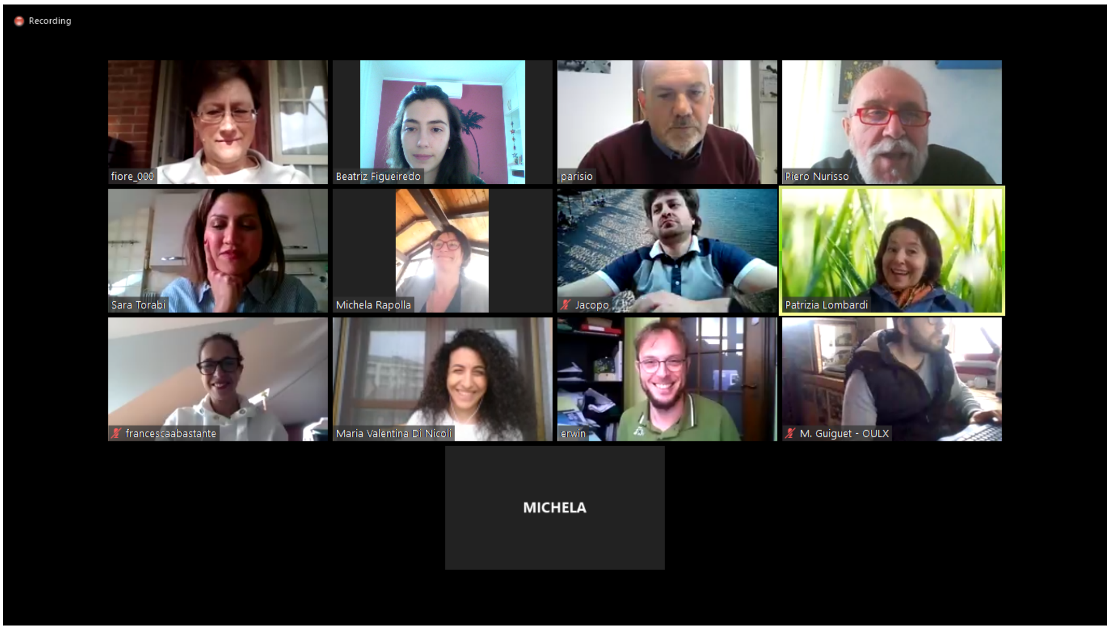


Figure 5.22: *Public administration participants in the online workshop.*

Source: Author, 2020.

After the introductory part, the second part was designed to collect the individual Storytelling about the current energy scenario in the Susa Valley. In this way, the participants were asked to fill the second online survey, which was the first part of the story spine. They created a character or even used themselves as example and answered some questions about the character's typical day life in relation to the use of thermal energy and some problems regarding it.

Figure 5.23 illustrates the written storytelling from one participant of the public administration workshop. In this example, the character is a man (34 years old) from Venaus and a local administrator working as a territorial planner. He wants to have a more sustainable consumption of the local resources and he thinks that this *"should be an added value of living in the Susa Valley"*. In his typical day, he goes to work in Turin by car and when he returns home, he turns on his wood-fired boiler. His main concerns are the energy efficiency of Susa Valley's housing; the poor public transportation system; and the lack of energy incentives and cost savings investments in the area.

Workshop **PUBLIC ADMINISTRATION (17.04.2020)** | The creation of the Energy Community in the Susa Valley

STORY SPINE 01 - Current Scenario

Participant 01
Residence City: **Venaus**

In the Susa Valley there is a ______________________________ (citizen/expert/member of the public administration) who lives in the region.
Describe the character in terms of age, career, job status, etc. Maximum 5 lines.

In the Susa Valley, there is a 34-year-old local administrator, named Artuso, who is a territorial planner. He would like to use the resources where he lives and works in a more sustainable and healthier manner. In a way to be respectful to the environment and more resilient to changes. Moreover, he believes that the resources consumption should be dynamic regarding the knowledge networks and well-being, and in an awareness and enriched context of the opportunities and limits of social relationships and the mountain context. These should be an added value of living in the Susa Valley.

From the point of view of the use of thermal energy, your typical day is ...
Describe the typical day of the character illustrated previously by focusing the story on its energy habits with respect to the heating system. Maximum 10 lines.

Every day Artuso goes to work in Turin with his own car, taking about one hour to go to his work and one hour back on the return. When he returns home, he turns on his wood-burning boiler which supplies heat for the whole unit where he lives.

For ____________________ (name of the character) the main problems (max 5) that it encounters regarding the use and management of energy are ...
List a maximum of 5 issues that you believe would be important to solve from the point of view of energy for heating. For example: expenses, transport of energy, etc.

For Artuso the main problems are:
- In the valley context, the real estate assets are mostly energy inefficient;
- The inefficient transport system: poor TPL; it does not meet the needs of residents and tourists and they are outdated transport facilities (private and public);
- Despite having sufficient energy production facilities to meet the total needs of the Valley, there are no incentives or cost savings investment in the area.

Figure 5.23: *Current scenario written by one participant from the public administration workshop.*

Source: Author, 2020.

The stories were analysed by reading them several times and highlight their main affirmations. By doing it, it was possible to understand more in deep their answers and correlate their answers between the other participants and also from the other workshop with the citizens. Regarding the other stories from the participants of this workshop (shown in Appendix C), it is possible to make some remarkable and briefly comments. The participants were classified afterwards in numbers, to preserve their identity.

For the first question, **Participant 02** (or more shortened, **P2**), wrote about a man that works in the energy sector. As he has two daughters, he thinks in *"a better future for the new generations"* regarding the energy system. He also knows that through his work he can help to construct a better environment and, therefore, support the energy transition for his daughters' future. **P4** character is a municipality mayor who has *"serious economic difficulties"*, intensified in this period of COVID-19 and post austerity. Besides this, he is worried that he has to buy a large amount of diesel every year to provide heat for a municipality school.

When illustrating their characters' typical day in the second question, some participants as **P1** and **P3**, commented about renewable energy sources (wood and/or solar PV) used to heat their house/offices. They also mentioned the use of different "modals" to obtain energy. **P3** said that he, as a *"freelancer and topographic technician"*, lives and works in the same house. He *"isolated his house externally through a cover and pvc windows with 22 mm double glazing"*, showing that he is aware of energy efficiency measures. Moreover, the participants also commented about their systems control, when they usually turn on and off the systems. **P5** gave several examples of energy uses in her typical day and how she already uses wood stove to heat her house. She commented that she learned to turn on the stove in *"wood energy seminars"*. This information was used to elaborate some recommendations in the end of the thesis based on the characters' experiences.

Moreover, in the last question, the public administration participants mentioned some problems they encounter when they use energy and some they see in energy management in the Susa Valley. Most of the problems were about technical issues, as energy storage (i.e., **P3** said that the main problems are *"collecting the large amount of heat produced by the heating system in summer to be able to use it in winter"*), distribution of heat supply (**P1**, **P5**) and energy efficiency improvement (**P1**, **P5**, **P6**). On the other hand, some talked about the lack of incentives (**P1**, **P4**) and bureaucracy (**P2**) in the Susa Valley. **P5** was concerned about environmental issues as *"control of stove emissions"* and necessity to *"check the* *forest's ability to respond to wood requirements"*. In the end, some participants also gave some thinks and suggestions to overcome the mentioned problems. **P4** said that as a mayor, he was thinking to address some taxes in the energy bills to reduce consumption. In order to have an answer to citizens *"economically and ecologically sustainable"* to overcome the financial issues and high consumption of diesel in his municipality.

After this first story spine, during the plenary section, participants were asked to share the stories and their daily life behaviour, regarding thermal energy in the current scenario in the Susa Valley. Some participants illustrated these scenarios and discussed how the thermal energy influence their daily choices. This contributed for the discussion among the participants, where they could find similarities between themselves, but also disparities, which allowed for new interpretations. Figure 5.24 shows the moment where one participant from the public administration workshop was telling his story to other participants.

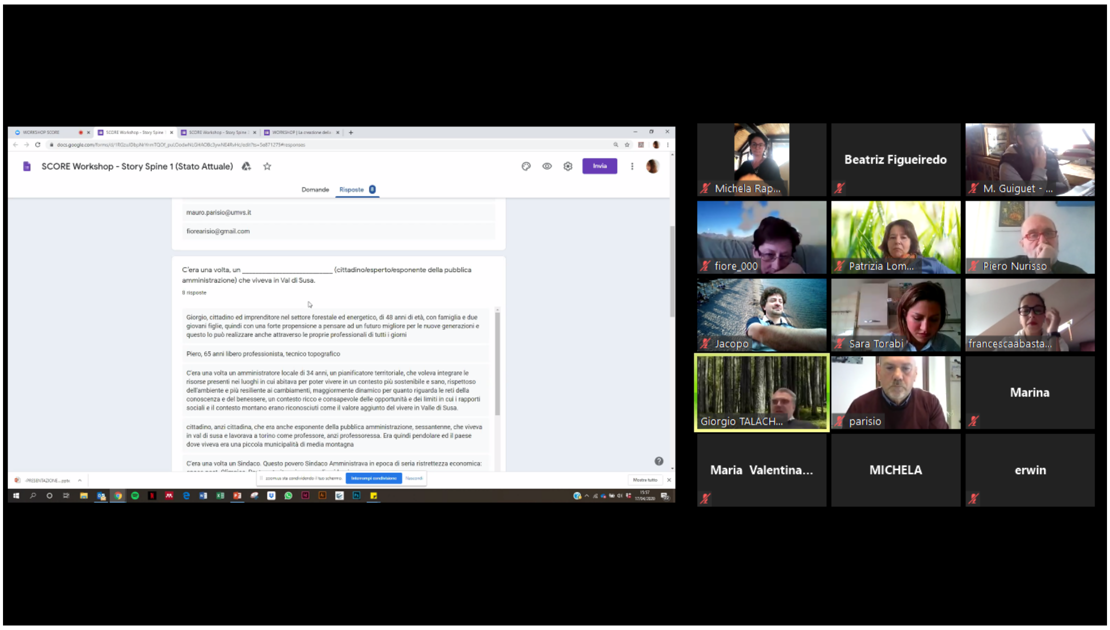


Figure 5.24: *Plenary session with one participant illustrating his current scenario story.*

Source: Author, 2020.

Following the individual creation of the current scenario, a co-creation scenario was carried out, which was supported by the SCORE group moderation. This second story spine was designed with the aim at creating collectively a future scenario for the energy community in the Susa Valley. The moderators asked how the participants' typical day would be after becoming a co-owner of the REC system. As they were public administration members, they co-created one collective and participatory story from their point of view in relation of the energy community. Figure 5.25 illustrates the future scenarios discussed. Most of them were linked to the transference of energy management from public administration to a co-ownership model, involving citizens participation. This would give more time *"to work in other things for the public administration"* as the *"energy community will be managed by someone else"*. Moreover, they said that REC will "free" them from "*domestic commitments"* and it will give an energy security with *"stabilized prices"*, giving a support to the public administrators. In the end, they said that EC will *"address and enforce the concept of community"*.

Workshop **PUBLIC ADMINISTRATION (17.04.2020)** | The creation of the Energy Community in the Susa Valley

STORY SPINE 02 - Future Scenario

Collective

One day, in the Susa Valley, an energy community was created and _______________ (name of the character) became co-owner of the energy management. Consequently, his typical day will be like this.

Imagine a future scenario in which the energy community is a reality and describe the typical day of a character belonging to this energy community. What is expected from the energy community?

For us, it is expected to have the following future scenarios:

1- More time dedicated to the management of the plants entrusted to other subjects (more time to work in other things for the public administration);

2- The energy community will be managed by someone else, the citizens (users) will be only the supervisor/ co-owner.

3- Regarding the independent houses (that have their own autonomous energy source), they will be the users who have the greatest differences in their typical day. They will change from autonomous management to centralized management. Therefore, they will have less effort in energy management, and it will be entrusted to others.

4- It will free yourselves (public administration) from domestic commitments; we will have stabilized prices; and we will have security that the service will be done as it is entrusted to others but, at the same time, we can check if the work have been done.

5- It will address and enforce the concept of community in the Energy Communities (EC).

6- It will give support for the public administrators.

Figure 5.25: *Co-creation of future scenarios (collectively) by the participants of the public administration workshop.*

Source: Author, 2020.

In a way to illustrate the stories of participant **P1** during the workshop, Figure 5.26 represents, in a type of illustration drawing, those scenarios (current and future). In the first scenario on the left, it describes his daily life and his main energy problems regarding the current situation in the Susa Valley (no incentives and no energy efficiency in the buildings). After that, on the right, the drawing illustrates his future scenario. It shows what he thinks it would look like after the energy community has been deployed. He could have more time to engage in different types of administrative issues in the city when energy issues would be managed by a consortium made up of public and private partners.

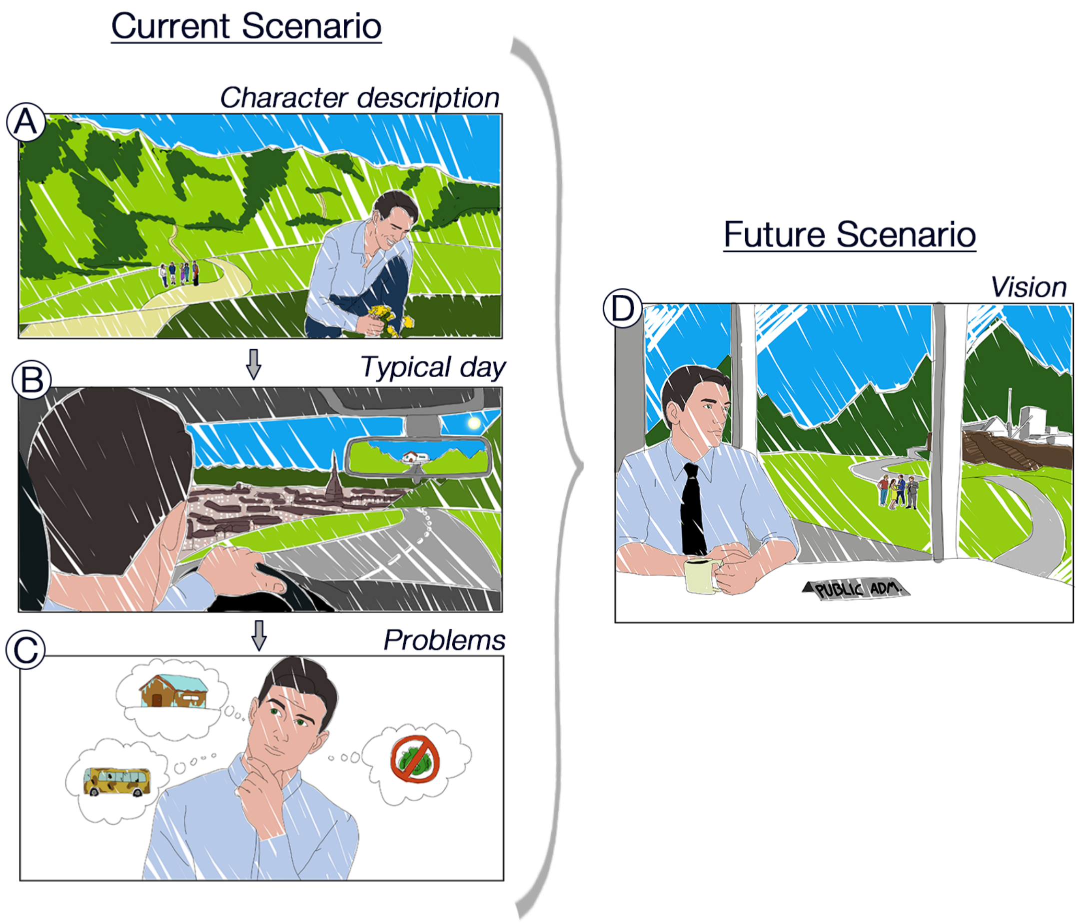


Figure 5.26: *Illustration of the story narrated by the public administration participant in the creation of the current (left) and future (right) scenario of the renewable energy community in the Susa Valley.*

Source: Igor Terror and Author, 2020.

In this way, the next story spine was to ask them which are the strengths and weaknesses they think this energy community could have in the energy management. Different points of views and perspectives were listened and written. The information collected is an example of how the stakeholders comprehend the project, and which are the meaningful characteristics of the energy community for them. Table 5.8 illustrates all the weaknesses and strengths addressed by them.

Strengths	Weaknesses
1- Use of local resources 2- Creation of a sense of community among the citizens 3- Rationalization of consumption 4- Increase of security in energy management 5- Reduction of energy expenditure 6- Energy autonomy for the electric (car park) 7- Forest management 8- Rationalization of other renewable energy sources (photovoltaic, hydroelectric, ...) than existing systems. Solving the problem of characteristic discontinuity of renewable energy 9- Decrease in air pollution 10- Social aspect, attention to vulnerable groups (social inclusion)	1- Conversion costs: what sources can be use and how much should be investing 2- Operating costs 3- Logistics (e.g., distance from the plant) 4- Difficulty in establishing the Energy Communities (EC) 5- Bureaucratic-normative issues 6- Critical points in the beginning of the EC (e.g., social inclusion: it is not automatic; it has difficulties due to the land poverty) 7- We need to have a good communication: the benefits must be understood among the citizens. We must motivate! 8- Internal management with different stakeholders. Those who manage must know how to mediate people's interests with different objectives (citizens, private, public etc.) 9- We need to know how to manage a forest

Table 5.8: *Strengths/ Weaknesses addressed by the participants of the Public Administration workshop.*

Source: Author,2020.

Citizens Workshop

The second workshop was on 23^{rd} April 2020 with eleven participants, citizens from the Susa Valley municipalities. Members of the SCORE project supported and intermediate the workshop during all the time, making sure that everyone had a voice and could participate equally. The participants were contacted during the preliminary meeting and through the known local authorities via e-mail or personal contact. Following a similar agenda to the previous workshop, this workshop lasted four hours with three main sections: the introduction and the application of the Storytelling methodology for the current and future scenario. The citizens were from all the Susa Valley region, but mostly from the cities Susa, Bussoleno and Chianocco. Their residence heating system are autonomous biomass or gas; a hybrid system that combines more than one type

(Gas boiler + wood fireplace, heat pump + boiler, etc ...); or none of them. Most of them had the hybrid system, follow by the autonomous gas system. Figure 5.27 shows the citizens participants of the online workshop at the ZOOM Platform.

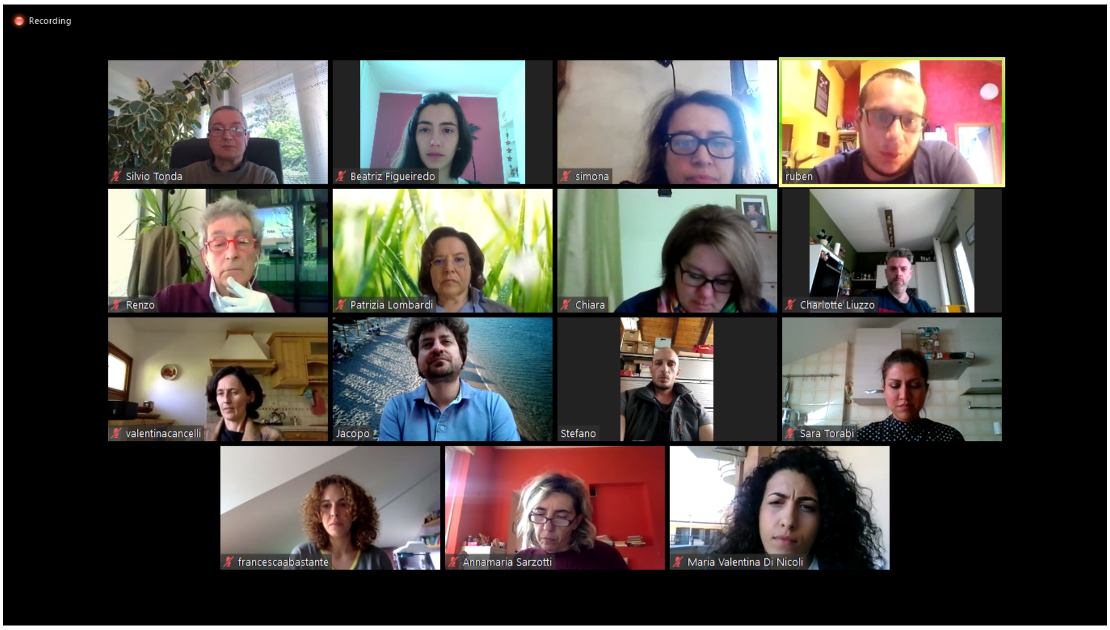


Figure 5.27: *Citizens participants of the online workshop.*

Source: Author, 2020.

After that, the methodology and the objectives of the workshop were explained for the participants. Figure 5.28 shows this moment, where it was presented the objectives of the workshop: sharing the project research outputs with the Susa Valley community; creating awareness among them about the project benefits; and co-creating scenarios to define the energy community in the Valley that is shared between all stakeholders. Afterwards, instructions were given about the workshop and, in particularly, about the Google Forms surveys tool, the Storytelling methodology and the plenary sections during the discussions.

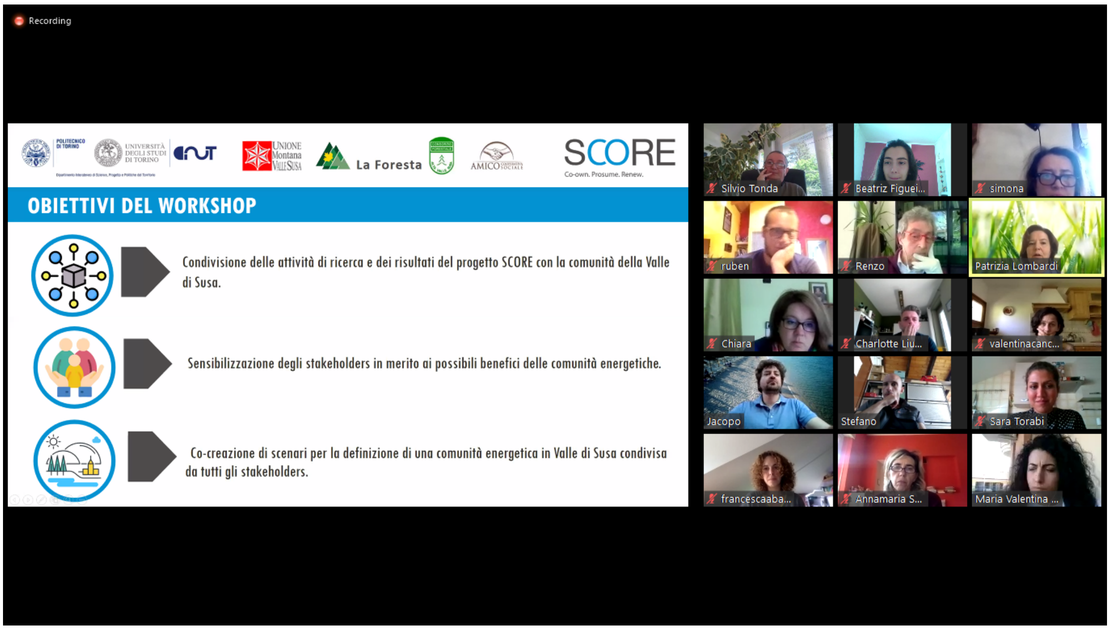


Figure 5.28: *Objectives being illustrated during the workshop.*

Source: Author, 2020.

Following the introduction, the second and third Google Forms surveys were about the construction of the current and future scenarios using the methodology of the individual storytelling. Although in the first workshop the construction of the future scenario was collective, as explained in Subsection 5.2.2, on this second workshop it was individual. Therefore, they discussed their stories in the plenary section afterwards and we had more time for discussions and personal insights.

Figure 5.29 shows a written story of one citizen participant, Participant 1 (**P1**), about the current scenario. He is a citizen from Chianocco, in the Susa Valley. He works as a farmer with fruits and vegetables and at night he goes to dinner and *"really likes this moment with his family"*. He has energy saving devices at his home and working place and in this way, he can schedule the heating time of his boiler for the morning and during the meals (lunch and dinner) at home *"to be warm and comfortable for his family members"*. He already uses renewable energy sources as photovoltaic panels and *"energy-efficiency home appliances"*. However, for him, the main problem regarding the use and management of energy is to have money to invest and implement these energy saving technologies. As he states that he does not have *"the possibility of obtaining funds to strengthen his ideas regarding energy savings"*.

Workshop **CITIZENS (23.04.2020)** | The creation of the Energy Community in the Susa Valley

STORY SPINE 01 - Current Scenario

Participant 01
Residence City: **Chianocco**

In the Susa Valley there is a ____ (citizen/expert/member of the public administration) who lives in the region.
Describe the character in terms of age, career, job status, etc. Maximum 5 lines.

Ernesto is an honest citizen of the Susa Valley who works as a farmer. In the morning he wakes up early and goes to work in the fields of small fruits and vegetables. In the afternoon he takes care of the administrative part of his business. In the evening he returns home to his family for dinner. Ernesto really likes this moment with his family with the sharing of their day.

From the point of view of the use of thermal energy, your typical day is ...
Describe the typical day of the character illustrated previously by focusing the story on its energy habits with respect to the heating system. Maximum 10 lines.

Ernesto sets up the boiler to turn on at 5:00 in the morning in the winter to allow the house to be warm and comfortable for his family members. He also scheduled the heating for lunch time and dinner. Ernesto has purchased energy-efficient home appliances over the years. He has a photovoltaic system on the roof of the house and on the company building. For the summer, he uses a heat pump to cool the rooms.

For __________________________ (name of the character) the main problems (max 5) that it encounters regarding the use and management of energy are ...
List a maximum of 5 issues that you believe would be important to solve from the point of view of energy for heating. For example: expenses, transport of energy, etc.

For Ernesto the biggest problems are the possibility of obtaining funds to strengthen his ideas regarding energy savings. He would also like to install a turbine (hydroelectric power plant to produce energy for his packaging works, etc.) in the land where he works but currently, he does not have the money to do it.

Figure 5.29: *Current scenario written by one participant from the citizens workshop.*

Source: Author, 2020.

Following the same methodology of the first workshop, the stories were analysed by reading them several times and highlight their main affirmations. The other stories from the participants of this workshop are shown in Appendix D. The participants were classified in numbers, to preserve their identity.

For the first question, **Participant 11** (or more shortened, **P11**), wrote about a man that works in a company and it is *"sensitive to environmental issues"*. He is considering *"the possibility of changing the heating method"* and for this means, he will purchase pellet stove. This choice is because he may be able to purchase collectively with his company colleagues a wholesale pallet. Moreover, **P3** is a man, freelancer, that considers himself *"active in the socio-cultural context of the area"*, and it was the only participant that later comments about a *"political-business lobby"* that imposes *"strategic choices"* for the community, without collective and weights decision makings. Besides this, **P5** is a woman, who *"does not have much time to explore topics that interest her... She is always so tired!"* However, *"heating is a big concern for her, both from organizational and an economic point of view"*. **P6** is a man who starts building a *"semi-total energy independence"*, although he has a big opposition by *"many people and mainly his relatives"*.

Telling their energy daily habits in the second question, **P2** says that he *"likes to stay in a warm environment"* and because of this, he turns on his heating. **P3** lives in an apartment with his family and through his *"independent natural gas"* heating, he *"programs the temperature of the local according to the requests of the family members"*. **P4** is a woman, who has a pellet fireplace and keeps it on all day and in the evening, she turns on also the wood stove. **P5** have a wood-fired boiler and a gas boiler, that interchanges as she needed. *"As the wood source is given to her, she prefers to use the wood stove"*. However, she does not have a regulation system and a thermostat, and it heats up every day. But she says that in this way *"she never stays in the cold"*. **P6** has fun understand the energy *"real operating feasibility"*. He thinks that energy savings is a *"form of pension"* and it is an investment that will *"lead to well-being"*. **P9** is a young man, owner of a restaurant in the Susa Valley. He uses gas boiler and spends *"too much money"*. And to shift this situation, he *"changed several utilities"*, slightly improving his last situation. **P8** does not have a good system of heating and his dream is to go home and find a comfortable temperature to stay with his partner. **P9** and **P10** have a heating program system and thermostat.

For the last question about use and management of energy, as for the first workshop, this workshop also had several regarding technical issues. For example, the issue of program the system effectively (**P2**, **P5**, **P7**, **P8**), the home appliances without energy efficiency (**P2**, **P5**, **P7**), without a properly place to store their wood sources (**P2**) and also the quality of the wood used make the house unable to remain warm during the day (**P8**). However, in this workshop the complaining about political and financial issues were higher. **P3** said that because the energy sources are centralized, the lobbies control more the systems. He also comments about *"the complexity and low transparency of tariff"*. **P11** says that the source of the boiler is expensive and it *"requires refuelling by a company that must be notified days before"*. **P5** states that *"energy and above all, heating, should be a right for all people"*. She says that the gas bills are really high and *"through her work she gets to know a lot of people who are unable to pay gas and electricity bills"*. She thinks *"people should become more aware of the processes that allow to have energy in your home and understand how a system works"*. **P10** also complained about the management fees that are charged on the bill. Moreover, **P8** says that he and his partner would like to buy or renovate their house, but *"the precariousness of the work does not allow them to face this expense and (because of the bureaucracy) they are not able to access incentives"*. **P4** claims about the environmental issues and social issues of having an energy company not from the region, the energy *"comes from far away and it gives work to people far away"*. Also, this energy can be produced in countries where the *"environmental pollution is underestimated"*.

After the writing of the current scenario stories, a plenary section was made, and the participants were asked to share their stories and explain their daily life behaviour regarding thermal energy. Some people illustrated it and talked about how the thermal energy influence their daily choices as a citizen in a Susa Valley municipality. As for the first workshop, this contributed to find similarities between them (e.g., same economic issues; same behaviour regarding the heating methodology of their homes with hybrid system to spare money). Or even some disparities (e.g., the use only with biomass or the hybrid system) that allow new interpretations by sharing challenges and experiences. Figure 5.30 shows the moment where one citizen was telling his story for other participants.

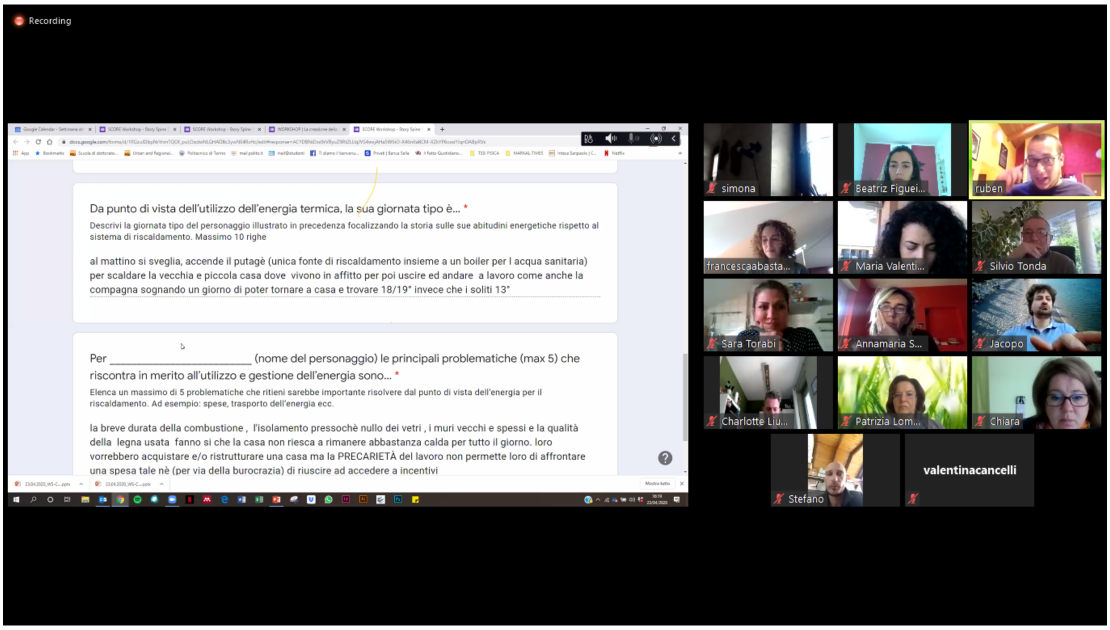


Figure 5.30: *Plenary session with one participant illustrating his current scenario story.*

Source: Author, 2020.

Following the creation of the current scenario, another storytelling was applied to create a future scenario for the energy community in the Susa Valley. Figure 5.31 illustrates a scenario made by one participant of the citizens' workshop. He says that now (after the installation of the energy community) he finally managed to install the hydroelectric plant he wanted for a long time. He is *"fulfilled his dream"* and it is *"very happy with this innovation"*. He is now a *"part of the energy community"* and as the technology is super productive, he can also produce energy for his neighbourhood.

Workshop **CITIZENS (23.04.2020)** | The creation of the Energy Community in the Susa Valley

STORY SPINE 02 - Future Scenario

Participant 01
Residence City: **Chianocco**

One day, in the Val di Susa, an energy community was created and ____________________ (name of the character) became co-owner of the energy management. Consequently, his typical day will be like this.

Imagine a future scenario in which the energy community is a reality and describe the typical day of a character belonging to this energy community. What is expected from the energy community?

Ernesto is part of the energy community of the Municipality of Chianocco. He finally fulfilled his dream of installing the hydroelectric power plant on his land, to produce electricity for his packaging processes, etc. He is very happy with this innovation also because the turbine he installed is more powerful than he had dreamed 10 years ago, so with this new turbine he can also produce energy for some of his neighbors.

Figure 5.31: *Future scenario written by one participant from the citizens workshop.*

Source: Author, 2020.

The stories about the future scenario of the other participants are shown in Appendix D. Although three participants of this workshop did not participate specifically in this story spine (**P5**, **P10** and **P11**), it was possible to obtained great stories from the remaining eight participants. **P2** said that although he does not have a lot of savings and did not make a large investment, he still joined the energy community. He has been able *"install thermostats to optimize the heating"* and he could reduce his fuel consumption, **P3** invested 5.000 euros in the energy community. He said that was difficult to find an agreement and decision making between the multiple project stakeholders. And despite the investment did not *"produces significant direct economic results"*, he already sees *"results both locally and supra-local"*. *"People are employed in the production chain and in construction"*, the *"confidence has also increased in the future"* and there is *"a long-term economic advantage"*. The house of **P4** is warmer and more comfortable now, but the cost of heating has not gone down. **P6** commented that the EC did not disrupt his life, because he is *"enjoying the energy saving, energy production and the satisfaction of using a free source"*. He said that it is *"something to teach and encourage men"*. His has extra security and respect the environment, by consuming less resources. **P7** would like that the excess of energy produced (e.g., from her photovoltaics panels) to remain in the territory and *"maybe it would be stored and redistributed even in the evening"*. She would also like that through the EC, she had more access to *"precise and simple information"* or even *"more access to subsidized loans"*. With the EC, **P9** could solve his problems and did not need to close his business, because he integrated his boiler with solar panels and insulate his house. **P8** said that he is *"now a member of the energy community"*. He wakes up in a *"heated environment"* and *"pollutes less"*. As he bills are a little lighter, *"he can go out for dinner in the restaurant of his city and therefore making more money run inside the community"*. He also thinks that EC is a *"small step towards the realization of a wider idea of community"*, that could be also extend to creation of agricultural communities.

Figure 5.32 represents the scenarios (current and future) described by participant **P1** of the citizens workshop. In the first scenario, on the left, he describes his daily life working in a farm and his administrative business, having dinner with his family. He has a heating system and energy efficiency appliances, as solar panels. But he still thinking to implement more sustainable devices, although he does not have any fund or money to invest on it. Afterwards, on the right side, in the creation of the future scenario he imagined the implantation of his sustainable ideas in his land and an energy share between the community.

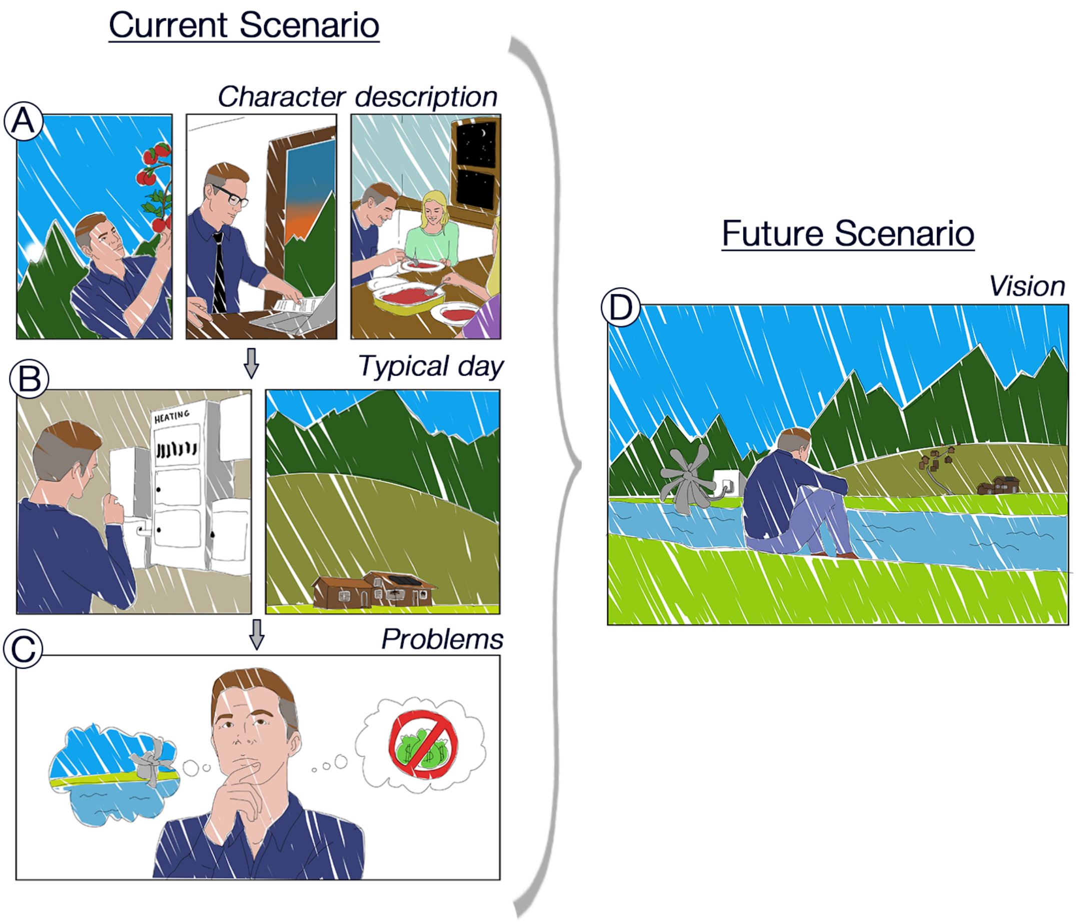


Figure 5.32: *Illustration of the story narrated by the citizen participant in the creation of the current (left) and future (right) scenario of the renewable energy community in the Susa Valley.*

Source: Igor Terror and Author, 2020.

Following the scenarios creation for the community energy in Susa Valley, a discussion was carried out by the SCORE group with the participants in order to illustrate some of the written future scenarios and potential conflicts, doubts, or certainty. In this way, the next step was to ask them which are the strengths and weaknesses they think of this energy community. As in the first workshop, different points of views and perspectives were listened and written. This information was aggregated at the same time with a google survey and in the end, it gave to the group an idea how the stakeholders comprehend the project, and which are the meaningful characteristics of the energy community for them. Table 5.9 illustrates all the weaknesses and strengths addressed in the workshop with the citizens.

Strengths	Weaknesses
1- Cost reduction 2- Better use of energy 3- Better comfort 4- Possibility to use in the production chain 5- Transparency of information 6- Better management of consumption 7- Use of local resources 8- Better environmental conditions (external) 9- Investment confidence (following precise information) 10- Less dependence ("release") from large energy multinationals 11- Not just biomass! Openness to various energy sources	1- Shared decisions (element of uncertainty) 2- Investment in non-owned properties (for how long?) 3- Innovation of the Energy Communities (EC) model (e.g., regulatory point of view) 4- Proximity of buildings (essential for thermal energy, no problem for electrical energy)

Table 5.9: *Strengths/ Weaknesses addressed by the participants of the Citizens workshop.*

Source: Author, 2020.

Discussion of Phase 02 results

The stakeholder's involvement on the workshops can be analysed after the assessment of the online surveys and the participation during both workshops. Firstly, in the introduction, the participants had to answer the survey about their personal information and residence heating system. The participants were mostly from all the region of Susa Valley, having the maximum (two citizens and one public administration) from the city of Susa. Figure 5.33 shows their city of residence on both workshops. In this way, these workshops covered a considerable part of the Susa Valley and it was possible to understand different points of view regarding different locations of the stakeholders.

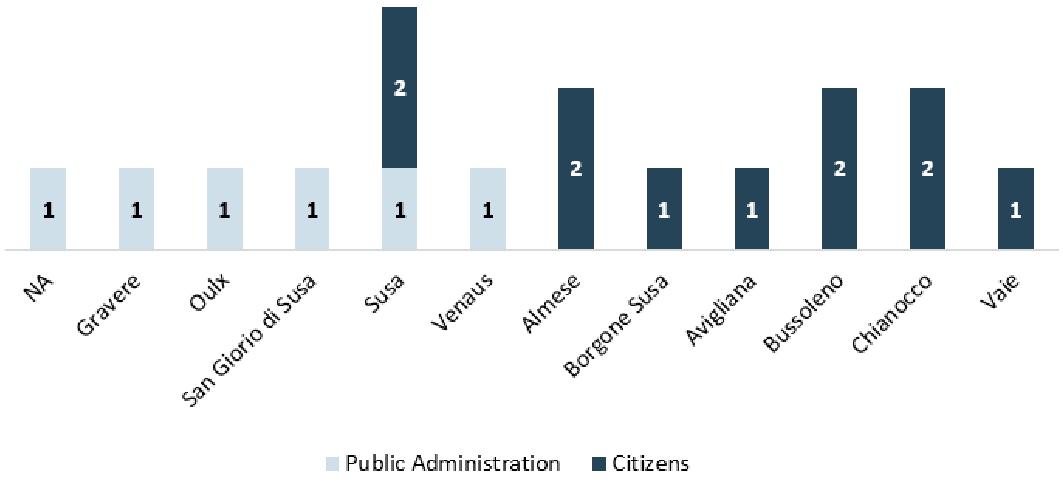


Figure 5.33: *Number of participants per residence city of both workshops.*

Source: Author, 2020.

Secondly, the participants answered what was the source of heating system on their residence among autonomous biomass, diesel oil, gas or a hybrid system that combines more than one type (Gas boiler + wood fireplace, heat pump + boiler, etc.). Mostly had a hybrid system or an autonomous gas system. In the public administration the system of autonomous biomass was higher while among the citizens the hybrid system was the most common source used to residence heating (45%). This could characterize a demand, from the public administration part, for systems that are independent or less independent from the carbon sources (gas/diesel). Either because it is less expensive or because of environmental/ecological reasons. Figure 5.34 shows their answers about the heating systems clustered in graphs.

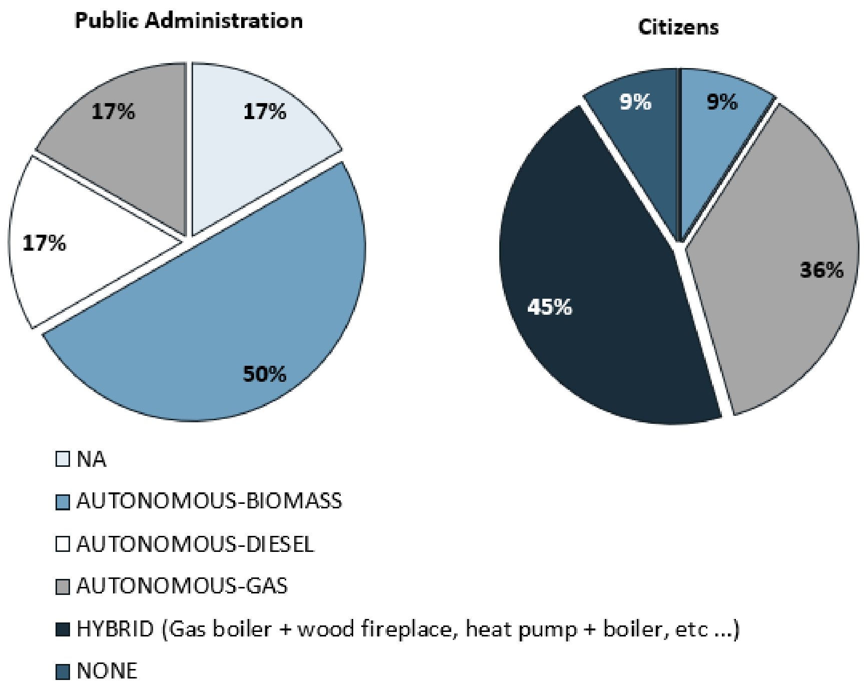


Figure 5.34: *Percentage of the type of residence heating system from both workshops participants.*

Source: Author, 2020.

Thirdly, although in the workshops they had to describe a character, mostly of the participants described similar characteristics with real life. Therefore, this analysis is not real, but it has some similarly with reality. Their age and gender, answered in the first story spine in the workshops, were really mixed. The first workshop had 6 participants in total, where five were men and just one was woman. The age range varied from 34 to 60 years old. On the other side, in the citizens workshop were eleven participants, being seven men and four women. The age range varied from 29 to 57 years old. In this way, the last workshop was the one with more women participating and the one with higher difference of age.

Fourthly, for the scenarios creation of the Susa Valley and the application of the Storytelling method, the analyses of the stories are extending and complex. The details were commented in the last sections and the complete stories are in Appendix C, for the public administration workshop, and Appendix D, for the citizens workshop. Some general conclusions can be made about this, in order to have an overall understanding. In general, the public administration members were more contained in their stories, without much detail and examples. This may have been because of the position they occupy and their interests. Also, the discussions in the citizens workshop were more enriched and more engaged than the ones with the public administration members.

About the stories, for the current scenario, the public administrations members commented more about their typical day related to their personal life, which complicated to understand their role in the municipality administration. Besides this, their energy related typical day were more relate to different types of renewable sources than the citizens workshops (in this one they commented more specifically about wood, pallets, and PV). Following this, it is interesting to observe that the RES chosen for the Italian pilot (biomass) is a resource that they already use and know their characteristics. No wonder it was the resource chosen by the consortium. In addition, public administration participants talked more about the situation in a future prospective (e.g., for the next generations, after the pandemic crisis), while the citizens in general retained their rhetoric in the present (e.g., no money now, energy inefficiency of the buildings). In summary, the problems reported in the first workshop were more about technical issues (e.g., energy systems function, rationalization of energy), with few about financial, bureaucracy and environmental. On the other side, the problems approached by the citizens were from diverse spheres of sustainability: environmental, social, financial... They were concerned about centralized energy systems, no incentives, low transparency, environmental pollution, local jobs, no knowledge of energy topics and high bills. Along these lines, it is interesting to observe that these problems approached in the workshops could be solved with the CSOP model and the co-ownership in RECs suggested by the SCORE project.

For the future scenario, the stories of the public administration were a co-creation in a plenary section. This made their stories less individualized and more guided by the moderators of the workshop. The main points for them in the creation of RECs are the energy security and the support this project would give for them. It would give them more time to address other issues of the community and therefore, improve the administration in the municipalities. On the other side, as the citizens workshop the creation of the future scenarios were done individually, it was possible to achieve more diverse answers. Through their stories, it was possible to see that they trust in the project and they see it as a solution for some of their problems and as a form of security.

Fifthly, it was to ask to them which are the strengths and weaknesses they think this energy community could have in the energy management, previously showed for each workshop in Table 5.8 and Table 5.9. Along these lines, these weaknesses and strengths were classified in four types: Environmental (e.g., decrease in air pollution); Economic (e.g., reduction of energy expenditure); Technical (e.g., logistics, less distance from the plant); and Social (e.g., attention to vulnerable groups). Figure 5.35 illustrates the results of this classification for the two workshops in percentage, separating it between the two workshops and the weaknesses/ strengths. For the citizens and the public administration, most of the weaknesses of the project are about technical issues, although the last one has higher percentage (33%) in social weaknesses than the first one (25%). However, for the strengths, the public administration has a more balanced percentage among the four types, while the citizens have most of the strengths about economic topics (45%) and less about social topics (9%).

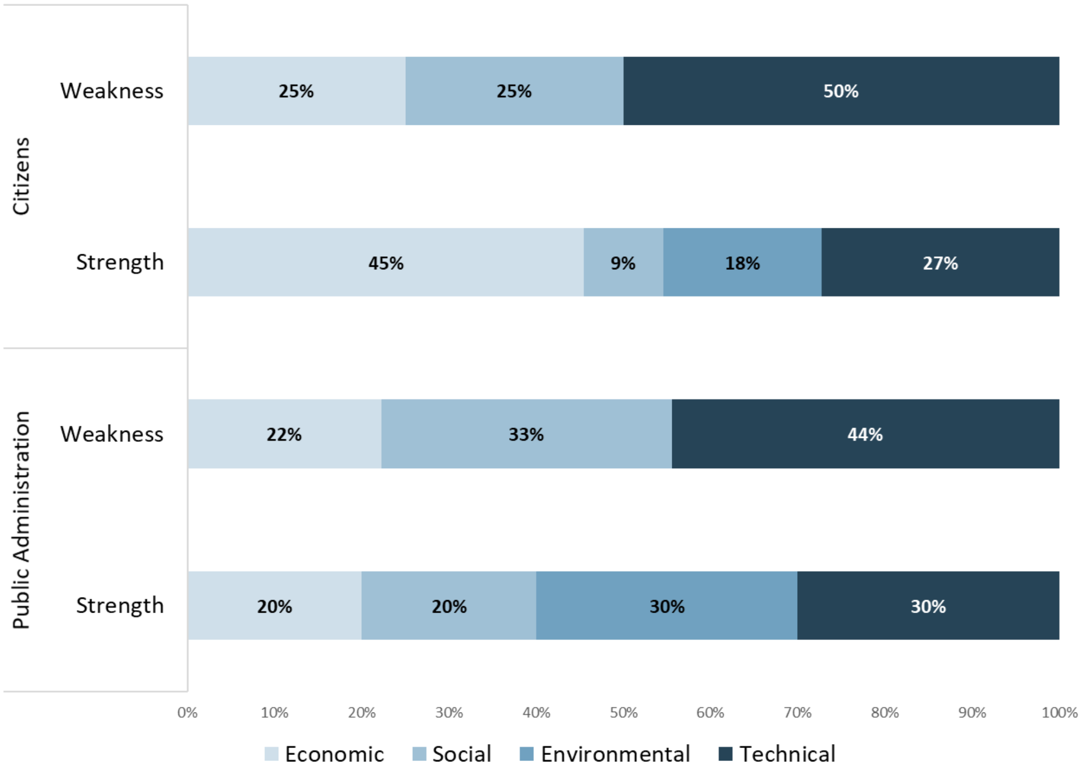


Figure 5.35: *Weaknesses and Strengths addressed on both workshops.*

Source: Author, 2020.

Besides that, these strengths and weaknesses were analysed, and it was found equivalent points addressed of both workshops, illustrated in Table 5.10. The use of local resources, better use and consumption of energy ,and also a cost reduction were similar points addressed, that both types of stakeholders think they are good points of the energy community project in the Susa Valley. However, both types of stakeholders think that involving different types of stakeholders must be in an efficient way manageable to have a feasibly project. Also, normative and bureaucratic issues are a concerning among them, which were always mentioned during the workshops. Moreover, their similar weaknesses regarding the technical issues could be solved after showing the project's details elaborated by the consortium.

Strengths	Weaknesses
- Use of local resources - Rationalization of consumption - Increase security in energy use - Cost reduction - Use of different energy sources - Improve environmental issues	- Technical issues regarding the distance between the buildings and the thermal plant - Bureaucratic-normative issues - Uncertainty about the project management and decisions with different stakeholders

Table 5.10: *Equivalent Strengths/ Weaknesses addressed by the participants of both workshops.*

Source: Author, 2020.

5.3 Recommendations

After a post assessment of the learnings and outcomes from the two above Phases, six recommendations were elaborated. They aim to promote policies on prosumership in Renewable Energy Communities (RECs), where local consumers are encouraged to become prosumers of the energy system. Based on the key findings from the Susa Valley (Italy) study site, some of the recommendations can be also feasible for other projects at EU level. By doing this, this thesis intends to involve European and local stakeholders in the production of energy and to empower them to play an active role in their community.

The mixed methodology of this thesis, combining qualitative and quantitative approaches, enabled the design of interdisciplinary recommendations. They go over social, environmental, and economic dimensions of sustainability under the phenomenon of prosumerism. Although these recommendations have a limitation due it was not possible to make a post consultation with experts to see its application, they may be used to support decision-making processes by coupling different areas and multi-actors.

The six recommendations are:

1 Creation of communication channels between local community and public administration;

2 Promotion of information and awareness-raising activities for RECs' stakeholders;

3 Creation of financial policy measures to include vulnerable citizens in RECs;

4 Design REC interventions schemes considering local Key Performance Indicators (KPIs);

5 Creation of gender-responsive policy for women inclusion in RECs;

6 Adoption of social qualitative methods to engage multi-stakeholders in RECs.

Therefore, following the six structured points explained in Section 3.1.3, the six recommendations are detailed below by giving:

- Level of Applicability: EU level and/or Local level (Susa Valley, Italy)
- Linkage with the Sustainable Development Goals (SDGs)

Source: Kanuri et al. (2016).

- Background information and justification
- Description of the recommendation
- Examples and/or references related to the recommendations, to better reflect the idea behind it.

Recommendation 01

Creation of communication channels between local community and public administration

Level of Applicability	Local level
Linkage with SDGs	

Background and justification:

The main weaknesses addressed on the workshops of this thesis were about social inclusion, communication with citizens and inclusion of different objectives in the decision-making processes. Considering Art.18 of the RED II Directive, information is a key component for enabling citizens and communities to become active players on the energy markets (*European Commission*, 2018). Taking this into account and the main problems discussed on the workshops of this thesis, it is essential to reinforce the communication through solid and inclusive channels. These channels should solve questions between the public administration and citizens, in order to consider other points of views and support information agreement.

Description of the recommendation:

Local administration should create communication channels with the local community. They can create channels through an Application software designed for the local community, to facilitate the communication and social inclusion, where the community can send requests or visualize information about the project. This will promote dialogue between two nucleus that usually are unlikely to meet. Considering the COVID-19 pandemic period with social meeting restrictions, the substantial area covered by mobile network (*UN Economic and Social Council*, 2020) and the great versatility of software applications, this channel can be useful to receive requests from the population or directly communicate information about RECs in progress.

Examples and/or references:

The municipality of Sao Paulo, through the Municipal Secretariat for Urban Development, has launched an Application software called "Olhares Urbanos", on which the population could participated in the revision of city zoning law process. The application allowed the population to know the city plans, and though the software, they could dialogue with the municipality sending requests or doubts (https://gestaourbana.prefeitura.sp.gov.br/master-plan/).

Recommendation 02

Promotion of information and awareness-raising activities for RECs' stakeholders

Level of Applicability	Local level
Linkage with SDGs	

Background and justification:

The circulation of "not-in-my-backyard" narratives (NIMBY) and the lack of information on the topic may contribute to local resistance to the spread of renewable energy cooperatives (*Devine-Wright*, 2014). For example, the NIMBY forum reported that 317 infrastructures were subject to disapproval in the period from 2017 to 2018 in Italy. Among the trends, the disapproval was justified as "negative externalities on the quality of life", followed by "negative externalities for the environment" (in the case of biomass installations). Besides this, the main problems regarding the management of energy discussed on the workshops of this thesis were about technical energy issues. Taking these points into consideration and the Art.18 of the RED II Directive (which stated that information and training are key components for enabling citizens and communities to become active players on the energy markets *European Commission* (2018)), it is essential to promote activities of information and awareness raising for stakeholders. These training activities may solve disagreements and questions regarding RECs and boost stakeholders acceptance.

Description of the recommendation:

Local administration should create training activities with the local REC's stakeholders. In one hand by implementing capacity building programmes, as energy seminars. These training programmes can be carried out with energy technician partners solving technical issues/doubts of the local community and public administration. On the other hand, by creating awareness raising campaigns through local government on prosumer opportunities and procedures. These actions may be repeated on a regular basis.

Examples and/or references:

Some energy seminars were already done in the past in the Susa Valley (as the Participant 04 from the Public Administration workshop had already said during the discussion). They can be a reference for the capacity building programmes and may be improved by adding information about the SCORE project. The awareness raising campaigns can be based on the PROSEU project, an EU Horizon 2020 programme that aim to enable the mainstreaming of the renewable energy Prosumer phenomenon into the Energy Union. They have done a similar recommendation on the topic (*Petrick et al.*, 2019).

Recommendation 03

Creation of financial policy measures to include vulnerable citizens in RECs

Level of Applicability	EU level Local level
Linkage with SDGs	

Background and justification:

The main financial obstacles to include vulnerable consumers as prosumers in RECs are the large investment capital, either savings or access to credit, and the system of social redistribution in European Welfare states. Although the CSOP model helps on that, means-tested transfers are a barrier to vulnerable citizens to enter as investors in RECs. To be eligible for social transfer payments, vulnerable citizens must liquidate all assets. This is considered a "welfare dilemma" of the social welfare legislation. In which vulnerable citizens become excluded from participating in RECs investments as they do not want to lose their social transfer payments, due to the legislation prohibition of asset ownership, income, and often the participation in co-ownership of RE installations (*Lowitzsch and Hanke*, 2019). In addition to this, in the Preliminary Workshop in AMICO, social cooperative from the Susa Valley, (briefly commented in this thesis and on the work of (*Torabi Moghadam et al.*, 2020)), one of the points discussed with the vulnerable citizens are these financial barriers and problems regarding the welfare dilemma into the Italian financial system. Considering these points, policy measures to include vulnerable citizens in RECs financial system are extremely necessary to solve this dilemma and to help the transposition of RED II 2018/2001 into National levels (e.g., by ensuring the participation in RECs is open to all consumers involved, including those belonging to low-income or vulnerable families, *Repubblica Italiana* (2020)).

Description of the recommendation:

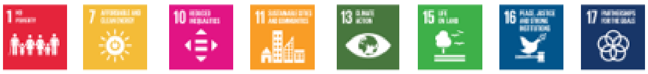
Creation of financial policy measures to facilitate the inclusion of vulnerable consumers in RECs. By creating exemptions in the social welfare legislation in relation of investments in RECs, to eliminate the necessity to liquidate one's assets (regarding ownership in RE installations) when applying to means-tested social transfers.

Examples and/or references:

The French transposition law of RED II includes vulnerable citizens (Art. 41) by stating that when a collective self-consumption operation brings together low-income housing, they can be designated as the legal person organizing the operation. Moreover, Art. L. 424-3 states that low-income housing organizations can create, manage and participate in collective self-consumption operations of electricity (*République Française*, 2019). Besides this, the work of *Hanke and Lowitzsch* (2020) (based on the practices from *Lowitzsch et al.* (2017)) suggests that "investments in RECs should be exempt from necessity to liquidate one's assets when applying for means-tested social transfers" by having a cap of at least EUR 1 000 per person per year.

Recommendation 04

Design REC interventions schemes considering local Key Performance Indicators (KPIs)

Level of Applicability	EU level Local level
Linkage with SDGs	

Background and justification:

A shift towards sustainable energy solutions is essential to the achievement of the Paris Agreement targets adopted under the United Nations Framework Convention on Climate Change (*Kanuri et al.*, 2016). In this scenario, the evaluation of available solutions requires quantitative assessment, through the adoption of representative Key Performance Indicators (KPIs) for the projects. The KPIs can assess the project's social approval either by the policy-making bodies or by the local society; and the relevant legal framework requirements that need to be met, before being implemented in a large scale (*Pramangioulis et al.*, 2019). Therefore, for a successful REC implementation, the refurbishment alternative or construction of a project scheme should consider the local community preferences. It will help the propose to be tailored for their needs and for the local environment, boosting stakeholders involvement. Following this and based on this thesis, a framework tailored by Key Perform Indicators (KPIs) selected by interest stakeholders, is necessary to design the individual RECs schemes and to choose the best alternative for the local community.

Description of the recommendation:

National governments should consider designing Renewable Energy Communities (RECs) intervention schemes tailored to the needs of the local community. It should be properly integrated, through voluntary or mandatory regulations and schemes, in RECs project investments and included in the initial project's design. It should consider Key Performance Indicators (KPIs) to provide for stakeholders a useful comparison among the proposed solutions. It will facilitate stakeholder's involvement and the design of cost-efficient and socially fair RECs.

Examples and/or references:

Several tools and methodologies available in Europe, like CESBA MED, become examples for urban planners to incorporate different KPIs in urban projects *CESBA Med Commission* (2019). Moreover, UNECE member States conceived a project to help countries develop, implement, and track national sustainable energy policies to mitigate climate change and contribute to sustainable development called "Pathways to Sustainable Energy". The project was designed to inform decision-makers about effective policy and technology options to attain sustainable energy through a set of Key Performance Indicators (KPIs) (*United Nations Economic Commission for Europe*, 2020).

Recommendation 05

Creation of gender-responsive policy for women inclusion in RECs

Level of Applicability	EU level Local level
Linkage with SDGs	

Background and justification:

Taking into account that prosumership characteristics are male, middle aged, well-educated and with a higher income; the participation of women and social groups vulnerable to fuel poverty are underrepresented. One of the SCORE project objectives is the inclusion of women and low-income households (LIH) into energy systems prosumership. However, in the Thesis' workshops the presence of women were underrepresented: only one woman participated in the Public administration Workshop and four women in the Citizens. Therefore, encouraging and empowering women to participate in workshops and RE projects decision making processes are important for an inclusive REC and to ensure a just energy transition.

Description of the recommendation:

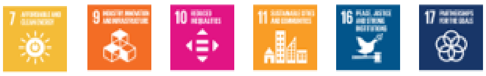
Regions and towns when developing a REC should implement a gender-responsive policy and framework for women inclusion in RECs in order to encourage a minimal percentage of women inclusion in decisions making committee.

Examples and/or references:

The SDG Fund programme on Women's Economic Empowerment has been developed to accelerate economic empowerment of women in Ethiopia. The programme aims to create a gender-responsive policy and an institutional environment for women's economic empowerment. Some of the project approaches are the promotion of savings and leadership for women; and the strengthening of policies and programmes that promote women's agency and voice in producer associations, financial cooperatives, and unions (https://www.sdgfund.org/joint-programme-gender-equality-and-women-empowerment-rural-women-economic-empowerment-component).

Recommendation 06

Adoption of social qualitative methods to engage multi-stakeholders in RECs

Level of Applicability	EU level Local level
Linkage with SDGs	

Background and justification:

To address complex challenges of urban and regional energy planning, an interdisciplinary and integrated spectrum is desired (*Brömmelstroet et al.*, 2014). However, social qualitative methods and humanities research are usually less applied in shaping European energy policy than Science, Technology, Engineering and Mathematics (STEM) disciplines (*Mourik et al.*, 2017). The use of the qualitative method (i.e., storytelling) in the Susa Valley Workshops of this Thesis was essential to understand the stakeholders' demand and to engage them into RECs scenarios creation. For these reasons, the adoption of social qualitative methods taking into account disciplines beyond "STEM" are fundamental to have an inclusive multi-stakeholders decision making with a wide spectrum of approaches.

Description of the recommendation:

Social qualitative methods should be properly integrated, through voluntary or mandatory regulations and schemes, in energy project investments. In order to engage multi-stakeholders into decision processes involving energy policymaking, innovation, and research in RECs.

Examples and/or references:

SHAPE ENERGY is a European platform for energy-related social sciences and humanities (energy-SSH), and it aims to develop expertise in using and applying energy-SSH. It seeks to bring energy researchers/practitioners together around a commonly agreed Research & Innovation Agenda 2020-2030 for future interdisciplinary energy-related works. Their innovative Platform brings together those who 'demand' energy research (e.g., businesses, policymakers, NGOs) with those who 'supply' that research (https://shapeenergy.eu/index.php/about/).

6

Conclusions and future developments

The energy transition from fossil fuels to renewable sources requires a complex adjustment of society. Through new energy infrastructures, the transition needs to motivate consumers to change their consumption habits and accept new technologies. The launch of new EU Policies and the implementation by the European Commission of regulatory frameworks bring "citizens at its core". They pledge not only to include consumers as the main beneficiaries, but also to consider them as a "policy target group to be activated". In this way, the legislation framework seeks to involve them in the energy market by reconstructing traditional market roles and institutional configurations. The consumer co-ownership model in RES, implemented by the SCORE project and underlined in this thesis, aims to transform the consumers in "prosumers" and boost their engagement in RECs. The transformation of consumers in prosumers is, therefore, a decisive manner to finally establish the citizens and consumers as "central players on the energy markets". In turn, their ownership in RES can promote positive behavioural changes in the energy consumption, by using new technologies to reduce their bills and participating actively in the market (*Hanke and Lowitzsch*, 2020; *Lowitzsch*, 2019a).

When dealing with complex challenges in complex systems - such as energy transitions and climate challenges - there are a wide variety of relevant bodies of knowledge. Alongside with Science, Technology, Engineering and Mathematics (STEM) disciplines, there is a need of social sciences and humanities energy (energy-SSH) research to integrate these disciplines (*Mourik et al.*, 2017). For this reason, to understand the process of stakeholders involvement in RECs, this thesis applied an interdisciplinary integrated methodological framework and aggregated innovative methods of energy-related topics.

The thesis was focused on the Italian pilot of the EU Horizon 2020 project called SCORE (Supporting Consumer co-Ownership in Renewable Energies) and concentrated the research in the stakeholders involvement in the project development. The methodology was divided in three Phases, integrating quantitative and qualitative in an interdisciplinary approach. The Phases and objectives of the thesis were:

- **Phase 01 - Assessment and Evaluation**
  Objective: Assessment of different Key Performance Indicators (KPIs) in five case studies in the Susa Valley, in order to determine the best refurbishment alternative for the creation of the Renewable Energy Communities. Taking into account energy efficiency and including social, environmental, technical and economic aspects.
- **Phase 02 - Visualization and participative Workshops**
  Objective: Involvement of the stakeholders in co-ownership models and evaluation of impacts regarding the creation of Renewable Energy Communities in the Italian pilot.
- **Phase 03 - Recommendations**
  Objective: Elaboration of recommendations for consumer co-ownership in Renewable Energy Communities (RECs) to enable policies on prosumership at EU and local level.

First Phase

In the first Phase, retrofit alternatives for the study site were assessed and evaluated. The retrofit alternatives are proposals from the SCORE consortium to refurbishment the heating system from the cities of the Italian pilot. They suggest new energy systems to overcome the use of fossil fuels in favour of renewable sources (i.e., Biomass and/or Photovoltaics) and to improve the energy efficiency of the systems. These objectives are one of the main goals of the SCORE project. Therefore, following the PROMETHEE method and doing a Multi-Criteria Analysis, the best retrofit alternatives were chosen for each city in the study site. Key Performance Indicators (KPIs) were considering, containing a wide range of environmental, economic, technical and social aspects.

This thesis focused on the Phase 01 in five cities of the Susa Valley pilot: Almese, Bardonecchia, Bussoleno, San Giorio di Susa and Susa. The best alternatives obtained for each city was the last proposed (A2, A2, A3, A3 and A2, respectively) and this can be explained due to the characteristics of the last alternatives. They were the ones that had the best performance in the KPIs and in the software. Among the KPIs, the ones from the Environmental category were the most decisive ones, since many of the Economy indicators did not change for the different alternatives and the only indicator of the Social category (S1) was redundant. Furthermore, it was possible to classify the case studies of this Thesis in order of "investment preference". In this way, the city Bardonecchia was the most preferred, followed by Susa, Bussoleno, Almese and San Giorio di Susa.

Considering all these, it is important to highlight some limitations and proposals from the first Phase:

- As the KPIs and weights were defined in a previous work, this thesis only followed it. It would be recommendable to further refine them to each case study, as many were redundant;
- A possible explaining reason for the redundancy and the achievement of similar results for all scenarios is the simple financial assessment framework used (updated are expected);
- Although the research achieved the similar results for different scenarios and weights in this work, it is an important process in the PROMETHEE method, potentially leading to different results in other case studies;
- PROMETHEE was the selected MCA method because it was used before in the project and it is accessible to use. As a future development of this research, it could be enriching to apply another MCA process (e.g., ELECTRE) and compare the results;
- Given the nature of the thesis, some KPIs were defined making assumptions based on expert suggestions and previous works. It would be necessary in the future to adjust these parameters, as the project relies on the data;
- The choice of the thresholds is a critical step during the MCA process. Until now the project is using the preference function (V-Shape), with the preference value calculated as the standard deviation of each indicator and without indifference value. This was done due to the impossibility of accessing accurate data from the stakeholders. It is relevant for the future to reduce the assumptions made;

- Whenever the project obtains the actual numbers of families benefited, it would be useful to analyze each indicator per capita. These values would enable the feasibility analysis between the case studies and, perhaps, the operation of a new MCA to decide which city is more likely to be invested first or to be the focus for the fulfillment of the green goals.

Second Phase

The second Phase aimed to involve the stakeholders and focus groups into co-ownership models focused on the Italian pilot of the project. The second Phase transformed the data from the previous phase into an inclusive data visualization tool: the WebGIS. This tool helped showing the stakeholders in the workshops later, the proposes from the SCORE project to their community and to visualize the future low-carbon scenario at the urban level. The later workshops were the main part of this thesis. Following the storytelling method, the participants elaborated current and future scenarios for the Susa Valley. The qualitative analysis of this phase demanded an interdisciplinary approach.

It was possible to evaluate the impacts in Subsection 5.2.3 regarding the creation of Renewable Energy Communities in the Italian study site, through the stories and personal opinions. It was possible to conclude that: they are already familiar with the use of biomass, the renewable energy source chosen for the Italian pilot of the SCORE project; and the discussions about the stories in plenary sections contributed to general development. Furthermore, the experience in the workshops and the analysis of the stories helped to understand their context and elaborate the recommendations.

However, it is important to highlight some limitations and proposals in the second Phase:

- These workshops were firstly intended to be presential in the Susa Valley, in one day workshop with the two groups together. But due to the unprecedented conditions and restrictions of COVID-19 pandemic, the workshops were online through the ZOOM platform. Although this affected the initial procedure of the workshops and the personal interactions (important for the Storytelling method), we believe meaningful results were still attained;

- The creation of the future scenario, through the Storytelling method, was collective for the public administration and individual for the citizens. This change interfered in the results, which in the plenary section for the citizens workshop, the discussions seemed more interactive and enriched;

- Due to online workshops being shorter in time, the plenary sessions were reduced. More time for the workshop could potentially lead to more information;
- Since the discussion of the storytelling method results and the stories are subjective, they are affected by personal values and experiences of the person evaluation it. Therefore, the final outputs of this thesis can be affected by language and context barriers;
- Given the complexity of the issue, more workshops and a comparison with other pilots could enrich the conclusions;
- The involvement of women, one of the focus groups of the SCORE project, in the workshops were not so effective, since most of the participants were not women;
- The identification of vulnerable citizens is a challenge, due to the difficulty of understanding who is LIH among the participating citizens, if they do not comment;
- Not all the participants of the workshops answered the surveys, so we had missing stories;
- In the story spine, participants must write about a character; although most have written about themselves, the stories may not be real but just an "imagination" and because of that, they can be difficult to assess. On the other hand, creating a character made them more comfortable speaking to a public audience;

Third Phase

The last Phase was the conclusion of the thesis. By joining some important remarks of the previous phases and basing on the literature review, interdisciplinary recommendations were elaborated for consumer co-ownership in Renewable Energy Communities (RECs). They aggregate difficulties, achievements and learnings provided by the study research. Furthermore, the final framework was improved during the research visit period in Europa-Universität Viadrina, EUV. These recommendations are intended to enable policies on prosumership at EU and local level for future research, and to support the followers cities of the SCORE project.

Thus, the six recommendations of this thesis are:

1 Creation of communication channels between local community and public administration;

2 Promotion of information and awareness-raising activities for RECs' stakeholders;

3 Creation of financial policy measures to include vulnerable citizens in RECs;

4 Design REC interventions schemes considering local Key Performance Indicators (KPIs);

5 Creation of gender-responsive policy for women inclusion in RECs;

6 Adoption of social qualitative methods to engage multi-stakeholders in RECs.

One limitation of this Phase is that due COVID-19 and other restrictions, interviews with experts and stakeholders were impractical to done in achievable time to understand better their feasibility. Considering this limitation, these recommendations can be considered just a conclusion of this thesis and a guideline for future research, and they would need some further validation to become formal recommendations.

Final Remarks

The definition of planning objectives, specific activities and outcomes of energy projects respond to multiple objectives and trade-offs, related to stakeholders that occasionally have opposing expectations. Considering the particular topic of this thesis, the local community need to be the central point and the main beneficiaries. The thesis carried a mixed methodology aimed to consider the stakeholders visions and to involve them into the project. The Multi-Criteria Analysis and decision-making of the first phase, based on KPIs with different spheres of sustainability, helped to provide a vision and future scenario for the RECs in the Susa Valley. It gave a feasible alternative to refurbishing the cities with an energy transition using renewable sources, following a low-carbon urban strategy. However, the way these outputs are communicated to the public has to accessible, from vulnerable citizens to public administration members. Therefore, the integration of social sciences and humanities into the traditional STEM disciplines (*Sonetti et al.*, 2020) were essential to the accomplishment of this thesis. By doing workshops in the Susa Valley and applying the storytelling method, we brought the research outputs to the local communities and a basis for dialogue. Stakeholders learnt not only about facts, but also how to relate with others and how they could frame their particular visions. By hearing their scenarios creation, we could understand the stakeholder values and visions in relation to the project. It helped to promoted social learning among stakeholders and confidence, indispensable to overcome the complex problem of energy poverty.

Thus, this thesis hopes to improve the traditional thinking in energy planning. Decision makers and urban planners should consider different fields of science when developing urban projects. We currently face problems that are complex and globalized. But even in global problems, as climate change, we need to consider local contexts and values in order to have a successful project. Vulnerable citizens are aware of the complex problems and they go beyond the rational-economic reasoning to engage in sustainable initiatives; this underlines the importance of listening to the communities and of involving them in the project. Moreover, by implementing a decentralized energy production involving local community and encouraging them through social, environmental and financial incentives, RECs can create a "positive domino", allowing for vulnerability overcoming and, in a broad aspect, energy poverty reduction. As an example, the money obtained in the REC investment can also be invested in other areas, empowering the community in ways beyond the initial energetic question. This strategy can also contribute to local jobs and local wealth creation as the money stays within the community.

To conclude, doing a project at the European level and bringing together those who 'demand' energy research - citizens, businesses, policymakers - with those who 'supply' that research (*Mourik et al.*, 2017) is essential to delineate the global energy landscape. It helps to articulate connections between legal frameworks, society-relevant research and multi-stakeholder cooperation. Therefore, in the end, the tools and methods described in this thesis can help to trigger interdisciplinary research and enhance communication on complex energy topics.

Future Developments

The EU Horizon2020 SCORE project has until 2021 to finish its goals, by implementing RECs initially in three pilots and extending it to followers cities in Europe. Within this framework, the work carried out during this thesis contributes directly to the objectives of SCORE. However, some future developments can be proposed to further encourage the thesis extension:

- For the refurbishment alternatives in the case studies, some indicators can be updated, and assumptions assessed, achieving a more accurate analysis for the study site;
- Further examination of the questionnaires' outputs in the Italian pilot's project, for a better understanding of the stakeholders' profiles and more developed storytelling workshops;
- To aggregate all the future results and outputs of the other pilots in the same WebGIS base, in order to have a complete visualization tool;
- To consult with experts and local stakeholders the validity of the recommendations made through this thesis and to see its applicability;
- In order to have a complete and solid methodology, more case studies will be necessary to explore the applicability and the usability of the thesis' methods. It will be interesting to, at least, explore and compare the workshop methodology in the other two pilots of the SCORE project: the Czech pilot in Litoměřice and the German pilot in Essen.

The Litoměřice pilot already followed this methodology on November in the Czech pilot workshop. In the next months, a comparative study will be done between the pilot workshops. Besides this, part of the results of this thesis research will contribute to prepare a deliverable of the SCORE project in the next months.

These future developments will help to expand research in energy communities, cooperate with the SCORE project and continue the work done by the thesis. And, in this way, the learning can broaden up visions and create space for adaptability in the energy environment. Future developments in community energy planning not only drive forward a truly sustainable energy transition but have the potential to facilitate the inclusion of stakeholders as consumer co-owners to mitigate energy poverty. These issues are essential to strengthen a common vision for renewable energy communities, accompanied by future research.

Bibliography

A.I.R.U. (2018), Il Riscaldamento Urbano, Associazione Italiana Riscaldamento Urbano Annuario, *64*, 388, ISSN: 1972-6953.

Alvial-Palavicino, C., N. Garrido-Echeverría, G. Jiménez-Estévez, L. Reyes, and R. Palma-Behnke (2011), A methodology for community engagement in the introduction of renewable based smart microgrid, *Energy for Sustainable Development*, *15*(3), 314 – 323, doi: 10.1016/j.esd.2011.06.007, ISSN: 0973-0826.

Anderson, K. T., and P. Wales (2012), Can You Design for Agency?: The Ideological Mediation of an Out-of-School Digital Storytelling Workshop, *Critical Inquiry in Language Studies*, *9*(3), 165–190, doi: 10.1080/15427587.2012.627021.

Associazione PEFC Italia (2020), Standard PEFC Internazionale: Catena di Custodia dei prodotti di origine forestale e arborea requisiti (ITA 1002:2020).

Azarova, V., J. Cohen, C. Friedl, and J. Reichl (2019), Designing local renewable energy communities to increase social acceptance: Evidence from a choice experiment in Austria, Germany, Italy, and Switzerland, *Energy Policy*, *132*, 1176 – 1183, doi: 10.1016/j.enpol.2019.06.067, ISSN: 0301-4215.

Baker, T. R. (2015), WebGIS in Education, in *Geospatial Technologies and Geography Education in a Changing World: Geospatial Practices and Lessons Learned*, edited by O. Muñiz Solari, A. Demirci, and J. Schee, pp. 105–115, Springer Japan, Tokyo, doi: 10.1007/978-4-431-55519-3_9, ISBN: 978-4-431-55519-3.

Becchio, C., D. G. Ferrando, E. Fregonara, N. Milani, C. Quercia, and V. Serra (2016), The cost-optimal methodology for the energy retrofit of an ex-industrial building located in Northern Italy, *Energy and Buildings*, *127*, 590–602.

Borroni, A., J. Lowitzsch, and A. Tartaglia (2020), Introduzione alle comunitá energetiche - quadro normativo di riferimento, misure di attuazione e incentivi, *Rivista di Ateneo - Tutela e Sicurezza del Lavoro*, (1), 48, ISSN:2283-9224.

Brans, J., P. Vincke, and B. Mareschal (1986), How to select and how to rank projects: The PROMETHEE method, *European Journal of Operational Research*, *24*(2), 228 – 238, doi: 10.1016/0377-2217(86)90044-5, ISSN:0377-2217.

Brömmelstroet, M. t., C. Silva, and L. Bertolini (2014), *COST Action TU1002 - Assessing usability of accessibility instruments*, 191 pp., Brussels: COST, ISBN:9789090282121.

Brummer, V. (2018a), Community energy - benefits and barriers: A comparative literature review of Community Energy in the UK, Germany and the USA, the benefits it provides for society and the barriers it faces, *Renewable and Sustainable Energy Reviews*, *94*, 187 – 196, doi: 10.1016/j.rser.2018.06.013, ISSN:1364-0321.

Brummer, V. (2018b), Of expertise, social capital, and democracy: Assessing the organizational governance and decision-making in German Renewable Energy Cooperatives, *Energy Research & Social Science*, *37*, 111 – 121, doi: 10.1016/j.erss.2017.09.039, ISSN:2214-6296.

Cajot, S., A. Mirakyan, A. Koch, and F. Maréchal (2017), Multicriteria decisions in urban energy system planning: A review, *Frontiers in Energy Research*, *5*(10), 25, doi: 10.3389/fenrg.2017.00010, ISSN:2296-598X.

Caramizaru, A. and Uihlein, A. (2020), Energy Communities: An Overview of Energy and Social Innovation, *JRC Science for Policy Report JRC119433*, doi: 10.2760/180576, ISBN:978-92-76-10713-2.

Caritas (2020), La Caritas Italiana. Organismo pastorale della Cei in Susa, https://www.caritas.it/caritasitaliana/s2magazine/index1.jsp?idPagina=4550, Viewed 29 September 2020.

CESBA Med Commission (2019), CESBA MED Policy Paper - Deliverable 5.3.1., p. 17.

Cohen, J., K. Moeltner, J. Reichl, and M. Schmidthaler (2016), An Empirical Analysis of Local Opposition to New Transmission Lines Across the EU-27, *The Energy Journal*, *37*(3), doi: 10.5547/01956574.37.3.jcoh.

Council of European Energy Regulators (2019), Regulatory Aspects of Self- Consumption and Energy Communities CEER Report, p. 53.

Dall 'O', G., M. F. Norese, A. Galante, and C. Novello (2013), A multi-criteria methodology to support public administration decision making concerning sustainable energy action plans, *Energies*, *6*(8), 4308–4330, doi: 10.3390/en6084308, ISSN:1996-1073.

Dantsiou, D. (2017), (De) constructing and transforming workplace practices: Feedback as an intervention, Ph.D. thesis, University of Cambridge, doi: 10.17863/CAM.12812.

De Montis, A., P. De Toro, B. Droste-Franke, I. Omann, and S. Stagl (2004), Assessing the quality of different mcda methods, *Alternatives for environmental valuation*, *4*, 99–133.

Devine-Wright, P. (2005), 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*(2), 125–139.

Devine-Wright, P. (2014), *Renewable Energy and the Public: from NIMBY to Participation*, Routledge.

Di Nicoli, M., S. Torabi Moghadam, and P. Lombardi (2019), A Framework for Selecting the Best Refurbishment Alternative in Renewable Energies Towards, in *Energy for Sustainability International Conference 2019. Designing a Sustainable Future*, Turin.

Diakoulaki, D., and F. Karangelis (2007), Multi-criteria decision analysis and cost-benefit analysis of alternative scenarios for the power generation sector in Greece, *Renewable and Sustainable Energy Reviews*, *11*(4), 716 – 727, doi: 10.1016/j.rser.2005.06.007, ISSN:1364-0321.

Directorate General for Research and Innovation (2018), *Final Report of the High-Level Panel of the European Decarbonisation Pathways Initiative*, 184 pp., doi: 10.2777/636, ISBN:9789279968266.

Dirutigliano, D., C. Delmastro, and S. Torabi Moghadam (2017), Energy efficient urban districts: A multi-criteria application for selecting retrofit actions, *International Journal of Heat and Technology*, *35*(1), 49–57.

Dobbins, A., F. Fuso Nerini, P. Deane, and S. Pye (2019), Strengthening the EU response to energy poverty, *Nature Energy*, *4*, 2–5, doi: 10.1038/s41560-018-0316-8.

Eadson, W., J. Dobson, J. Shepherd, E. Bridge, and J. Hall (2019), *Catalysing People-powered Energy in Yorkshire and the Humber*, Centre for Regional Economic and Social Research, Sheffield Hallam University.

European Commission (2014), *HORIZON 2020 in brief*, 40 pp., Directorate-General for Research and Innovation. Publications Office of the European Union, Luxembourg, doi: 10.2777/3719, ISBN:9789279330575.

European Commission (2016), *Clean Energy for all Europeans. COM/2016/0860 final*, Brussels.

European Commission (2018), Regulation (EU) 2018/1999 of the European Parliament and of the Council of 11 December 2018 on the Governance of the Energy Union and Climate Action, amending Regulations (EC) No 663/2009 and (EC) No 715/2009 of the European Parliament and of the Council, *Tech. rep.*, Directives 94/22/EC, 98/70/EC, 2009/31/EC, 2009/73/EC, 2010/31/EU, 2012/27/EU and 2013/30/EU of the European Parliament and of the Council, Council Directives 2009/119/EC and (EU) 2015/652 and repealing Regulation (EU) No 525/2013 of the European Parliament and of the Council (Text with EEA relevance.).

European Commission (2019), Clean energy for all Europeans, *Energy*, p. 24, doi: 10.2833/9937, ISBN:978-92-79-99835-5.

European Energy Network (2019), *EnR Position Paper on Energy Poverty in the European Union*, 29 pp., Italian Agency for New Technologies, Energy and Sustainable Economic Development (ENEA), Energy Efficiency Department, Roma, Italy.

European Environment Agency (2018), *Air quality-2018 report*, 12, 88 pp., doi: 10.2800/777411, ISBN:978-92-9213-989-6.

Faiella, I., and L. Lavecchia (2015), La povertà energetica in Italia, *Politica economica*, *31*(1), 27–76, doi: 10.1429/80536, ISSN:1120-9496.

Ferretti, V. (2016), From stakeholders analysis to cognitive mapping and Multi-Attribute Value Theory: An integrated approach for policy support, *European Journal of Operational Research*, *253*(2), 524–541, doi: 10.1016/j.ejor.2016.02.054, ISSN:0377-2217.

Fog, K., C. Budtz, and B. Yakaboylu (2005), *Storytelling: Branding in practice*, Springer.

Franceschini, F., M. Galetto, and D. Maisano (2007), *Management by measurement: Designing key indicators and performance measurement systems*, Springer Science & Business Media.

Frieden, D., J. Roberts, and A. Gubina (2019), Collective self-consumption and energy communities: Overview of emerging regulatory approaches in Europe, doi: 10.1109/EEM.2019.8916222.

Gorroño Albizuand Karl Sperling, L., and S. Djørup (2019), The past, present and uncertain future of community energy in Denmark: Critically reviewing and conceptualising citizen ownership, *Energy Research & Social Science*, *57*, 12, doi: 10.1016/j.erss.2019.101231, ISSN:2214-6296.

Gregg, R., J. Kershner, and L. Hansen (2015), Strategies for climate change adaptation: A synthesis, in *Reference Module in Earth Systems and Environmental Sciences*, Elsevier, doi: 10.1016/B978-0-12-409548-9.09365-9, ISBN:978-0-12-409548-9.

Hanke, F., and J. Lowitzsch (2020), Empowering Vulnerable Consumers to Join Renewable Energy Communities - Towards an Inclusive Design of the Clean Energy Package, *Energies*, *13*(7), 26, doi: 10.3390/en13071615, ISSN:1996-1073.

Heaslip, E., and F. Fahy (2018), Developing transdisciplinary approaches to community energy transitions: An island case study, *Energy Research & Social Science*, *45*, 153 – 163, doi: 10.1016/j.erss.2018.07.013, ISSN:2214-6296.

Heinrich Böll Foundation, Friends of the Earth Europe, European Renewable Energies Federation, and Green European Foundation (2018), Energy Atlas 2018 - Facts and Figures about Renewables in Europe.

Herbes, C., V. Brummer, J. Rognli, S. Blazejewski, and N. Gericke (2017), Responding to policy change: New business models for renewable energy cooperatives - Barriers perceived by cooperatives' members, *Energy Policy*, *109*, 82 – 95, doi: 10.1016/j.enpol.2017.06.051, ISSN:0301-4215.

International Energy Agency (2020), Energy Policy Review - European Union 2020.

IPCC (2014), 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, p. 151, IPCC, Geneva, Switzerland.

IPCC (2018), Summary for policymakers, in *Global warming of 1.5°C an IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*, edited by V. Masson-Delmotte, P. Zhai, H. Pörtner, D. Roberts, P. Skea, J. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. Matthews, Y. Chen, X. Zhou, M. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield, p. 32, World Meteorological Organization, Geneva, Switzerland.

ISTAT (2020), Popolazione residente al 1° gennaio: Piemonte (dato provvisorio), http://dati.istat.it/Index.aspx?QueryId=18540, Viewed 03 September 2020.

Italian Government (2019), Integrated national energy and climate, *Tech. rep.*, Ministry of Economic Development, Ministry of the Environment and Protection of Natural Resources and the Sea, and Ministry of Infrastructure and Transport.

Janda, K. B., and M. Topouzi (2015), Telling tales: using stories to remake energy policy, *Building Research & Information*, *43*(4), 516–533, doi: 10.1080/09613218.2015.1020217.

Jefferson, G. (1978), Sequential aspects of storytelling in conversation, in *Studies in the organization of conversational interaction*, pp. 219–248, Elsevier.

Kalkbrenner, B. J., and J. Roosen (2016), Citizens' willingness to participate in local renewable energy projects: The role of community and trust in Germany, *Energy Research & Social Science*, *13*, 60 – 70, doi: 10.1016/j.erss.2015.12.006, ISSN:2214-6296.

Kanuri, C., A. Revi, J. Espey, and H. Kuhle (2016), Getting started with the SDGs in cities, *Tech. rep.*, Sustainable Development Solutions Network: A Global initiative for the United Nations, New York, USA.

Kurtz, C. (2008), Working with Stories: in Your Community or Organization.

Li, Y., J. O'Donnell, R. García-Castro, and S. Vega-Sánchez (2017), Identifying stakeholders and key performance indicators for district and building energy performance analysis, *Energy and Buildings*, *155*, 15, doi: 10.1016/j.enbuild.2017.09.003, ISSN:0378-7788.

Lowitzsch, J. (Ed.) (2019a), *Energy Transition: Financing Consumer Co-Ownership in Renewables*, 1, 794 pp., Palgrave Macmillan, Cham, Switzerland, doi: 10.1007/978-3-319-93518-8, ISBN:978-3-319-93518-8.

Lowitzsch, J. (2019b), Financing Renewables while Implementing Energy Efficiency Measures through Consumer Stock Ownership Plans (CSOPs)-The H2020 Project SCORE, in *IOP Conference Series: Earth and Environmental Science*, vol. 290, p. 10, IOP Publishing, doi: 10.1088/1755-1315/290/1/012051.

Lowitzsch, J., and F. Hanke (2019), Consumer (Co-)ownership in Renewables, Energy Efficiency and the Fight Against Energy Poverty - a Dilemma of Energy Transitions, *Renewable Energy Law and Policy Review: RELP*, *9*(3), 5–21, ISSN:2190-8265.

Lowitzsch, J., S. Dunsch, and I. Hashi (2017), *Spanish Sociedades Laborales - Activating the Unemployed: A Potential New EU Active Labour Market Policy Instrument*, 1, 129 pp., Palgrave Macmillan, Cham, Switzerland, doi: 10.1007/978-3-319-54870-8, ISBN:978-3-319-54870-8.

Lowitzsch, J., C. Hoicka, and F. van Tulder (2020), Renewable energy communities under the 2019 European Clean Energy Package - Governance model for the energy clusters of the future?, *Renewable and Sustainable Energy Reviews*, *122*, 13, doi: 10.1016/j.rser.2019.109489, ISSN:1364-0321.

Mourik, R., R. Robison, and S. Breukers (2017), *Storytelling - SHAPE ENERGY facilitation guidelines for interdisciplinary and multi-stakeholder processes*, Cambridge: SHAPE ENERGY.

Ngar-yin Mah, D. (2019), Community solar energy initiatives in urban energy transitions: A comparative study of Foshan, China and Seoul, South Korea, *Energy Research & Social Science*, *50*, 129 – 142, doi: 10.1016/j.erss.2018.11.011, ISSN:2214-6296.

Oteman, M., M. Wiering, and J. Helderman (2014), The institutional space of community initiatives for renewable energy: a comparative case study of the Netherlands, Germany and Denmark, *Energy, Sustainability and Society*, *4*(11), 17.

Petrick, K., J. Fosse, and S. Klarwein (2019), Principles for Prosumer Policy Options. PROSEU - Prosumers for the Energy Union: Mainstreaming active participation of citizens in the energy transition (D3.3).

Pramangioulis, D., K. Atsonios, N. Nikolopoulos, D. Rakopoulos, P. Grammelis, and E. Kakaras (2019), A Methodology for Determination and Definition of Key Performance Indicators for Smart Grids Development in Island Energy Systems, *Energies*, *12*(242), 22, doi: 10.3390/en12020242, ISSN:1996-1073.

Radtke, J. (2014), A closer look inside collaborative action: civic engagement and participation in community energy initiatives, *People, Place and Policy*, *8*(3), 235–248, doi: 10.3351/ppp.0008.0003.0008.

Regione Piemonte (2018), LEGGE regionale 3 agosto 2018, n. 12. Promozione dell'istituzione delle comunita energetiche.

Repubblica Italiana (2015), DECRETO LEGISLATIVO 28 dicembre 2015. Disposizioni in materia ambientale per promuovere misure di green economy e per il contenimento dell'uso eccessivo di risorse naturali., *Gazzetta Ufficiale 18 gennaio 2016*, p. 103.

Repubblica Italiana (2019), LEGGE 27 dicembre 2019, n. 160. Bilancio di previsione dello Stato per l'anno finanziario 2020 e bilancio pluriennale per il triennio 2020-2022., *Gazzetta Ufficiale Della Repubblica Italiana*, p. 198.

Repubblica Italiana (2020), DECRETO-LEGGE 30 dicembre 2019, n. 162. Coordinato con la legge di conversione 28 febbraio 2020, n. 8. Disposizioni urgenti in materia di proroga di termini legislativi, di organizzazione delle pubbliche amministrazioni, nonche' di innovazione tecnologica, *Gazzetta Ufficiale 28 febbraio 2020*, p. 84.

République Française (2019), LOI no 2019-1147 du 8 novembre 2019 relative à l'énergie et au climat (1) , *Journal Officiel de la République Française*, p. 34.

Restrepo Arias, S., S. Torabi Moghadam, and P. Lombardi (2020), Scenario Analysis for Incremental Community Planning in an African Context, *Sustainability*, *12*(19), 29, doi: 10.3390/su12198133.

Roth, L., J. Lowitzsch, O. Yildiz, and A. Hashani (2018), Does (Co-)ownership in renewables matter for an electricity consumer's demand flexibility? Empirical evidence from Germany, *Energy Research & Social Science*, *46*, 169 – 182, doi: 10.1016/j.erss.2018.07.009, ISSN:2214-6296.

Rotmann, S. (2017), Once upon a time... Eliciting energy and behaviour change stories using a fairy tale story spine, *Energy Research & Social Science*, *31*, 303 – 310, doi: 10.1016/j.erss.2017.06.033, ISSN:2214-6296.

Schreuer, A. (2016), The establishment of citizen power plants in Austria: A process of empowerment?, *Energy Research & Social Science*, *13*, 126 – 135, doi: 10.1016/j.erss.2015.12.003, ISSN:2214-6296.

SCORE Consortium (2018), D 2.1. Country Update Reports on Investment Conditions, p. 71.

SCORE Consortium (2019), D3.1. Manual on Energy Refurbishing: Including the mitigation on Rebound effects., p. 64.

Seidl, R., T. von Wirth, and P. Kruetli (2019), Social acceptance of distributed energy systems in Swiss, German, and Austrian energy transitions, *Energy Research & Social Science*, *54*, 117 – 128, doi: 10.1016/j.erss.2019.04.006, ISSN:2214-6296.

Seyfang, G., J. J. Park, and A. Smith (2013), A thousand flowers blooming? An examination of community energy in the UK, *Energy Policy*, *61*, 977 – 989, doi: 10.1016/j.enpol.2013.06.030, ISSN:0301-4215.

Sonetti, G., O. Arrobbio, P. Lombardi, I. M. Lami, and S. Monaci (2020), Only Social Scientists Laughed": Reflections on Social Sciences and Humanities Integration in European Energy Projects, *Energy Research & Social Science*, *61*(101342), 13, doi: 10.1016/j.erss.2019.101342, ISSN:2214-6296.

Sperling, K. (2017), How does a pioneer community energy project succeed in practice? The case of the Samsø Renewable Energy Island, *Renewable and Sustainable Energy Reviews*, *71*, 884 – 897, doi: 10.1016/j.rser.2016.12.116, ISSN:1364-0321.

Tegou, L., H. Polatidis, and D. Haralambopoulos (2012), A multi-criteria framework for an isolated electricity system design with renewable energy sources in the context of distributed generation: the case study of Lesvos Island, Greece, *International journal of green energy*, *9*(3), 256–279, doi: 10.1080/15435075.2011.621484.

Torabi Moghadam, S., C. Delmastro, S. P. Corgnati, and P. Lombardi (2017), Urban energy planning procedure for sustainable development in the built environment: A review of available spatial approaches, *Journal of Cleaner Production*, *165*, 811 – 827, doi: 10.1016/j.jclepro.2017.07.142, ISSN:0959-6526.

Torabi Moghadam, S., M. V. D. Nicoli, A. Giacomini, P. Lombardi, and J. Toniolo (2019), The role of prosumers in supporting renewable energies sources, in *IOP Conference Series: Earth and Environmental Science*, vol. 297, p. 9, IOP Publishing, doi: 10.1088/1755-1315/297/1/012041.

Torabi Moghadam, S., M. V. Di Nicoli, S. Manzo, and P. Lombardi (2020), Mainstreaming energy communities in the transition to a low-carbon future: A methodological approach, *Energies*, *13*(7), 27, doi: 10.3390/en13071597.

UN Economic and Social Council (2020), Progress towards the Sustainable Development Goals, *Report of the Secretary-General*, p. 23.

UN-Habitat (2016), Addressing climate change in National Urban Policy: A policy guide for low-carbon and climate-resilient urban development, *Policy note*, *4*.

UNEP (2019), *Emissions Gap Report 2019*, 82 pp.

Ungaro, P. (2014), L'indagine Istat sui consumi energetici delle famiglie: principali risultati, *ISTAT: Roma, Italia*.

United Nations Economic Commission for Europe (2020), *Pathways to Sustainable Energy. Accelerating Energy Transition in the UNECE Region*, vol. 67, 64 pp.

U.S Energy Information Administration (2019), Energy Information Administration, *Choice Reviews Online*, *44*(7), doi: 10.5860/choice.44-3624, ISSN:0009-4978.

Van der Schoor, T., H. van Lente, B. Scholtens, and A. Peine (2016), Challenging obduracy: How local communities transform the energy system, *Energy Research & Social Science*, *13*, 94 – 105, doi: 10.1016/j.erss.2015.12.009, ISSN:2214-6296.

Virdis, M. R., M. Gaeta, E. De Cian, R. Parrado, C. Martini, M. Tommasino, and A. Antimiani (2015), Pathways to deep decarbonization in Italy, *SDSN-IDDRI: Paris, France*.

Vuichard, P., A. Stauch, and N. Dallenbach (2019), Individual or collective? Community investment, local taxes, and the social acceptance of wind energy in Switzerland, *Energy Research & Social Science*, *58*(101275), 12, doi: 10.1016/j.erss.2019.101275, ISSN:2214-6296.

Vulević, T., and N. Dragović (2017), Multi-criteria decision analysis for sub-watersheds ranking via the PROMETHEE method, *International Soil and Water Conservation Research*, *5*(1), 50 – 55, doi: 10.1016/j.iswcr.2017.01.003, ISSN:2095-6339.

Wang, J.-J., Y.-Y. Jing, C.-F. Zhang, and J.-H. Zhao (2009), Review on multi-criteria decision analysis aid in sustainable energy decision-making, *Renewable and Sustainable Energy Reviews*, *13*(9), 2263 – 2278, doi: 10.1016/j.rser.2009.06.021, ISSN:1364-0321.

Woo, J., S. Chung, C. Lee, and S. Huh (2019), Willingness to participate in community-based renewable energy projects: A contingent valuation study in South Korea, *Renewable and Sustainable Energy Reviews*, *112*, 643 – 652, doi: 10.1016/j.rser.2019.06.010, ISSN:1364-0321.

World Energy Council (2019), World Energy Trilemma Index 2019, *Tech. rep.*, London, United Kingdom.

Wüstenhagen, R., M. Wolsink, and M. J. Bürer (2007), Social acceptance of renewable energy innovation: An introduction to the concept, *Energy Policy*, *35*(5), 2683 – 2691, doi: 10.1016/j.enpol.2006.12.001, ISSN:0301-4215.

Zanon, B., and S. Verones (2013), Climate change, urban energy and planning practices: Italian experiences of innovation in land management tools, *Land Use Policy*, *32*, 343 – 355, doi: 10.1016/j.landusepol.2012.11.009, ISSN:0264-8377.

Appendix A

Pilot retrofit analysis documents

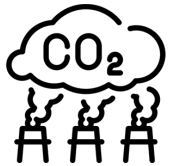
These are the PDF documents inserted on the WebGIS tool (discussed on Subsection 5.2.1) following the dossiers' assessment of the Italian pilot and the best retrofit evaluation through the PROMETHEE method. They were elaborated for each municipality of the Italian pilot: Almese; Bardonecchia; Bussoleno; Novalesa; Oulx; Rueglio; San Giorio di Susa (building and city scale); Susa; and Villar Dora (respectively). It contains the succeeding information separated in three columns in Italian language:

- The main current problems regarding the energy efficiency and retrofitting of the pilot.
- Suitable retrofit proposals for the pilot suggested by the SCORE consortium and the selected retrofit after doing the PROMETHEE method.
- The main benefits of the selected retrofit evaluated through the evaluation matrix and the Key Performance Indicators (KPIs).

VALLE DI SUSA: ALMESE

SCORE
Co-own. Prosume. Renew.

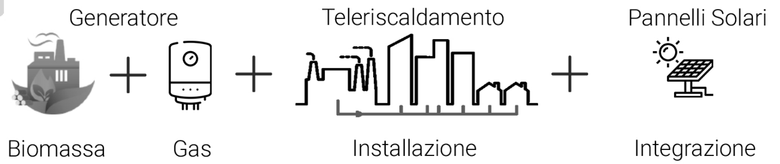
PROBLEMI



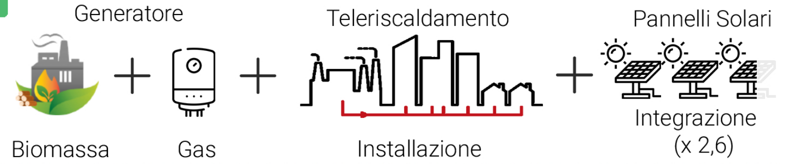
Risorse energetiche non pulite (gas naturale) e conseguente elevato livello di emissioni di CO2 e fornitura di energia totalmente non rinnovabile

PROPOSTE DI RETROFIT

1



2

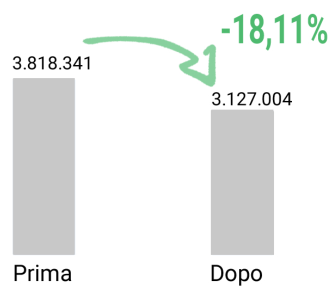


Selezionata

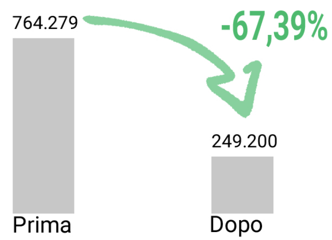
BENEFICI

Retrofit n.2

Riduzione di **energia primaria** (kWh/anno)



Riduzione delle **emissioni globali di CO2** (kgCO2eq)



Benefici **finanziari:**

Tempo di rientro	2,83 anni
Incentivi pubblici	30 %
Costo dell'investimento	1.170.000 euro
Costo materiale	900.000 euro
Costo del lavoro	270.000 euro
Costo del lavoro (cooperativa sociale)	67.500 euro

VALLE DI SUSA: BARDONECCHIA

SCORE
Co-own. Prosume. Renew.

PROBLEMI

Risorse energetiche non pulite (gas naturale) e conseguente elevato livello di emissioni di CO2 e fornitura di energia totalmente non rinnovabile

PROPOSTE DI RETROFIT

1
Generatore
Biomassa

2
Generatore
Biomassa + Gas

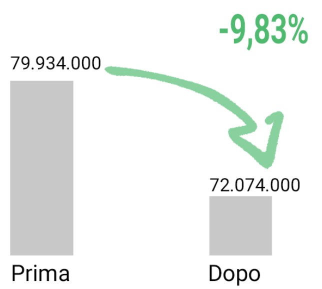
3
Generatore
Biomassa (x 3,5) + Gas

Selezionata

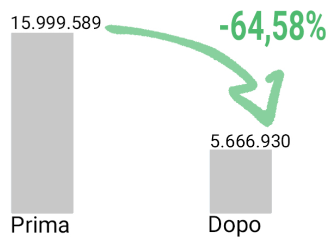
BENEFICI

Retrofit n.3

Riduzione di **energia primaria** (kWh/anno)



Riduzione delle **emissioni globali di CO2** (kgCO2eq)



Benefici **finanziari:**

Tempo di rientro	0,19 anni
Incentivi pubblici	30 %
Costo dell'investimento	1.560.000 euro
Costo materiale	1.200.000 euro
Costo del lavoro	360.000 euro
Costo del lavoro (cooperativa sociale)	90.000 euro

VALLE DI SUSA: BUSSOLENO

SCORE
Co-own. Prosume. Renew.

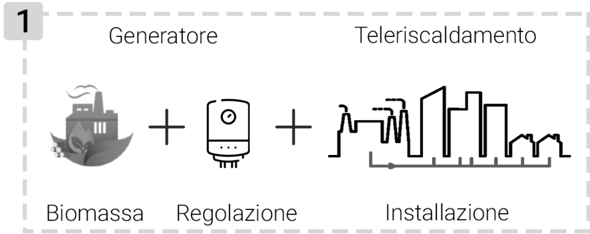
PROBLEMI

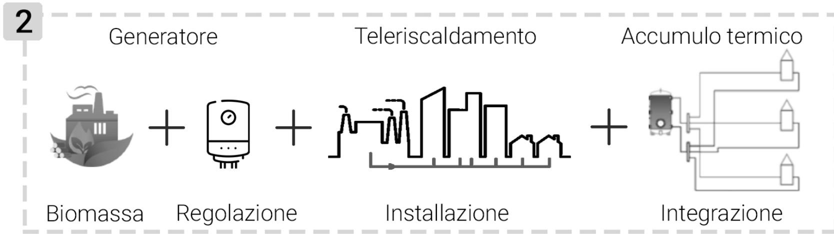
Risorse energetiche non pulite (gas naturale) e conseguente elevato livello di emissioni di CO2 e fornitura di energia totalmente non rinnovabile

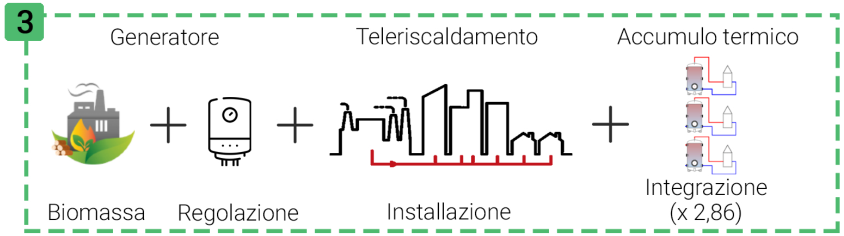
Tecnologia di generazione del calore obsoleta (caldaie a gas, più di 20 anni, senza condensa) con un basso livello di efficienza

Multiple generatori senza integrazione tra loro

PROPOSTE DI RETROFIT





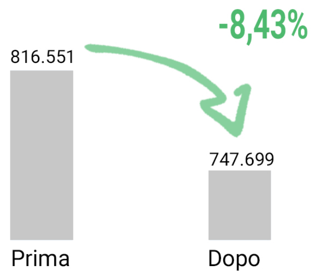


Selezionata

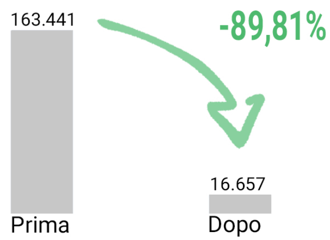
BENEFICI

Retrofit n.3

Riduzione di **energia primaria** (kWh/anno)



Riduzione delle **emissioni globali di CO2** (kgCO2eq)



Benefici **finanziari:**

Tempo di rientro	9,1 anni
Incentivi pubblici	30 %
Costo dell'investimento	1.072.500 euro
Costo materiale	825.000 euro
Costo del lavoro	247.500 euro
Costo del lavoro (cooperativa sociale)	61.875 euro

VALLE DI SUSA: NOVALESA

SCORE
Co-own. Prosume. Renew.

PROBLEMI

Risorse energetiche non pulite (diesel) e conseguente elevato livello di emissioni di CO2 e fornitura di energia totalmente non rinnovabile

Tecnologia di generazione del calore obsoleta (caldaie a gasolio, senza condensa)

Siti storici dal 726 d.c. e dal 1800 d.C. che richiedono limitate opzioni di retrofit e sono cauti sull'importanza storica degli edifici.

PROPOSTE DI RETROFIT

1

Generatore

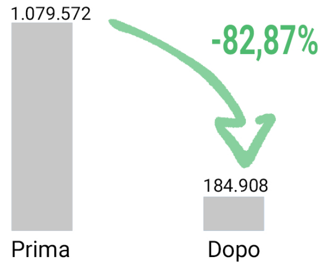
Biomassa + Regolazione

Selezionata

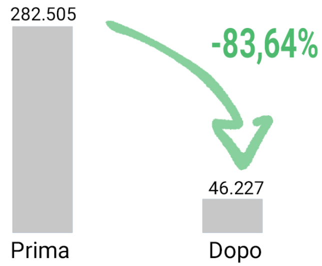
BENEFICI

Retrofit n.1

Riduzione di **energia primaria** (kWh/anno)



Riduzione delle **emissioni globali di CO2** (kgCO2eq)



Benefici **finanziari:**

Tempo di rientro	2,3 anni
Incentivi pubblici	40 %
Costo dell'investimento	350.675 euro
Costo materiale	269.750 euro
Costo del lavoro	80.925 euro
Costo del lavoro (cooperativa sociale)	20.231 euro

VALLE DI SUSA: OULX

SCORE
Co-own. Prosume. Renew.

PROBLEMI

Risorse energetiche non pulite (gasolio) e conseguente elevato livello di emissioni di CO2 e fornitura di energia totalmente non rinnovabile

Tecnologia di generazione del calore obsoleta (caldaie a gasolio, più di 10 anni, senza condensa)

Perdita di energia dovuta a involucro opaco

PROPOSTE DI RETROFIT

1 Generatore: Biomassa + Regolazione

2 Generatore: Biomassa + Regolazione + Tetto: Isolamento

3 Generatore: Biomassa + Regolazione + Tetto: Isolamento + Pareti: Isolamento

4 Generatore: Biomassa + Regolazione + Tetto: Isolamento (x2) + Pareti: Isolamento (x2) — n ZEB

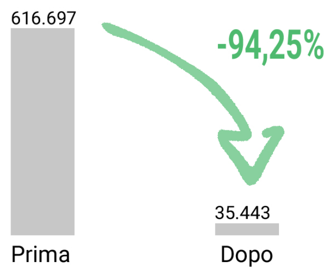
5 Generatore: Biomassa + Regolazione + Tetto: Isolamento (x3) + Pareti: Isolamento (x3) — n ZEB — **Selezionata**

6 Generatore: Biomassa + Regolazione + Tetto: Isolamento + Pareti: Isolamento + Finestre: Sostituzione — n ZEB

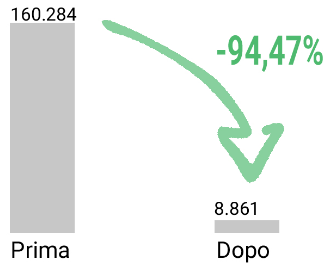
BENEFICI

Retrofit n.5

Riduzione di **energia primaria** (kWh/anno)



Riduzione delle **emissioni globali di CO2** (kgCO2eq)



Benefici **finanziari:**

Tempo di rientro	8,1 anni
Incentivi pubblici	65 %
Costo dell'investimento	802.425 euro
Costo materiale	617.257 euro
Costo del lavoro	185.175 euro
Costo del lavoro (cooperativa sociale)	46.294 euro

VALLE DI SUSA: RUEGLIO

SCORE
Co-own. Prosume. Renew.

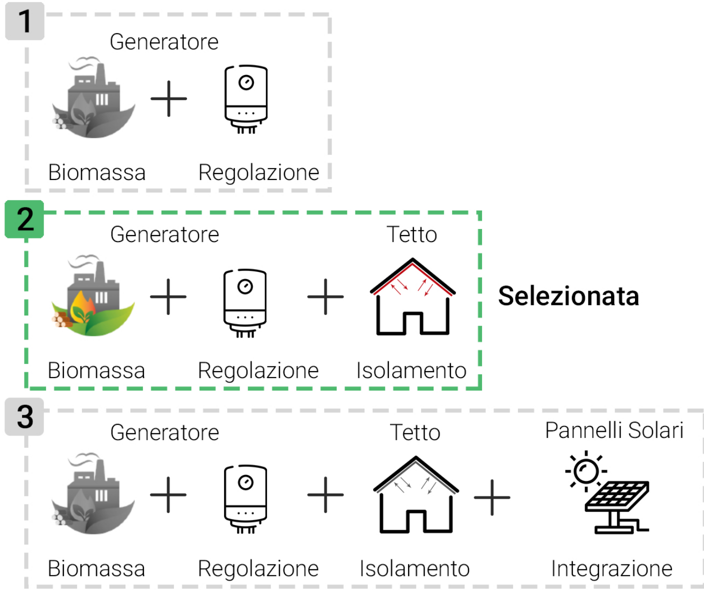
PROBLEMI

Risorse energetiche non pulite (diesel) e conseguente elevato livello di emissioni di CO2 e fornitura di energia totalmente non rinnovabile

Tecnologia di generazione del calore obsoleta (caldaie a gasolio, più di 10 anni, senza condensa)

Perdita di energia dovuta a involucro opaco

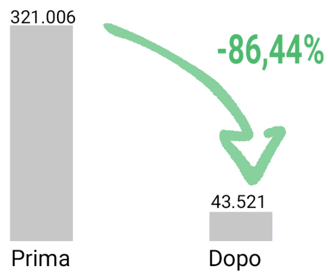
PROPOSTE DI RETROFIT



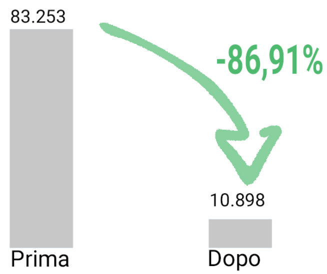
BENEFICI

Retrofit n.2

Riduzione di **energia primaria** (kWh/anno)



Riduzione delle **emissioni globali di CO2** (kgCO2eq)



Benefici **finanziari:**

Tempo di rientro	8,6 anni
Incentivi pubblici	40 %
Costo dell'investimento	407.485 euro
Costo materiale	313.450 euro
Costo del lavoro	94.035 euro
Costo del lavoro (cooperativa sociale)	23.509 euro

VALLE DI SUSA: SAN GIORIO

SCORE
Co-own. Prosume. Renew.

PROBLEMI

Risorse energetiche non pulite (gas metano) e conseguente elevato livello di emissioni di CO_2 e fornitura di energia totalmente non rinnovabile

Tecnologia di generazione del calore obsoleta (caldaia tradizionale a gas, senza condensa)

Perdita di energia dovuta a involucro opaco

PROPOSTE DI RETROFIT

1
Generatore: Biomassa + Regolazione

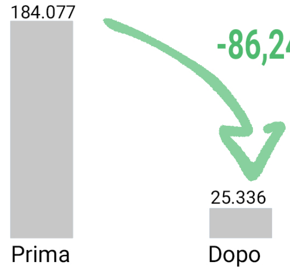
2
Generatore: Biomassa + Regolazione + Tetto: Isolamento + Pareti: Isolamento

Selezionata

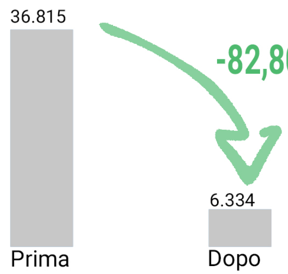
BENEFICI

Retrofit n.2

Riduzione di **energia primaria** (kWh/anno)



Riduzione delle **emissioni globali di CO2** (kgCO2eq)



Benefici **finanziari:**

Tempo di rientro	15,8 anni
Incentivi pubblici	40 %
Costo dell'investimento	418.457 euro
Costo materiale	321.890 euro
Costo del lavoro	96.567 euro
Costo del lavoro (cooperativa sociale)	24.142 euro

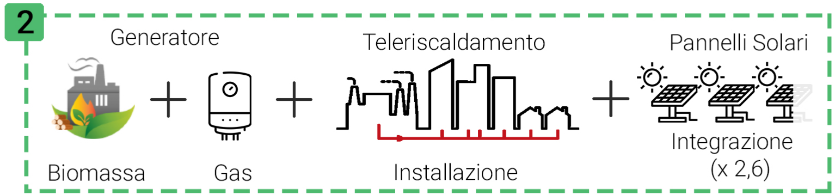
VALLE DI SUSA: SAN GIORIO
(scala della città)

SCORE
Co-own. Prosume. Renew.

PROBLEMI

Risorse energetiche non pulite (gas naturale) e conseguente elevato livello di emissioni di CO2 e fornitura di energia totalmente non rinnovabile

PROPOSTE DI RETROFIT

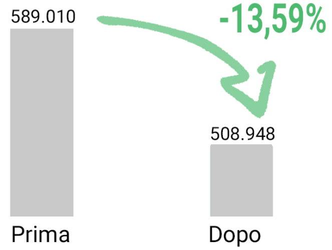


Selezionata

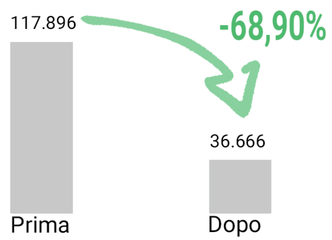
BENEFICI

Retrofit n.2

Riduzione di **energia primaria** (kWh/anno)



Riduzione delle **emissioni globali di CO2** (kgCO2eq)



Benefici **finanziari:**

Tempo di rientro	15,95 anni
Incentivi pubblici	30 %
Costo dell'investimento	1.040.000 euro
Costo materiale	800.000 euro
Costo del lavoro	240.000 euro
Costo del lavoro (cooperativa sociale)	60.000 euro

VALLE DI SUSA: SUSA

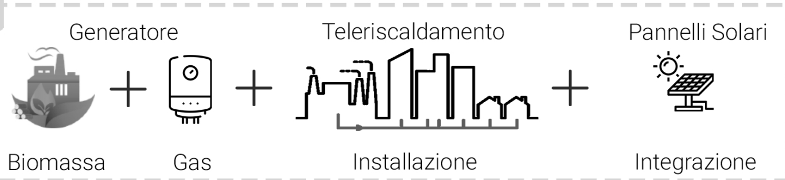
SCORE
Co-own. Prosume. Renew.

PROBLEMI

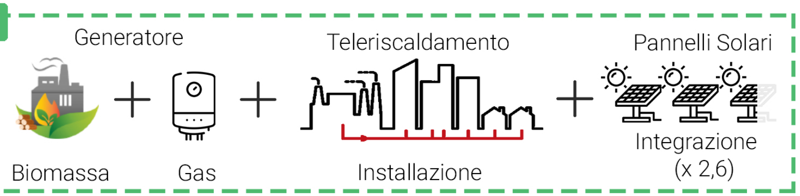
Risorse energetiche non pulite (gas naturale) e conseguente elevato livello di emissioni di CO2 e fornitura di energia totalmente non rinnovabile

PROPOSTE DI RETROFIT

1



2

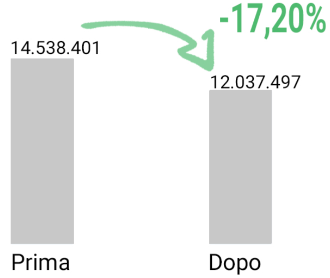


Selezionata

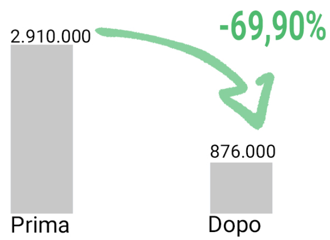
BENEFICI

Retrofit n.2

Riduzione di **energia primaria** (kWh/anno)



Riduzione delle **emissioni globali di CO2** (kgCO2eq)



Benefici **finanziari:**

Tempo di rientro	1,79 anni
Incentivi pubblici	30 %
Costo dell'investimento	2.925.000 euro
Costo materiale	2.250.000 euro
Costo del lavoro	675.000 euro
Costo del lavoro (cooperativa sociale)	168.750 euro

VALLE DI SUSA: VILLAR DORA

SCORE
Co-own. Prosume. Renew.

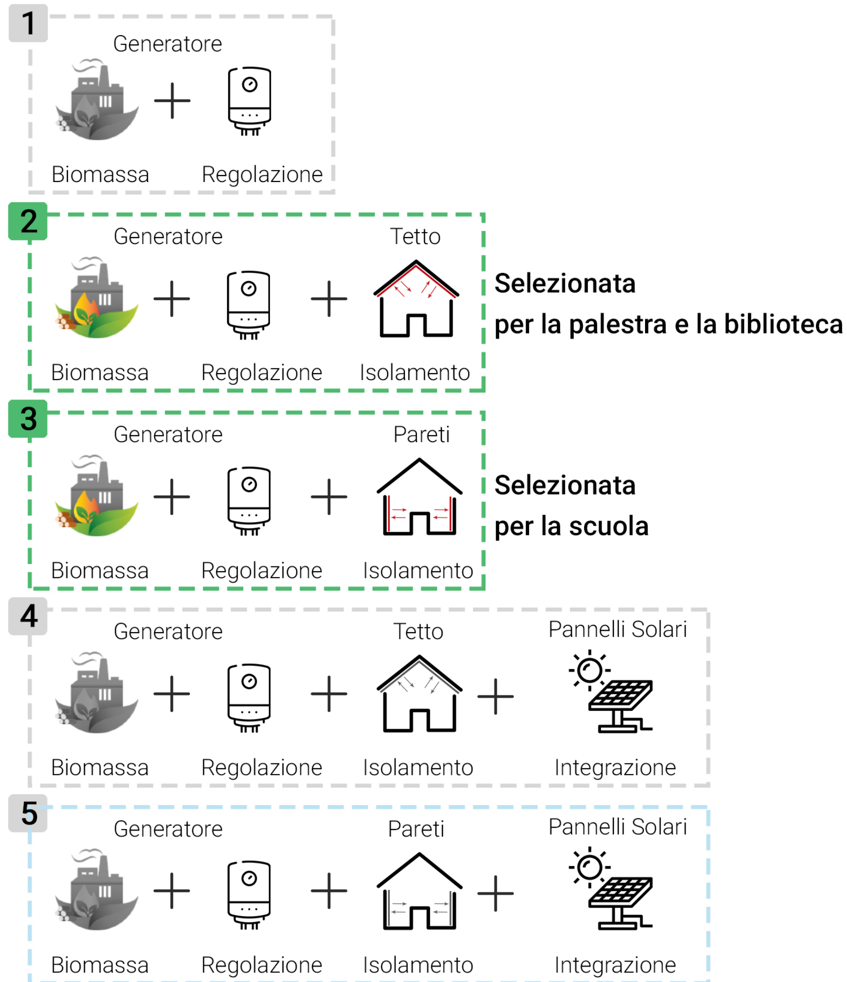
PROBLEMI

Risorse energetiche non pulite (gas naturale) e conseguente elevato livello di emissioni di CO2 e fornitura di energia totalmente non rinnovabile

Tecnologia di generazione del calore obsoleta (caldaie a gas, senza condensa) e sistema di regolazione mancante con energia sprecata generata

Perdita di energia dovuta a involucro opaco

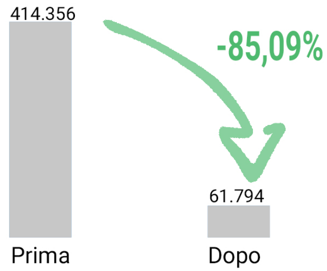
PROPOSTE DI RETROFIT



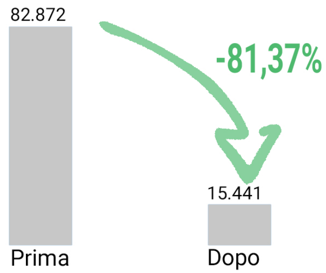
BENEFICI

Retrofit n.2 e n.3

Riduzione di **energia primaria** (kWh/anno)



Riduzione delle **emissioni globali di CO2** (kgCO2eq)



Benefici **finanziari:**

Tempo di rientro	13,8 anni
Incentivi pubblici	40 %
Costo dell'investimento	486.265 euro
Costo materiale	374.050 euro
Costo del lavoro	112.215 euro
Costo del lavoro (cooperativa sociale)	28.054 euro

Appendix B

Google Forms templates

The Google Forms templates used during the participative workshops in the Susa Valley are presented here, translated into English. The Google docs were applied according to the storytelling methodology of Section 3.1.1, following a story spine. The first was used in the introduction to know the participants and their characteristics. The second, in the story spine about the current scenario in the Susa Valley, where the participants introduced their characters and their daily life. The third and fourth, in the story spine about the future scenario, where the participants created their scenarios after the installation of the renewable energy communities in the Susa Valley.

WORKSHOP | The creation of the Energy Community in the Susa Valley

23.04.2020

*Required

Email address *

Your email address

Name and Surname *

Your answer

Entity / Position *

Your answer

If a representative of the Public Administration, Municipality in which you work.

Your answer

Municipality of residence *

Your answer

What heating system do you have at home? *

- NONE
- AUTONOMOUS-GAS
- AUTONOMOUS-DIESEL OIL
- AUTONOMOUS-BIOMASS
- CENTRALIZED-GAS
- CENTRALIZED-DIESEL OIL
- CENTRALIZED-BIOMASS
- HYBRID (gas boiler + fireplace, heat pump + boiler, etc ...)
- I DO NOT KNOW

Submit

WORKSHOP | The creation of the Energy Community in the Susa Valley

Story Spine 1 - Current Scenario
23/04/2020

*Required

Email address *

Your email address

In the Susa Valley there is a ________________ (citizen/expert/member of the public administration) who lives in the region. *

Describe the character in terms of age, career, job status, etc. Maximum 5 lines.

Your answer

From the point of view of the use of thermal energy, your typical day is ... *

Describe the typical day of the character illustrated previously by focusing the story on its energy habits with respect to the heating system. Maximum 10 lines.

Your answer

For __________________ (name of the character) the main problems (max5) that it encounters regarding the use and management of energy are ... *

List a maximum of 5 issues that you believe would be important to solve from the point of view of energy for heating. For example: expenses, transport of energy, etc.

Your answer

Submit

WORKSHOP | The creation of the Energy Community in the Susa Valley

Story Spine 2 - Creation of future scenarios
23/04/2020

*Required

Email address *

Your email address

One day, in the Val di Susa, an energy community was created and_______________ (name of the character) became co-owner of the energy management. Consequently, his typical day will be like this. *

Imagine a future scenario in which the energy community is a reality and describe the typical day of a character belonging to this energy community. What is expected from the energy community?

Your answer

Submit

WORKSHOP | The creation of the Energy Community in the Susa Valley

Story Spine 3 - Co-creation of future scenarios
23/04/2020

*Required

Highlight the Strengths that this energy community could have in energy management: *

Your answer

Highlight the Weaknesses that this energy community could have in energy management: *

Your answer

Submit

Never submit passwords through Google Forms.

Appendix C

Stories from Public Administration' Workshop participants

Here is presented the results of the Public Administration Workshop after the implementation of the storytelling methodology through Google Forms surveys. These are the stories from the Story Spine 01 of the other participants, translated into English.

Workshop **PUBLIC ADMINISTRATION (17.04.2020)** | The creation of the Energy Community in the Susa Valley

STORY SPINE 01 - Current Scenario

Participant 02
Residence City: **Susa**

In the Susa Valley there is a ________________________________ (citizen/expert/member of the public administration) who lives in the region.
Describe the character in terms of age, career, job status, etc. Maximum 5 lines.

In the Susa Valley, there is Giorgio, a citizen and entrepreneur in the forestry and energy sector, 48 years old, who has a family and two young daughters. Because of that, he has a strong propensity to think about a better future for the new generations and this can also be achieved through his own job everyday.

From the point of view of the use of thermal energy, your typical day is ...
Describe the typical day of the character illustrated previously by focusing the story on its energy habits with respect to the heating system. Maximum 10 lines.

As Giorgio deals with energy and the environment throughout the day, one of the limitations is that all his actions, even in a reflex and conditioned way, are focused on these issues.

For ____________________ (name of the character) the main problems (max 5) that it encounters regarding the use and management of energy are ...
List a maximum of 5 issues that you believe would be important to solve from the point of view of energy for heating. For example: expenses, transport of energy, etc.

Giorgio lives in a country where he cannot reward the deserving nor punish the guilty citizens. So, many times he hides behind the bureaucracy to make mediocrity float.

Workshop **PUBLIC ADMINISTRATION (17.04.2020)**
STORY SPINE 01 - Current Scenario

Participant 03
Residence City: **Gravere**

In the Susa Valley there is a ____ (citizen/expert/member of the public administration) who lives in the region.
Describe the character in terms of age, career, job status, etc. Maximum 5 lines.

In the Susa Valley, there is Piero, 65, who is freelancer and topographic technician.

From the point of view of the use of thermal energy, your typical day is ...
Describe the typical day of the character illustrated in step 1 by focusing the story on its energy habits with respect to the heating system. Maximum 10 lines.

Piero lives and works in the same house, He isolated his house externally through a cover and pvc windows with 25 mm double glazing. Also he made a methane thermal power plant by integrating the heating with the vacuum thermal panels and installing a photovoltaic system of 7.2 kW.

For ______________________ (name of the character) the main problems (max 5) that it encounters regarding the use and management of energy are ...
List a maximum of 5 issues that you believe would be important to solve from the point of view of energy for heating. For example: expenses, transport of energy, etc.

For Piero, the main problems are collecting the large amount of heat produced by the heating system in summer to be able to use it in winter. He needs to cover 2 of the 3 thermal panels in the summer.

Workshop **PUBLIC ADMINISTRATION (17.04.2020)**
STORY SPINE 01 - Current Scenario

Participant 04
Residence City: **Oulx**

In the Susa Valley there is a ______________________________ (citizen/expert/member of the public administration) who lives in the region.
Describe the character in terms of age, career, job status, etc. Maximum 5 lines.

In the Susa Valley there is a Mayor called Andrea. This poor administrative Mayor is in a time of serious economic difficulties: post era Olympics, Post austerity ... in an era of epidemic.

From the point of view of the use of thermal energy, your typical day is ...
Describe the typical day of the character illustrated in step 1 by focusing the story on its energy habits with respect to the heating system. Maximum 10 lines.

In his typical day, the Mayor Andrea has to provide heat source for the municipality school and because of this, he has to buy 80,000 liters of pure diesel every year.

For ______________________ (name of the character) the main problems (max 5) that it encounters regarding the use and management of energy are ...
List a maximum of 5 issues that you believe would be important to solve from the point of view of energy for heating. For example: expenses, transport of energy, etc.

For Andrea, it is a priority to provide a solution as soon as possible because the old oil boiler will not last much longer. The mayor came with a flash of genius: “what if I addressed the thermal bill? Maybe I could give an answer to citizens economically and ecologically sustainable”. However, the mayor still have some big doubts: timing of funding? Site timing? Put into operation… The poor mayor is still breaking his head without certain answers.

Workshop **PUBLIC ADMINISTRATION (17.04.2020)**
STORY SPINE 01 - Current Scenario

Participant 05
Residence City: **San Giorio di Susa**

In the Susa Valley there is a ____ (citizen/expert/member of the public administration) who lives in the region.
Describe the character in terms of age, career, job status, etc. Maximum 5 lines.

In the Susa Valley, there is a citizen who is also a member of the public administration. She is sixty years old and lives in the Susa Valley and works in Turin as a professor. She is therefore a commuter and the community where she lives is a small municipality of the Media Montagna (Susa Valley).

From the point of view of the use of thermal energy, your typical day is ...
Describe the typical day of the character illustrated in step 1 by focusing the story on its energy habits with respect to the heating system. Maximum 10 lines.

In the morning she takes shower using hot water from the solar thermal system, then she makes coffee with LPG, except in summer when she uses the induction plate stove already powered by the home photovoltaic system. In winter, the house is heated by a wood stove, powered by logs from the maintenance of the rows surrounding the house. The stove is turned on, as she learned in wood energy seminars, for three to four hours a day, usually after 5 pm, enough to keep inside home a temperature between 16 and 21 ° C, and it is distributed in the rooms thanks to the ventilation system forced mechanics, with heat recovery.

For ___________________________ (name of the character) the main problems (max 5) that it encounters regarding the use and management of energy are ...

List a maximum of 5 issues that you believe would be important to solve from the point of view of energy for heating. For example: expenses, transport of energy, etc.

For her the main problems are: the distribution of the heat supply during the day; the regulation of the use with energy improvement, but also with a correct user behavior; necessity of short periods of heating in specific areas, such as bathrooms; checking the forest's ability to respond to wood requirements and compatibility with the need to increase and not decrease in wooded areas; control of stove emissions.

Workshop **PUBLIC ADMINISTRATION (17.04.2020)**
STORY SPINE 01 - Current Scenario

Participant 06
Residence City: **Bussoleno**

In the Susa Valley there is a ____ (citizen/expert/member of the public administration) who lives in the region.
Describe the character in terms of age, career, job status, etc. Maximum 5 lines.

In the Susa Valley, there is a citizen, 60 years old, who is a technician in a public office.

From the point of view of the use of thermal energy, your typical day is ...
Describe the typical day of the character illustrated in step 1 by focusing the story on its energy habits with respect to the heating system. Maximum 10 lines.

In the morning, he shaves and has a shower. Then his house is empty until mid afternoon because he is in the office. In the office, the heating is set to maximum with thermostatic valves, but it is difficult to have comfort. In the evening, he turns on the heating until 11.30 pm.

For __________________________ (name of the character) the main problems (max 5) that it encounters regarding the use and management of energy are ...
List a maximum of 5 issues that you believe would be important to solve from the point of view of energy for heating. For example: expenses, transport of energy, etc.

For him, the main problems regarding the use and management of energy are:
1 - Monitoring of consumption and costs, for example monthly;
2 -Reduction of the heating period of his home;
3 - In the office: rationalization of the heating in the common rooms.

Appendix D

Stories from Citizens' Workshop participants

Here is presented the results of the Citizens Workshop after the implementation of the storytelling methodology through Google Forms surveys. These are the stories from the Story Spines 01 and 02 of the other participants, translated into English.

Workshop **CITIZENS (23.04.2020)** | The creation of the Energy Community in the Susa Valley

STORY SPINE 01 - Current Scenario

Participant 02
Residence City: **Almese**

In the Susa Valley there is a ____ (citizen/expert/member of the public administration) who lives in the region.
Describe the character in terms of age, career, job status, etc. Maximum 5 lines.

In the Susa Valley, there is Billy, who is 53 years old and lives outside the city center and works in a local detergent company.

From the point of view of the use of thermal energy, your typical day is ...
Describe the typical day of the character illustrated previously by focusing the story on its energy habits with respect to the heating system. Maximum 10 lines.

In the morning Billy wakes up in the cold and turns on the boiler to have hot water to warm up. He stays out of the house all day leaving the system off and when he returns in the evening, he turns on the heating because he likes to stay in a warm environment.

For ___________________________ (name of the character) the main problems (max 5) that it encounters regarding the use and management of energy are ...
List a maximum of 5 issues that you believe would be important to solve from the point of view of energy for heating. For example: expenses, transport of energy, etc.

For Billy, the main problem is that he is unable to program the system effectively. Weekly he has to transport wood to his home, and he does not have a properly place to store it. It is very hot with the system on and very cold with the system off.

Workshop **CITIZENS (23.04.2020)**
STORY SPINE 01 - Current Scenario

Participant 03
Residence City: **Susa**

In the Susa Valley there is a ____ (citizen/expert/member of the public administration) who lives in the region.
Describe the character in terms of age, career, job status, etc. Maximum 5 lines.

In the Susa Valley, there is a citizen, 57 years old, who is a freelancer and active in the socio-cultural context of the area.

From the point of view of the use of thermal energy, your typical day is ...
Describe the typical day of the character illustrated in step 1 by focusing the story on its energy habits with respect to the heating system. Maximum 10 lines.

He lives with his family of four members in an apartment with independent natural gas heating in a condominium. He programs the temperature of the local according to the requests of the family members. The apartment is well configurated, so it requires relatively little energy for heating.

For ___________________________ (name of the character) the main problems (max 5) that it encounters regarding the use and management of energy are ...
List a maximum of 5 issues that you believe would be important to solve from the point of view of energy for heating. For example: expenses, transport of energy, etc.

The main problems for him regarding the use and management of energy are:
1 - Dependence on strategic choices imposed by political-business lobbies, rather than by choices through collective, weighted, shared and oriented assessments;
2 - Energy sources are generally centralized because they are more controllable from the lobbies mentioned above;
3 - The complexity and low transparency of tariffs.

Workshop **CITIZENS (23.04.2020)**
STORY SPINE 01 - Current Scenario

Participant 04
Residence City: **Vaie**

In the Susa Valley there is a ____ (citizen/expert/member of the public administration) who lives in the region.
Describe the character in terms of age, career, job status, etc. Maximum 5 lines.

In the Susa Valley, there is a 30 years old woman called Lucia, who is mother of a 5 years old girl and who works as an employee.

From the point of view of the use of thermal energy, your typical day is ...
Describe the typical day of the character illustrated in step 1 by focusing the story on its energy habits with respect to the heating system. Maximum 10 lines.

Lucia has a pellet fireplace that is turned on an hour before breakfast and it stays on all day until the evening. When she returns from work, she turns on also the wood stove.

For ____________________________ (name of the character) the main problems (max 5) that it encounters regarding the use and management of energy are ...
List a maximum of 5 issues that you believe would be important to solve from the point of view of energy for heating. For example: expenses, transport of energy, etc.

For Lucia the environmental problem is very important. For this reason, she would like to use renewable sources, but it is very expensive. Another problem is the transport of energy. It comes from far away and it gives work to people from far away and in countries where the environmental pollution is underestimated.

Workshop **CITIZENS (23.04.2020)**
STORY SPINE 01 - Current Scenario

Participant 05
Residence City: **Bussoleno**

In the Susa Valley there is a ____ (citizen/expert/member of the public administration) who lives in the region.
Describe the character in terms of age, career, job status, etc. Maximum 5 lines.

In the Susa Valley, there is Mariuccia, a 50-year-old woman, employed, graduated, who does not have much time to explore topics that interest her... She is always so tired! She lives in a semi-detached house with neighbors who are all her friends.

From the point of view of the use of thermal energy, your typical day is ...
Describe the typical day of the character illustrated in step 1 by focusing the story on its energy habits with respect to the heating system. Maximum 10 lines.

If Mauriccia goes to work, that is almost every day, she goes out and leaves everything as it is. She does not usually program the heating because she has a wood-fired boiler and a gas boiler that interchanges as needed. As the wood source is given to her, she prefers to use the wood stove. So, she hopes that if her children stay at home, they will turn it on. If nobody turns it on, she will do it after returning home. Fortunately, she has renovated the roof in the past years and now her house holds more the heat. She uses the gas boiler when the weather does not allow her to stay only with the wood boiler. Heating is a big concern for her, both from an "organizational" and an economic point of view. In general, she does not use a regulation system, she does not even use a thermostat. It heats up every day. But in this way, she never stays in the cold!

For ____________________________ (name of the character) the main problems (max 5) that it encounters regarding the use and management of energy are ...

List a maximum of 5 issues that you believe would be important to solve from the point of view of energy for heating. For example: expenses, transport of energy, etc.

Mariuccia thinks that energy and above all, heating, should be a right for all people. Gas bills are really high. Through her work she gets to know many people who are unable to pay gas and electricity bills and they are slowly "messed up" with money and arrears. She thinks people should become more aware of the processes that allow to have energy in your home and understand how a system works. Mariuccia does not have technical training and she is not able to explain how a light bulb works. To make her machine works (the wood-fired boiler is now a bit old and now she has to give it a boost ...) she learned something, but she always feels inadequate when something unexpected happens.

Workshop **CITIZENS (23.04.2020)**
STORY SPINE 01 - Current Scenario

Participant 06
Residence City: **Borgone Susa**

In the Susa Valley there is a ____ (citizen/expert/member of the public administration) who lives in the region.
Describe the character in terms of age, career, job status, etc. Maximum 5 lines.

In the Susa Valley there is a man, who is 31 years old. He is a very small entrepreneur, enrolled to pursue a certification for electrotechnical experts with skills in energy saving. Opposed by many people and mainly his relatives, he started building a semi-total energy independence. After several years of solar radiation measurements, in 1977 he deduced that it was possible to build such a building in the valley. In 1980, the construction of his building begins.

From the point of view of the use of thermal energy, your typical day is ...
Describe the typical day of the character illustrated in step 1 by focusing the story on its energy habits with respect to the heating system. Maximum 10 lines.

Every day he personally checks heat exchangers, electric pumps, insolation of Kw/h per square meters, temperatures in the storage tanks, wind speed, maximum and minimum external temperatures, etc. He reports every data for future processing, and he has fun understanding the real operating feasibility. He thinks that it is a form of pension because it is an expense that can never be deducted from his salary. It is an investment that will actually lead to a well-being. He will have one less expense to deal with and therefore, he carries out various experiments. He discovered that in winter he can also create an ice room and have a refrigerator room where the cold of the night can accumulate in the form of ice. Having a different type to accumulate energy. It is a pity that being poor everything becomes difficult to implement.

For ___________________________ (name of the character) the main problems (max 5) that it encounters regarding the use and management of energy are ...
List a maximum of 5 issues that you believe would be important to solve from the point of view of energy for heating. For example: expenses, transport of energy, etc.

For him, there are no problems. And being a fan of this sector, he sees no difficulties.

Workshop **CITIZENS (23.04.2020)**
STORY SPINE 01 - Current Scenario

Participant 07
Residence City: **Susa**

In the Susa Valley there is a ____ (citizen/expert/member of the public administration) who lives in the region.
Describe the character in terms of age, career, job status, etc. Maximum 5 lines.

In the Susa Valley, there is a woman, who is citizen of 40-year-old and teaches in a town a few kilometers away.

From the point of view of the use of thermal energy, your typical day is ...
Describe the typical day of the character illustrated in step 1 by focusing the story on its energy habits with respect to the heating system. Maximum 10 lines.

She heats the house with the wood cut independently. In this way, she turns on the heating only when she wakes up. During the morning, the heating is turned off because there is nobody at home. She turns on the natural gas heating specially to heat the water for the shower and she uses photovoltaic panels for electricity.

For ___________________________ (name of the character) the main problems (max 5) that it encounters regarding the use and management of energy are ...
List a maximum of 5 issues that you believe would be important to solve from the point of view of energy for heating. For example: expenses, transport of energy, etc.

For her the main problems regarding the use and management of energy are:
1. Making the hot water; 2. The house is big and rooms that are not really used are also heated; 3. She often uses electricity when the panels are not working (in the evening); 4. When she works at home, she must keep the temperature of the house quite high; 5. There are always freezers on, and they consume a lot; 6. It is difficult to make the thermal cover because there is another family downstairs who disagrees about that.

Workshop **CITIZENS (23.04.2020)**
STORY SPINE 01 - Current Scenario

Participant 08
Residence City: **Bussoleno**

In the Susa Valley there is a ____ (citizen/expert/member of the public administration) who lives in the region.
Describe the character in terms of age, career, job status, etc. Maximum 5 lines.

In the Susa Valley there is a citizen called Mr. Brushless. He is 32 years old and he works with a temporary and precarious contract. He lives with a companion who is also vulnerable, and they would like to build a family, buy an isolated house with a piece of land to self-produce food as much as possible.

From the point of view of the use of thermal energy, your typical day is ...
Describe the typical day of the character illustrated in step 1 by focusing the story on its energy habits with respect to the heating system. Maximum 10 lines.

In the morning he wakes up, turns on the "putagè" (the only source of heating together with a boiler for shower water) to heat the old and small house where they live by rent. After, he goes out and goes to work as well as his partner. They are dreaming of one day being able to go home and find the temperature of 18/19 °C instead of the usual 13 °C.

For ________________________ (name of the character) the main problems (max 5) that it encounters regarding the use and management of energy are ...
List a maximum of 5 issues that you believe would be important to solve from the point of view of energy for heating. For example: expenses, transport of energy, etc.

For Mr. Brushless, the main problems are: the short duration of the combustion; the almost zero insulation of the glass; the old and thick walls; and the quality of the wood used that make the house unable to remain warm enough for the whole day. They would like to buy and/or renovate a house, but the precariousness of the work does not allow them to face this expense and (because of the bureaucracy) they are not able to access incentives.

Workshop **CITIZENS (23.04.2020)**
STORY SPINE 01 - Current Scenario

Participant 09
Residence City: **Chianocco**

In the Susa Valley there is a ____ (citizen/expert/member of the public administration) who lives in the region.
Describe the character in terms of age, career, job status, etc. Maximum 5 lines.

In the Susa Valley, there is a citizen called Gianni, who is a 29-year-old and is the owner of a restaurant. He opens the restaurant and cooks fusion cuisine every day for 50 people in the Susa Valley.

From the point of view of the use of thermal energy, your typical day is ...
Describe the typical day of the character illustrated in step 1 by focusing the story on its energy habits with respect to the heating system. Maximum 10 lines.

Gianni's restaurant is moderately large, and he uses a gas boiler to warm up it. However, he spends too much money and to be able to go on, he changed several utilities, slightly improving the situation.

For ____________________________ (name of the character) the main problems (max 5) that it encounters regarding the use and management of energy are ...
List a maximum of 5 issues that you believe would be important to solve from the point of view of energy for heating. For example: expenses, transport of energy, etc.

In fact, all the companies have very high transport costs, which make the costs rise too severely. In addition, Gianni's restaurant has a high heat loss because the building where it is located is from the 70s and it was never renovated. So the energy consumption costs are also very high in the final bills.

Workshop **CITIZENS (23.04.2020)**
STORY SPINE 01 - Current Scenario

Participant 10
Residence City: **Almese**

In the Susa Valley there is a ____ (citizen/expert/member of the public administration) who lives in the region.
Describe the character in terms of age, career, job status, etc. Maximum 5 lines.

In the Susa Valley, there is a citizen, 51-year-old, from a town in the Susa valley, employed and currently working by a local cooperative. She lives in a village in the lower valley, with her family and three children of school age.

From the point of view of the use of thermal energy, your typical day is ...
Describe the typical day of the character illustrated in step 1 by focusing the story on its energy habits with respect to the heating system. Maximum 10 lines.

Her day mostly takes place in the office when her boys are at school. Since nobody is in the house, the heating system is programmed to switch-on only for the evening.

For __________________________ (name of the character) the main problems (max 5) that it encounters regarding the use and management of energy are ...
List a maximum of 5 issues that you believe would be important to solve from the point of view of energy for heating. For example: expenses, transport of energy, etc.

For her the main problem is the management fees that are charged on the bill.

Workshop **CITIZENS (23.04.2020)**
STORY SPINE 01 - Current Scenario

Participant 11
Residence City: **Avigliana**

In the Susa Valley there is a ____ (citizen/expert/member of the public administration) who lives in the region.
Describe the character in terms of age, career, job status, etc. Maximum 5 lines.

In the Susa Valley there is a middle-aged citizen called Pippo, employed for an indefinite period, sensitive to environmental issues and who is part of a company that purchases food products. He is considering the possibility of changing the heating method. He may focus on a pellet stove because he probably will be able to purchase wholesale pellets with other members of his company.

From the point of view of the use of thermal energy, your typical day is ...
Describe the typical day of the character illustrated in step 1 by focusing the story on its energy habits with respect to the heating system. Maximum 10 lines.

Pippo's heating is autonomous, and his home thermostat is set to heat in the early hours of the morning, when the family gets up and prepares to go to work / school. After 9:00, the temperature drops and it rises again around 4:00 in the afternoon until midnight in the evening, then after it drops again.

For __________________________ (name of the character) the main problems (max 5) that it encounters regarding the use and management of energy are ...
List a maximum of 5 issues that you believe would be important to solve from the point of view of energy for heating. For example: expenses, transport of energy, etc.

For Pippo the main problems are the current power source of the boiler that is expensive and requires refueling by a company that must be notified days before (with the problem of holidays).

Workshop **CITIZENS (23.04.2020)** | The creation of the Energy Community in the Susa Valley

STORY SPINE 02 - Future Scenario

Participant 02
Residence City: **Almese**

One day, in the Val di Susa, an energy community was created and ____________________ (name of the character) became co-owner of the energy management. Consequently, his typical day will be like this.
Imagine a future scenario in which the energy community is a reality and describe the typical day of a character belonging to this energy community. What is expected from the energy community?

Billy doesn't have a lot of savings and he has never been able to make large investments in energy saving. Since joining the energy community he has been able to install thermostats to optimize the heating of the rooms he uses the most. By installing more efficient windows, it can minimize heat loss. Now when he gets up, the heating has already been on for one hour as well as when he returns home in the evening. In the evening it can reduce fuel consumption.

Participant 03
Residence City: **Susa**

One day, in the Val di Susa, an energy community was created and ____________________ (name of the character) became co-owner of the energy management. Consequently, his typical day will be like this.
Imagine a future scenario in which the energy community is a reality and describe the typical day of a character belonging to this energy community. What is expected from the energy community?

The 57-year-old citizen invested 5,000 euros in the energy community. The community struggled to take off, due to the difficulty of converging the various participants' approaches with private and public, but ultimately the most reasonable direction prevailed. The choice of the citizens representative was also widely discussed but acceptable. At the moment the investment has not yet produced significant direct economic results but already the first results both locally and supralocal have occurred. Locally several young people are employed in the production chain of primary resources and in the construction of plants. Confidence has also increased in the future and there is also a long-term economic advantage.

Workshop **CITIZENS (23.04.2020)**
STORY SPINE 02 - Future Scenario

Participant 04
Residence City: **Vaie**

One day, in the Val di Susa, an energy community was created and ____________________ (name of the character) became co-owner of the energy management. Consequently, his typical day will be like this.
Imagine a future scenario in which the energy community is a reality and describe the typical day of a character belonging to this energy community. What is expected from the energy community?

Lucia gets up and her house is already warm and comfortable. Now she prepares breakfast and leaves the house with her little girl, carry her to school and goes to work. In the evening when she comes back, she doesn't have to turn on the wood stove anymore because the house is warm, so she has more time to be with her daughter. Although the cost of heating hasn't gone down that much.

Participant 06
Residence City: **Borgone Susa**

One day, in the Val di Susa, an energy community was created and ____________________ (name of the character) became co-owner of the energy management. Consequently, his typical day will be like this.
Imagine a future scenario in which the energy community is a reality and describe the typical day of a character belonging to this energy community. What is expected from the energy community?

After the energy community was created, it did not disrupt the life he is accustomed to lead, because he is enjoying the energy saving, energy production and the satisfaction of using a free source. These are a passion for him in the good sense, he has extra security and life is going really well in respect of the environment and as a warning to the new generations to continue the fun. It is something to teach and encourage men... Making it clear that it is not because he possess these satisfactions but because he manages to live consuming very little world resources, and perhaps increasing reserves. If he can live without consuming, it means that it is almost like producing resources for others, because his resources are available to those who are unable to live like him.

Workshop **CITIZENS (23.04.2020)**
STORY SPINE 02 - Future Scenario

Participant 07
Residence City: **Susa**

One day, in the Val di Susa, an energy community was created and ____________________ (name of the character) became co-owner of the energy management. Consequently, his typical day will be like this.
Imagine a future scenario in which the energy community is a reality and describe the typical day of a character belonging to this energy community. What is expected from the energy community?

I don't think that the teacher's daily life would change much. It would be nice, however, to think that the excess energy produced by her photovoltaic panels would remain in the territory and maybe it would be stored and redistributed even in the evening. It would be nice that, through the energy community, she had more access to precise and simple information, for example on how to isolate the house. Or more access to subsidized loans.

Participant 08
Residence City: **Bussoleno**

One day, in the Val di Susa, an energy community was created and ____________________ (name of the character) became co-owner of the energy management. Consequently, his typical day will be like this.
Imagine a future scenario in which the energy community is a reality and describe the typical day of a character belonging to this energy community. What is expected from the energy community?

BRUSHLESS is now a member of the energy community and for him there are 2 main innovations:
1- He wakes up in a heated environment and he has breakfast in it. When he returns, he finds the house warm. All without having to do the hard work of recover, cut, split the wood and also, he pollutes less. In addition, his bill is a little lighter so he can go out for dinner in the restaurant of his city and therefore making more money run inside the community;
2- He thinks that the idea of a community applied to energy is a small step towards the realization of a wider idea of community. Which also extends to the creation of agricultural communities for self-production of many other things, primarily food!

Participant 09
Residence City: **Chianocco**

One day, in the Val di Susa, an energy community was created and ____________________ (name of the character) became co-owner of the energy management. Consequently, his typical day will be like this.
Imagine a future scenario in which the energy community is a reality and describe the typical day of a character belonging to this energy community. What is expected from the energy community?

Now Gianni has solved some of his problems. He no longer has such high energy transport costs. He has integrated his boiler with solar panels, and he has managed to insulate walls and windows in a satisfactory way. Maybe he will not need to close his business.

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SCORE
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