POLITECNICO DI TORINO

College of Engineering and Management

Master of Science in Engineering and Management

Master of Science Thesis

Development of a multi-criteria analysis for supporting Energy Community in Susa Valley

Supervisors:

Prof. Patrizia Lombardi
Dr. Sara Torabi Moghadam
Prof. Domenico Maisano

Candidate:

Santiago Manzo

March 2020

Declaration

I hereby declare that the contents and organization of this dissertation constitute my own original work and do not compromise in any way the rights of third parties, including those related to the security of personal data. Part of the work described in the thesis was previously published in the publications listed in Appendix.

Santiago Manzo

2020

Part of the work described in this thesis was also previously published in the following publications. Minor grammatical changes and some information extensions have been made to integrate the articles within this dissertation. Both scientific articles are included in the Appendix section.

- **Article 1. Torabi Moghadam, S., Di Nicoli, M. V, Manzo, S., & Lombardi, P. (2020). Mainstreaming energy communities in the transition to a low-carbon future: a methodological approach.** ***Energies Journal.*** (Under revision)
  - Submitted to section: Energy and Buildings.
  - Special Issues: Building Energy Audits – Diagnosis and Retrofitting***.***

- **Article 2. Torabi Moghadam, S., Di Nicoli, M. V, Manzo, S., & Lombardi, P. (2019). Supporting Consumer Co-Ownership in Renewable Energies.** Presented in SBE19 Malta conference. (Under revision).
  - Submitted to Conference Proceeding

Abstract

It is currently possible to detect a continuous and alarming increase in primary energy consumption and gas emissions through the analysis of historical data and future perspectives.

The main goal of the present study is to analyse the feasibility of different refurbishment alternatives that were proposed in five municipalities along the Susa Valley, Italy, in order to increase the energy efficiency of building systems and reduce the energy consumption. This will be made through a Multi-Criteria Analysis (MCA), assessing seventeen key performance indicators (KPIs) from technical, economic, environmental and social points of view.

The proposed study covers a middle phase of the ongoing SCORE (Supporting Consumer co-Ownership in Renewable Energies) project. This project is supported by the European Union, within the scope of the Horizon 2020 program. Specifically, "SCORE" aims at overcoming the usage of fossil fuel energy in favour of renewable energy sources (RES), through the creation of "Energy Communities". The term "Energy Communities" denotes a project carried out by citizens, which autonomously organized themselves in order to construct a new energy structure that aggregate producers and consumers in matter of energy, creating "Prosumers". The project provided for the realization of three practical case studies; in Italy, Poland and Czech Republic, also with the support of teams from Germany and Bulgaria.

During this study, two articles were written, "Supporting Consumer Co-Ownership in Renewable Energies: SCORE H2020 project" presented in SBE Malta[1] and "Mainstreaming energy communities in the transition to a low-carbon future: a methodological approach" which is under revision for Energies Journal.

[1] SBE19 Malta was an International Conference about sustainability and resilience, held on 21-22 November 2019

Acknowledgements

First, I would like to thank my parents, Pablo and Carolina, and my sister Florencia, for the constant support in my life and for allowing me to realize this incredible experience abroad.

I also want to take the opportunity to thank Sara Torabi Moghadam for guiding and support me during these months, and for the useful critics that improved my work. I am also grateful to Prof. Patrizia Lombardi, Prof. Domenico Maisano and Maria Valentina Di Nicoli for their kind help and advice.

I wish to show my gratitude to Candela, for being my partner, for the unconditional and emotional support at the distance and for being present at the proclamation day.

Last but not least, I would like to thank my entire family, including Octavio and Adela, and my friends because without them this experience would not have been the same.

Thank you,

Santiago Manzo

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List of Acronym

Btu: British thermal unit.

CO_2: Carbon Dioxide.

CSOP: Consumer Stock Ownership Plan.

DH: District Heating.

DHW: Domestic Hot Water.

DM: Decision Maker.

EC: Energy Community.

EEC: Energy Efficiency Certificates.

EIA: Energy Information Administration.

EU: European Union.

GAIA: Graphical Analysis for Interactive Aid.

GJ: Giga Joule

IEMD: Internal Electricity Market Directive.

KPIs: Key Performance Indicators.

MCA: Multi-Criteria Analysis.

MCDM: Multiple Criteria Decision Making.

nZEB: Nearly Zero Energy Building.

OECD: Organization for Economic Cooperation and Development.

PBP: Pay-Back Period.

PEFC: Program for Endorsement of Forest Certification schemes.

PM: Particulate Matter.

PROMETHEE: Preference Ranking Organization Method for Enrichment Evaluations.

RES: Renewable Energy Sources.

SCORE: Supporting Consumer co-Ownership in Renewable Energies.

SDG: Sustainable Development Goals.

SEN: National Energy Strategy.

SME: Small and Medium Enterprises.

TAA: Thermal Account Access

CHAPTER 1: INTRODUCTION

1.1 Problem Statement and background

The world energy panorama is constantly changing, the global energy consumption has about doubled in the last three decades of the past century, growing in a roughly exponential way. The doubling-up nature becomes a concern: energy consumption cannot continue doubling forever. This situation sounds alarming and it could be associated to different factors, such as geoclimatic, technological and demographic, that have been changing during the last decades. Among the various elements that have increased the amount of primary energy consumed, the most influential ones could be: social development and industrialization, population growth and technological and scientific advances (Beretta, 2007).

Looking at Figure 1, it is easy to see a constant growth in primary energy consumption, and the real problem is that this increase is also reflected in future projections.

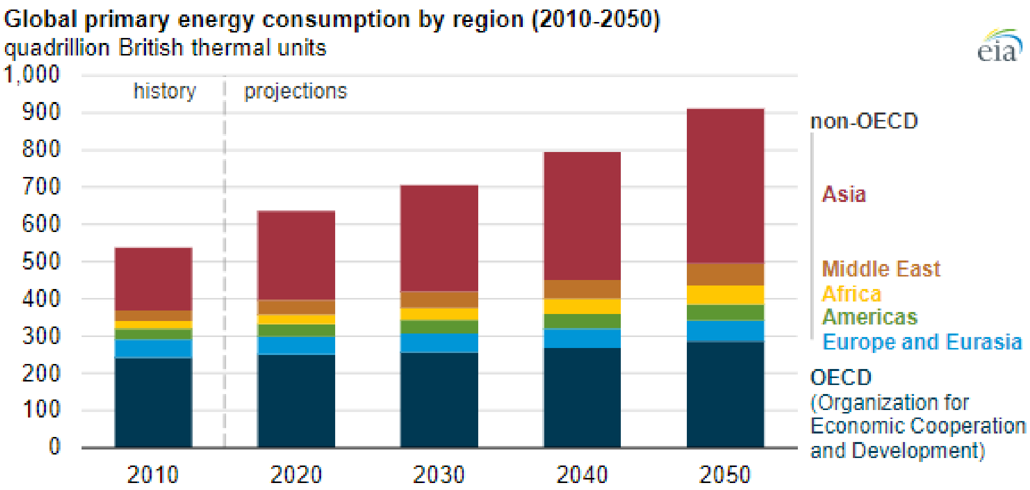


Figure 1: Global primary energy consumption by region (2010-2050) in British thermal units [2](BTU).

The U.S. Energy Information Administration (EIA) projects that world energy consumption will grow by nearly 50% between 2018 and 2050 (Energy Information Administration, 2019). Most of this growth comes from countries that are not part of the Organization for Economic Cooperation and

[2] A British thermal unit (Btu) is a measure of the heat content of fuels or energy sources. It is the quantity of heat required to raise the temperature of one pound of liquid water by 1 degree Fahrenheit at the temperature that water has its greatest density.

Development (OECD)[3]. The increment is principally focused in regions where strong economic growth will be demanded, particularly in Asia, including China and India. On the other side, in OECD countries there is a fairly constant trend, despite being accompanied by a growing development of the markets. This is due to greater energy efficiency, technically speaking, and a gradual supply from energy sources in favour of renewable ones.

In Figure 2a it is represented the current portion of primary energy consumption that is destined to renewable sources such as hydro, wind, wave, solar heat and biomass. Only the 7% of the total amount is provided by renewable sources, leaving a clear dominance to non-renewable carbon-based fuel oil, gas and coal, with almost 86% of energy consumption. This is a concern due to all the negative aspects and consequences that the use of fossil fuels implicates (Ashby, 2009).

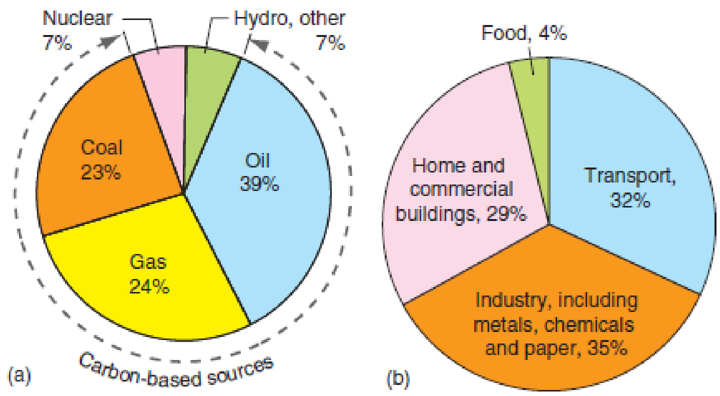


Figure 2: World energy consumption (a) by source and (b) by use.

It is important to say that currently most of the energy consumption goes into three big sectors: transportation, buildings (heating, cooling, lighting), and industry (Figure 2b). The industrial sector, which includes refining, mining, manufacturing, agriculture, and construction, accounts for the largest share of energy consumption of any end-use sector, with more than 50% of the total end-use energy consumption during the entire projection period (Figure 3). World industrial sector energy use increases by more than 30% from 2018 to 2050, most of the increase in industrial sector energy use occurs in non-OECD nations.

[3] It is an international organisation that works with governments, policy makers and citizens, establishing international norms and finding evidence-based solutions to a range of social, economic and environmental challenges.

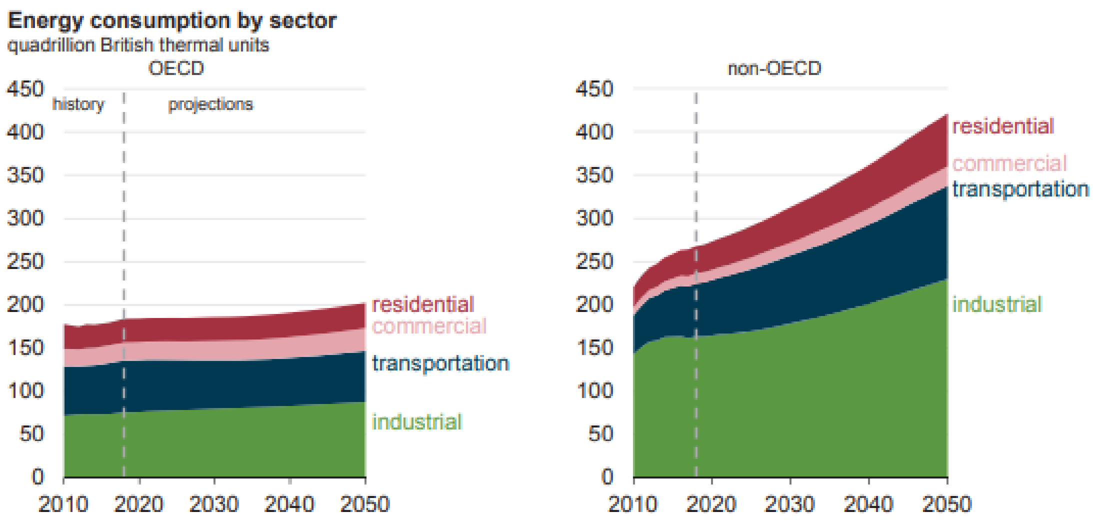


Figure 3: Energy consumption by sector (source: EIA).

Even more alarming is the fact that for every unit of energy, produced by combustion of fossil fuels, we introduce in the atmosphere tons of polluting emissions, among which the most relevant is carbon dioxide (CO_2). This contributes directly to greenhouse-gas effect and leads to increasingly evident ecological and climatic imbalances and changes. The emission of particulates such as PM_{10}[4], affects human health on the local and regional scale. Due to the particulates dimensions, they can be carried over large distances along with movements of air masses.

For all the reasons presented, it is necessary to develop a "decarbonisation process" towards the energy transition. Energy transition means moving from energy from fossil fuels in favour of renewables one and improving the efficiency related to energy production (Piwowar & Dzikuć, 2019).

1.2 Energy Community

Taking into account the current and alarming energy framework described, it is strictly necessary to find an urgent solution in order to reduce the primary energy consumption and therefore the pollutant gas emission. This can affect the human health and contributes directly to climate change, causing all types of environmental issues. One of the plausible responses could be the creation of autonomous "Energy Communities (EC)", which focus on overcoming the usage of fossil fuels in

[4] Is particulate matter 10 micrometres or less in diameter.

favour of renewable energy sources. This kind of communities are made-up of citizens who organize themselves independently to self-produce renewable energy.

As it is known, certain forms of communities focused on renewable energy have been developing in different countries across Europe, like in Germany, Sweden, Denmark and the Netherlands. This has been happening since the 1970s, and it has subsequently occurred in other European countries. The European Federation of renewable energy cooperatives accounts in 2018 for 1250 energy cooperatives; overall about one million citizens are involved in distributed energy generation and management. Currently, Germany is leading the field of renewable energy communities, with over 500 energy co-operatives and 80,000 members involved. Globally, thousands of initiatives are now counted as examples of energy communities, the challenge is to make them come real at a big scale. (Moroni, Alberti, Antoniucci, & Bisello, 2019).

The new "RES Directive" (RED II), by the end of 2018 and for the first time, includes a definition of a 'renewable energy community' at a European level (Lowitzsch, 2019). The text defines it as:

A legal entity: i) which, according to applicable national law, is based on open and voluntary participation, is autonomous, and is effectively controlled by shareholders or members that are located in the proximity of the renewable energy projects owned and developed by that community; ii) whose shareholders or members are natural persons, local authorities, including municipalities, or small and medium enterprises (SMEs); iii) whose primary purpose is to provide environmental, economic or social community benefits for its members or the local areas where it operates rather than financial profits (European Union., 2018).

1.2.1 How Energy Communities work

Energy communities involve energy generation from renewable sources in which, the technologies that are involved, are partly or wholly owned by local citizens (Dóci et al., 2006). The energy is self-produced, distributed and consumed regardless of the national network, leading into a new form of management and consumption of energy, which makes the market more efficient and democratic.

As can be seen from the RES directive definition of renewable energy communities, they are made up of a group of citizens, who can be public or private subjects, integrated by a common goal that is to produce energy from renewable sources.

There can be conventionally three types of users within ECs:

- The residential ones, which represent the citizens' housing users. They may belong to a single house or to multiple housing units, as a condominium.
- There are also industrial users, these typically need a greater amount of energy, as was demonstrated in the first chapter in the definition of 1.1 Problem Statement and background.
- Finally, the tertiary ones, which represents different services such as schools, hospitals, shopping or logistics centres (Politecnico di Milano, 2014).

Figure 4: Represents how an Energy community works (Casaeclima.it).

Energy communities aim to be able to sell energy without intermediaries. Assuming that a private citizen is in possession of an electricity production plant (such as photovoltaic panels, wind turbines), if that citizen cannot consume all the energy produced, he/she could feed the national electricity grid selling energy. Therefore, if users located in neighbouring areas need energy, they could purchase it directly from the national electricity grid and not from the producer. In fact, this way of distributing energy optimize the consumption, obtaining a higher energy efficiency and reducing network losses.

1.2.2 Legislative framework

In this context, on 30th November 2016, the "Clean Energy for All Europeans package" was presented by the European Commission. This focuses in keeping EU competitive as the energy transition global energy markets (Lowitzsch, 2020). The RED II rules are part of this package and are embedded in the 2019 Internal Electricity Market Directive (IEMD). RED II legislative initiative has four main goals that are:

- Energy efficiency.
- Global leadership in RE.
- A fair deal for consumers.
- Redesign of the internal electricity market.

These directives define national targets for each country, taking into account the actual production level and the potential production of renewable energy for the next years. Also defines action plans in order to reach those targets. These rules enable stakeholders to join ECs that produce energy (e.g., electricity) for self-consumption and to share the energy produced within the EC. In this way, the "prosumer" has an active role in the production and consumption of energy from EC, sanctioning the right of citizens and communities to produce, store and consume energy from RES.

As was mentioned before, energy communities are already present in different countries. In most of them, it is partially or totally regulated (Van Der Schoor & Scholtens, 2015). A different case is Italy, in which there is still no national law governing such initiatives.

Article 71[5] on OIL FREE ZONES frame, in some way, the problematic in Italy at a national level, focusing on the emancipation from fossil fuels in favour of clean energy from renewables. It is effective since 02/02/2016 and express the following:

"Oil free zone" means a territorial area in which, within a certain period of time and on the basis of specific act of address adopted by the municipalities of the territory of reference, the progressive replacement of the oil and its derivatives with energies produced from renewable sources (Law from 28/12/2015 n. 221 -, 2016).

This article was dictated by the National Energy Strategy (SEN) and is part of a ten-year plan of the Italian Government to manage the change in the energy system. The SEN, places the figure of the consumer at the centre considering it the "engine of the energy transition".

[5] From Law n. 221 since 28/12/2015 – "Disposizioni in materia ambientale per promuovere misure di green economy e per il contenimento dell'uso eccessivo di risorse naturali" in Italian.

Going more specifically, at a regional level it is located the Piedmont Region, where the Italian pilot case study of SCORE project will be placed. The first Piedmont regional law was about “Promotion of the institution of energy communities” and it was promulgated in August 2018[6], (Bu, 2018). This law has the purpose of overcoming dependence on petrochemical products, promoting procurement from renewable sources and promoting energy efficiency. The law establishes that these communities must be non-profit and that the proposals come from the municipalities themselves. Both public and private entities can participate and states that in order to qualify as an energy producer the person in question must have a minimum self-consumption of 70%. In addition, the Piedmont Region hereby undertakes to financially support these communities by allocating 25,000 euros for the year 2018 and 2019.

The regional law also provides of a permanent technical panel between the ECs and the region in order to acquire data related to the reduction of primary energy consumption, on the amount of self-consumption and on the share of use of renewable energy. All of this, allows to analyse and identify more efficient methods related to management of energy networks.

1.2.3 Positive aspects of Energy Community implementation

There are many benefits and advantages due to the implementation of this kind of projects at a local level:

- With the decentralization of energy generation, from medium-large size energy production centres to medium-small ones, more individuals and businesses are able to play a role in the energy system. This enables new business models and ownership structures of energy to emerge.
- Another positive aspect could be that that profits and energy costs do not flow out of the region when generating energy locally. Also reduce the energy dependence from abroad and the development of national supply chains. This could undoubtedly help to bring down the cost of energy in the long run compared to the traditional supply, benefiting people.
- As installations are operated and owned at the regional level, new jobs are created both directly and indirectly. Direct jobs are those created to manage the operation and management, whilst indirect jobs result from local supply chains, such as using regional

[6] Regional law 3 August 2018, n. 12. - “Promozione e sostegno per l’istituzione delle comunità energetiche” in Italian.

biomass resources. If public authorities play an active role in a renewable energy community, then they can benefit from cheaper energy for public utilities, such as street lighting, and savings can be refocused on those at risk of energy poverty, or on other regional priorities (Dóci et al., 2006).

- In addition, this innovative concept could be particularly convenient for those countries suffering from geographic isolation. In such places, as mountain communities can be, for example, having an electricity generation plant, and the ability to administer it according to need could certainly bring an energy advantage, improving the efficiency of the network, and economic; giving new motivation to these communities. The implementation is very advantageous where there are no suitable storage systems for the energy produced because the generation of renewable energy can be discontinuous, with a massive production of energy in limited periods of time (European Commission, 2013).
- Finally, there are important environmental benefits as the reduction of polluting emissions and primary energy consumption, trying to eradicate energy poverty.
- In this way, energy community can help to increase the acceptance of renewable energies in societies.

1.2.4 Challenges

Whilst there are many positive aspects obtained from creating an energy community, there are a number of challenges that can difficult their development. Examples of them could be the availability of leadership, skills and finance needed, as well as the roles of regulation, the existing energy market, and also cultural issues (Dóci et al., 2006).

People who are interested in creating an energy community need to be co-ordinated in order to build a legal, administrative and management structure. It is required full awareness of regional resources and to have legal and financial knowledge. Without political motivation and direction from a public authority, it can be difficult to overcome this.

Significant initial investment is usually required in this kind of projects, whilst other costs such as operation and maintenance, are low in the long run. External financing, as banks, will be required if it is not possible to raise the initial amount. And the issue is that nowadays, banks and financial intermediaries have low awareness of community energy structures and how they work, and convincing them can be a tough challenge.

Entering to the energy market could also be another of the challenging aspects. Gaining access to grids and competing on a fair basis with the existing and traditional energy utilities, could be difficult if distribution system operators do not recognize an EC structure as a supplier, or prioritize energy from other resources (Lowitzsch, 2019).

Last but not least, cultural issues related to common ownership may impact in the development of community. There are examples of countries like Germany and Denmark which have long traditions of co-operative ownership and decision-making, partly explaining their success in community energy (Dóci et al., 2006; Roberts, Bodman, & Rybski, 2014). Post-communist countries, on the other hand, may offer resistance and oppose to this “innovative” community or co-operative schemes.

1.3 SCORE project

The Agenda 2030 for Sustainable Development adopted by the United Nations on 2015, is an action plan for people, planet and prosperity. It focuses in strengthen universal peace, eradicate poverty and hunger and to secure the planet from degradation. For this reason, 17 Sustainable Development Goals (SDG) were announced, stimulating action in areas of critical importance over the next 15 years (Ferri, 2010).

Figure 5: Sustainable Development Goals (sustainabledevelopment.un.org)

In this context, the ongoing Horizon 2020 project named SCORE (Supporting Consumer co-Ownership in Renewable Energies) was funded and financially supported by the European Union (EU). It focuses particularly on Goal 11 “Make cities and human settlements inclusive, safe, resilient and sustainable”. This project has received funding from EU’s Horizon 2020 research and innovation programme under grant agreement N°784960.

Specifically, the main objective of SCORE project is the engagement of private and or public consumers towards sustainable energy transition. To accomplish this objective, there are different issues that will also be addressed in the course of the project, like: overcoming the usage of energy from fossil fuels by promoting and facilitating the production of energy from renewable sources, increasing energy efficiency of building systems, as envelope or energy system, and reduce energy consumption through behavioural change of the users of the buildings/neighbourhood (Nicoli, Moghadam, & Lombardi, 2020).

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

Supporting Consumer co-Ownership In Renewable Energies

Figure 6: SCORE project logo (SCORE-h2020.eu)

In addition, the project focuses on the dynamics of the society, analysing the role of citizens, trying to shift from individual to community, and therefore from consumer to prosumer of renewable energy. The concept of “prosumer” is new in the energy field and denotes a consumer who both consumes and produces energy, participating in the production and distribution phases. Prosumers produce energy primarily for their own needs but can also sell the excess. Into this, they obtain benefits by generating a part of the energy they consume, reducing their overall expenditure for energy and receiving a second source of income due to the sale of remaining production. From this, “SCORE” aims to encourage the consumers to play an active role, contributing himself to the production of energy.

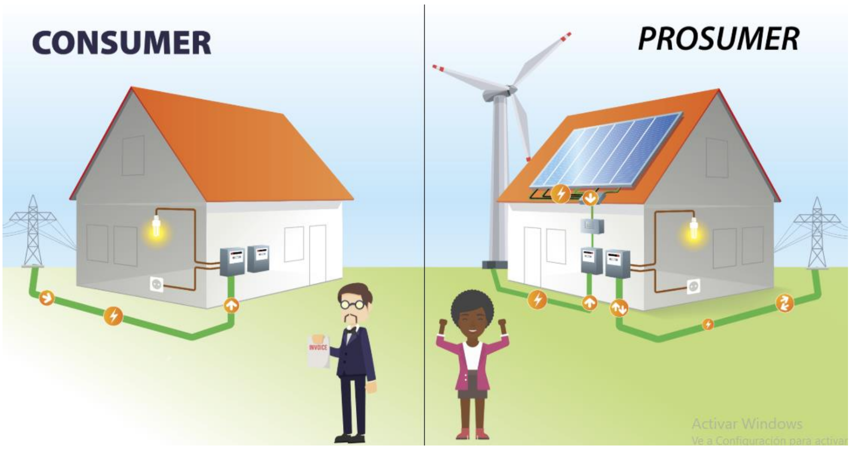


Figure 7: Consumer and Prosumer model representation (Energy.gov)

The project has a duration of 36 months starting in 1 April 2018 and ending on 31 March 2021, and involves partners from different countries as it is shown.

Table 1: Partners from SCORE project

Partner	Short name	Established in
Stiftung Europa, Universitat Viadrina Frankfurt (Oder)	EUV	Germany
Ec Brec Instytut Energetyki Odnawialnej Sp Zoo	IEO	Poland
Climate Alliance, Klima-Buendnis, Alianza Del Clima e.V.	CA	Germany
Center For The Study Of Democracy	CSD	Bulgaria
Politecnico Di Torino	**POLITO**	**Italy**
Co2online Genuetzige Beratungsgesellschaft MBH	CO2ONLINE	Germany
Porsenna O.P.S.	PORSENNA	Czech Republic
La Foresta Società Cooperativa	FORESTA	Italy
Miasto Slupsk	PLUPSK	Poland
Mesto Litomerice	LITOMERICE	Czech Republic
Consorzio Forestale Alta Valle Susa	CFAVS	Italy
Deutscher Caritasverband EV	CARITAS	Germany
Amico Società Cooperativa Sociale	AMICO s.c.s.	Italy
Federacja Konsumentow Stowarzyszenie	FedKon	Poland

The four local partners in charge of the Italian pilot are: Politecnico di Torino, the forestry and lumber cooperative La Foresta, the Consorzio Forestale, and the social cooperative AMICO (Grant

Agreement, 2018). Below there is a brief description of each of the Italian partners and their function within the project.

- **Politecnico di Torino** is as a technical-scientific university and research body. It offers both theoretical and applicative support, as well as organizational and production process management skills.
- **Consorzio Forestale** is a well-known company located in the Susa Valley and founded in 1953. It coordinates public authorities and private firms in harvesting the woods, developing the project design. The company manages the forestry conjointly owned by the municipalities of the valley
- **La Foresta** was founded in 1996 that extended its expertise five years ago to installing and managing heat power plants of small and medium size (20-300 kW) and already operates in the Susa Valley. In 2012, it obtained the PEFC[7] certification for wood and wood chips. Within the working group for the SCORE project, he plays the role of a qualified person in plant and design consultancy.
- **The social cooperative AMICO**, a well-known non-profit organisation related to Catholic Church, reaches out to low-income families involving disabled employees. For SCORE project purposes, the company will be responsible for the reintegration of marginalized people, acting as an intermediary to reach the weak sections of the population, which is one of the SCOREs' main objectives.

Figure 8: Project partners' logo (Consumer & Ownership, 2019)

[7] From the English acronym "Program for Endorsement of Forest Certification schemes".

1.3.1 The aim

Nowadays, the most represented group related to EC and prosumership are men belonging to a middle age and high income group. SCORE particularly focuses in the participation and inclusion of women and low-income households, specially unemployed.

The participation of these under-represented groups as prosumers is a core element in the fight against energy poverty, which is defined as the lack of access to energy or pay the necessary energy to meet basic needs in order to reach adequate living condition (Ahmed & Gasparatos, 2019).

The project aims at implementing these energy communities in three pilot regions:

- Italy, Susa Valley (biomass district heating)
- Poland, City of Słupsk (photovoltaics)
- Czech Republic, City of Litoměřice (photovoltaics).

These pilot projects have to demonstrate the practical feasibility of optimized joint prosumer investments with local municipalities in order to be extended to various other follower cities across Europe in a near future (Moghadam, Di Nicoli, Giacomini, Lombardi, & Toniolo, 2019a). Germany, as a pioneer in prosumership, will serve as leader country, and Bulgaria is central to the development of an approach for the inclusion of households affected by fuel poverty. (www.score-h2020.eu, 2018).

The SCORE project main objective is related to the engagement of private and/or public consumers towards sustainable energy transition. Energy transition is not the replacement of fossil fuels in favour of renewable sources, it is also an improvement of the efficiency of the energy system in the production phase and aware building users and citizens about energy consumption. The different purposes of the project could be summarized as following:

- Motivates consumers to become prosumers of RE; firstly, in three pilot regions (Italy, Poland and the Czech Republic) and, secondly, expand this type of communities in cities across Europe, following the pilot projects. Increasing the awareness of consumers regarding the advantages of investing in project that involves RE in a local context (co-ownership).
- Demonstrates to local authorities and consumers the positive impact co-ownership has on consumer behaviour. It shows the ability of this democratic participation model to include women as well as low-income households, in particular unemployed.

- Empowers consumers and municipalities in a capacity-building program through the launch of an interactive software "RE Prosumer Investment Calculator" and different seminars in the five partner countries (Germany, Italy, Bulgaria, Poland, Czech Republic).
- Formulates policy recommendations to promote prosumership and to remove barriers for consumers to become active market players at the EU and national levels. SCORE enables municipalities in the partner countries to develop innovative and successful legal and financial solutions that are compatible with future European legislation, and can be customized for local needs.

1.3.2 Italian Pilot

The Susa Valley (45° 8' 12 north, 7° 3' 29 east, from 300 to 3.612 m ASL[8]) was the selected Italian pilot case to be studied during the SCORE project. It is one of the widest and deepest Italian alpine valleys and it is located in the northern part of Italy, in Torino province. It extends for about 100 km in length, starting in the city of Turin via the western part of Piedmont region, bordering France. It contains nearly 90,000 inhabitants distributed in 39 municipalities, being the largest and most populous valley in Piedmont. The different morphological, altitudinal and climatic characteristics within the valley have contributed to differentiate the development of the territory, aggregating the municipalities into four geographical areas: Oulx, Susa, Condove and Avigliana.

SCORE focuses on replacing existing heating facilities powered by diesel and oil fuel, with low efficiency and a lot of air pollutants, with new ones fuelled by biomass by wood chips that are locally produced. Approximately 2,200 households will benefit from changing their heating energy source from fossils to renewables. This process is further accompanied by energy efficiency measures (Consumer & Ownership, 2019).

In the Susa Valley area, wood biomass appears to be a plentiful resource and was decided to be exploited during the project. It is important to know that if the area is harvested below the annual growth rate, then woody biomass stocks are not depleted and therefore harvesting is considered sustainable. However, if annual harvesting exceeds incremental growth, it is unsustainable, leading to a decline of woody biomass, forest degradation and net carbon emissions (Piwowar & Dzikuć, 2019).

[8] Above sea level.

The main reasons of the biomass selection are that is a renewable resource widely available in the chosen area, it aims to promote a certified and controlled supply chain, according to sustainable development principles. Also, biomass is considered as a good starting point for the creation of energy communities, due to low-risk investments. Another reason is that biomass allows programmable energy generation, unlike other renewables which are discontinuous energy sources.

It is intended to exploit this resource with a sustainable forest administration view, through the controlled supply chain of wood. Having a forest certification allows consumer to have a wood-based product from forests managed in an economically, ecologically and socially sustainable way. Specifically, SCORE relies on the PEFC certification. The main objective of PEFC is to provide the users of forest products with precise and verifiable information on the content of the material coming from PEFC certified forests, managed sustainably, from recycled material and from controlled sources.

PEFC enables companies to demonstrate legal and sustainable sourcing of forest products to customers. It also provides a variety of advantages that help the environment, people, and the company in itself, accessing to new markets and to have compliance with legislation (PEFC, 2015).

1.4 Research objectives

During the first's phases of the SCORE project in Susa Valley, the Italian pilot, different case studies were selected during a preliminary analysis. The two main objectives of the current thesis are:

- Assess KPIs defined within the SCORE project, doing an impact assessment.
- Select the best refurbishment alternative through MCA for each case study of the Italian pilot.

To make it possible, it was necessary to perform a multi-criteria decision method, evaluating each alternative through different key performance indicators. The indicators represent the project as a whole, including economic, social, environmental and technical aspects. Overall, the thesis aims to analyse specifically the different projects proposed and to express, taking into account the definition of the problem, which are the best alternatives from a sustainable perspective.

Based on the results that emerged from the method employed, the project will continue the analysis by focusing on the alternatives proposed and evaluating different scenarios for each, applying a sensitive analysis to check the robustness of the model.

1.5 Thesis Structure

As for the structure of the paper, the thesis is organized as indicated below.

In the next chapter, the methodology will be described in detail, to show the different steps that will be involved during the analysis, in order to arrive to the best retrofit alternative for each previously selected case studies located in Susa Valley. The methodology process is divided in three phases, the first one involves the preparation of data and buildings, which is already done. The second and most important one for my thesis purposes, is about a preliminary and feasibility analysis, and the last step is about target group involvement which is currently starting. During the chapter, the ten different pilot case studies within Susa Valley will be explained.

In the third chapter, the methodology will be applied in order to outline the preferable refurbishment alternative among those proposed for the realization of the Italian case study. The choice will be made on the basis of various criteria, regarding environmental, economic, technical and social aspects. These criteria will be assessed and particularly described taking into account the stakeholders' preferences. To check the robustness of the model, a sensitivity analysis will be performed during the chapter. It is carried out making changes in the weights of each key performance indicator. In this part the collected data will be processed. The values thus obtained will be presented in the evaluation matrix. This will be used as starting data for the "Visual PROMETHEE" software. The method will rank the retrofit energy systems proposed for the construction and generate the resulting values for each case study.

In the fourth chapter, the results obtained at the end of the entire proposed methodological procedure will be exposed and discussed. The focus will be on the sensitivity analysis proposed in the previous chapter.

In the last chapter, the conclusions drawn from the thesis work and the perspectives for the continuation of the SCORE project will be reported.

The appendix will be divided in two:

- Appendix 1: Contains the two scientific articles generated during the writing of this thesis *"Mainstreaming energy communities in the transition to a low-carbon future: a methodological approach"* which is under revision to be published in Energies Journal and *"Supporting Consumer Co-Ownership in Renewable Energies"* presented in SBE19 in Malta.

- Appendix 2: Contains screenshots of Visual PROMETHEE software of each municipality analysed during this thesis.

CHAPTER 2: METHODOLOGY

2.1 Methodology approach

The methodological framework of the development of Energy Communities in Susa Valley, consists of three major phases: (I) the preparation, which includes the building identification and data collection; (II) the preliminary and feasibility analysis of different retrofit alternatives to shift from fossil fuels to renewable energy, reduce energy consumption and increase the efficiency of the building envelope and/or energy system. To perform this phase, a multi-criteria analysis (MCA) was employed to compare and select the best alternative based on the Key Performance Indicators (KPIs) considering different stakeholders' opinions. Finally, (III) which focuses in citizens and public/private entity's involvement, focusing on SDG number eleven, eradicating energy poverty.

It is helpful to break it down into elements to understand the research process steps employed in this study. To this end, in **¡Error! No se encuentra el origen de la referencia.**a schematic flowchart of the methodological approaches of the research is shown. Each phase is explained in detail illustrating their outputs and used methods.

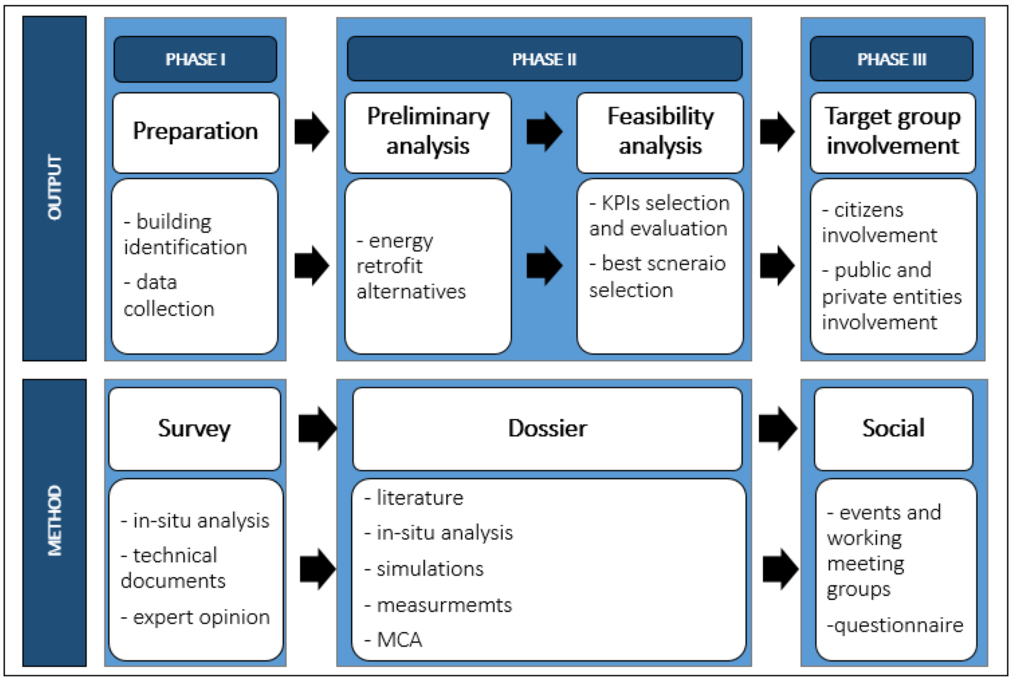


Figure 9: Work-flow of different steps. This Image was taken from: Torabi Moghadam, S., Di Nicoli, M. V, Manzo, S., & Lombardi, P. (2020). Mainstreaming energy communities in the transition to a low-carbon future: a methodological approach. Scientific article that is currently under revision.

2.1.1 Phase I: Preparation

Within the first phase, preparation, the different pilot case studies located in Susa Valley are identified, and their characteristics are described. The pilots are small municipalities in which some buildings have been identified as air pollutant and with an inefficient energy system fuelled by non-renewable sources like diesel or natural gas. All the data was collected through two pre-defined surveys provided by project partners (Torabi Moghadam, Di Nicoli, Giacomini, Lombardi, & Toniolo, 2019). In-situ analysis were done in order to fill the surveys and complete this phase, taking into account the expert opinion and different technical documents.

The first survey regards the investments' identification of RES. The aim was to collect information about the buildings involved in each case study, describing the actual geometry and characteristics, the current energy plant system and the planned project in term of RES and financial aspects. This present survey is composed by five sections:

1. The first part identifies the building characteristics such as building ownership, building construction year, year of the last refurbishment, heat and domestic hot water (DHW) distribution system operator, average of consumptions expenses, the total number of dwellings or offices, the total official number of inhabitants/employees, number of floors, total usable area and total roof area.
2. The second one investigates the existing conventional energy sources or external supplier. Involving the type of energy sources, installed power or purchased power if the district heating (DH) network is present.
3. The third part describes the existing renewable energy sources, including type of energy sources, installed power and active surface if photovoltaics and solar thermal panels are present.
4. In the fourth part, the planned renewable energy sources are investigated.
5. Finally, the five and last section is dedicated to the planned structured of financial sources for the RES investment. Taking into account, type of financial sources and percentage of overall costs.

The aim of the second survey is to collect data about the use of non-renewable energy sources in terms of energy costs and tariffs for the actual situation. Information like average consumption fee [€/GJ], annual consumption [GJ], historical data for oil and natural gas cost [€/GJ] and the average fixed fee [€/month] is collected.

2.1.2 Phase II: Preliminary and feasibility analysis

This second phase consists in the preliminary and feasibility analysis in order to reach the best refurbishment alternative for each pilot. The core of this thesis is centred in this section, so it is considered the most important one.

This phase is investigated within a specific document, called "Dossier" (Nicoli et al., 2019). The "Dossier" represents a guideline through which it is possible to collect and present the information related to the pilot projects. The refurbishment alternatives are described and evaluated within the Dossier in order to improve and increase the energy efficiency.

Particularly, the Dossier shows the comparison between the current situation and the refurbishment scenarios focusing on the achievement of "SCORE" objectives. It is divided in different sections, the first part include an analysis of the current situation taking into account the context, buildings involved and energy consumption for space heating, DHW and lightning. This is particularly done by collecting measured data and in-situ analysis. Then, the retrofit alternatives are presented understanding the needs of the pilot projects. The goal is to propose at least two different refurbishment alternatives for each case study. After that, an environmental impact assessment is done illustrating the strategies to minimize environmental impact. Finally, a security plan, a risk and investment cost assessment and a full business plan have been defined to determine and evaluate if the alternative could be appropriate in economic and financial terms.

Nowadays the involvement of different aspects like technical, social, economic and environmental has become complex the process of energy planning for the decision makers. It turns complicated to optimize energy alternatives taking into account each indicator separately. Multiple criteria decision making (MCDM) is a branch of operational research which deals with the presented problem, developing optimal results in complex scenarios providing flexibility and including various indicators, conflicting objectives and criteria (Kumar et al., 2017).

In order to select the best scenario for each case study, an outranking multi-criteria analysis (MCA) has been implemented. The use of an MCA assesses the best refurbishment alternative, considering the comparison of different KPIs that were primarily selected. The target is to provide a comprehensive overview of the best alternative.

The "Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE)" method will be applied, with the help of the "Visual PROMETHEE" software. This out-ranking method for decision aid, was chosen because it allows a careful study of the problems related to the study of energy systems (Dirutigliano, Delmastro, & Torabi Moghadam, 2017). It is based on a partial aggregation approach, which allows to simultaneously evaluate qualitative and quantitative criteria and provide a complete order of preference for the proposed case study alternatives. It also allows you to deal with any conflicts that often exist between various criteria are involved. Compensations between criteria is one of the advantage of this method. It allows to make a sensitivity analysis and enable the decision-maker (DM) to stay closer to the actual decision problem.

The correct choice of the KPIs is essential to then evaluate and identify the most feasible and sustainable project that will fit on each pilot. The KPIs have been defined based on three main steps.

1. The first step is performed through a comprehensive review of the existing literature (Strantzali & Aravossis, 2016; Wang, Jing, Zhang, & Zhao, 2009).
2. In the second step, the number of KPIs were reduced as a result of five internal discussion rounds among relevant experts.
3. The third step, the final set of KPIs is selected through a participatory workshop in which the "playing card" method was employed, as was detailed on (Moghadam et al., 2019a). This Playing Card method is a semi-structured participative procedure proposed by Simos J. in 1990. This method is appropriate to support different group discussions, the specific aim is to stimulate the interactive and constructive discussion between different stakeholders with different backgrounds.

These indicators cover different areas of the project, from the economic to the social, through the technical and environment, so it was important the participation of the project partners.

2.1.3 Phase III: Target group involvement

As mentioned in the introduction, in the Energy Community, the citizens cover an important role and one of the purposes of the "SCORE project" is to encourage the active role of consumers. The first two phases have a technical character, they are focused in defining the best alternative, instead in the third and last phase social aspects are examined.

The project focus especially on the users, and search that they will be not only simple consumers but prosumers, participating actively in the phases of decision, dissemination, production and distribution of energy. In this context, the creation of a financial model based on co-ownership

(CSOP) would bring the possibility to different kind of users, such as municipalities, small and medium-sized enterprises and citizens, to become co-owners of the new energy plant system. In order to understand and promote the users' cooperation, two phases are necessary: the questionnaires and the operational phase, including different events and working meetings.

This analysis helps in understanding the citizens' subjective willingness to engage in local energy initiatives. At the same time, the aim of is to obtain objective data about users' characteristics in order to identify the main favour/hinder drivers of their participation. Specifically, a questionnaire is designed, which is composed by four sections. The survey consists in gathering opinions and attitudes, about the topic of energy community, of citizens in a specific context. The survey questions are divided in 4 parts:

1. Socio-demographic information such as age, gender, education level, nationality, marital status and belonging municipality.
2. Socio-economic information like personal and family income, number and family composition, year of building construction and building property.
3. Attitude and willingness to participate in Energy Community
4. Feeling related to community identity information such as level of feeling related to trust, satisfaction, pride, hope, disgust, shame, fear, boredom.

The output phase will be a citizen's division in population segments that share common features. This study allows to reach one of the main objectives of SCORE project that is the encouragement of consumers to play an active role in the community. To carry out the aforementioned, it is necessary users' cooperation to become co-owners of the new energy plant system (CSOP model).

The definition of different population segment will highlight the under-represented groups that do not have the possibility to participate in EC but are interested in being part in this kind of projects, like women, low-income households, and vulnerable groups, etc. giving them social protection and fighting against energy poverty.

2.2 Pilot case studies

Ten municipalities have been chosen in Susa Valley as case studies, where different retrofit alternatives will be applied. As was explained, the implementation focuses in the substitution of the existing heating system fuelled by diesel oil and natural gas. The new planned systems will be fed by local biomass, particularly wood chips, instead of pellets or wood blocks that are the typical solution for small individual boilers. It is intended to extend the energy community created within SCORE to all 39 municipalities in Susa Valley.

Figure 10: Location of 5 Italian pilot project in Susa Valley (source: Google Earth).

Table 2 shows the different municipalities that are involved in the project. These municipalities were selected during the first phases of SCORE project, due to a feasibility analysis. The table also shows the different buildings of each municipality that will be part of the EC, the current energy system that is used for heating and the type of installation.

Table 2: Pilot case studies

No	Municipality (city)	Building	Existing energy sources for heating	Type of installation
1	Oulx	School and gym Nursery Gym Municipality Touristic office Social activity building Building (residential)	Oil and natural gas boiler (individual generators)	DH network (biomass)
2	Novalesa	Abbey Private building 1 Private building 2	Oil and LGP boiler (individual generators)	DH network (biomass)
3	Rueglio	Municipality Retirement house	Oil boiler (individual generators)	DH network (biomass)
4	San Giorio di Susa (building scale)	Multi-use room and bar	Natural gas boiler (individual generators)	DH network (biomass)
5	San Giorio di Susa (city scale)	Private residential buildings	Individual oil Stove	DH network (biomass)
6	Villar Dora	School and gym Kindergarten	Natural gas boiler	DH network (biomass) and solar thermal collectors
7	Susa	DH network	Oil and natural gas boiler (individual generators)	DH network (biomass)
8	Bardonecchia	DH network	Oil and natural gas boiler (individual generators)	DH network (biomass)
9	Bussoleno	DH network	Natural gas boiler (individual generators)	DH network (biomass)
10	Almese	Sport (facilities) buildings Middle school Private buildings	Natural gas boiler (individual generators)	DH network (biomass)

Currently, in the Susa Valley, 75% of the pilot projects originates energy from fossil fuels leaving the rest produced by RES, mostly from biomass. Although there is vast quantity of local biomass sources in the region, due to the extended amount of forest, the biomass used is not locally produced but imported from other European and Non-European countries. Moreover, another issue is that the majority of the imported biomass is not certified and cannot be statistically quantified since it is subjected to the grey market.

One of the presented issues in Susa Valley is energy poverty, due to inefficient energy systems. Energy vulnerable groups are not located in a particular area, but are spread over the valley, especially in areas with lack of sun exposure due to their geographical position (specifically the north slope of the Dora). Some associations like Con.I.S.A.[9], COOPAMICO[10] and Caritas[11] work with these vulnerable groups in order to help them. The planned EC facilitates the replacement of old utilities and the provision of locally sourced wood chips as fuel.

[9] Con.I.S.A. is Consorzio Intercomunale Socio Assistenziale in Italian. Born in 1997, and has accession of 38 municipalities. http://www.conisa.it/
[10] http://www.coopamico.it/
[11] https://www.caritas.torino.it/

CHAPTER 3: APPLICATION OF METHODOLOGY ON CASE STUDIES AND RESULTS

As was explained before, there is a process through phases and methods involved to obtain the final results for each case study. In this chapter, the methodology described in CHAPTER 2: METHODOLOGY will be applied on five out of ten case studies. Oulx, Villar Dora, Rueglio, Novalesa and San Giorio di Susa at city scale, were the five municipalities chosen to start analysing the feasibility of EC. These pilots were selected due to the prior approval and engagement of municipalities, and the variety of possible refurbishment alternatives proposed. The aspects before mentioned will enrich the procedure of selection.

The first phase of the procedure involves the preparation and collection of data and information, as it is shown in the work-flow (Figure 9). For each case study, the collected data will be presented, and used to start the analysis.

As mentioned above, the second phase, accounts for the preliminary and feasibility analysis, and it has been performed through dossier documents. This phase starts with the general description and historical information of the buildings involved, the current situation regarding the energy sources and a brief investigation of the planned RES. During the analysis, some physical properties as the materials used for the construction of the building (walls, roofs, slabs, windows) have been acquired.

After defining the appropriate retrofit alternatives and simulating their energy performances results, the definition of the different indicators has been performed. These indicators are used to realize an impact assessment through the defined retrofit alternatives and identify the most feasible and sustainable project that will fit on each pilot.

For the pilots, an important data collection was made and a matrix was created to incorporate all the data collected. The matrix that collects the data of the various hypothetical refurbishment alternatives is identified as the "evaluation matrix".

The indicators that are present in this matrix, involves the project as a whole, including different areas such as environmental, economic, social and technical.

Those indicators were primarily developed based on a review of existing literature and verified in a workshop in which the “Playing card” (Torabi Moghadam, 2019) method was employed, involving different the different partners. Afterward, new modifications were introduced to select the final set of key performance indicators (KPIs) shown in Table 3. These last changes were emerging during the progress of the project, in different meetings and workshops, and they were explicitly detailed and presented, and then accepted by the partners.

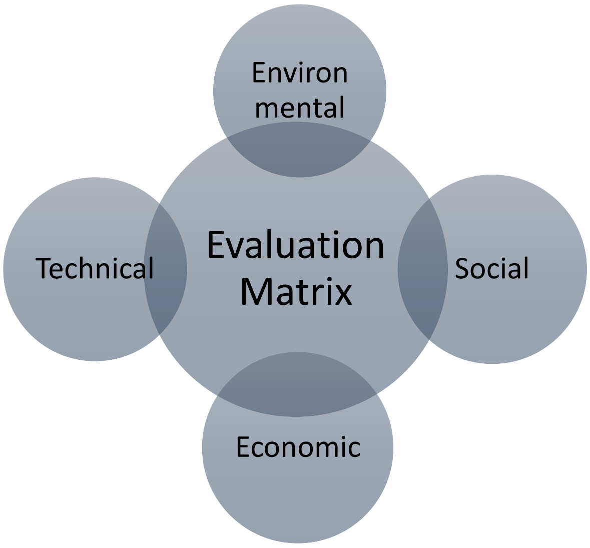


Figure 11: Evaluation matrix

The goal of this part of the feasibility analysis is to reduce the amount of criteria during the selection, in order to obtain a practical but still significant number that is sufficient for conducting a sustainability assessment. The final list of KPIs is presented on Table 3, with their respective category, code, type of data source, preference and unit of measurement (Franceschini, F., Galetto, M., Maisano, D. 2019).

Table 3: Key Performance Indicator matrix

Category	Code	Indicator	Type	Data Source	Preference	Unit
Environmental	ENV1	Primary energy saving	Quantitative	Estimated or metered data	Max	[$kWh_{primary\ energy}$/year]
	ENV2	Global emissions CO_2 reduction	Quantitative	Estimated or metered data	Max	[kg/year]
	ENV3	Local emissions NO_X reduction	Quantitative	Estimated or metered data	Max	[kg/year]
	ENV4	Local emissions PM_{10} reduction	Quantitative	Estimated or metered data	Max	[kg/year]
Economic	EC1	Payback period (PBP)	Quantitative	Calculation	Min	[Years]
	EC2	Investment cost	Quantitative	Calculation	Min	[Euro]
	EC3	Public incentives	Quantitative	Process documentation	Max	[%]
	EC4	Savings on energy expenditure	Quantitative	Calculation	Max	[Euro/year]

	EC5	Labor cost	Quantitative	Estimated or metered data	Min	[Euro/year]
	EC6	Labor cost by a social cooperative	Quantitative	Estimated or metered data	Min	[Euro/year]
	EC7	Material cost	Quantitative	Estimated or metered data	Min	[Euro]
	EC8	Material cost purchased on the territory	Quantitative	Estimated or metered data	Min	[Euro]
	EC9	Running cost	Quantitative	Calculation	Min	[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	Max	[%]
	T2	Installed power reduction	Quantitative	Estimated or metered data	Max	[kW]
Social	S1	Architectural impact	Qualitative	Process documentation	-	[Ordinal]

Environmental Indicators.

- ***Primary energy saving***. Represents the primary energy that would be saved if the new plant was built. It is linked to the renewable nature of the investment and to the interventions on the building envelope. The criterion allows to understand the buildings primary energy consumption through different retrofit alternatives. “Primary energy” means this energy from renewable and non-renewable sources which has not undergone any conversion or transformation process (Indicators & Scale, 2018).
  This indicator aims at the reduction of the total primary energy consumption related to fossil fuels, and the increase the share of renewables sources consumption on site (Mittermaier, 2014).
  It was calculated with a specific software called EDILCLIMA[12] in which the material, thickness, thermic transmittance and internal surface resistance are some inputs needed (Wang et al., 2009).
- ***Global emissions CO2 reduction***. The building’s energy systems CO2 emission is undoubtedly a criterion that should be assessed for the sustainable development of cities. Naturally, it is

[12] Edilclima is a software which develops calculation programs for plant design and verify compliance with legal constraints. Edilclima's focus is in investigating the methodological and regulatory aspects and the research of solutions for thermo-technical-plant design. The goal of Edilclima is to provide flexible calculation tools that return the primary decision-making role to the designer (https://www.edilclima.it/).

considered one of principal indicators to be evaluated in environmental terms. It was reported that this gas contributes with almost the 25% of the greenhouse effect, leading to global warming. It is mainly released through the combustion of oil and natural gas in the energy systems, the two different types of boilers included in the study (Wang et al., 2009).

It is calculated comparing the current situation with the different alternatives proposed. And the increase of this indicator will lower the potential influence on global warming and the related impacts on the environment.

- ***Local emissions NOx reduction***. NOx is a generic term for mono-nitrogen oxides including NO and NO_2. NOx produces air toxic pollution, acid deposition and global climate change. NOx reacts with different compounds and organic chemicals to form toxic products that affects the health of individuals and cause biological mutations.

  NOx it is produced during the combustion of non-renewable sources, especially fossil fuel ones, at high temperatures. This contributes to harm the environment, climate and vegetation (Wang et al., 2009).
- ***Local emissions PM_{10} reduction***. PM_{10} emissions are caused by fuel burning and heavy industrial processes and are among the most harmful of all air pollutant, damaging directly the human health (Indicators & Scale, 2018). These emission cause lung diseases, heart attacks and arrhythmias, cancer, atherosclerosis, childhood respiratory disease and premature death. These particulate matter consists of very small liquid and solid particles floating in the air. It is a mixture of materials that can include smoke, soot, dust, salt, acids, and metals. Particulate matter also forms when gases emitted from motor vehicles and industry undergo chemical reactions the atmosphere. When inhaled these particles evade the respiratory system's natural defences and lodge deep in the lungs.

  According data provided by the Piedmont environment report, the annual average limit value for the protection of human health is equal to 40 µg/m3 calculated as an average over a calendar year. And the daily limit value is 50 µg/m3, not to be exceeded more than 35 times per calendar year. This annual average indicator is foreseen in the 2030 Agenda for objective 11 about making the cities sustainable.

  The criterion allows to evaluate the kilograms of PM_{10} that are reduced over the years with the application of a retrofit alternative.

The assessment methodology for local emissions will be performed based on different conversions factors that are shown in Table 4. Those values were obtained from IREA, Inventario Regionale delle Emissioni in Atmosfera in Italian. This service allows to estimate the annual emissions into the atmosphere deriving from human and natural activities carried out in the Piedmont area. Through the estimations it is possible to evaluate the air quality and identify the sectors in which to intervene for the reduction of polluting emissions.

Table 4: Emission factors.

	NOx emissions [mg/MWh]	PM10 emissions [mg/MWh]
Oil Boiler	180	13
Gas Boiler	107	0.72

Economic Indicators.

- ***Payback period (PBP).*** PBP, simple or discounted, is a popular criterion that represent the time in which negative and positive cash flows are equal. The PBP has been a widely used as a capital budgeting tool in the analysis of profitable projects, because it represents the moment after which the expenses are amortized and there is the actual gain.
This criterion gives immediate insight to investors in the event that there is a preference to shorten the PBP (Awomewe & Ogundele, 2008). The Payback period is assessed as shown in (1):

$$PBP = \frac{Investment\ costs}{annual\ savings\ on\ energy\ expenditure} \tag{1}$$

- ***Investment cost***. Many studies consider investment costs as the most important criterion to evaluate energy savings interventions. The investment cost incurs all the costs related to refurbishment of the building and/or new heating system and DHW (Standard, 2007). Including:
    - The purchase of building material for the building envelope and energy system. Including the boiler and control system (valve, sensor, heat exchanger and pump), wall and attic insulation, pipes, concrete, solar collectors, etc.
    - Technological installation, with control, audits, mounting and project of the proposed plants modification.
    - Manpower.
- ***Public incentives.*** It is defined as the percentage of savings, and it is directly linked to the share of investment cost covered by administrative incentives. The 2017 Stability Law confirmed the extension of 65% tax reductions for energy efficiency measures and 50% for restructuring

buildings (Economico, 2017; Conto Termico, 2017). Specifically, “Conto Termico” involves the following financial incentives:

- Up to 65% of the expenditure incurred for "Near-zero Energy Buildings" (nZEB[13]);
- Up to 40% for wall and ceiling insulation, replacement of windows, solar shading, indoor lighting, building automation technologies, boilers;
- Up to 50% for thermal insulation work in climate zones E/F and up to 55% in case of thermal insulation and replacement of window seals when combined with other interventions (heat pumps, solar thermal, etc.).

To have access to these incentives, there are some aspects to be accomplished like certification by an accredited body that certifies compliance with the UNI EN 303-5 standard; like useful thermal efficiency not lower than a certain percentage of the nominal power of the device; atmospheric emissions not above a certain value verified by an accredited body, based on the relevant measurement method, the pellets used must be certified by an accredited certification body that certifies compliance with the UNI EN ISO 17225-2 standard, etc.

On the other side, there is another way of public incentives that are the called "Energy Efficiency Certificates" (EEC), which focus on the achievement of energy savings through the application of efficient technologies and systems. They are issued by Electricity Market Manager (GME in Italian) based on the savings achieved certifications. A certificate is equivalent to saving 1 ton of oil equivalent (toe), which is the conventional unit of measurement commonly used in energy balances to express all energy sources taking into account their calorific value.

The promotion of "energy saving" through EEC was launched by the ministerial decrees on 2004 and establishes that mandatory savings targets are set each year for electricity distributors and natural gas distributors. The objectives are increasing over time, and can be achieved through the implementation of interventions for final consumers (e.g. installation of high efficiency appliances or boilers, thermal insulation of buildings, interventions to increase the energy efficiency of processes industrial, high efficiency bulbs etc.) that derive from it

[13] NZEB means buildings that have a very high energy performance. This kind of buildings usually use energy derived from renewable sources located on-site or nearby. This definition is provided by the Directive 2010/31/EU on the energy performance of buildings, which is nowadays the main legislative instrument at EU level for improving the energy efficiency of buildings (European Commission, 2013). It is useful to reach nZEB (nearly zero-energy buildings) conditions in order to obtain the incentives offered by the “Conto Termico”.

direct benefit in terms of reducing your energy expenditure. This Italian experience is the first in the world to apply this market tool to promote energy efficiency in end uses.
Each year the authority determines the amount of the contribution to be made to distributors for the fulfilment of their obligations. The current contribution is equal to 100 Euro for each toe saved.

- ***Savings on energy expenditure***. Represents the savings on annual expenditure due to energy. Takes into account the primary energy savings calculated previously in the environmental section, and the cost of the different fuels involved, determined in Table 5.

Table 5: Fuel costs

Fuel	Cost (Including IVA) [Euro/MWh]
Biomass	100
Gasoil	170
Natural gas	100

- ***Labor cost***. It represents the amount of money paid to employees who are directly involved in production activities, services as general repairs and maintenance performance, and supervision (Wang et al., 2009). It is composed by the following expenses:
    - Salaries and wages
    - Social and medical taxes
    - Compensations
    - Insurance

  Due to the lack of precise information, it is assumed to be 40% of Investment costs, as an expert on the field suggested during an internal meeting.
- ***Labor cost by a social cooperative***. The part of labour cost which will be done by the Italian social cooperative AMICO. It is important to remark that one of the main objectives of SCORE is to fight against energy poverty, involving under-represented groups in EC. It is assumed that one out of four workers will be part of this social cooperative. This number will be adjusted whilst the project continues.
- ***Material cost***. The costs of raw materials or parts that go directly into producing products or providing services. A list with materials, quantities and their respectively prices was done by the experts and it is shown below in Table 6: Material costs. Table 6:

Table 6: Material costs.

Materials	Price [€/Unit]	Quantity [Unit]	Amount [€]
Wall insulation	100	2.000	200,000
Upper-attic insulation	100	1.200	120,000
Audits	6,250	1	6,250
Building site	20,000	1	20,000
Lean concrete	2,500	1	2,500
Foundation	15,000	1	15,000
Walls	3,750	4	15,000
Slab	12,500	1	12.500
Waterproofing	1,000	1	1,000
Passages	5,000	1	5,000
District pipes	20,000	1	20,000
Biomass boiler	70,000	1	70,000
Plants modifications	10,000	4	40,000

- ***Material cost purchased on the territory***. This criterion evaluates the portion of material cost that remains in the territory. "Territory" is intended to be all the Susa Valley, including the material purchased in any of the 37 municipalities.

  The biomass boiler and the insulations, including wall and upper-attic, are provided from other countries, as partner of the project said in an internal meeting. They represent almost the 65% of the total material costs taking a look on Table 6. Taking into account this, it is possible to assume that the remaining percentage (35%) of the material costs will be purchased in the territory.
- ***Running cost***. It is calculated as the energy costs plus maintenance costs. On one side, the energy costs are intended as the operational cost for the energy in the building. Of the total energy consumed, 80% are provided by renewable sources and the other 20% by the actual energy system. The cost of the different fuels are presented in Table 5, and were provided by experts in energy field.

  On the other side, there are the maintenance costs. Due to the impossibility to calculate the exact amount of maintenance costs expended in a year, they are assumed as the 2% of investment cost according to (Guazzi, Bellazzi, Meroni, & Magrini, 2017).

- ***Type Thermal Account Access (TAA) vs. Energy Efficiency Certificates (EEC)***. It represents the access to the Italian public incentives carried out by Energy services management.

Technical Indicators.

- ***Increase of plant system efficiency***. It is the increase in the efficiency of the new system plant compared to the existing one, measured in percentage (Wang et al., 2009).
- ***Installed power reduction***. It represents the reduction of installed new biomass boiler power.

Both technical indicators are focused in improve parameters of the new boiler that will be installed in each case study. They contribute directly in energy reduction, one of the main objectives of SCORE project.

Social Indicators.

- ***Architectural impact.*** This indicator evaluates the visual outcome that may be created by the application of retrofitting measurements for the municipality.
  This indicator has higher values when refurbishment measures lead to aesthetic improvement of the city. According to a study (Dall'O', Norese, Galante, & Novello, 2013) five scores of impact are presented in Table 7. This criterion adopts an ordinal scale to rank the strategies, from the best to the worst.

Table 7: Architectural impact criterion.

Typology of criterion	Description of criterion	Numerical value of criterion	Description of intervention
Positive	Great positive impact	1	External Thermal Insulation Composite Systems
	Positive impact	2	Windows replacement
Neutral	No impact	3	Roof insulation – Boiler replacement – Lightning replacement
Negative	Little negative impact	4	Photovoltaic panels
	Negative impact	5	Solar thermal collector

After the appropriate selection and the definition of the KPIs, the next step consists in assessing each indicator and filling the evaluation matrix for each case study, which is fundamental to reach the final selection. The evaluation matrix allows the comparison of each refurbishment alternative proposed in the preliminary analysis between themselves and with the current situation, taking into account all the selected KPIs.

To fill this matrix, the collaboration of different parties is necessary, since the indicators cover the different areas of the project, from the economic to the social, through the technical and environmental. Also, it was necessary analysis of literature and different measurements taken during in-situ analysis.

To proceed with the feasibility analysis, PROMETHEE (preference ranking organization method for enrichment evaluation) method developed by Brans, was chosen in order to rank the different refurbishment alternatives previously mentioned.

This multi-criteria decision aid method, is useful to:

- Evaluate several possible decisions according to multiple conflicting criteria.
- Identify the best possible decision.
- Rank the decisions from the best to the worst one.
- Justify or invalidate decisions based on objective elements.

The PROMETHEE method uses the partial aggregation and it is very useful in ranking a limited number of alternatives, considering conflicting criteria. It is based on the pair-wise comparison, checking if one of two alternatives outrank the other or not (Dirutigliano et al., 2017).

In order to implement this method, two specific types of information are need:

- The criteria weights and,
- The decision-maker's preference function for comparing the contribution of the alternatives in terms of each separate criterion.

The weight of a criterion is a measure of how much it is important with respect to the other criteria. The weights can be adjusted according to the priorities of the DM.

For each criterion, it is necessary to choose a preference function and set the values of the corresponding thresholds.

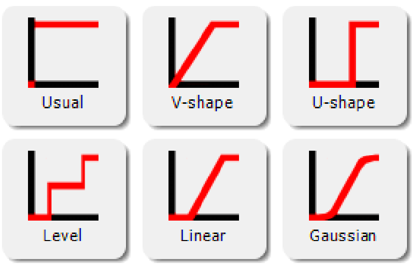


Figure 12: PROMETHEE preference functions

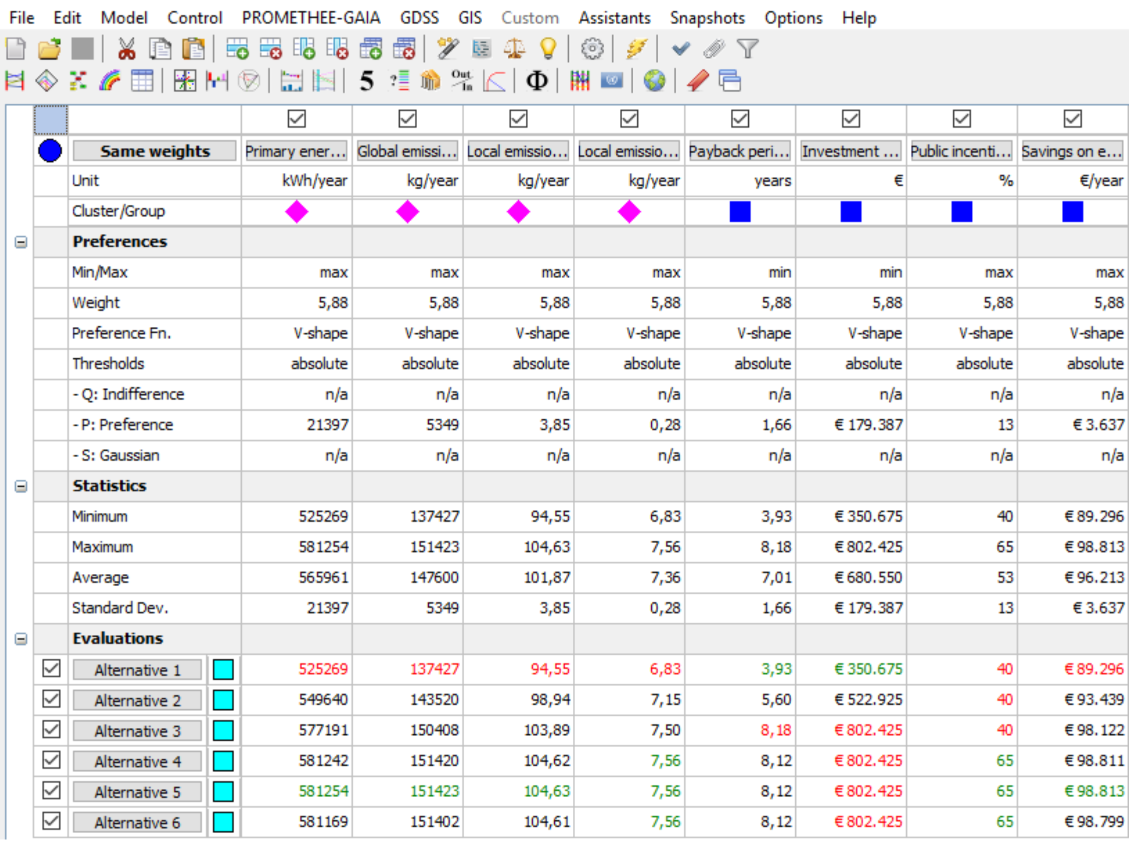
The V-Shape preference function is considered for all the indicators, with the preference value calculated as the standard deviation of each indicator and without indifference value.

Both aspects will be modified in order to perform a sensitivity analysis and check how the ranking varies and the robustness of the model.

To apply the chosen model, the academic software available for free "Visual PROMETHEE" is employed (PROMETHEE, 2013). To obtain the final results there is a series of steps:

1. First the set of criteria have been defined and added. It is necessary to give every criterion a direction of preference, decided whether the criterion must be minimized or maximized. With the maximization is given a greater preference to higher values; instead, with minimization, it is established that a greater value indicates a worse response than the alternative.
2. Therefore, the different retrofit alternatives for each case study had to be reconstructed within the program.
3. Finally, for each criterion inserted the measurement scale of the criterion that can be qualitative or quantitative must be established.

Below is an example of a screenshot generated within the software.



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	5,88	5,88	5,88	5,88	5,88	5,88	5,88	5,88
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	21397	5349	3,85	0,28	1,66	€ 179.387	13	€ 3.637
- S: Gaussian	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Statistics								
Minimum	525269	137427	94,55	6,83	3,93	€ 350.675	40	€ 89.296
Maximum	581254	151423	104,63	7,56	8,18	€ 802.425	65	€ 98.813
Average	565961	147600	101,87	7,36	7,01	€ 680.550	53	€ 96.213
Standard Dev.	21397	5349	3,85	0,28	1,66	€ 179.387	13	€ 3.637
Evaluations								
Alternative 1	525269	137427	94,55	6,83	3,93	€ 350.675	40	€ 89.296
Alternative 2	549640	143520	98,94	7,15	5,60	€ 522.925	40	€ 93.439
Alternative 3	577191	150408	103,89	7,50	8,18	€ 802.425	40	€ 98.122
Alternative 4	581242	151420	104,62	7,56	8,12	€ 802.425	65	€ 98.811
Alternative 5	581254	151423	104,63	7,56	8,12	€ 802.425	65	€ 98.813
Alternative 6	581169	151402	104,61	7,56	8,12	€ 802.425	65	€ 98.799

Figure 13: Visual PROMETHEE example

Visual PROMETHEE allows to quantify the degree of preference, indicated as π $(a,\ b)$, of a generic alternative "a" compared to "b", calculated as in the following equation:

$$\pi\ (\mathrm{a,\,b}) = \sum_{j=1}^{n} W_j \times\ P_j\ (a, b) \tag{2}$$

Where W_j is the weight assigned to each j-th criterion and P_j (a, b) is the preference function. Both will be changed to see how sensitive the model is.

The software then allows you to calculate the outgoing and incoming flows for each alternative. The outgoing flow is indicated with ϕ+ and represents the measure of the robustness of the analysed alternative. The outgoing flow calculated as in the next equation, varies between 0 and 1. The more the outgoing flow approaches to 1, the more preferable is the alternative considered in comparison to the other, on the other side, if equal to 0, the action in question does not has advantage over the others.

$$\phi{+}(a) = \frac{1}{n-1} \sum_{b \neq a} \pi\ (\mathrm{a,b}) \qquad \phi{+}(a) \in [0{,}1] \tag{3}$$

On the other side, there is the incoming flow. The notation $\phi-$ represents the measure of the weakness of the action in analysis with respect to other alternative. Also, this parameter varies between 0 and 1, but on the contrary, where $\phi-$ = 0 means that the selected alternative has a degree of weakness equal to zero, and therefore represents the best alternative, on the contrary $\phi-$ = 1 represents the worst one. The following formula is used for making the calculation:

$$\phi{-}(a) = \frac{1}{n-1} \sum_{b \neq a} \pi\ (\mathrm{a,b}) \qquad \phi{-}(a) \in [0{,}1] \tag{4}$$

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 you to directly compare the proposed alternatives and provide the ranking of alternatives as shown in next equation (5).

$$\phi{-}(a) = \phi{+}(a)\ \text{-}\ \phi{-}(a) \tag{5}$$

As was said, a sensitivity analysis is proposed by changing different weights with respect to the Baseline alternative, according to stakeholders' interests and opinions.

The **Baseline** model assigns same weight for each category (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 of the number of KPIs included on that category.

- Each Environmental indicator will get a weight of 0.0625 percent, obtained through the division of 25 percent by 4 indicators.
- Each Economic indicator will get a weight of 0.025 percent, obtained through the division of 25 percent by 10 indicators.
- Each Technical indicator will get a weight of 0.125 percent, obtained through the division of 25 percent by 2 indicators.
- Each Social indicator will get a weight of 0.25 percent, obtained through the division of 25 percent by 1 indicator.

While, **Change 1** proposes the same weight for each indicator (e.g., ENV1, EC1, and T2), 5.9 percent each one. This leads into different weight for each category of indicators:

- 23.5 percent for Environmental category,
- 11.8 percent for Technical,
- 5.9 percent for Social and
- 58.8 percent for Economic.

Change 2 focuses on the two categories that have more impact in the project, the Environmental and Economic. Taking into account the relevance of these two, a higher weight has been assigned (30 percent each one), leaving the rest to social and technical aspects, divided equally.

- 30 percent for Environmental category and 0.075 percent for each Environmental indicator.
- 30 percent for Economic category and 0.03 percent for each Economic indicator.
- 20 percent for Technical category and 0.1 percent for each Technical indicator.
- 20 percent for Social category and 0.2 percent for each Social indicator.

Table 8. Sensitivity analysis. The table shows the particular weight of each indicator considering the different changes proposed.[14]

		ENV1	ENV2	ENV3	ENV4	T1	T2	S1
Baseline	weight	0.0625	0.0625	0.0625	0.0625	0.125	0.125	0.25
Change 1	weight	0.059	0.059	0.059	0.059	0.059	0.059	0.059
Change 2	weight	0.075	0.075	0.075	0.075	0.1	0.1	0.2

[14] Each indicator code is in "Table 3: Key Performance Indicator matrix"

		EC1	EC2	EC3	EC4	EC5	EC6	EC7	EC8	EC9	EC10
Baseline	w	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Change 1	w	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059
Change 2	w	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03

From here till the end of the chapter, the selected methodology will be applied on each case study obtaining the final results.

3.1 OUXL

3.1.1 Phase I: Preparation

During this phase, the significant data collected regarding Oulx pilot project will be presented.

The data collected through the questionnaire is shown in Table 9, involving: the building ownership, function, the construction year, the latest refurbishment year, the average heat and domestic hot water (DHW) expenses, the total number of building zones (dwellings or offices), the total number of users (inhabitants or employees), the total usable area and finally, the average annual energy consumption.

Table 9: Oulx information collected through survey.

No.	Building	Ownership and function	Construction year	Latest refurbishment year	Av. heat and DHW expenses [€/y]	Total number of users	Total usable area [m²]	Existing energy system
1.a	Middle school ("P. P. Lambert") with gym	Public; Non-residential (educational-sport)	1958	2018 (seismic)	57.915	250	2800	Oil boiler
1.b	Nursery	Public; Non residential (educational)	1988	none	5.585	50	270	Oil boiler
1.c	Municipality	Public; Non-residential (administrative)	1980	2016 (windows)	13.831	26	660	Gas boiler
1.d	Touristic office	Public; Non-residential (services)	1995	none	14.669	6	700	Gas boiler

1.e	Cultural activity building ("Casa della Cultura")	Public; Non-residential (services)	First years of 1900	2016 (structural)	3.000	2	300	Gas boiler

Although the information was collected over five different buildings, only the first two buildings are the subject of the energy analysis (1.a, and 1.b). This is because they can reach the Nearly Zero Energy Building (nZEB) condition, through the current energy system, obtaining public incentives.

3.1.2 Phase IIA: Preliminary analysis

The method used to perform the second phase of the methodology is the dossier. Particularly, Oulx dossier investigates a school complex that is the subjected of energy retrofitting in order to access the “Conto Termico”. The mentioned school area includes three different buildings:

1. An elementary and middle school building, with a basement floor and three overlying floors in elevation.
2. A gym that has only a ground floor with a common wall with the school (on the eastern side of the school).
3. A prefabricated nursery building, that covers a single ground floor and is located beside the school.

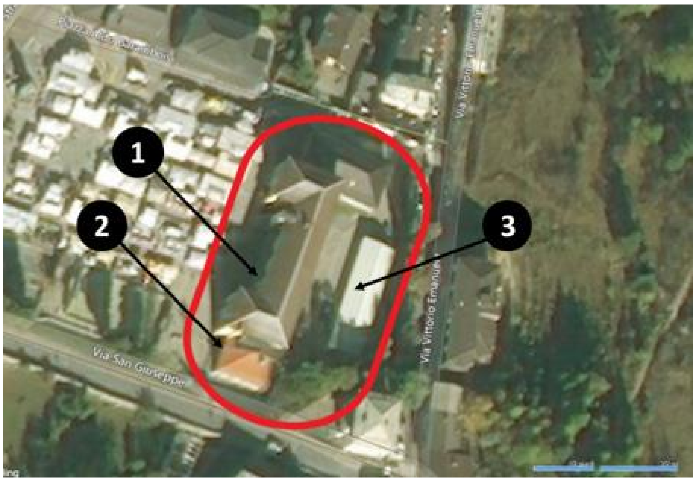


Figure 14: Oulx buildings involved (www.bing.com/maps)

Currently, the buildings are equipped by two oil boilers (diesel fuel) characterized by different circuits and by different kinds of heaters (radiators, fan heaters and air nozzles) for the school, the gym and the nursery. The absence of integration between the buildings lead into some negative consequences related to the efficiency of the energy system. This in only one critical issues of the building among others:

- Significant energy leakage through the opaque casing. It is represented in Table 15 by the thermic transmittance;
- Obsolete regulation and balance systems. It only has a simple regulation on-off, with no internal temperature compensation;
- Obsolete heat generation technology. The actual boilers have than 10 years old, with lower maintenance;
- Non-renewable energy source (Oil) and consequent high emission level of CO_2.

Also, the thermal efficiencies of the two traditional oil boilers with blast burners were collected, they are:

- Generator of 300 kW with a thermal efficiency of 81.5%.
- Generator of 130 kW with a thermal efficiency of 78.9%.

Regarding the domestic hot water (DHW), it is produced by centralized generation combined with the heating generation.

In addition, data in terms of energy costs and tariffs were collected for the actual situation, using non-renewable energy sources. Due to the impossibility of accessing to current information, the current values are assumed like the presented ones. The information presented in Table 10 are provided by the administrative municipal accounting.

Table 10: Energy costs for buildings involved

Client	Cost	Years
Middle school	46,857 €	2012
Elementary school	17,620 € (average)	2003-2012
Nursery	5,050 €	2013

The mathematic model that shows the performances of the building, analysing the different retrofit alternatives of this study, has been created with a software certified by CTI (Comitato Termotecnico Italiano), called EDILCLIMA. The resulting values have been validated taking into account the trends of utilization of the buildings, as it is shown below:

Table 11: Trend of building utilization

Zone	Day of utilization	Hours per day	Internal temperature point set when used/not used
School	5	12	20°/16°C
Gym	7	12	20°/16°C
Nursery	5	12	22°/19°C

Then, it was performed a preliminary analysis regarding the energy indicators, using the mentioned EDILCLIMA model.

Table 12, shows two different energy indicators:

- The primary energy consumption (Qp) of the school complex.
- The primary energy consumption normalized respect the floor area (EP), of the school complex.

It was made a distinction between the two different services involved, heating and DHW, and also regarding the renewable and non-renewable. It is shown that currently there is no energy fuelled by renewable sources, so the total consumption is the same as the non-renewable one.

Table 12: Oulx energy indicators.

Service	Qp,nren [kWh]	Qp,ren [kWh]	Qp,tot [kWh]	EP,nren [kWh/m²]	EP,ren [kWh/m²]	EP,tot [kWh/m²]
Heating	491,432	0	491,432	172.98	0	172.98
DHW	37,919	0	37,919	13.35	0	13.35
TOTAL	529,350	0	529,350	186.32	0	186.32

3.1.2.1 Energy retrofit alternatives

After the identification of the weaknesses of the energy system and a brief energy analysis of the actual situation, different retrofit alternatives were proposed and studied in order to improve the current energy situation while minimizing the environmental impact.

Table 13: Retrofit alternatives for Oulx

Code of simulation	Interventions
0.0	As built simulation model.
0.1	As built simulation model from real consumption (benchmark).

1	Simulation 0 and replacement of the boilers with a unique biomass-fired one and regulation retrofitting.
2	Simulation 1 and the upper-attic slabs insulation (18cm).
3	Simulation 2 and external walls insulation for the school and the gym (18cm).
4	Simulation 1 and nZEB conditions obtained with the upper-attic slabs insulation (40cm), external walls insulation for the school and the gym (30cm) and nursery's external walls (25cm).
5	Simulation 1 and nZEB conditions obtained with the upper-attic slabs insulation (50cm for the school and the gym, 40cm for the nursery), external walls insulation for the school and the gym (40cm) and nursery's external walls as built.
6	Simulation 1 and nZEB conditions obtained with the replacement of the windows with more efficient components (Transmittance: <1,0 W/m^2K), upper-attic slabs insulation (15 cm for the school and the gym, 12cm for the nursery), external walls insulation for the school and the gym (15cm) and nursery's external walls as built.

Looking at Table 13, it is possible to detect that in order to reduce the energy consumption and use the local RES, it was decided to change the envelope system, heating plant system and control system with the following refurbishment actions:

- Replacement of the boilers, with a single system fed by biomass.
- Installation of external wall insulation system.
- Installation of a roof insulation system.
- Thermostatic valves for each emission system.
- Review of balance and flow settings.
- Implement control systems to reduce energy losses.

Through the energy simulation done by EDILCLIMA software, it can be demonstrated the changes in primary energy consumption and the related CO_2 emissions, comparing the different retrofit alternatives with the actual situation. In Table 14 it is represented the abovementioned, making a distinction between energy consumed from renewable (Qp,ren) and for not renewable sources (Qp,nren).

Table 14: Oulx energy simulations results.

Code of simulation	Qp,tot	Qp,ren		Qp,nren		CO_2 emissions	
	[kWh/y]	[kWh/y]	% (ren/tot)	[kWh/a]	% (nren/tot)	[kgCO2eq/y]	% (VS 0.1)
0.0	529,350	-	-	529,350	100%	137,551	85.84%
0.1	616,697	-	-	549,061	100%	160,248	100%
1	457,140	365,712	80%	91,428	20%	22,857	14.26%
2	335,284	268,228	80%	67,057	20%	16,764	10.46%
3	197,529	158,023	80%	39,506	20%	9,876	6.16%
4	177,276	141,821	80%	35,455	20%	8,864	5.53 %
5	177,213	141,771	80%	35,443	20%	8,861	5.53%
6	177,638	142,110	80%	35,528	20%	8,882	5.54%

In the next figure (Figure 15: Global emissions CO2), it is represented how the global emission of CO_2 varies throughout the different retrofit alternatives proposed. It is possible to see a great decrease between the actual situation and the first alternative, a lower fall between A1 and A2 and also between A2 and A3. For the next scenarios, it is almost a constant trend regarding this aspect.

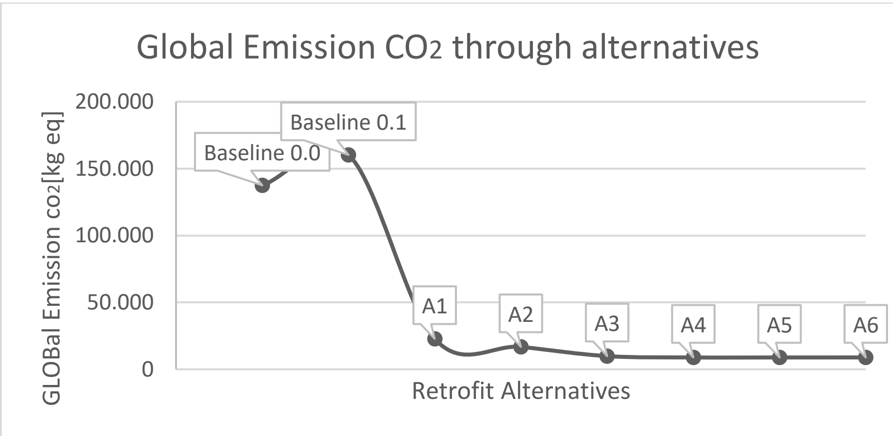


Figure 15: Global emissions CO2

Table 15 considers the “Thickness” and “Thermic transmittance” of the constructive elements before and after retrofitting. The “After” values were obtained applying Edilclima software, using Alternative 4. This is because it is the first one, which allows to reach the nZEB condition, obtaining public incentives.

Table 15: Oulx envelope system characteristics, before and after retrofitting

	Before		After	
Element	Thickness [mm]	Thermic transmittance [W/m^{2}K]	Thickness [mm]	Thermic transmittance [W/m^{2}K]
External wall	400	0.847	720	0.110
Gym wall	290	1.020	610	0.112
Nursery wall	70	0.332	320	0.103
Upper-attic slab	200	2.401	600	0.084
Gym upper-attic slab	60	1.429	460	0.082
Nursery upper-attic slab	50	0.438	450	0.073

3.1.3 Phase IIB: Feasibility analysis

During this second part of the phase two, the evaluation matrix is presented (Table 16). This matrix compares each retrofit alternative with the indicators. As was said, all this information was collected during prior steps, with the collaboration of all the stakeholders and partners of the project.

Table 16: Oulx evaluation matrix.

Category	Indicator	A.1	A.2	A.3	A.4	A.5	A.6
Environmental	Primary energy saving [kWh/y]	525269	549640	577191	581242	581254	581169
	Global emissions CO2 reduction [kgCO2eq]	137427	143520	150408	151420	151423	151402
	Local emissions NO_X reduction [kg/y]	94,55	98,94	103,89	104,62	104,63	104,61
	Local emissions PM10 reduction [kg/y]	6,83	7,15	7,50	7,56	7,56	7,56
Economic	Payback period (PBP) [years]	3,9	5,6	8,2	8,1	8,1	8,1
	Investment cost [euro]	350675	522925	802425	802425	802425	802425
	Public incentives [%]	40	40	40	65	65	65
	Savings on energy expenditure [euro/year]	89296	93439	98122	98811	98813	98799
	Labor cost [euro]	80925	120675	185175	185175	185175	185175
	Labor cost by a social cooperative [euro]	20231	30169	46294	46294	46294	46294
	Material cost [euro]	269750	402250	617250	617250	617250	617250

	Material cost purchased on the territory [euro]	94413	140788	216038	216038	216038	216038
	Running cost [euro]	59127	48681	38567	36258	36251	36299
	Type Thermal Account Access (TAA) vs. Energy Efficiency Certificates (EEC)	TAA	TAA	TAA	TAA	TAA	TAA
Technical	Increase of plant system efficiency [%]			9,8			
	Installed power reduction [kW]			175			
Socia l	Architectural impact [-]	3	4	4	4	4	5

Best scenario selection

After the creation of the Evaluation Matrix, it is time to apply PROMETHEE, the multi-criteria method presented previously.

As I have explained before, there are three different weight scenarios in order to check the robustness of the model. The first results analysed are the one obtained by the baseline weights, a 25 percent of the weight for each of the categories, distributed equally respecting the indicators. The results are shown in Table 17 and the ranking is presented in Figure 16.

Table 17: Oulx Baseline results

Rank	Alternative	Phi +	Phi -	Net Phi
1	A5	0,1963	0,0649	0,1314
2	A4	0,1961	0,0650	0,1312
3	A6	0,1472	0,0653	0,0819
4	A3	0,1675	0,1176	0,0500
5	A2	0,2379	0,2854	-0,0475
6	A1	0,1612	0,5081	-0,3469

Figure 16: Oulx Baseline ranking

After the baseline case, different changes in the weights were applied. In the next two tables (Table 18 and Table 19), the results of Change 1 and Change 2, with their respective rankings, are presented in Figure 14 and Figure 18.

Table 18: Oulx Change 1 results.

Alternative	A1	A2	A3	A4	A5	A6
Net phi	-0,0847	-0,0212	-0,0684	0,0622	0,0624	0,0496
Rank	6	4	5	2	1	3

Figure 17: Oulx Change 1 ranking

Table 19: Oulx Change 2 results.

Alternative	A1	A2	A3	A4	A5	A6
Net phi	-0,3370	-0,0762	0,0405	0,1373	0,1376	0,0978
Rank	6	5	4	2	1	3

Figure 18: Oulx Change 2 ranking

3.2 VILLAR DORA

3.2.1 Phase I: Preparation

The data collected with the different surveys regarding the municipality of Villar Dora is presented in Table 20. There were specifically two buildings identified as potential owners of an Energy Community.

Table 20: Villar Dora information collected through survey.

Building	Ownership and function	Construction year	Total number of dwellings/ offices	Av. heat and DHW expenses [€/y]	Total number of users	Total usable area [m²]	Existing energy system
Gym and library	Public; Non residential (sports and leisure)	1996	20	20250	150	1374	Gas boiler

School and kindergarten	Public; Non residential (educational)	1996	11	9546	50	563	Gas boiler

3.2.2 Phase IIA: Preliminary analysis

The selected area within the municipality includes two buildings:

1. The biggest building, which contains three connected zones, two belong to the gym and one belongs to the library ("Centro comunale polivalente" in the image).
2. The other building host the kindergarten ("Scuola Materna La Giostra" in the image).

Figure 19: Villar Dora buildings involved (Google Maps)

Currently, the buildings have two boilers fueled by gas to supply energy:

- One of the boilers has a power of 280 kW with an efficiency of 78.2% and it is used for the gym and the library.
- The other one is smaller compared with the first one, with 45kW of power and an efficiency of 95.3%, and it is used for the kindergarten.

The consumption of DHW is considered higher for gym than the kindergarden. In order to apply the Edilclima simulation, it has been supposed a number of 100 users every day in the gym with a need of 50 liters each. For the kindergarten it is supposed a number of 60 children with a need of 8 liters each. It is also supposed a continuous utilization of the building during the whole year.

The administrative municipal accounting and concern provides the energy bills to determine the historical energy consumption. The results, considering some losses generated by a wrong utilization of the structures, show a consumption of:

- 27.000 m3 per year of natural gas to meet the gym's and the library's needs and,
- 12.700 m3 per year of natural gas to meet kindergarten's needs.

Below in Table 21 are shown the primary energy indicators about the space heating and domestic hot water and the total values, with the help of Edilclima.

Table 21: Villar Dora energy indicators.

Service	Qp,nren [kWh]	Qp,ren [kWh]	Qp,tot [kWh]	EP,nren [kWh/m^2]	EP,ren [kWh/m^2]	EP,tot [kWh/m^2]
Heating (gym & library)	221.792	0	221.792	191,42	0	191,42
Heating (kindergarten)	123.399	0	123.399	178,54	0	178,54
Domestic hot water (gym & library)	74262	0	74.262	64,09	0	64,09
Domestic hot water (kindergarten)	6451	0	6.451	9,33	0	9,33
TOTAL	425.903	0	**425.903**	443,38	0	**443,38**

It is possible to see, that nowadays there is no energy consumption derived from renewable sources. This is the case in which an EC will have the greatest impact.

The different constraints and critical issues that characterize the case study from the energy point of view are presented above. This point is a prerequisite for the definition of retrofit alternatives in order to increase the building efficiency.

- Significant energy leakage through the opaque casing.
- Obsolete regulation and control systems (simple regulation on-off with no internal temperature compensation).
- Significant amount of wasted energy generated by a missing regulation system.
- Obsolete heat generation technology (gas boilers without condensation).
- Multiple generators with no integration between each other.
- Not clean energy resource (natural gas) and consequent high emission level of CO_2 and totally not renewable energy supply.

3.2.2.1 Energy retrofit alternatives

Different alternatives of retrofitting are possible. It is considered useful to obtain the incentives offered by the "Conto Termico" for public buildings about renewable energy supply. The tables below (Table 22, Table 23 and Table 24) show the simulations designed for this study and the values of energetic indicators for each simulation obtained by Edilclima simulations.

Table 22: Retrofit alternatives for Villar Dora.

Code of simulation	Interventions
0.0)	As built simulation model
0.1)	As built simulation model from real consumption (benchmark)
1)	Simulation 0) and replacement of the boilers with a unique biomass-fired one and regulation retrofitting.
2)	Simulation 1) and external wall insulation (8 cm) for kindergarten and upper-attic slabs insulation (10 cm) for gym and library
3)	Simulation 2) and integration with solar collectors 14 m^2 for kindergarten and 28 m2 for gym and library.

The principal aim is to reach a better utilization of buildings by an important reduction of energy needs, using local renewable sources and sustainable materials.

All the alternatives includes a replacement of installed boilers with a unique wood chip-fired boiler, using biomass from the surrounding forests. This will be done to improve efficiency and brake down emission levels and environmental impact. The proposed biomass boiler, is equipped with an air supply fan and an automatic loading system, with a nominal power of 201 kW and a generation thermal efficiency of 92.4% compared to total primary energy.

Also, to control the energy system, thermostatic valves for emission system and climatic and internal air sensors to improve regulation of the heating plant are proposed. This will generate feedback to review the balance and flow settings and therefore to reach a better working point of the system.

In order to improve the envelope system, the installation of an external wall insulation system in the kindergarten and external insulation system on the gym roof are proposed. The last refurbishment alternative propose the integration of solar thermal collectors and a thermal storage system to supply hot water needs.

Table 23: Energy Simulations results from Gym and library

Case	$Q_{p,tot}$		$Q_{p,ren}$		$Q_{p,nren}$		CO_2 Emissions	
	[kWh/y]	% (VS 0.1)	[kWh/y]	% ren/tot	[kWh/y]	% nren/tot	[$kgCO_{2eq}$/y]	% (VS 0.1)
0.0)	296.054	105,06%	0	0,00%	296.054	100,00%	59.211	105,06%
0.1)	281.804	100,00%	0	0,00%	281.804	100,00%	56.361	100,00%
1)	226.164	80,26%	180.931	80,00%	45.233	20,00%	11.308	20,06%
2)	200.054	70,99%	160.043	80,00%	40.011	20,00%	10.003	17,75%
3)	199.009	70,62%	162.118	81,46%	36.891	18,54%	9.049	16,06%

Table 24: Energy simulation results from Kindergarten.

Case	$Q_{p,tot}$		$Q_{p,ren}$		$Q_{p,nren}$		CO_2 Emissions	
	[kWh/y]	% (VS 0.1)	[kWh/y]	% ren/tot	[kWh/y]	% nren/tot	[$kgCO_{2eq}$]	% (VS 0.1)
0.0)	129.849	97,96%	0	0,00%	129.849	100,00%	25.970	97,96%
0.1)	132.552	100,00%	0	0,00%	132.552	100,00%	26.511	100,00%
1)	115.296	86,98%	92.237	80,00%	23.059	20,00%	5.765	21,75%
2)	108.767	82,06%	87.013	80,00%	21.753	20,00%	5.438	20,51%
3)	108.742	82,04%	87.696	80,65%	21.046	19,35%	5.150	19,43%

It is possible to observe that, due to the introduction of biomass as a renewable energy source, the level of carbon dioxide emissions fall almost 80 percent, compared to the current situation.

3.2.2 Phase IIB: Feasibility analysis

In this part of the second phase, the evaluation matrix is presented. It contains all the information regarding the different KPIs and alternatives, being ready to be compared through an MCA.

Table 25: Villar Dora evaluation matrix.

Category	Indicator	A.1	A.2	A.3
Environmental	Primary energy saving [kWh/y]	346034	352562	356389
	Global emissions CO2 reduction [kgCO2eq]	65799	67431	68673
	Local emissions NO_X reduction [kg/y]	37,03	37,72	38,13
	Local emissions PM10 reduction [kg/y]	24,91	25,38	25,66
	Payback period (PBP) [years]	10,1	13,8	14,4

Economic	Investment cost [euro]	350675	486265	512265
	Public incentives [%]	40	40	40
	Savings on energy expenditure [euro/year]	34603	35256	35639
	Labor cost [euro]	80925	112215	118215
	Labor cost by a social cooperative [euro]	20231	28054	29554
	Material cost [euro]	269750	374050	394050
	Material cost purchased on the territory [euro]	94413	130918	137918
	Running cost [euro]	41160	40607	41020
	Type Thermal Account Access (TAA) vs. Energy Efficiency Certificates (EEC)	EEC	EEC	EEC
Technical	Increase of plant system efficiency [%]		3	
	Installed power reduction [kW]		249	
Soci.	Architectural impact [-]	3	3	5

Best scenario selection

In this section, PROMETHEE is applied taking into account the sensitivity analysis, to check robustness on the model. The results of the different changes regarding the weights of the different KPIs are presented below.

Table 26: Villar Dora baseline results

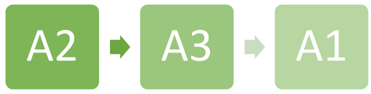
Rank	Alternative	Phi	Phi+	Phi-
1	Alternative 2	0,0968	0,3112	0,2144
2	Alternative 1	-0,0451	0,2623	0,3074
3	Alternative 3	-0,0517	0,2970	0,3487

Table 27: Villar Dora Change 1 results

Rank	Alternative	Phi	Phi+	Phi-
1	Alternative 3	0,0677	0,3588	0,2911
2	Alternative 2	-0,0179	0,3525	0,3704
3	Alternative 1	-0,0498	0,2911	0,3408

Table 28: Villar Dora Change 2 results

Rank	action	Phi	Phi+	Phi-
1	Alternative 2	0,0593	0,3209	0,2617
2	Alternative 3	0,0313	0,3522	0,3209
3	Alternative 1	-0,0906	0,2738	0,3645



3.3 RUEGLIO

3.3.1 Phase I: Preparation

The information collected during the surveys and the analysis of technical documents of the municipality of Rueglio is shown in Table 29. It was decided to analyse two buildings.

Table 29: Rueglio information collected through survey.

Building	Ownership and function	Construction year	Latest refurbishment year	Total number of offices	Av. heat and DHW expenses [€/y]	Total number of users	Total usable area [m²]	Existing energy system
Municipality	Public; Non-residential (administration)	1900	none	8	13000	20	840	Oil boiler
Public building	Public; Non residential (accommodation)	1980	2014*	1	31500	40	1010	Oil boiler

*Roof intervention and PV installation

3.3.2 Phase IIA: Preliminary analysis

During the surveys, the properties of the materials used for the construction of the building (walls, roofs, slabs, windows) have been acquired.

The structure is composed by two connected buildings:

1. The principal one has three habitable floors and an unheated upper-attic. It hosts the sleeping area and other common spaces.
2. The second building is on the eastern side of the principal one and contain in a unique ground floor some spaces of the living area. There is an upper-attic space unheated also in this building.

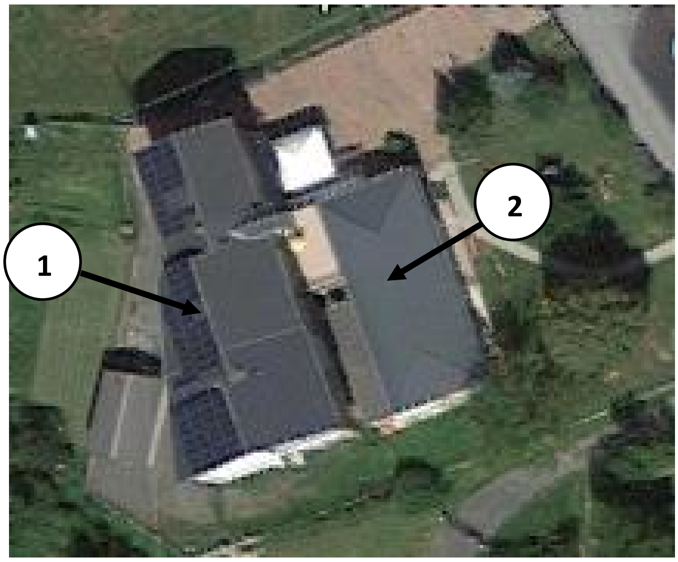


Figure 20: Rueglio buildings involved (Google Maps)

To supply energy to the buildings, currently there is a unique oil boiler (Buderus/Logano GE 315/140*)* with a nominal power of 140.9 kW and a generation efficiency of 79.4% compared to total primary energy. All the heaters are radiators.

To run the boiler, almost 30.000 litres of diesel fuel are need every year, taking into account some losses that are generated by a wrong utilization of the structures. This data come from the administrative accounting of the structure and concern annual providing from 2015 to 2017 (Table 30). It has been considered an average of fuel consumption during this period. It is supposed a continuous utilization of the building during the whole year.

Table 30: Historical energy consumption

Historical consumption (elderly care residence)			
YEAR	DIESEL FUEL	FUEL COST	MANAGEMENT+ MAINTENANCE + SUPERVISION
	litres	€	€
2015	30.000	31.703,23	2.021,00
2016	33.000	28.292,22	2.220,00
2017	27.000	27.700,15	2.602,00

Below, in Table 311, the primary energy indicators about space heating and domestic hot water and the total values are shown. Looking at that table, it is possible to see that currently a negligible part of the energy is produced by renewable sources.

Table 31: Rueglio energy indicators.

Service	Qp,nren [kWh]	Qp,ren [kWh]	Qp,tot [kWh]	EP,nren [kWh/m^2]	EP,ren [kWh/m^2]	EP,tot [kWh/m^2]
Heating	282.168	472	282.640	369,67	0,62	370,29
Domestic hot water	14.568	40	14.608	19,09	0,05	19,14
TOTAL	296.737	511	**297.248**	388,75	0,67	**389,42**

The building's weaknesses and critical issues from the energy point of view are presented below. This point is a prerequisite for the definition of retrofit alternatives in order to increase the building efficiency, energetically talking.

- Significant energy leakage through the opaque casing.
- Obsolete regulation and balance systems (simple regulation on-off with no internal temperature compensation).
- Obsolete heat generation technology (oil boilers, more than 10 years old, no condensation).
- Not clean energy resource (diesel fuel) and consequent high emission level of CO_2 and totally not renewable energy supply.

3.3.2.1 Energy retrofit alternatives

The table below shows the simulations designed for this study and the values of energetic indicators for each simulation.

Table 32:Rueglio retrofit alternatives.

Code of simulation	Interventions
0.0)	As built simulation model
0.1)	As built simulation model from real consumption (benchmark)
1)	Simulation 0) and replacement of the boilers with a unique biomass-fired one and regulation retrofitting.
2)	Simulation 1) and the upper-attic slabs insulation (20 cm)
3)	Simulation 2) and integration with solar collectors (28 m^2)

The principal aim is to reach a better utilization of building by an important reduction of energy needs and using local renewable sources and sustainable materials from local supply chain.

The retrofit alternatives propose changes regarding the energy system:

- It is proposed a replacement of the installed boiler with a biomass one of 203 kW and an efficiency of 89.8% to break down emission levels and environmental impact.
- Taking into account the envelope system refurbishment, it will be an installation of upper-attic slabs insulation of 20 cm.
- In the last intervention, it is integrated solar thermal collectors and a thermal storage system to supply hot water needs (Figure 21).

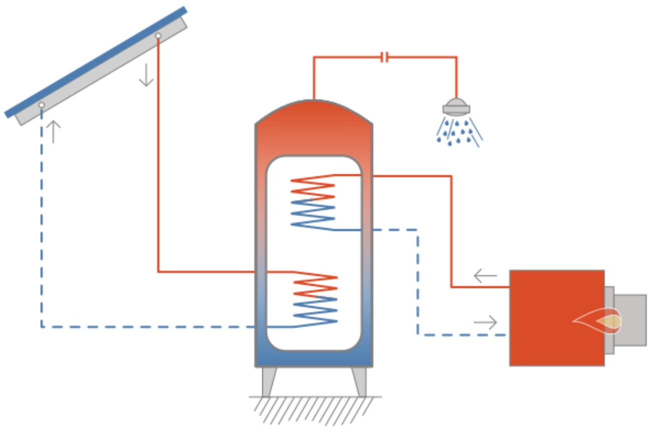


Figure 21: Solar collectors and biomass boiler integration

- Also it will be implemented a control system by the installation of thermostatic valves for each emission system, climatic and internal air sensors to improve regulation of the heating plant. The implementation of the control systems will reduce energy losses, improve remote regulations and take historical data for monitoring the operative phase and supporting any following analysis.

The indicator values utilized to represent the retrofitted situation by EDILCLIMA are:

- Qp: the total energy consumption of the buildings and systems. It is done the distinction between the portion of the energy consumption that is provided by renewable and non-renewable sources.

- Emission of CO_2 consequent to fuel consumption. It is possible to observe that the reduction in carbon dioxide emissions are reduced an 85%, in average, compared to the current situation.

Table 33: Energy simulation results

Case	$Q_{p,tot}$		$Q_{p,ren}$		$Q_{p,nren}$		CO_2 Emissions	
	[kWh/y]	% (VS 0.1)	[kWh/y]	% ren/tot	[kWh/y]	% nren/tot	[kgCO_{2eq}/y]	% (VS 0.1)
0.0)	297.248	92,60%	-	-	297.248	100%	72.153	86,67%
0.1)	321.006	100%	-	-	321.006	100 %	83.253	100%
1)	239.469	74,60%	191.575	80%	47.894	20%	11.973	14,38%
2)	217.604	67,79%	174.083	80%	43.521	20%	10.880	13,07%
3)	217.293	67,69%	175.419	80,73%	41.874	19,27%	10.295	12,37%

3.3.3 Phase IIB: Feasibility analysis

To perform the feasibility analysis, the evaluation matrix is filled. This is a critical step to select the best refurbishment alternative. The three alternatives are compared through the seventeen selected indicators.

Table 34: Rueglio evaluation matrix.

Category	Indicator	A.1	A.2	A.3
Environmental	Primary energy saving [kWh/y]	273112	277485	273112
	Global emissions CO2 reduction [kgCO2eq]	71262	72355	71262
	Local emissions NO_X reduction [kg/y]	49,16	49,95	49,16
	Local emissions PM10 reduction [kg/y]	3,55	3,61	3,55
Economic	Payback period (PBP) [years]	7,6	8,6	7,6
	Investment cost [euro]	350675	407485	350675
	Public incentives [%]	40	40	40
	Savings on energy expenditure [euro/year]	46429	47172	46429
	Labor cost [euro]	80925	94035	80925
	Labor cost by a social cooperative [euro]	20231	23509	20231
	Material cost [euro]	269750	313450	269750
	Material cost purchased on the territory [euro]	94413	109708	94413
	Running cost [euro]	44371	42096	44371

	Type Thermal Account Access (TAA) vs. Energy Efficiency Certificates (EEC)	TAA	TAA	TAA
Technical	Increase of plant system efficiency [%]		10,4	
	Installed power reduction [kW]		-62,1	
Social	Architectural impact [-]	3	3	5

Best scenario selection

Phase 2 ends whit the application of PROMETHEE. The rankings obtained from Visual Promethee are presented in the next three tables with their respective figures.

Table 35: Rueglio Baseline results

Rank	Alternative	Phi	Phi+	Phi-
1	Alternative 2	0,1590	0,3084	0,1494
2	Alternative 1	0,0375	0,2750	0,2375
3	Alternative 3	-0,1965	0,1931	0,3896

Table 36: Rueglio Change 1 results

Rank	Alternative	Phi	Phi+	Phi-
1	Alternative 1	0,0882	0,3824	0,2941
2	Alternative 2	0,0706	0,3285	0,2579
3	Alternative 3	-0,1588	0,2285	0,3873

Table 37: Rueglio Change 2 results

Rank	Alternative	Phi	Phi+	Phi-
1	2	0,1371	0,3213	0,1841
2	1	0,0079	0,2902	0,2823
3	3	-0,1451	0,2286	0,3736

3.4 NOVALESA

3.4.1 Phase I: Preparation

The following table shows Novalesa data collection during the first phase of the methodology employed. There were three buildings identified to be analysed.

Table 38: Novalesa information collected through survey.

Building	Ownership and function	Construction year	Latest refurbishment year	Av. heat and DHW expenses [€/y]	Total number of users	Total usable area [m²]	Existing energy system
Abbey and church	Public (administration)	726	1972*	90000	10	3500	Oil boiler
Private house	Private (family house)	726	none	-	1	240	Gas boiler
Accommodation building	Private (accommodation)	1800	none	-	23	500	Gas boiler

* Structural intervention and oil boiler installation.

3.4.2 Phase IIA: Preliminary analysis

The structure is composed by three buildings:

1. An abbey and church, which was built with natural stones walls and slabs.
2. A private house which has solid brick walls and concrete slabs.
3. Accommodation building.

Figure 22: Novalesa buildings involved (Google Maps)

Currently, to supply energy to the buildings, there is one oil boiler with blast burner of 520 kW of nominal power and a generation thermal efficiency of 75.6% compared to total primary energy. It is important to remark that there is no insulation in the whole construction.

There are two different circuits for heating spaces, and different kind of heaters for each circuit, including radiators and fan heaters.

To run the boiler, almost 85.000 kg of diesel fuel is need every year taking into account some differences that are probably generated by a wrong utilization of the structures. This data comes from the administrative accounting and concern by energy bills.

In order to determine the consumption of domestic hot water needed for the abbey residents, it has been estimated a daily consumption of 2.500 liters. The building is assumed to be utilized 12 hours every day of the week.

Below are shown the primary energy indicators about space heating and domestic hot water and the total values.

Table 39: Novalesa energy indicators.

Service	Qp,nren [kWh]	Qp,ren [kWh]	Qp,tot [kWh]	EP,nren [kWh/m^2]	EP,ren [kWh/m^2]	EP,tot [kWh/m^2]
Heating	1.123.143	0	1.123.143	373,63	0,00	373,63
Domestic hot water	47.412	0	47.412	15,77	0,00	15,77
TOTAL	**1.138.034**	0	**1.138.034**	**378,59**	0,00	**378,59**

Analysing Novalesa building's weaknesses and critical issues from the energy point of view, it is possible to denote the following:

- Regulation and balance systems can be improved.
- Obsolete heat generation technology (oil boiler, no condensation).
- Not clean energy resource (diesel fuel) and consequent high emission level of CO_2 and totally not renewable energy supply.

This point is a prerequisite for the definition of retrofit alternatives in order to increase the building efficiency.

3.4.2.1 Energy retrofit alternatives

To reduce the critical issues mentioned, different alternatives of retrofitting are defined. Is considered useful obtain the incentives offered by the "Conto Termico" for public buildings about renewable energy supply.

The table below shows the simulations designed.

Table 40: Novalesa retrofit alternatives.

Code of simulation	Interventions
0.0)	As built simulation model
0.1)	As built simulation model from real consumption
1)	Simulation 0) and replacement of the boilers with a unique biomass-fired one and regulation retrofitting.

Looking the intervention proposed, there are no operations on opaque or transparent casing planned. There is only one alternative, and this is due to the materials of construction and the impossibility to apply different retrofitting as wall or roof slabs insulation.

There will be a replacement of the installed boiler, with a unique wood chip-fired boiler, using biomass from the surrounding forests, to improve efficiency and brake down emission levels and environmental impact.

This generator has a nominal heating load of 550 kW and an efficiency of 90% compared to total primary energy, according to the reference standard UNI-12831 that quantify the heating requested for buildings. It will be equipped with an air supply fan and an automatic loading system.

Moreover, it will be an Installation of thermostatic valves for each emission system, climatic and internal air sensors to improve regulation of the heating plant. This is to reduce energy losses, improve remote regulations and take historical data for monitoring and supporting any following analysis.

The indicator values utilized to represent the retrofitted situation are:

- Qp: the total energy consumption of the buildings and systems (total/renewable/not renewable) and,
- Emission of CO_2 consequent to fuel consumption.

Table 41: Energy simulation results.

Case	$Q_{p,tot}$		$Q_{p,ren}$		$Q_{p,nren}$		Emissions	
	[kWh/y]	% (VS 0.1)	[kWh/y]	% $^{ren}/_{tot}$	[kWh/y]	% $^{nren}/_{tot}$	[$kgCO_{2eq}$/y]	% (VS 0.1)
0.0)	1.138.034	**105,42%**	0	0,00%	1.138.034	100,00%	297.803	105,42%
0.1)	1.079.572	**100,00%**	0	0,00%	1.079.572	100,00%	282.505	100,00%

1)	924.542	**85,64%**	739.634	80,00%	184.908	20,00%	46.227	16,36%

Table 42 shows that carbon dioxide emissions fall to almost 16 percent compared with the current situation.

3.4.3 Phase IIB: Feasibility analysis

Novalesa is a particular case in which there is only one alternative proposed. As I explained before, this is due to the characteristics of the materials present in the buildings construction and therefore impossibility to apply retrofitting apart from:

- The replacement of the boiler.
- Regulation retrofitting.

In Table 42, the indicators are calculated for the selected alternative.

Table 42: Novalesa evaluation matrix.

Category	Indicator	A.1
Environmental	Primary energy saving [kWh/y]	894664
	Global emissions CO2 reduction [kgCO2eq]	236278
	Local emissions NO_X reduction [kg/y]	161,04
	Local emissions PM10 reduction [kg/y]	11,63
Economic	Payback period (PBP) [years]	2,3
	Investment cost [euro]	350675
	Public incentives [%]	40
	Savings on energy expenditure [euro/year]	152093
	Labor cost [euro]	80925
	Labor cost by a social cooperative [euro]	20231
	Material cost [euro]	269750
	Material cost purchased on the territory [euro]	94413
	Running cost [euro]	151242
	Type Thermal Account Access (TAA) vs. Energy Efficiency Certificates (EEC)	TAA
Technical	Increase of plant system efficiency [%]	14,4
	Installed power reduction [kW]	21
Social	Architectural impact [-]	3

3.5 SAN GIORIO

3.5.1 Phase I: Preparation

As all the cases before, the first phase is about making an in-situ analysis and collecting data through surveys and expert opinions, in order to determine the buildings subject to be part of EC. The information is on Table 43.

Table 43: San Giorio information collected through survey.

Building	Ownership and function	Existing energy system
Hall	Public; Non residential (municipal multipurpose)	Gas boiler
Bar	Private; Non residential (family house)	Gas boiler

3.5.2 Phase IIA: Preliminary analysis

During the surveys, the properties of the materials used for the construction of the building (walls, roofs, slabs, windows) have been acquired.

The area includes one building, divided into two part with different uses:

1. Municipal multipurpose hall, in the central and western part of the building
2. The bar, in the eastern part of the building.

The ground floor is heated only in the central room, used as exposition area, while the remaining parts are unheated and host two heating plants and storerooms.

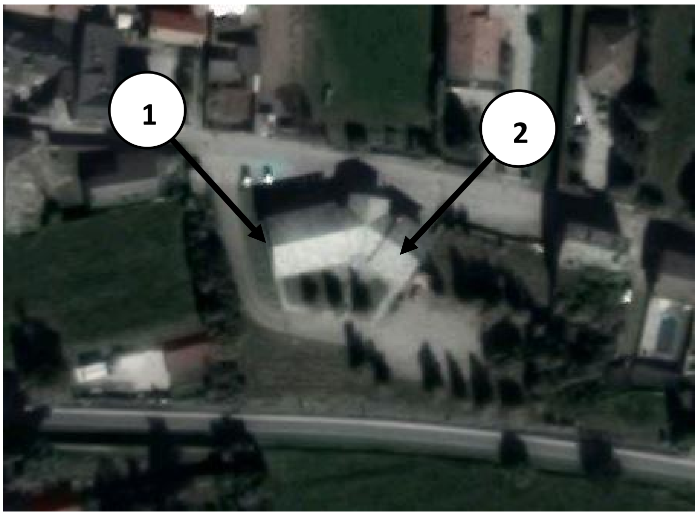


Figure 23: San Giorio buildings involved.

Currently, there is a unique gas boiler used for the heating service. This traditional gas boiler has a blast burner, a nominal power of 112 kW and a generation thermal efficiency of 79.9%.
The buildings have the same heater components, air fan heaters.

The estimated methane gas consumption is about 17.640 m3 per year, using constructive materials and values of similar buildings. The resulting values have been validated supposing a continuous trend of utilization of the buildings.

Domestic hot water is produced by electric boilers, so its contribution has not been considered in the following analysis of fuel consumption.

Table 44: Energy indicator simulation

Service	Qp,nren [kWh]	Qp,ren [kWh]	Qp,tot [kWh]	EP,nren [kWh/m^2]	EP,ren [kWh/m^2]	EP,tot [kWh/m^2]
Heating	184.077	0	**184.077**	502,08	0,00	**502,08**

The building's weaknesses and critical issues from the energy point of view are presented. This point is a prerequisite for the definition of retrofit alternatives in order to increase the building efficiency.

- Significant energy leakage through the opaque casing.
- Obsolete regulation and control systems (simple manual regulation with no internal temperature compensation).
- Obsolete heat generation technology (traditional gas-fired boiler without condensation).
- Not clean energy resource (methane gas) and consequent high emission level of CO_2 and totally not renewable energy supply.

Energy retrofit alternatives

Different alternatives of retrofitting are possible. Is considered useful obtain the incentives offered by the "Conto Termico" for public buildings about renewable energy supply.

The table below shows the simulations designed.

Table 45: Energy retrofit alternatives.

Code of simulation	Interventions
0.0)	As built simulation model
0.1)	As built simulation model from real consumption
1)	Simulation 0) and replacement of the boilers with a unique biomass-fired one and regulation retrofitting.
2)	Simulation 1) with upper-attic slabs and external floor slabs insulation (15cm)

The interventions involve installation of external insulation systems under the floor slabs and on the upper-attic slabs. A replacement of the installed boiler with a unique wood chip-fired boiler using biomass from the forest. This biomass boiler has a nominal power of 100 kW, calculated according to the standards, and a generation thermal efficiency of 90%

Installation of thermostatic valves for each emission system, climatic and internal air sensor to improve regulation of the heating plant.

Table 46: Energy indicators

Case	$Q_{p,tot}$		$Q_{p,ren}$		$Q_{p,nren}$		Emissions	
	[kWh/y]	% (VS 0.0)	[kWh/y]	% $^{ren}/_{tot}$	[kWh/y]	% $^{nren}/_{tot}$	[kgCO_{2eq}/y]	% (VS 0.0)
0.0)	184.077	**100,00%**	0	-	184.077	100,00%	36.815	100,00%
0.1)	unknown	**-**	-	-	-	-	-	-
1)	144.309	**78,40%**	115.447	80,00%	28.862	20,00%	7.215	19,60%
2)	126.681	**68,82%**	101.345	80,00%	25.336	20,00%	6.334	17,20%

3.5.3 Phase IIB: Feasibility analysis

In this phase, both alternatives are compared through all the indicators by the evaluation matrix, taking into account environmental, economic, technical and social aspects.

Table 47: San Giorio evaluation matrix.

Category	Indicator	A.1	A.2
Environmental	Primary energy saving [kWh/y]	155215	158741
	Global emissions CO2 reduction [kgCO2eq]	29600	30481
	Local emissions NO_X reduction [kg/y]	16,61	16,99
	Local emissions PM10 reduction [kg/y]	11,18	11,43
Economic	Payback period (PBP) [years]	13,6	15,8
	Investment cost [euro]	350675	418457
	Public incentives [%]	40	40
	Savings on energy expenditure [euro/year]	15522	15874
	Labor cost [euro]	80925	96567
	Labor cost by a social cooperative [euro]	20231	24142
	Material cost [euro]	269750	321890
	Material cost purchased on the territory [euro]	94413	112662
	Running cost [euro]	21444	27371
	Type Thermal Account Access (TAA) vs. Energy Efficiency Certificates (EEC)	EEC	EEC
Technical	Increase of plant system efficiency [%]	10	
	Installed power reduction [kW]	12	
Soci	Architectural impact [-]	3	3

Best scenario selection

In this section of the second phase, PROMETHEE is applied taking into account the sensitivity analysis, to check robustness on the model.

The results of the different changes regarding the weights of the different KPIs are presented below.

Table 48: San Giorio baseline results

Rank	Alternative	Phi	Phi+	Phi-
1	Alternative 2	0,0375	0,2125	0,1750
2	Alternative 1	-0,0375	0,1750	0,2125

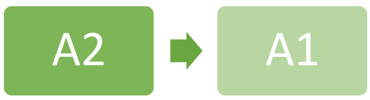


Table 49: San Giorio Change 1 results

Rank	Alternative	Phi	Phi+	Phi-
1	Alternative 1	0,1765	0,4118	0,2353
2	Alternative 2	-0,1765	0,2353	0,4118

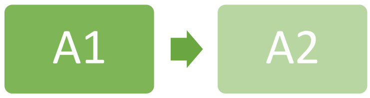
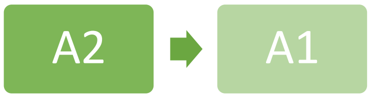


Table 50: San Giorio Change 2 results

Rank	Alternative	Phi	Phi+	Phi-
1	Alternative 2	0,0244	0,2500	0,2257
2	Alternative 1	-0,0244	0,2257	0,2500



CHAPTER 4: DISCUSSION OF RESULTS

In order to discuss the results, a summary of the best refurbishment alternative for each case study is presented.

OULX

The following figure (Figure 24) was obtained through the Visual PROMETHEE software, and shows graphically the outgoing and incoming flows for the different alternatives proposed, regarding the baseline case of weights (25 percent each category).

In the image, the best alternatives are positioned higher, showing the complete order of choice of the different alternatives and their respective net flow values, according to what emerged from the data.

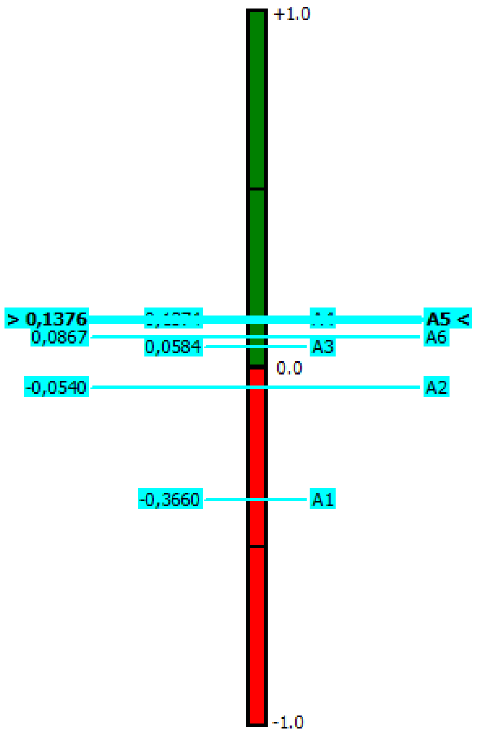


Figure 24: Oulx Net Phi ranking.

It is possible to observe that Alternative 1 and Alternative 2, have a negative Net phi and are far from the best case scenario. These are therefore the less favoured alternatives, according to what emerged from the data.

The second Alternative, A4 has a comparable Net Phi compared to Alternative 5. A5 is always the best case scenario in all the proposed changes. This refurbishment alternative proposes:

- Oil Boiler replacement with one fuelled by biomass.

- Thermostatic valves.
- Upper-attic slabs insulation for school, gym and nursery.
- External wall insulation for school and gym.

"Baseline", "Change 1" and "Change 2" present the same outranking of alternatives. In these changes, the rank position is not affected by the sensitivity analysis, even if Net Phi values vary for every retrofitting situation.

<u>VILLAR DORA</u>

As the Oulx municipality, for Villar Dora it was also generated the same figure was obtained through the Visual PROMETHEE software, regarding the baseline case of weights (25 percent each category).

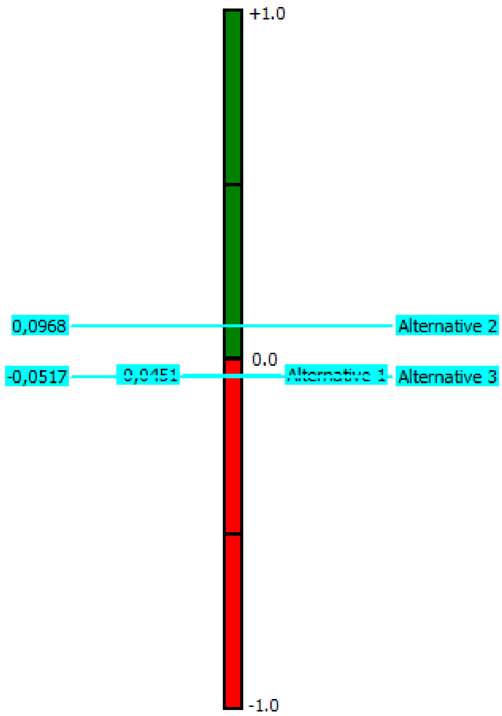


Figure 25: Villar Dora Net Phi ranking.

In this case the best scenario is the alternative 2, as Figure 25 shows. Moreover, it is the only one that presents a positive Net phi. This refurbishment alternative involves:

- Replacement of the current boiler with one fuelled by local biomass
- External wall insulation for the kindergarten
- Upper-attic slabs insulation for the gym and library

RUEGLIO

Looking at figure of the outgoing and incoming flows for the different alternatives proposed, regarding the baseline case of weights (25 percent each category), the second alternative is the most appropriate one. It proposes:

- Replacement of the boilers with a unique biomass-fired one.
- Upper-attic slabs insulation.
- Retrofitting regulation.

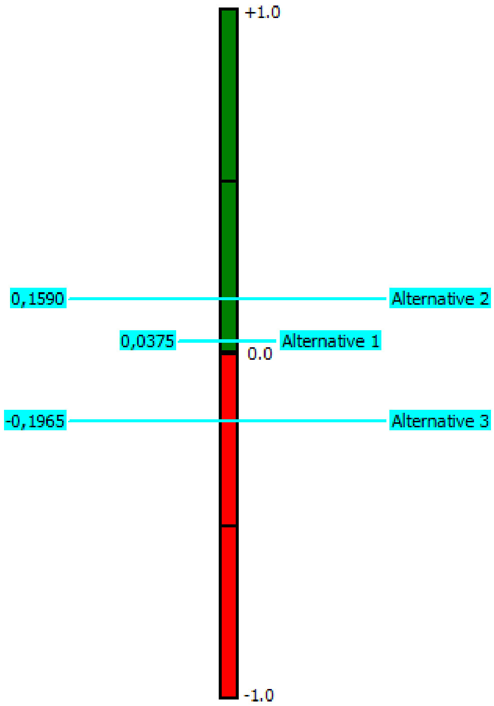


Figure 26: Rueglio Net phi ranking.

NOVALESA

As was explained, there is only one proposed alternative for the municipality of Novalesa, due to the materials of construction and the impossibility to apply different retrofitting as wall or roof slabs insulation.

The alternative includes:

- Replacement of the boilers with a unique biomass-fired one
- Regulation retrofitting.

SAN GIORIO

As in the previous cases, the following figure was obtained through the Visual PROMETHEE software, and shows graphically the outgoing and incoming flows for the different alternatives proposed, regarding the baseline case of weights (25 percent each category).

In this case the best scenario is the alternative 2, as Figure 27 shows. Moreover, it is the one that presents a positive Net phi. This refurbishment alternative involves:

- Replacement of the current boiler with one fuelled by local biomass.
- Regulation retrofitting.
- Upper-attic slabs and external floor slabs insulation (15 cm)

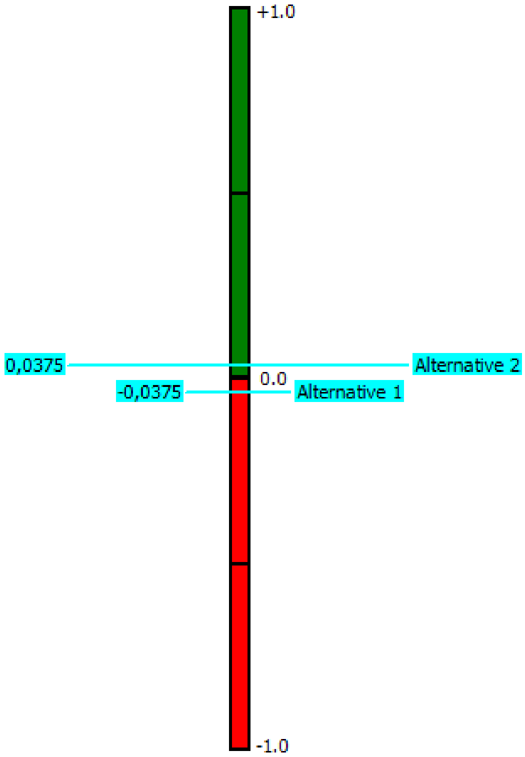


Figure 27: San Giorio Net phi ranking

Looking at the results obtained following the methodology, some differences can be noted taking into account the changes in KPIs' weights. The following table highlights the best refurbishment alternative for each municipality.

Table 51: Best refurbishment alternative for each case study, considering variation in weight.

	Oulx	Villar Dora	Rueglio	Novalesa	San Giorio
Baseline	A5	A2	A2	A1	A2
Change 1	A5	A3	A1	A1	A1
Change 2	A5	A2	A2	A1	A2

Observing Table 51, it is easy to detect that the best retrofit alternative for **Change 1** differs, in most of the cases, with **Baseline** and **Change 2** (Villar Dora, Rueglio and San Giorio). There are two exceptions, Novalesa in which only one alternative was proposed and Oulx, the municipality with most possible retrofitting situations (six). In all the municipalities, the best refurbishment alternative is the same regarding Baseline and Change 2. Taking into account this, the model seems not to be robust, but some extra analysis will be applied to check it more in deepness.

In an MCA, once all the KPIs have been identified, the relationships between the criteria must be assessed. Basically, a weight must be attributed to each criterion, based on the relevance it has within the analysis. These weights are of great importance, as they directly influence the result of the MCA.

As also defined by Wang (Wang et al., 2009), there are several methods of possible adoption. Specifically, it is possible to make use of two macro-families: the first allows to assign the same weight to each criterion, the second requires ordering the criteria by importance.

Change 1 was particularly defined by the first macro-family, by using the same weight for all criteria. This means giving all selected criteria the same importance. This method is useful when you do not have in-depth knowledge about the decision maker's priorities, allowing the obtension of results.

As the amount of indicators within each category varies, the weight for each category applying Change 1 also varies a lot. In the following table, the accumulated weight for each category is represented.

Table 52: Category weight applying sensitive analysis

	Environmental	Economic	Technical	Social
Baseline	25%	25%	25%	25%
Change 1	23,5%	58,8%	11,8%	5,9%
Change 2	30%	30%	20%	20%

According to the book "Designing performance measurement system" (Franceschini, F., Galetto, M., Maisano, D. 2019). The indicators must represent the process without omissions or redundancies. To this purpose, exhaustiveness and non-redundancy are two desirable properties:

- *Exhaustiveness:* Could be considered the most important property for a set of indicators. A set of indicators is considered non-exhaustive when:

  - The representation does not consider one or more important dimensions of the process. The set is incomplete.
  - One or more indicators do not map distinguished empirical manifestations into distinguished symbolic manifestations.
- *Non-redundancy*: If a set of indicators is exhaustive and it continues to be exhaustive even when removing one indicator, then the latter indicator is redundant.

Analysing the evaluation matrix for each municipality, I have noticed that for each municipality, the technical indicators are the same for all the alternatives. So, this category seems to be redundant. Therefore, I propose another change (Change 3) regarding weights of indicators, to check if the model is robust.

Change 3 propose the following:

- *Environmental category*: 33.33 percent, divided equally to each indicator (8.33 percent).
- *Economic category:* 33.33 percent, divided equally to each indicator (3.33 percent).
- *Technical category:* 0 percent due to redundancy.
- *Social category:* 33.33 percent, divided equally to each indicator (33.3 percent).

Applying Change 3 to each municipality, the results are:

Table 53: Change 3 Results.

OULX			SAN GIORIO			RUEGLIO			VILLAR DORA		
Rank	Alt.	Net Phi	Rank	Alt.	Net Phi	Rank	Alt.	Net Phi	Rank	Alt.	NetPhi
1	A5	0,177	1	A2	0,065	1	A2	0,212	1	A2	0,132
2	A4	0,176	2	A1	-0,065	2	A1	0,049	2	A1	-0,019
3	A6	0,107				3	A3	-0,261	3	A3	-0,112
4	A3	0,073									
5	A2	-0,058									
6	A1	-0,475									

With the results obtained by the application of Change 3, it is possible to update Table 51: Best refurbishment alternative for each case study, considering variation in weight.

Table 54: Best refurbishment alternative for each case study, considering variation in weight.

	Oulx	Villar Dora	Rueglio	Novalesa	San Giorio
Baseline	A5	A2	A2	A1	A2
Change 1	A5	A3	A1	A1	A1
Change 2	A5	A2	A2	A1	A2
Change 3	A5	A2	A2	A1	A2

Taking into account Table 54, I can express that:

- The model seems to be robust, considering that three out of four changes in weights provides the same retrofit alternative.
- The technical category is redundant, analysing the exhaustiveness property.
- Due to the amount of indicators, the Economic category is the most sensitive. Giving it more weight, as in Change 1, could lead in a different ranking.

CHAPTER 5: CONCLUSION AND FUTURE DEVELOPMENT

To sum up, during the first's phases of the SCORE project in Susa Valley, the Italian pilot, different case studies were selected during a preliminary analysis. Taking into account this, the two main objectives that this thesis tried to reach are:

- Assess seventeen KPIs defined within the SCORE project, doing an impact assessment.
- Select the best refurbishment alternative through MCA for each case study of the Italian pilot.

The present study illustrated and described the three different phases presented in the methodology:

I. The preparation phase, with identification and description of selected buildings,
II. The preliminary and feasibility analysis,
III. The target group involvement in implementing CSOP model.

The methodology was employed in five real cases (Oulx, Villar Dora, Rueglio, Novalesa and San Giorio) in the Susa Valley, the selected Italian pilot in order to achieve the objectives proposed (1.4 Research objectives) of my thesis and the SCOREs' ones. Particularly, this thesis work has been centred in the second phase, because the first one was already done, and the third one is currently starting.

The second phase was divided in two parts, the first one regarding the **preliminary analysis**, in which the proposal of different retrofit measures was done in order to overcome the use of fossil fuels in favour of renewable ones (biomass) and to increase the energy efficiency of the buildings, two of the main purposes of SCORE project.

The second part of Phase two was about the application of an MCA carried out by the outranking Visual PROMETHEE software. This section demonstrates the **feasibility** of different retrofit proposals to improve the energy efficiency of the selected buildings at local level, focusing on the creation of Energy Communities.

To carry out the Multi Criteria Analysis by PROMETHEE application, a set of seventeen Key Performance Indicators was selected and defined taking into account the stakeholders' preferences and then assessed. These KPIs evaluated the projects according different aspects, like environmental, economic, technical and social through an evaluation matrix.

Finally, a sensitivity analysis was done by changing the weights of the KPIs. It was performed to check and observe the ranking variation between changes. The model turns out to be particularly robust, allowing complete and reliable results to be obtained.

From the results obtained following the proposed methodology, it was possible to identify the best refurbishment alternative to be implemented in the municipalities of Susa Valley area. The following images represent the selected retrofit alternative for each case study, according to what was obtained through PROMETHEE application.

Oulx

Figure 28: Oulx best alternative (Biomass boiler, valves, roof and wall insulation).

Villar Dora

Figure 29: Villar Dora best alternative (Biomass boiler, valves, roof and wall insulation).

Rueglio

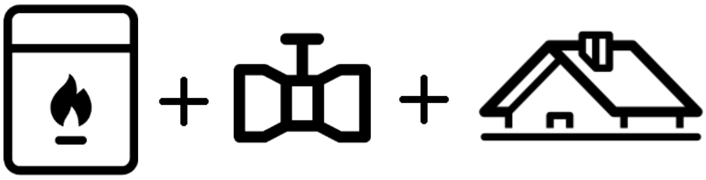


Figure 30: Rueglio best alternative (Biomass boiler, valves and roof insulation).

Novalesa

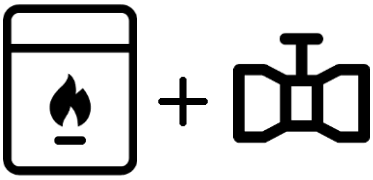


Figure 31: Novalesa best alternative (Biomass boiler and valves).

San Giorio

Figure 32: San Giorio best alternative (Biomass boiler, valves, roof and floor insulation).

The study shows that the proposed methodology is applicable at different scales and my help the decision makers in selecting among different possibilities. It shows that MCA methods are useful when many options, characterized by qualitative and quantitative criteria, are available.

On the other side, there are some criticisms and future development regarding the work done:

- PROMETHEE was the selected MC method because it is a method widespread in the energy area and it is easy to be used and undestood. Also, when I investigated the method, it demonstrated to be useful in ranking a limited number of alternatives, considering conflicting criteria. As future development of this work, it could be enriching to apply another multi-criteria analysis, ELECTRE for example, and compare the results.
- Due to the impossibility to access to precise data, some KPIs were defined making assumptions based on expert suggestions, as the example that one out of four workers will be part of this social cooperative. It is important adjust these numbers whilst the project continues to rely on the data.
- The choice of the thresholds is a very critical step during the application of MCA. In this case, it was selected for all the indicators the same 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 to access to precise data coming from stakeholders. While the project progresses, it is important to focus in the elimination of assumptions, which will lead in a consistent model.

The future steps regarding this work are:

- Develop and implement Consumer Stock Ownership Plans (CSOP), understanding the need of the municipalities in term of legal and financial expertise (2.1.3 Phase III: Target group involvement). Encouraging an active role of consumers, involving the SCORE target groups (women and low-income households).
- Apply this framework to the other five Italian case studies (Bussoleno, Bardonecchia, Susa, San Giorio city and Almese) and,

The implementation of CSOP, will be done through a social analysis using a questionnaire, working groups and events, like the one presented in Figure 33, to identify the main drivers and obstacles to their participation in energy communities.

Figure 33: Cover page Bussoleno workshop.

The results that SCORE project expects for its conclusion in 2021 are the creation of Energy Communities along the Susa Valley in northern Italy, one of the three pilot projects. With this creation, a proper engagement of private and or public consumers towards sustainable energy transition will have been carried out. This derives in the use of renewable fuels, energy improvement in the selected buildings and an inclusion of different social groups that today are marginalized, energetically talking.

Moreover, SCORE wants to make EC an example so that they can be replicated throughout Europe and thus combat climate change, the greenhouse gas effect and unhealthy gas emissions that are produced due to excessive primary energy consumption.

In this framework, the work carried out during this thesis contributes directly to the objectives of SCORE. Throughout this study, the most suitable refurbishment alternative will be selected for five of the ten municipalities involved in the Susa Valley. These alternatives propose: energy generation from renewable sources, biomass in this case due to the characteristics of the valley where they are located, increasing of the building energy efficiency and reduction the energy consumption, which are essential requisites to the creation of EC.

APPENDIX 1: Scientific Articles.

Article 1: Mainstreaming energy communities in the transition to a low-carbon future: a methodological approach

energies

MDPI

Article

Mainstreaming energy communities in the transition to a low-carbon future: a methodological approach

Sara Torabi Moghadam [1,*], Maria Valentina Di Nicoli [1,*], Santiago Manzo [2], Patrizia Lombardi [1]

1 Interuniversity Department of Regional and Urban Studies and Planning, patrizia.lombardi@polito.it
2 Interuniversity Department of Management and Production Engineering (DIGEP), santiago.manzo@studenti.polito.it

* Correspondence: sara.torabi@polito.it; mariavalentina.dinicoli@polito.it

Received: date; Accepted: date; Published: date

Abstract: The innovations in technical, financial and social aspects are crucial prerequisites for an effective sustainable energy transition. In this context, the construction of a new energy structure and the motivation of consumer towards a change in their consumption behaviours, to balance demand with a volatile energy supply, are important issues. At the same time, the Consumer Stock Ownership Plans (CSOPs), in renewable energies sources (RES), has proven to be an essential cornerstone to the overall success of energy transition. Indeed, when consumers acquire ownership in RES, they become prosumers, participating in the phase of production and distribution of energy. Into this, they are more beneficial by (i) generating a part of the energy they consume, (ii) reducing their overall expenditure for energy and (iii) receiving a second source of income from the sale of excess production. SCORE - Supporting Consumer Co-Ownership in Renewable Energies - is an ongoing Horizon 2020 project with the aim at overcoming the usage of energy from fossil sources in favour of RES, promoting the creation of Energy Communities (EC) and facilitating co-ownership of RE for consumers. SCORE hereby particularly emphasises the inclusion of women, low-income households and vulnerable groups affected by fuel poverty that are as a rule excluded from RE investments. In this framework, the main goal of the present study is to illustrate the general procedure and process of the EC creation. In particular, this paper focuses on the description of the methodological approach in implementing CSOP model which consists of threefold main phases: the identification and description of selected buildings (preparation phase), the preliminary and feasibility analysis phase, and finally the phase of target groups involvement. SCORE starts first in three pilot regions in Italy, Czech Republic and Poland, and later with the aim of extending the methodology in various other follower cities across Europe. In this study, Italian pilots were chosen as a case study to develop and test the methodology.

Keywords: Energy Community (EC); Renewable Energy Sources (RES); Citizens Involvement; Co-Ownership in Renewable Energies

1. Introduction

Nowadays, against the global environmental problems (i.e., the climate change and the increase of greenhouse gas emission) it is necessary to follow a "decarbonization process" towards the energy transition. Energy transition means, not only, a moving away from energy from fossil sources in favour of renewable ones, but also an improvement of the energy efficiency related to the energy production and a definition of an aware energy consumption by building users and citizens [1], [2].

In this regard, the Energy Community (EC) initiatives seems to be the way through which is possible to give a concrete answer to the aforementioned environmental issues. Moreover, the EC represents a new model which considers energy perspective, economic aspects and, also, social ones. This emerging concept leads to positive implications in different areas, e.g. CO_2 emissions reduction (at global scale), the reduction of local pollutants for an improvement in external air quality; an economic development such as creation of new job self-sufficiency, reduction of energy poverty and community cohesion [3]. In addition, apart from shifting towards a new market, no longer founded on large centralized plants fuelled by fossil fuels but towards small-centralized plants powered by renewable energy sources (RES), in this emerging system the consumer plays an active role. The consumers' willingness to actively participate in the decision joined to the production, distribution and consumption of energy from RES represents a key element in the EC definition. The EC born from a bottom-up willpower in which municipalities, small and medium enterprises and citizens, located in a specific area, share the willingness to self-produce, self-consume and exchange energy from renewable energy sources, between different users in different end-use buildings [3], [4]..

It is clear that the participation is the core topic of community projects, but the main and innovative issue addressed in this work is the inclusion of several target groups. Indeed, usually these projects are held up by men, middle aged and with a higher income whereas the women, low-income households and vulnerable groups affected by fuel poverty is uncommon and as a rule excluded from RE investments [5].

This new paradigm has to be supported by a legislative framework in order to allow the birth and proliferation of these communities. Currently, the allowed energy model in Italy is based on a "one to one configuration", from a single energy system to a single end-consumer; the case of a single-family house with a photovoltaic system installation for personal consumption or the case of a condominium with a photovoltaic system installation for the satisfaction of only common loads (e.g. elevator, lighting of common area, etc.) fall in this typology. The "one to many configuration", from a single system to multiple end-consumers (between different buildings with different end-uses), is allowed with the support of new legislative framework (as shown in **Figure 1**).

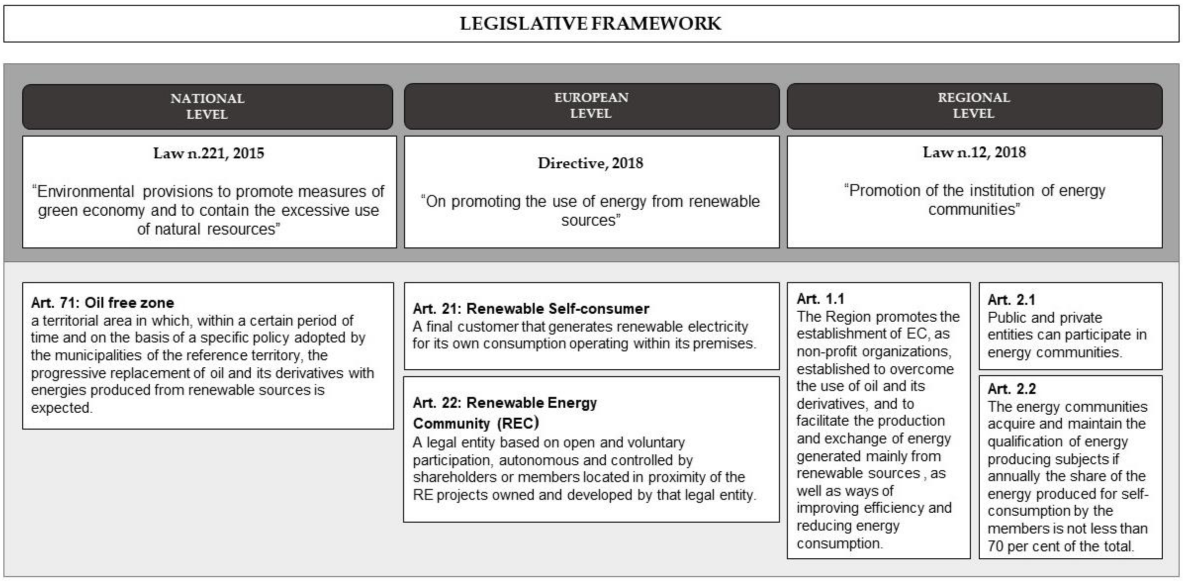


Figure 1. The legislative framework of Energy Communities.

In this context on 30th November 2016, the European Commission presented the "Clean Energy for All Europeans" package, also known as “Clean energy package”, which includes several measures legislation in the fields of energy efficiency, renewable energy and the internal energy market power [6]. Among all, two directives are important since they address significantly the ECs issues: (i) the RED II (2018) and (ii) the new directive on the new rules of electricity market (2019). The RED II overall target is to reach a 32% of energy consumption supplied by RES. In addition, the new Directive describes the 2020 national targets for each country taking into account the renewable energy production potential for the next years and the actual production level. In this way, each EU country define how to reach the targets through a National Energy Action Plans. Moreover, under RED II, Member States when transposing the new rules into national law will have to ensure that private consumers of RE in the same building are authorized to organise among themselves the exchange of the RE produced on their sites. In this regard, an innovative energy model is founded, overcoming mono-directional consumption by passive consumers from energy produced by large-scale industrial producers. Furthermore, RED II enables different stakeholders to join RECs that produce energy (e.g., electricity) for self-consumption and to share the energy produced within the REC. In this way, the “prosumer” has an active role in the production and consumption of energy from REC, sanctioning the right of citizens and communities to produce, store and consume energy from RES.

In Italy, at national level, recognition of the ECs can be found in the 2017 National Energy Strategy (SEN) containing the ten-year plan of the Italian Government to manage the change in the energy system. The SEN, in fact, places the figure of the consumer at the centre considering it the "engine of the energy transition, to decline in a greater involvement of the demand to the markets through the activation of the demand response, the opening of the markets to the consumers and self-producers the regulated development of energy communities". Furthermore, the Law 221 of 2015, “Environmental provisions to promote measures of green economy and to contain the excessive use of natural resources”, establishes within article 71, the possibility of creating areas free from the dependence of fossil fuels, so-called “oil free zone”. These territorial areas have the possibility of encouraging experiments, which also extend to new forms of association.

Following the new regulatory framework, the Piedmont Region act the willpower to “promote the birth of energy communities as non-profit organizations”. Indeed, the Piedmont Region is the first Italian region, with the Regional Law of 3 August 2018, n. 12 ("Promotion of the institution of energy communities"), that encourage the new paradigm related to the Energy Communities. This law launches these communities as non-profit organisations in which public and private subjects can take part. They are established to promote the energy transition facilitating the production and exchange of energy generated mainly from RES as well as to pave the way for an improvement of energy efficiency (EE) and a reduction of energy consumption. According to this law, the Municipalities that intend to set up an EC must adopt a specific protocol of understanding, drawn up on the basis of criteria that must be indicated by a subsequent regional implementing provision.

The Region, through future ad hoc incentives, undertakes to financially support the establishment of energy communities. This may also stipulate agreements with ARERA (Italian Regulatory Authority for Energy and Networks), in order to optimize the management and use of energy networks. The regional law also provides for the establishment of a permanent technical panel between the ECs and the region in order to acquire data on the reduction of energy consumption, on the amount of self-consumption and on the share of use of renewable energy and to identify the methods for more efficient management of energy networks. This action represents an important step in the direction of energy self-sufficiency and the construction of a new model of virtuous territorial cooperation.

Within this framework, the establishment of a cooperative is particularly advantageous as it permits to delegate contracts to members of the community since the Law does not prescribe a specific legal form for this type of energy community. A cooperative can be set up by at least nine members and it is characterised by:

- It is a legal entity and its functioning is regulated through its statutes;
- The assembly decides on everything and appoints a board of directors;
- The rule of "one member, one vote" is applied;
- Responsibility can be (and is almost always) limited, avoiding an intermingling with the shareholders' personal assets;
- It is an organisation which although it can make profits, has the primary aim to deliver benefits to its members, for example by providing goods and services on better terms than on the market or carrying out the activities of their corporate purpose;
- The number of members is variable, as is the capital which simplifies membership entries and exits. In addition to the share capital, the shareholders can lend money to the company depending on the establishment of a social loan regulation. This activity is not considered to be a collection of savings from the public and is therefore not subject to capital market regulation rules;
- Citizens as members of the cooperative thus control the operations of the EC of which the cooperative is the owner or holds majority shares. Moreover, the citizens may also hold minority stakes in other companies.

The present study presents the main results of an ongoing research project, which focuses mainly on the engagement of private and/or public consumers towards sustainable energy transition and the purposes could be summarized as following:

- Facilitates consumers to become prosumers of RE; firstly, in three pilot regions (Italy, Poland and the Czech Republic) and, secondly, in cities across Europe following the pilot projects. It applies Consumer Stock Ownership Plans (CSOPs) utilising established best practice up-dated by inclusive financing techniques and combined with energy efficiency measures.
- Activates local authorities and consumers demonstrating the positive impact co-ownership has on consumer behaviour. It shows the ability of this democratic participation model to include women as well as low-income households, in particular unemployed.
- Empowers consumers and municipalities in a capacity-building program through the launch of an interactive online “RE Prosumer Investment Calculator” and seminars in the five partner countries (Germany, Italy, Bulgaria, Poland, Czech Republic).
- Formulates policy recommendations to promote prosumership and to remove barriers for consumers to become active market players at the EU and national levels.

Considering the emerging regulatory framework and the European projects supporting the birth and creation of the new energy-economic-social system, the objective of this study is to make a contribution explaining how elements are important for the creation of EC highlighted, through a real case study application, which elements facilitate or do not facilitate the creation of these communities.

In this framework, the main goal of the present study is to illustrate the comprehensive procedure and process of the EC creation. In particular, this paper focuses on the description of the methodological approach in implementing CSOP model which consists of threefold main phases: the identification and description of selected buildings (preparation phase), the preliminary and feasibility analysis, and finally the target groups involvement. SCORE starts first in three pilot regions in Italy, Czech Republic and Poland, and later with the aim of extending the methodology in various other follower cities across Europe. Italian pilots were chosen as a case study to develop and test the methodology.

The paper is divided as follows. **Section 2** describes the details of methodological framework consisting in the succession of three main phases of the EC creation. **Section 3** illustrates the case study, which is used for testing the effectiveness of the proposed methodological framework. The results and discussions are presented in **Section 4**. Finally, conclusive remarks are discussed in **Section 5** and future developments are identified.

2. Methodological framework

The methodological framework of the creation of the CSOP model consists in a process determined by succession of three major phases, in which each phase (and sub-phase) is fundamental since its output represents the starting point for the next step. The first phase (I) is the preparation, which includes the building identification and data collection. The second phase (II) consists in the preliminary and feasibility analysis proposing different energy retrofit alternatives in order to shift from fossil fuels to renewable one, to reach a reduction of energy consumption and to increase the efficiency of the building envelope and the energy system. This second phase employs multi-criteria analysis (MCA) to select the best alternative based on the Key Performance Indicators (KPIs) considering different stakeholders' opinions. Finally, (III) the target group involvement, in which citizens, public and private entities will be a part of financial model. It is helpful to break it down into the main elements that frame it to understand the research process steps employed in this study. To this end, in **Figure 2** a schematic flowchart of the methodological approaches of the research is shown. Consequently, for each phase, the relative outputs and proposed methodologies are shown in a detailed way.

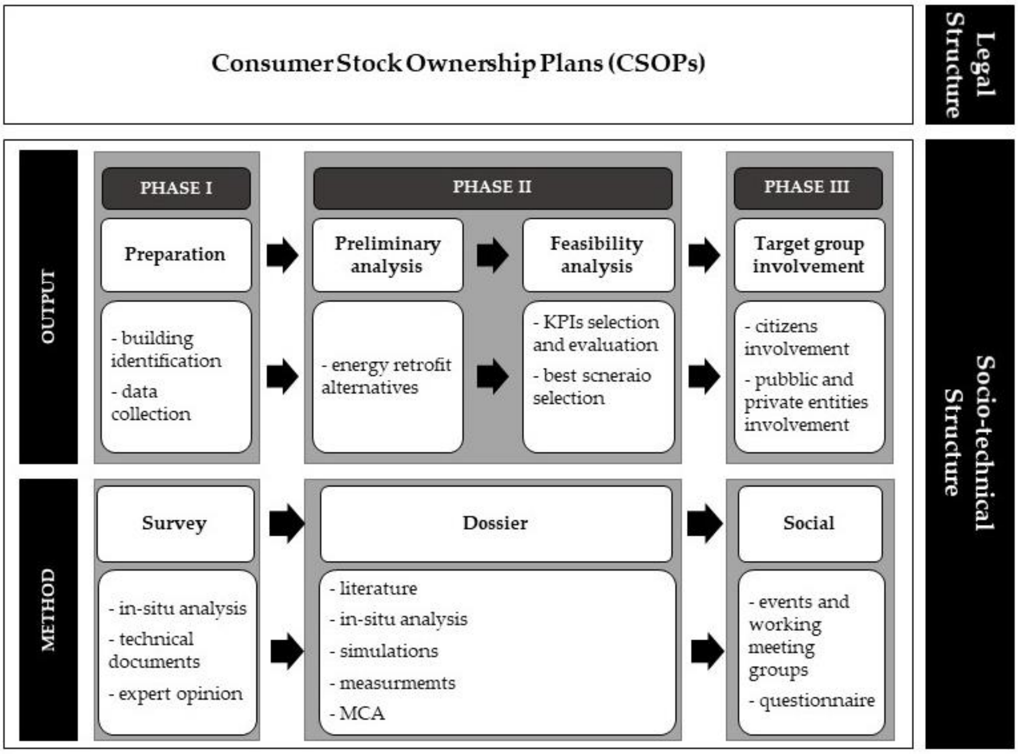


Figure 2. Flow-work: different step of work.

2.1. Phase I: preparation

Within the first phase, preparation, the different pilot case studies are identified, and their characteristics are described. Basically, the data is collected through filling in two pre-defined surveys. In order to fulfil the first phase different in-situ analyses have been done. Moreover, relative technical documents and expert opinions have been considered to compile the surveys.

The first survey regards the investments identification of RES, which is composed by five main sections [7]. This survey collects a general description of the buildings considered for each pilot case study, describing the current situation (i.e., geometry and energy plant system) and the design one (i.e., planned project in terms of RES and financial aspects). The first section identifies the building characteristics (e.g., building ownership, building construction year, year of the last refurbishment, heat and DHW distribution system operator, average of consumptions expenses, the total number of dwellings or offices, the total official number of inhabitants/employees, number of floors, total usable area and total roof area). The second one investigates the existing conventional energy sources or external supplier (e.g., type of energy sources, installed power or purchased power if the district heating (DH) network is present). The third section describes the existing RES for example the type of energy sources, installed power. In the fourth part, the planned RES is investigated. Finally, the fifth section is dedicated to the planned structure of financial sources for the RES investment (e.g., type of financial sources and percentage of overall costs). Since the target is local scale, the definition of the building's database is crucial.

The second survey reports the data in terms of energy costs and tariffs for the actual situation, for the use of non-renewable energy sources. The aim of this survey is to collect information about the use of non-renewable energy sources; specifically, the average consumption fee [€/GJ] are reported (e.g., annual consumption [GJ], historical data for oil and natural gas cost [€/GJ]) and the average fixed fee [€/month]).

2.2. Phase II: preliminary and feasibility analysis

The second phase, which consist of preliminary and feasibility analysis, is investigated within the specific document, called "Dossier" [8]. Dossier represents a guideline in order to illustrate the collected information and data related in order to improve and to increase the energy efficiency of the buildings pilot. Additional data has been collected for defining different refurbishment measures, which are described in dossier using simulation and measurements approaches. Issues addressed in the detailed dossiers are as following:

1. Energy Impact assessment at the current situation, which determines the energy needs and energy uses for space heating, DHW and lighting and equipment through collecting the measured data and in-situ analysis. Also, energy analysis has been assessed after implementing retrofitting measures through building energy simulation model. At least two different refurbishments alternative (for each case study) have been proposed. The retrofit alternatives concern the envelope system, the energy system installing RES and the control system.

Environmental impact assessment illustrates the strategies to minimize the environmental impact with each alternative.

Economic and financial assessment of the investment costs.

Finally, in order to select the best scenario, Multi-criteria analysis (MCA) has been implemented for which KPIs are first defined. In particular, the use of an MCA assesses the best refurbishment alternative, considering different KPIs. The choice of the KPIs to identify the most feasible and sustainable project were subject to previous work [7]. The KPIs have been defined based on three main steps. The first step is performed through a comprehensive review of the existing literature [9], [10] . In the second step, the number of KPIs were reduced as a result of five internal discussion rounds among relevant experts. The third step, the final set of KPIs is selected through a participatory workshop in which the playing card method was employed [11]. Finally, the MCA allows to define the best alternative, considering different indicators, which is the most feasible one. Once the best alternative is defined, in order to proceed to the effective realization of the project, it is necessary to define a business plan. The business plan allows to assess the economic profitability of the selected project and whether it can be increased to optimize economic feasibility.

2.3. Phase III : Target group involvement

The first two phases have a technical character aimed at defining the best alternative; instead, in the third phase, the social aspects are examined in depth to describe and define the new financial model based on co-ownership (CSOP). As mentioned in the introduction, one of the purposes of the project is to encourage the active role of consumers (private or public users). Indeed, the users undertake a crucial role in the EC, not only as simple consumer but also prosumers, participating actively in the phases of decision, dissemination, production and distribution of energy. In addition, considering the future role of EC in the energy market, it is necessary to understand the institutional setting based on financial participation schemes that (i) confer ownership rights in RE projects (ii), involve "active" consumers with the specific attention on vulnerable ones (iii) and consider local or regional area. Since the users' participation is the core topic of EC creation, the purpose of the third phase is to involve several target groups. Although the previous community projects are widespread, the inclusion of all citizens is not entirely deepened [5]. Moreover, these type of projects are usually held by men, middle aged and with a higher income whereas vulnerable groups (affected by fuel poverty) or women or low-income households are excluded from RE investments [5]. Into this, a social analysis will be conducted through a specific action plan to collect information through, first of all, (1) events and working group, and then, (2) surveys and questionnaires. These analyses help in understanding the citizens' subjective willingness to engage in local energy initiatives. At the same time, the aim of the social analyses is to obtain objective data about users' characteristics in order to identify the main favour/hinder drivers of their participation. As mentioned before, the citizens' involvement will take place through three steps:

1. Info-events: meetings with local institutions and organizations that work in the area in order to transmit the project objectives and dialogue on how to include citizens, without neglecting those belonging to vulnerable groups.
2. Workshops: this second way allows to inform invited citizens about a specific topic and create a semi-structured debate with them. Specifically, with the support of local authorities, known and recognized in the area, a diverse group of citizens were invited with the aim of giving them (i) some fundamental notions about the project topic, such as the meaning of energy transition, the use of energy from renewable sources, the energy community and the share ownership plan by consumers. At the same time, the educational moments are alternated with (ii) moments of learning verification through answers to questions or specific activities in order to express their thoughts and create a constructive debate. This is a semi-structured method in which people are free to express themselves.
3. Administering a specific questionnaire: through this way, the interviewees are asked to choose only one answer among those proposed; this method is more restrictive than the previous one. In particular, the results obtained in the "workshop meeting group" made it possible to define the questionnaire which in its final version is composed of five macro parts including detailed information:
    a. Attitude and willingness information: level of degree interest towards EC project;
    b. Feeling related to community identity information: level of feeling related do trust, satisfaction, pride, hope, disgust, shame, fear, boredom;
    c. Technical information: building type and age, type of heating system, efficiency work on the energy plant or building envelope;
    d. Socio-economic information: personal and family income, number and family composition, building construction year and building property;
    e. Socio-demographic information: age, gender, education level, nationality, marital status and belonging municipality.

The questionnaire is administrated between citizens in a specific context and the data analysis will produce a citizen's division in population segments that share common features. The study allows to understand and, subsequently, to promote the users' cooperation to become co-owners of the new energy plant system. The definition of different population segment will highlight the clusters that are interested or would like to be part of community project but, for different reasons, they do not have the possibility (e.g. women, low-income households, and vulnerable groups affected by energy poverty, etc.).

Then, at the end of the whole process, on the basis of technical and social analysis, the CSOP Operating Company is established including each population segment through ad hoc policies in order to facilitate their participation. In the Italian case studies, the financing model could be represented by the following scheme in **Figure 3**.

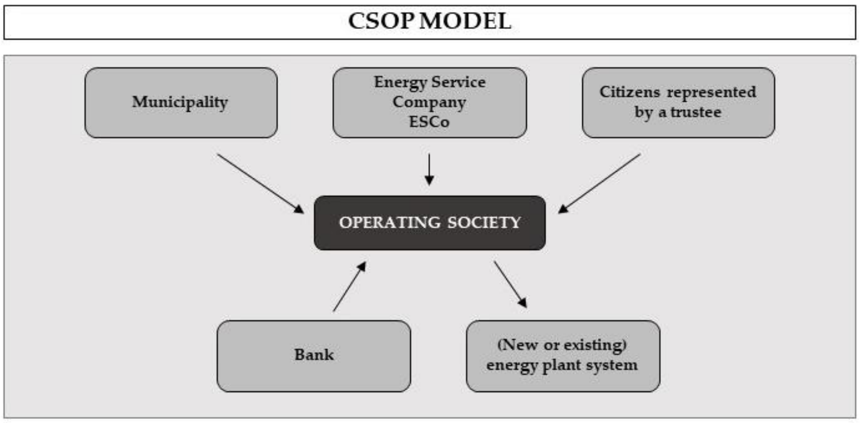


Figure 3. *Financing of a RE plant and EE measures through a CSOP, authors elaboration.*

Once all the three above mentioned phases (socio-technical structure) will be concluded the financial CSOP model (legal structure) could be implemented. The creation of CSOP enables consumers, especially those vulnerable, to become as a co-ownership stake in a utility they use and thus to become prosumers. Moreover, investments can be made into any kind of utility, for instance, energy, water, transportation. Moreover, CSOPs contribute to the energy transition and climate change mitigation by facilitating local, decentralized production by investing in renewable energy installations. Interestingly, in the CSOP model [12], [13] different actors become as owners of the new energy plant system of RE, as shown in Figure , and the main elements are:

- The participation in decision-making is possible through the trustee, who represents the citizens interested in CSOP, while individual consumer-shareholders may execute control rights on a supervisory board or advisory council. Therefore, the model is consumer-cantered investment for general services providing participation both financially and in regards to management decisions.
- Municipalities, small and medium-sized enterprises (SMEs) and other local stakeholders are permitted as co-investors. CSOP avoid personal liability of the consumer-shareholders.
- The Operating Society invests in new or existing RE plants and operates it on behalf of different actors as co-owners.
- The banks, from which it is possible to demand loan;
- New RE plant that supplies energy to consumers at fixed price and generates revenues from excess production sold to the grid.

3. Case study

The Susa Valley (45° 8' 12 North, 7° 3' 29 East, from 300 to 3.612 m asl), is selected as a pilot case study, which is one of the widest and deepest Italian alpine valleys. It extends for about 100 km in length, belonging to the Metropolitan Region of Turin via the western part of Piedmont region of northern Italy to the border of France. In Susa Valley, 39 municipalities have settled, characterized by different locations, territorial extensions, and demographic sizes. The different morphological, altitudinal and climatic characteristics have contributed to differentiate the development of the territory aggregating municipalities into four geographical areas: Oulx area, Susa area, Condove area and Avigliana area. The population is more than 90,000 and 30% of the valley's inhabitants live in the main towns Avigliana, Bardonecchia, Bussoleno and Susa.

Ten municipality pilot projects have been chosen in Susa Valley as case studies where the implementation contains substituting the existing heating system fuelled by diesel oil and natural gas. The new planned systems will be fed by local biomass, wood chips instead of pellets or wood blocks that are the typical solution for small individual boilers. To avoid repetitions in this paper of these ten projects one representative project is analysed in the following EE analysis; the remaining projects have similar properties to those analysed. **Table 1** shows the selected municipality pilot projects and their relative buildings indicating existing and planned heating systems.

Table 1. Pilot case studies.

No	Municipality (city)	Id. No	Building	Existing energy sources for heating	Type of installation
1	Oulx	1.a 1.b 1.c 1.d 1.e 1.f 1.g	School and gym Nursery Gym Municipality Touristic office Social activity building Building (residential)	Oil and natural gas boiler (individual generators)	DH network (biomass)
2	Novalesa	2.a 2.b 2.c	Abbey Private building 1 Private building 2	Oil and LGP boiler (individual generators)	DH network (biomass)
3	Rueglio	3.a 3.b	Municipality Retirement house	Oil boiler (individual generators)	DH network (biomass)
4	San Giorio di Susa (building scale)	4.a	Multi-use room and bar	Natural gas boiler (individual generators)	DH network (biomass)
5	San Giorio di Susa (city scale)	5.a	Private residential buildings	Individual oil Stove	DH network (biomass)
6	Villar Dora	6.a 6.b	School and gym Kindergarten	Natural gas boiler	DH network (biomass) and solar thermal collectors
7	Susa	7.a	DH network	Oil and natural gas boiler (individual generators)	DH network (biomass)
8	Bardonecchia	8.a	DH network	Oil and natural gas boiler (individual generators)	DH network (biomass)
9	Bussoleno	9.a	DH network	Natural gas boiler (individual generators)	DH network (biomass)
10	Almese	10.a 10.b 10.c	Sport (facilities) buildings Middle school Private buildings	Natural gas boiler (individual generators)	DH network (biomass)

3.1 RES in Susa Valley

Currently in the Susa Valley, 75% of the pilot projects originate from fossil fuels while 25% of energy is produced by RES, mostly from biomass. Although there is vast quantity of local biomass sources in the region, the biomass used is not produced locally but imported from other European and Non-European countries. Moreover, the majority of the imported biomass is not certified and cannot be statistically quantified since it is subjected to the grey market. Notably, in Susa Valley, eleven public buildings have already been connected to new biomass heating systems. These can play a significant role of replicators for the future sub-pilots.

3.2 Energy poverty in Susa Valley

One of the presented issues in Susa Valley is energy poverty. Energy poverty is defined as the lack of access to energy or the difficulty in paying the necessary energy which leads to decrease a sufficient living conditions [14]. Groups vulnerable to energy poverty are not located in a particular area, but rather spread over the municipal territory. Some areas of the Susa Valley, due to their geographical position and therefore lack of sunny exposure (specifically the north slope of the Dora) are not very attractive for housing. Hence vulnerable households are located there in these areas since the rent or the housing costs are low. Some associations work with these vulnerable groups (e.g., Con.I.S.A., COOPAMICO, Caritas[15]) in order to help them with issues involving poverty, unemployment and social services. With respect to energy behaviour and efficiency, vulnerable households tend to use older, less energy efficient stoves and consequently fossil fuels due to their low prices. The planned energy community facilitates the replacement of old utilities and the provision of locally sourced wood chips as fuel.

3.3. Implementing the EC project in Susa Valley

The main foreseen project activity in Susa Valley is to implement the new plant system fuelled by local and certified biomass with existing heating system, fuelled by diesel oil and natural gas. In some cases, a DH network might be developed (see **Table 1**). The idea is to substitute fossil fuels, imported by external countries, with local wood chips. This leads to generation of positive economic externalities for the territory since fuel will be provided by the local forest leading to a sustainable path. Indeed, the replacement of fossil sources with local wood chips entails (i) lower costs for energy, (ii) a high share (>80%) of energy cost remaining on the territory as well as (iii) less CO_2 emission (close carbon cycle). As mentioned above, the project aim is to create a RE community employing the CSOP model in the whole Susa Valley. Moreover, project sets a specific focus on low-income households and women to become co-owners and co-investors in RE CSOPs. For this reason, the Susa Valley action plan focuses specifically on the involvement of citizens and particularly vulnerable groups, as well as other residents, SMEs and municipalities. These main project activities will be undertaken in ten municipalities (**Table 1**). It is planned to extend the energy community created within SCORE to all 39 municipalities in Valley Susa. On one hand, the majority of the buildings identified in Susa Valley are public which provides economic security. On the other hand, the sub-pilot in San Giorio di Susa with activities at the city scale deals with residential buildings, which provides a crucial importance regarding citizen involvement. Incorporating residential buildings leads to involving citizens directly in the energy community.

4. Results and discussions

4.1 Phase I: Preparation

As was explained there is a process through phases and methods involved to obtain the final results. This phase, "Building identification and data collection", illustrates how the methodology is applied on one out of ten cases study. Oulx was the pilot chosen due to the prior approval and engagement of municipality, and the variety of possible refurbishment alternatives proposed. The aspects before mentioned will enrich the procedure of selection. The first phase involves the preparation, and therefore, the collection of data and information, as it is shown in the workflow (**Figure 2**). **Table 2** illustrates the main significant data collected regarding Oulx pilot project through the questionnaire prepared within phase I. As shown in **Table 2** below, each pilot building (detailed in **Table 1**) in Oulx has been described through the following information: the building ownership (private or public) and

15 Con.I.S.A. (Consorzio Intercomunale Socio-Assistenziale), COOPAMICO (Cooperativa Sociale Amico) and Caritas are three entities that operate on the Susa Valley territory and they deal with people in difficulty.

building function (residential or non-residential), the building construction year, the latest refurbishment year, the average heat and domestic hot water (DHW) expenses, the total number of building zones (dwellings or offices), the total number of users (inhabitants or employees), the total usable area and, finally, the average annual energy consumption.

Table 2. Oulx data and information collection.

No	Ownership and function	Construction year	Latest refurbishment year	Av. heat and DHW expenses [€/y]	Total number of zones	Total number of users	Total usable area [m²]	Av. annual consumption [MWh]
1.a *	Public; Non residential (educational)	1958	2018 (seismic)	57,915	27	250	2800	300
1.b*	Public; Non residential (educational)	1988	none	5,585	1	50	270	
1.c*	Public; Non residential (sportive)	NA	NA	NA	1	220	NA	
1.d	Public; Non residential (administrative)	1980	2016 (windows)	13,831	10	26	660	150
1.e	Public; Non residential (services)	1995	none	14,669	3	6	700	150
1.f	Public; Non residential (services)	First years of 1900	2016 (structural)	3,000	3	2	300	30

* The three buildings are the subject of the energy analysis in order to reach the Nearly Zero Energy Building (nZEB)[16] condition.

4.2 Phase II: preliminary and feasibility analysis

4.2.1 Preliminary analysis (Energy retrofit alternatives)

As mentioned above, Phase II, preliminary and feasibility analysis have been performed through dossier documents. This phase starts with the general description and historical information of the buildings involved, the current situation regarding the energy sources and a brief investigation of the planned RES. During the analysis, the physical properties of the materials used for the construction of the building (walls, roofs, slabs, windows) have been acquired. Specifically, the Oulx dossier investigates the school complex that is the subjected of energy retrofitting in order to access the "Conto

[16] nZEB are buildings that have very high energy performance. Pursuant to the Directive 2018/844 on the energy performance of buildings. O.J. L 156/75 the nearly zero or very low amount of energy required should be covered to a significant extent by energy from RES, including RE produced on-site or nearby; cf. recital (7) and Annex I point 2 of the Directive.

Termico”[17]. Later, a small DH network will be installed to cover also the adjacent buildings. The school area includes three different buildings (**Figure 4**):

1.a. An elementary and middle school building, with a basement floor and three overlying floors in elevation.

1.b. A gym that has only a ground floor with a common wall with the school (on the eastern side of the school).

1.c. A prefabricated nursery building, that covers a single ground floor and is located beside the school.

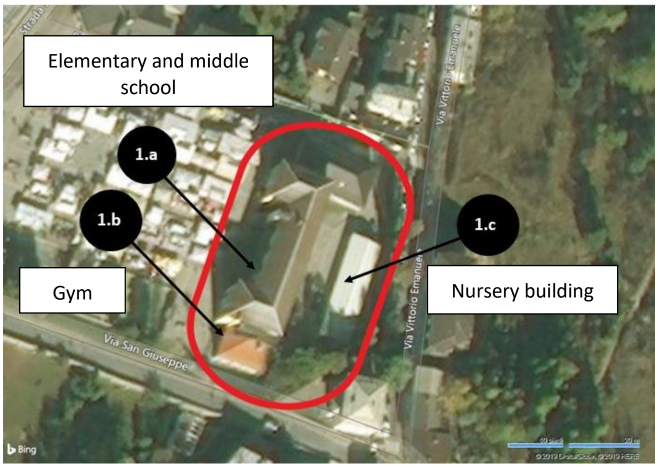


Figure 4. Buildings involved (www.bing.com/maps).

The buildings are equipped by two oil boilers characterized by different circuits and by different kinds of heaters (radiators, fan heaters and air nozzles) for the schools, the gym and the nursery; consequently, the absence of integration between each building is one of the critical issues from the energy point of view. The thermal efficiencies of the two traditional oil boilers with blast burners are 81.5% (generator of 300 kW) and 78.9% (generator of 130 kW). Regarding the domestic hot water (DHW) production there is a centralized generation combined with the heating generation. Other critical issues of the building are the following:

- Significant energy leakage through the opaque casing (as shown by the values of thermic transmittance in **Table 3**);
- Obsolete regulation and balance systems (simple regulation on-off with no internal temperature compensation);
- Obsolete heat generation technology (oil boilers with more than 10 years old);
- Not clean energy source (diesel fuel) and consequent high emission level of CO_2.

Table 3. Oulx envelope system characteristics (before retrofitting).

Element	Before	
	Thickness [mm]	**Thermic transmittance [W/m²K]**
School external wall	400	0.847
Gym external wall	290	1.020
Nursery external wall	70	0.332
School upper-attic slab	200	2.401

[17] A package of incentives and concessions set up with an Italian ministerial decree to promote measures to improve the EE of existing buildings and to encourage the production of RE.

Gym upper-attic slab	60	1.429
Nursery upper-attic slab	50	0.438

In addition, data in terms of energy costs and tariffs are collected for the actual situation, using non-renewable energy sources. Specifically, the information presented in **Table 4** are provided by the administrative municipal accounting and the current values are assumed the same values, due to the impossibility of access to recent information. Then, the litres of consumed diesel fuel in one year are calculated and a consumption of 57,746 litres/year is established to meet the needs of the three buildings.

Table 4. Energy costs for buildings involved.

Client	Cost	Years
Middle school	46,857 €	2012
Elementary school	17,620 € (average)	2003-2012
Nursery	5,050 €	2013

The mathematic model that shows the performances of the building and plants object of this study has been created with a software certified by CTI (Comitato Termotecnico Italiano). The resulting values have been validated taking into account the trends of utilization of the buildings, as shown in the **Table 5** below:

Table 5. Trend of building utilization.

Zone	Day of utilization	Hours per day	Internal temperature point set when used/not used
School	5	12	20°/16°C
Gym	7	12	20°/16°C
Nursery	5	12	22°/19°C

The primary energy indicator (total (Qp) and normalized with respect to the floor area (EP)) about the two services, space heating and domestic hot water, are shown in **Table 6** below. Specifically, the non-renewable, the renewable and the total values of consumption are calculated.

Table 6. Oulx energy indicators.

Service	Qp,nren [kWh]	Qp,ren [kWh]	Qp,tot [kWh]	EP,nren [kWh/m²]	EP,ren [kWh/m²]	EP,tot [kWh/m²]
Heating	491,432	0	491,432	172.98	0.0	172.98
Domestic hot water	37,919	0	37,919	13.35	0.0	13.35
TOTAL	529,350	0	529,350	186.32	0.0	186.32

After an energy analysis and identification of weaknesses and critical issues of the actual situation of the buildings pilot, different retrofit alternatives (**Table 7**) are studied in order to improve the current energy situation and minimize the environmental impact. Since the main purpose of the project is to facilitates consumers to become prosumers of RE and to become owners of RE energy plant (through the CSOP financing model), the first alternative concerns solely the replacement of the boilers with a unique biomass-fired one and regulation retrofitting. On the other hand, the subsequent alternatives intervene on the envelope of the buildings, insulating the external walls and roof with a growing thickness as the alternatives increase. Intervening only on the energy system is not enough; for a good result of the project it is, therefore, necessary to intervene on the envelope system, increasing its efficiency in order to reduce heat losses for transmission and ventilation. In this way the required winter load for the heating system will be less. In addition, as mentioned previously, it is considered useful to reach nZEB (nearly zero-energy buildings) conditions and to obtain the incentives offered by the "Conto Termico". **Table 8** shows the Oulx envelope system characteristics after the intervention A4, where the results start to reach nZEB. Consequently, through the energy simulation, the **Table 9** shows the reached results obtained in comparison to the current situation, considering the energy consumption of the building system from non-renewable sources (Qp,nren), the energy consumption of the building system from renewable sources (Qp,ren) and the CO_2 emissions consequent to fuel consumption. In addition, as shown in **Table 9**, the percentage of energy from renewable sources compared to the total energy used by the building is 80%. This value is defined as a "minimum requirement" derived from the Ministerial Decree of 26 June 2015[18].

Table 7. Retrofit alternatives for Oulx pilot case study.

Code of simulation	Interventions
0.0	As built simulation model.
0.1	As built simulation model from real consumption (benchmark).
A1	Simulation 0 and replacement of the boilers with a unique biomass-fired one and regulation retrofitting.
A2	Simulation 1 and the upper-attic slabs insulation (18cm).
A3	Simulation 2 and external walls insulation for the school and the gym (18cm).
A4	**Simulation 1 and nZEB conditions obtained with the upper-attic slabs insulation (40cm), external walls insulation for the school and the gym (30cm) and nursery's external walls (25cm).**
A5	Simulation 1 and nZEB conditions obtained with the upper-attic slabs insulation (50cm for the school and the gym, 40cm for the nursery), external walls insulation for the school and the gym (40cm) and nursery's external walls as built.
A6	Simulation 1 and nZEB conditions obtained with the replacement of the windows with more efficient components (Transmittance: <1,0 W/m²K), upper-attic slabs insulation (15 cm for the school and the gym, 12cm for the nursery), external walls insulation for the school and the gym (15cm) and nursery's external walls as built.

Table 8. Oulx envelope system characteristics (after the intervention A4).

	After*	
Element	**Thickness [mm]**	**Thermic transmittance [W/m²K]**
School external wall	720	0.110
Gym external wall	610	0.112
Nursery external wall	320	0.103
School upper-attic slab	600	0.084
Gym upper-attic slab	460	0.082
Nursery upper-attic slab	450	0.073

** A4 is the first alternative, which reach nZEB conditions.*

[18] https://www.mise.gov.it/images/stories/normativa/DM_requisiti_minimi_allegato1.pdf

Table 9. Oulx energy simulation results.

Code of simulation	Qp,tot	Qp,ren		Qp,nren		CO_2 emissions	
	[kWh/y]	[kWh/y]	% (ren/tot)	[kWh/a]	% (nren/tot)	[kgCO2eq /a]	% (VS 0.1)
0.0	529,350	-	-	529,350	100%	137,551	85.84%
0.1	616,697	-	-	549,061	100%	160,248	100%
A1	457,140	365,712	80%	91,428	20%	22,857	14.26%
A2	335,284	268,228	80%	67,057	20%	16,764	10.46%
A3	197,529	158,023	80%	39,506	20%	9,876	6.16%
A4	177,276	141,821	80%	35,455	20%	8,864	5.53 %
A5	177,213	141,771	80%	35,443	20%	8,861	5.53%
A6	177,638	142,110	80%	35,528	20%	8,882	5.54%

4.2.2 Feasibility analysis (KPIs selection and evaluation)

After defining the appropriate retrofit alternatives (**Table 7**), and consequently, simulating their energy performances results (**Table 9**), the definition of the different indicators has been performed. These indicators assess an impact of defined alternatives not just regarding the energy aspects but considering all the sustainable aspects (i.e., environmental, economic, technical and social). Based on indicators impact assessment, it is possible to identify the most feasible and sustainable project that will fit on each pilot. The criteria were primarily developed based on a review of existing literature and verified in a workshop in which the "Playing card" [15] method was employed, involving different parties as was detailed on [7].

Afterward, new modifications were introduced to select the final set of key performance indicators (KPIs) (**Table 10**). These last changes were emerging as the project progressed, during different meetings and workshops, and they were explicitly detailed and accepted by the partners. The goal of selection process is to reduce the criteria to obtain a practical but still significant number that is sufficient for conducting a sustainability assessment.

Table 10. Key Performance Indicator matrix.

Category	Code	Indicator	Type	Data Source	Unit
Environmental	ENV1	Primary energy saving	Quantitative	Estimated or metered data	[$kWh_{primary\ energy}$ /year]
	ENV2	Global emissions CO_2 reduction	Quantitative	Estimated or metered data	[kg/year]
	ENV3	Local emissions NO_X reduction	Quantitative	Estimated or metered data	[kg/year]
	ENV4	Local emissions PM_{10} 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 documentati on	[%]

	EC4	Savings on energy expenditure	Quantitative	Calculation	[Euro/year]
	EC5	Labor cost	Quantitative	Estimated or metered data	[Euro/year]
	EC6	Labor 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 documentati on	[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 documentati on	[Ordinal]

Hereafter, the impact assessment methodology for each selected indicator, with respect to the different retrofitting measures developed previously will be illustrated. The evaluation process provides quantitative and qualitative information giving a support for each retrofitting measurement. They can be classified into four main categories: environmental, economic, technical and social. **Table 10** shows the selected KPIs with which the different refurbishment alternatives are evaluated alongside environmental, economic, technical and social aspects. Each detailed KPI Matrix addresses – subject to availability of data and depending on the RES – some or all of the following KPIs.

Environmental Indicators.

- *ENV1- Primary energy saving.* Primary energy that would be saved if the new plant was built. It is linked to the renewable nature of the investment and to the interventions on the building envelope. It was calculated with a specific software in which the material, thickness, thermic transmittance and internal surface resistance are some of the inputs needed [9].
- *ENV2- Global emissions CO_2 reduction*. The building's energy systems CO_2 emission is undoubtedly a criterion that should be assessed for the sustainable development of cities [16], [17]. It is calculated comparing the current situation with the different alternatives proposed.
- *ENV3- Local emissions NOx reduction*. NO_x produces toxic pollution that affects the health of individuals, also harming the environment, climate and vegetation [18]. This also implies that there is an indirect impact on the social health of communities [19].
- *ENV4- Local emissions PM_{10} reduction.* PM_{10} emissions are caused by fuel burning and heavy industrial processes and are very harmful to human health [18]. These emissions cause lung diseases, heart attacks and arrhythmias, cancer, atherosclerosis, childhood respiratory disease and premature death.

Economic Indicators.

- *EC1-Payback period (PBP)*. PBP, simple or discounted, is a popular criterion that represents the time in which negative and positive cash flows are equal. It represents the moment after which the expenses are amortized and there is the actual gain. This criterion gives immediate insight to investors in the event that there is a preference to shorten the PBP [20]. The Payback period is assessed as shown in equation (6):

$$PBP = \frac{investment\ costs}{annual\ savings\ on\ energy\ expenditure} \tag{6}$$

- *EC2-Investment cost*. Many studies consider investment costs as the most important criterion to evaluate energy savings interventions. The investment cost incurs all the costs related to refurbishment of the building and/or new heating system; it includes the purchase of building material, technological installation, manpower and set up of the cost for each individual element of the renovation project (building envelope and energy systems) as it is demonstrated on **Table 11** [21], [22].

Table 11. Oulx investment costs.

Materials/ service	Price [€/Unit]	Quantity [Unit]	Amount [€]
wall insulation	100	2,000	200,000
upper-attic insulation	100	1,200	120,000
audits	6,250	1	6,250
building site	20,000	1	20,000
lean concrete	2,500	1	2,500
foundation	15,000	1	15,000
walls	3,750	4	15,000
slab	12,500	1	12.500
waterproofing	1,000	1	1,000
passages	5,000	1	5,000
district pipes	20,000	1	20,000
biomass boiler	70,000	1	70,000
plants modifications	10,000	4	40,000
control	20,000	1	20,000
mounting	30,000	1	30,000
project	20,000	1	20,000
Tele management	20,000	1	20,000
TOTAL			617,250

- *EC3-Public incentives.* It is the percentage of savings linked to the share of investment cost covered by administrative incentives. The Stability Law confirmed the extension of 65% tax reductions for energy efficiency measures and 50% for restructuring buildings completed by the end of 2017 [23]. "Conto Termico" involves the following incentives:
    - Up to 65% of the expenditure incurred for "Near-zero Energy Buildings" (nZEB);
    - Up to 40% for wall and ceiling insulation, replacement of windows, solar shading, indoor lighting, building automation technologies, boilers;
    - Up to 50% for thermal insulation work in climate zones E/F and up to 55% in case of thermal insulation and replacement of window seals when combined with other interventions (heat pumps, solar thermal, etc.).

To have access to these incentives, there are some aspects to take into account like certification by an accredited body that certifies compliance with the UNI EN 303-5 standard; useful thermal efficiency not lower than 87% + log (Pn), where Pn is the nominal power of the device; atmospheric emissions not above a certain value verified by an accredited body, based on the relevant measurement method, the pellets used must be certified by an accredited certification body that certifies compliance with the UNI EN ISO 17225-2 standard, etc.

- *EC4-Savings on energy expenditure.* The savings on annual expenditure taking into account the primary energy savings calculated previously.
- *EC5-Labor 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 on the field suggested during an internal meeting [24], [25].
- *EC6-Labor cost by a social cooperative*. The part of labour cost which will be done by social cooperative.
- *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 one at the beginning of the project (one off) including aspects like the boiler, insulation, and concrete.
- *EC8-Material cost purchased on the territory.* This criterion evaluates the portion of material cost that remains in the territory. Territory is intended to be Susa Valley.
- *EC9-Running cost*. It is the energy costs plus maintenance costs. The Maintenance costs are assumed as the 2% of investment cost according to [26].
- EC10-*Type Thermal Account Access (TAA) vs. Energy Efficiency Certificates (EEC)*. It represents the access to the thermal account and energy efficiency certificates, Italian public incentives carried out by Energy services management.

Technical Indicators.

- *T1-Increase of plant system efficiency*. It is the increase in the efficiency of the new system plant compared to the existing one [9].
- *T2-Installed power reduction.* It represents the reduction of installed power; it is always an aspect that contributes directly in energy reduction.

Social Indicators.

- *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 12** according to the study conducted by Dall'O' et al. [27], with reference to specific measures. This criterion adopts an ordinal scale to rank the strategies, from the best to the worst.

Table 12. Architectural impact criterion.

Typology of criterion	Description of criterion	Numerical value of criterion	Description of intervention
Positive	Great positive impact	1	External Thermal Insulation Composite Systems
	Positive impact	2	Windows replacement
Neutral	No impact	3	Roof insulation – Boiler replacement – Lightning replacement
Negative	Little negative impact	4	Photovoltaic panels

Negative impact	5	Solar thermal collector

After the appropriate selection and the definition of the performance indicators, the next step consists in assessing each KPI and establishing the evaluation matrix shown in **Table 13**, which is fundamental to reach the final selection. It allows the comparison of each refurbishment alternative proposed in the preliminary analysis with the current situation, taking into account the selected KPIs. To complete it, the collaboration of different parties is necessary, since the indicators cover the different areas of the project, from the economic to the social, through the technical and environmental. The EDILCLIMA software was employed to simulate the energy alternatives and to obtain the data, while, for assessing each KPIs the specific method is used as explained above (**Section 4.2.2**).

Table 13. Evaluation matrix.

Category	Indicator	A1	A2	A3	A4	A5	A6
Environmental	ENV1 [$kWh_{primary\ energy}$/year]	525,269	549,640	577,191	581,242	581,254	581,169
	ENV2 [kg/year]	137,427	143,520	150,408	151,420	151,423	151,402
	ENV3 [kg/year]	94.55	98.94	103.89	104.62	104.63	104.61
	ENV4 [kg/year]	6.83	7.15	7.50	7.56	7.56	7.56
Economic	EC1 (PBP) [years]	8.3	11.7	16.5	16.3	16.3	16.3
	EC2 [euro]	284,750	417,250	617,250	617,250	617,250	617,250
	EC3 [%]	40%	40%	40%	65%	65%	65%
	EC4 [euro/year]	34,142	35,727	37,517	37,781	37,782	37,776
	EC5 [euro/year]	136,250	136,250	136,250	136,250	136,250	136,250
	EC6 [euro/year]	34,063	34,063	34,063	34,063	34,063	34,063
	EC7 [euro]	148,500	281,000	481,000	481,000	481,000	481,000
	EC8 [euro]	51,975	98,350	168,350	168,350	168,350	168,350
	EC9 [euro/year]	39,523	33,156	26,962	25,630	25,459	25,490
	EC10 [TAA/EEC]	TAA	TAA	TAA	TAA	TAA	TAA
Technical	T1 [%]	9.80%	9.80%	9.80%	9.80%	9.80%	9.80%
	T2 [kW]	175	175	175	175	175	175
Social	S1 [-]	3	1	1	1	1	2

4.2.3 Feasibility analysis (best scenario selection)

To proceed with this step, an outranking Multi Criteria Analysis (MCA), called PROMETHEE (preference ranking organization method for enrichment evaluation), was chosen in order to outrank the different energy retrofit interventions proposed previously on each case study [28]. The target is to provide a comprehensive overview of the best alternative. Moreover, a sensitivity analysis was carried out, modifying the weights and preferences of each alternative, in order to observe how their ranking varies.

The PROMETHEE method belongs to the outranking category, which has been developed by Brans et al. [28]. The PROMETHEE method uses the partial aggregation and it is very useful in ranking a limited number of alternatives, considering conflicting criteria [29]. It is based on the pair-wise comparison, checking if one of two alternatives outranks the other or not [30]. Two specific types of information are necessary in order to implement this method, the criteria weights and the decision-maker's preference function for comparing the contribution of the alternatives in terms of each separate criterion [31].

In order to apply the chosen model, the "Visual PROMETHEE" is employed. First of all, the set of criteria have been defined and added, which in the MCA must generally be in finite number. Therefore, the six different retrofit alternatives for Oulx case study had to be reconstructed within the program. It is necessary to give every criterion a direction of preference. Specifically, it must be decided whether the criterion must be minimized or maximized. With the maximization is given a greater preference to higher values; instead, with minimization, it is established that a greater value indicates a worse response than the alternative. Finally, for each criterion inserted the measurement scale of the criterion that can be qualitative or quantitative must be established [32]. In the present case there are two qualitative criteria. For the "Architectural impact" indicator it was decided to use the "5-points" ordinal scale **Table**.

The other indicator that is considered as qualitative is Access to "Conto Termico", and the corresponding scale is yes/no.

For all other indicators, quantitative criteria have been set. The criteria for which the maximization choice was made are: Primary energy saving, Global emissions CO_2 reduction, Local emissions NO_x reduction, Local emissions PM_{10} reduction, Public incentives, Savings on energy expenditure, Increase of plant system efficiency and Installed power reduction. On the contrary, the criteria to which the minimization function has been associated are: PBP, Investment cost, Labour cost, Labour cost by a social cooperative, Material cost, Material cost purchased on the territory and Running cost. It was decided to classify all the criteria of the same type within the same cluster. Later, all previously processed data were added and the matrix was composed. Visual PROMETHEE allows to quantify the degree of preference, indicated as $\pi\ (a,\ b)$, of a generic alternative "a" compared to "b", calculated as in the following equation (7).

$$\pi\ (\mathrm{a,\ b}) = \sum_{j=1}^{n} W_j P_j\ (a, b) \tag{7}$$

Where W_j is the weight assigned to each j-th criterion and P_j (a, b) is the preference function. For each criterion a P_j (a, b) is representing a function of the difference between the two alternatives. Preference function is applied to decide how much the alternative a is preferred to the alternative b:

$$Pj\ (a, b)\ =\ Fj\ [dj\ (a, b)]\ ,\ \ 0 \leq\ Pj\ (a, b)\ \leq 1 \tag{3}$$

The value of preference function varies between 0 and 1 (0 for no preference or indifference, 1 for strict preference), meaning that the larger the deviations, larger the preferences. The preference function could be of different types: Usual, U-shape, V-shape, Level, Linear, and Gaussian [33]. In this study, the V-Shape (i.e., criterion with linear preference) preference function is considered for all the indicators, with the preference value calculated as the standard deviation of each indicator and without indifference value. PROMETHEE allows to calculate the outgoing and incoming flows for each alternative. The outgoing flow is indicated with $\phi+$ and represents the measure of the robustness of the analysed alternative. The outgoing flow calculated as in the next equation (4), varies between 0 and 1. The more $\phi+$ approaches to 1, the more preferable is the alternative considered in comparison to the others, on the other side, if equal to 0, the action in question does not has no advantage over the others.

$$\phi+(a) = \frac{1}{n-1} \sum_{b \neq a} \pi\ (\mathrm{a, b}) \qquad \phi+(a) \in [0,1] \tag{4}$$

As far as the incoming flow is concerned, the notation $\phi-$ represents the measure of the weakness of the action in analysis with respect to the other alternatives. Also this parameter varies between 0 and 1, but on the contrary, where $\phi- = 0$ means that the selected alternative has a degree of weakness equal to zero, and therefore represents the best alternative, on the contrary $\phi- = 1$ represents the worst one. The following formula (5) is used for the calculation:

$$\phi-(a) = \frac{1}{n-1} \sum_{b \neq a} \pi\,(\mathrm{a,b}) \qquad \phi-(a) \in [0,1] \tag{5}$$

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 you to directly compare the proposed alternatives and provide the ranking of alternatives as shown in (6).

$$\phi-(a) = \phi+(a) - \phi-(a) \tag{6}$$

The result of the best alternative is presented after implementing the sensitivity analysis. A sensitivity analysis is proposed by changing different weights with respect to the Baseline alternative, according to stakeholders' interests and opinions (**Table 13**). This last part is useful to test the robustness of the model.

Table 13. Sensitivity analysis.

		ENV1	ENV2	ENV3	ENV4	T1	T2	S1
Baseline	w	0.0625	0.0625	0.0625	0.0625	0.125	0.125	0.25
	p	21397	5349	3.85	0.28	9.8	175	0.76
Change 1	w	0.059	0.059	0.059	0.059	0.059	0.059	0.059
	p	21397	5349	3.85	0.28	9.8	175	0.76
Change 2	w	0.075	0.075	0.075	0.075	0.1	0.1	0.2
	p	21397	5349	3.85	0.28	9.8	175	0.76

		EC1	EC2	EC3	EC4	EC5	EC6	EC7	EC8	EC9	EC10
Baseline	w	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Change 1	p	1.66	179387	13	3637	41397	10349	137990	48296	8627	1
Change 1	w	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059

The Baseline model assigns same weight for each category (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 of the number of KPIs included on that category (

Alternative	A1	A2	A3	A4	A5	A6
Net phi	-0.3156	0.0020	0.0514	0.1042	0.1043	0.0538
Rank	6	5	4	2	1	3

Table Table 14).

- Each Environmental indicator will get a weight of 0.0625 percent, obtained through the division of 25 percent by 4 indicators.

- Each Economic indicator will get a weight of 0.025 percent, obtained through the division of 25 percent by 10 indicators.
- Each Technical indicator will get a weight of 0.125 percent, obtained through the division of 25 percent by 2 indicators.
- Each Social indicator will get a weight of 0.25 percent, obtained through the division of 25 percent by 1 indicator.

While, Change 1 proposes the same weight for each indicator (e.g., ENV1, EC1, T2), 5.9 percent each one (**Table 15**.). This leads into different weight for each category of indicators:

- 23.5 percent for Environmental indicators,
- 11.8 percent for Technical ones,
- 5.9 percent for social ones and
- 58.8 percent for economic ones

Change 2 focuses on the two categories that have more impact in the project, the Environmental and Economic. Taking into account the relevance of these two, a higher weight has been assigned (30 percent each one), leaving the rest to social and technical aspects, divided equally (**Table 16**).

- 30 percent for Environmental category and 0.075 percent for each Environmental indicator
- 30 percent for Economic category and 0.03 percent for each Economic indicator
- 20 percent for Technical category and 0.1 percent for each Technical indicator
- 20 percent for Social category and 0.2 percent for each Social indicator

Table 14. Baseline results.

Alternative	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**
Net phi	-0.3156	0.0020	0.0514	0.1042	0.1043	0.0538
Rank	6	5	4	2	1	3

Table 15. Change 1 results.

Alternative	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**
Net phi	-0.0516	0.0208	-0.0629	0.0353	0.0354	0.0230
Rank	5	4	6	2	1	3

Table 16. Change 2 results.

Alternative	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**
Net phi	-0.2923	-0.0158	0.0384	0.1032	0.1034	0.0631
Rank	6	5	4	2	1	3

From the model runs, by changing the weights, the best alternative is always A5 followed by A4 and A6, as it is shown in **Table 14**, **Table 15** and **Table 16.** The main reason is because they reach nZeb conditions, obtaining a great amount of public incentives. Simulation 5 and 4 only differ in the thickness of insulation, which is the reason why they obtain similar values of net phi. The lowest values are associated to Alternative 1 (just adding an oil boiler).

4.3 Phase III: Target group involvement

4.3.1 Info-events.

During the months of November and December, 12 events have been organized involving local institutions (e.g. mayors) and organizations that work in the area of Susa Valley. The purpose of these events was (i) to inform and share the research activities and the project results (mainly related to the technical analysis) with the Susa Valley community; (ii) to raising awareness among stakeholders about the energy community benefits and, finally, (iii) to co-create an action plan, to be implemented in the following months, shared by all stakeholders for the definition of an energy community in the Susa Valley.

4.3.2 Workshops

On February 7, 2020, the first workshop was organized in Almese with the collaboration of Deutscher Caritas Verband and Cooperativa Sociale Amico. Indeed, thanks to their contribution since they know local people well and people know them, 20 citizens are invited (through personal communication) to attend this event. The duration was about half of day and the educational approach were alternated with 3 parts of debate and activities, in which the participants were called to express their thoughts and opinions.

After a first part in which the aim of the project and the meaning of "energy transition", "renewable energy sources", "energy community" and "CSOP (financing model)" are described and explained, the first discussion was introduced related the characteristics of the heating system in their home. Pre-defined questions were asked as following:

"What type of heating system do you have in your home? What are the costs? Are you satisfied with your system? Do you think your heating bill is too high? Are you having problems keeping your home adequately heated?"

It was a free discussion, and the answers obtained showed that most of citizens are not satisfied with the energy expenditure since the heating bills are too high. The energy expenditure depends on several factors: the cost of the energy established by the supplier, the volume of the apartment to be heated, the house typology, etc. but it has emerged that the level of efficiency of the envelope (windows, presence of wall insulation, etc.) is the factor that has the greatest impact.

Afterwards, the CSOP model was explained in more detail and the five key points of this model were highlighted. On the basis of this, each participant was asked to express their preference regarding only three elements of the CSOP "*What are the CSOP benefits you are most interested in?*". Specifically, the key elements were written on sheets (1 per sheet). Participants were given at maximum 3 dots, one red to stick on the sheet with the most important benefit for them, and two green dots to put on the sheets with benefits for them. In this way, two elements are left without choice, that is, those that are not important to them. The results show that the "small source of income" benefit has not been successful because: on one hand, the source is small and, on the other hand they are a little bit sceptical about obtaining money. Indeed, this benefit obtained only the 11.4% of the consents divided as follows, for the 75% are red and for 25% are green). For this reason, "environmental issues" and "low investment", both with a preference of 28.5%, have been more successful. Specifically, it has been said that if a low investment is required, they would agree to contribute as it is an interesting project from which the whole community can benefit. In addition, the "the trusted administrator helps and represents consumers" (8,5%) and "independence from the national energy supply" (22.8%) are the benefits that the participants were not interested in.

Finally, a debate was opened with the participants through the following question: "*In your opinion, what are the obstacles/problems in participating in a CSOP based on renewable energy?*" The obtained answer could be summarized in 3 following points:

- Distrust because, being an innovative project, there is no one who can say if the project will be successful. In this case no one can give feedback on the success of this type of project;
- Control and verification due to the disparity of investment of the various actors. This is to avoid that if an entity invests a great amount of money, it is more represented;

- Bureaucracy, the topic and the necessary documentation could be complicated for simple citizen not working in the legal field.

Therefore, the workshop allowed to understand the citizens' energy habits and to understand any problems, attributable to the low efficiency of the building envelope and, consequently, to a high energy expenditure (for heating). Following the subsequent activity, the participants showed interest in the topic of energy communities by explaining in which benefits of the CSOP they are interested in and the barriers they could encounter. The collection of these elements has been fundamental to refine the survey questions.

5. Conclusions and future developments

In conclusion the present study illustrated and described the three different phases underlying the creation of EC through a legal framework (CSOP): (i) the identification and description of selected buildings (preparation phase), (ii) the preliminary and feasibility analysis, and finally (iii) the target group involvement in implementing CSOP model. Specifically, Phase I and Phase II have been taken in detail. The first action was the data collection and the proposal of different retrofit measures in order to avoid (as much as possible) the use of fossil fuels in favour of renewable ones, to increase the efficiency of the building energy plant system and of the building envelope system and, finally, to reduce the energy consumption also through a change in behaviour. Once the different proposals were defined, the best solution was chosen through a MC analysis based on Key Performance Indicators (KPIs) considering different stakeholders' opinions. The procedure was applied to a real case study (Oulx, Susa Valley), showing the different phases aimed at creating an energy community. Specifically, the actual situation of the involved buildings in Oulx were described and, then, several (six) appropriate retrofit alternatives were defined and simulated in order to obtain the future designed energy consumption and environmental emission values. In addition, indicators related to different sustainable aspects (not only energy or environmental, but also economic, technical and social) were assessed in order to identify the most feasible and sustainable project to be carried out for the actual realization. Finally, first through a filling of an evaluation matrix and then a PROMETHEE application, it was possible to order and to rank the six proposed retrofit interventions. Considering also a sensitivity analysis in which a change of the weights and preferences of each indicators was carried out to highlight and observe a ranking variation, the final results show that the best alternative is always the A5 followed by A4 and A6. The main reason underlying this result is because the achievement of a nZeb conditions is linked to numerous public incentives. In addition, simulations 5 and 4 are very similar and they differ in the thickness of insulation, which is the reason why similar values of net phi are obtained. The lowest values are associated to Alternative 1 (just adding an oil boiler).

The future step is to encourage the active role of consumers (private or public users) since they undertake a crucial role in the EC, e.g. the participation in the new financial model based on co-ownership (CSOP). The main future task is to involve several target groups (also women, low-income and people affected by poverty) through a social analysis using the information collected with the questionnaire, events and working group in order to identify the main favour/hinder drivers of their participation in energy communities.

Author Contributions: S.T.M. formal analysis, investigation, methodology, writing—original draft preparation, supervision; M.V.D.N. formal analysis, investigation, methodology, writing—original draft preparation writing—original draft preparation, supervision; S.M. formal analysis, investigation, methodology, writing — original draft; P.L. funding acquisition, supervision.

Funding: This research was funded by the H2020 project, entitled Supporting Consumer Co-Ownership in Renewable Energies - "SCORE", grant number 784960- SCORE-H2020-EE-2016-2017/H2020-EE-2017-CSA-PPI.

Acknowledgments: The authors of this study wish to acknowledge the contributions of a number of colleagues, partners and institutions involved in the SCORE project, including: Eng. Luca de Giorgis, Cooperativa La Foresta, Consorzio Forestale Alta Valle Susa, Cooperativa Sociale Amico, Prof. Jen Lowitzsch , Politecnico di Torino, Centre for the Study of Democracy, Město Litoměřice, Miasto Słupsk, Climate Alliance, co2online, Deutscher Caritas Verband, Europa Universität Viadrina, Frankfurt (Oder), Federacja Konsumentów, Instytut Energetyki Odnawialnej, Porsenna.

Conflicts of Interest: The authors declare no conflict of interest.

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Article 2: Supporting Consumer Co-Ownership in Renewable Energies: SCORE H2020 project.

Supporting Consumer Co-Ownership in Renewable Energies: SCORE H2020 project

Sara Torabi Moghadam[1], Maria Valentina Di Nicoli[1], Santiago Manzo[2], Patrizia Lombardi[1]

[1] Interuniversity Department of Regional and Urban Studies and Planning (DIST), Politecnico di Torino, Viale Mattioli 39, 10125, Torino, Italy.
[2] Department of Management and Production Engineering (DIGEP), Politecnico di Torino, Corso Duca degli Abruzzi, 24, 10129, Torino, Italy.

sara.torabi@polito.it

Abstract. An on-going Horizon 2020 project, named “SCORE” (Supporting Consumer Co-Ownership in Renewable Energies), is focused on Sustainable Development Goal-SDG11. Particularly, this project aims at overcoming the usage of energy from fossil sources in favour of renewable energy sources (RES). In particular, technical, financial and social innovations are crucial prerequisites for a fruitful transition from fossil fuels to RES. It is essential to build new energy infrastructure and motivate consumers to change their consumption behaviours to balance demand with a volatile energy supply. Moreover, increasing acceptance of new technologies is another issue to be considered. In this context, Consumer Stock Ownership Plans (CSOPs) in RE has proven to be an essential cornerstone to the overall success of energy transition. When consumers acquire ownership in RE, they become prosumers. Into this, they are more beneficial by (i) generating a part of the energy they consume (ii) reducing their overall expenditure for energy (iii) receiving a second source of income from the sale of excess production. The first project’s task was the identification and description of different case studies. Afterward, for each case study, several retrofit alternatives are defined. In this framework, the main goal of the present study is to illustrate how the alternatives are defined, how indicators have been selected and assessed, and how the project aims at involving the citizen in CSOP Model. The next step is building an evaluative matrix, which later makes it possible to analyse the feasibility of the different case studies and choose the best retrofit alternative through a Multi-Criteria Analysis (MCA).

Keywords: Co-Ownership; Sustainable Development Goals (SDG); Energy Community; SCORE H2020; Prosumer

1. Introduction

In the current context, the implementation of the 2030 Agenda contributes to global development, focusing on people, the planet and prosperity. The mentioned action program encompasses 17 Sustainable Development Goals (SDGs) guiding the world on the road ahead over the next years. In this framework, the European Union funds the on-going Horizon 2020 project named "SCORE" (Supporting Consumer co-Ownership in Renewable Energies). This project focuses mainly on the Goal 11 "Sustainable cities and communities", which makes cities and human settlements inclusive, safe, resilient and sustainable [1]. Specifically the targets of "SCORE" are (1) overcome the usage of energy coming from fossil sources by taking advantage of renewable energy sources (RES), (2) reduce the energy consumption due to changes on users' behaviour and (3) increase the energy efficiency of building systems [2]. The achievement of these goals leads to positive effects on the community not just the improvement of the air quality, due to CO_2 and NO_x emission reduction, but also economic development, creation of new jobs, cheaper energy, etc. In addition, the project focus on the dynamics of society analysing the role of citizens, trying to shift from consumer to prosumer of renewable energy. The concept of "prosumer" is new in the energy field and denotes a consumer who both consumes and produces energy. Prosumers produce energy primarily for their own needs but can also sell the excess of energy. This leads to a new and efficient way of producing and distributing energy, decentralising the market, spreading the concept of "self-produced energy sharing". From this, "SCORE" aims to encourage the consumers to play an active role, contributing himself to the production of energy in the community. Therefore, the core of the research is to identify the segments of the population that are interested or would like to be part of the project but for different reasons they do not have the possibility, taking into account that nowadays the typical "prosumer" is male, middle aged and has a higher income. The project aims at implementing these energy communities in three pilot regions: Italy, Poland and Czech Republic. These pilot projects have to demonstrate the practical feasibility of optimized joint prosumer investments with local municipalities in order to be extended to various other follower cities across Europe in a near future. Once the first task of the project, concerning the identification and the characteristics description of different case studies in each pilot region, is completed, the next steps regards their implementation. Among different Italian pilot case studies (Susa Valley, in Piedmont region), a feasibility analysis was performed through a Multi-Criteria Analysis (MCA); which allowed to support the choice of the best project through an analysis in which different aspects (social, technical, economic, environmental and administrative) were assessed. Once the appropriate case studies were selected, the next step focuses on the selection of the best retrofit alternative for each project.
In particular, the present study aims at illustrating an on-going mid result, which consist of analysing key performance indicators (KPI) under different scenarios; in order to address the "SCORE" purposes. The paper is divided as follows. Section 2 illustrates the methodological approach through which the evaluation criteria were defined and will be ranked. In section 3, the results will be discussed in detail. The paper lasts giving a few perspectives for the current work (section 4).

2. Methodology

This section describes the methodology employed to create a hierarchy rank among the different selected energy alternatives. In this regard, the selection process consists of five phases according to a feasibility analysis and a final one related to user involvement, applying the CSOP model. The process begins with data collection regarded renewable energy alternatives that will be appropriate for the different cases studies on Susa Valley. It continues with the selection of the evaluation criteria, taking into account the stakeholders' objectives and preferences. This last part starts with a preliminary analysis of the energy alternatives and ends by a final selection of a set of criteria. After this is time to proceed with the last step concerning the user involvement. The selection process has been carried out in the following order as shown in Figure 1.

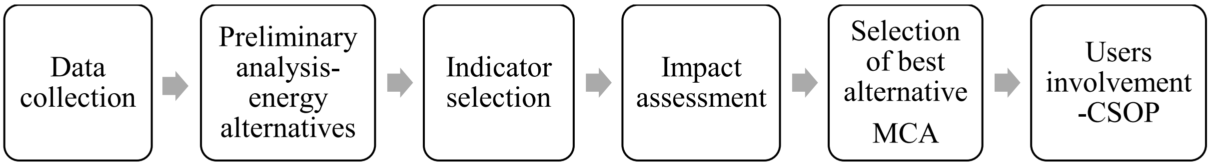

Figure 1. The steps of the selection process

<u>Data collection</u>: The data of the different case studies pilots was collected using two questionnaires provided by project partners [3]. The first one regarding the investments identification of renewable energy sources and the second one about energy costs for the current situation regarding the usage of non-renewable sources.

The aim of the first survey was to collect information about the buildings involved in each case study, describing the geometry and characteristics, the current energy plant system and the planned project in term of RES and financial aspects. On the other side, the focus of the second questionnaire was related to the average consumption fee (€/GJ) and analysis of historical data for oil and natural gas, the two non-renewable energy sources present on the pilot projects.

<u>Preliminary analysis and energy alternatives</u>: In order to reach the best refurbishment alternative for each pilot at the final selection, it was necessary to develop a preliminary analysis of the data collected. In this framework, a "Dossier" for each case study was created [4]. Specifically, a "Dossier" is a document through which it is possible to collect and present the information related to the pilot projects, describing and evaluating the different refurbishment alternatives, in order to improve and increase the energy efficiency. Particularly, it shows the comparison between the current situation and the refurbishment scenarios focusing on the achievement of "SCORE" objectives. The "Dossier" is divided in different sections, which analysis of the current situation taking into account the context, buildings involved and energy consumption for space heating, domestic hot water (DHW) and lightning. Consequently, the retrofit alternatives, understanding the needs of the pilot projects, taking into account a security plan, a risk and investment cost assessment and a full business plan have been defined. These documents will be helpful to show clearly the data collected to the partners involved. Once the retrofit alternative is chosen, then it will be the time to implement an education and dissemination plan, trying to avoid the rebound effect (CSOP model), involving the citizens, encouraging them to play an active role in their community.

<u>Indicator selection</u>: The correct choice of the KPI is essential to then evaluate and identify the most feasible and sustainable project that will fit on each pilot. The criteria was primarily developed based on a review of existing literature [5], [6], [7]; and completed in a workshop in which the "Playing card" method was employed involving the different parties as was detailed on [3]. Generally, the following principles are used to select the criteria used to energy decision-making, taken from [8] and [9]:

- Systemic principle. The criteria system should roundly reflect the essential characteristic and the whole performance of the energy systems. The comprehensive evaluation function of multi-criteria can obtain better results than the sum of single criteria evaluations.
- Consistency principle. The criteria system should be consistent with the objectives.
- Independency principle. The criteria should not have inclusion relationship at the same level criteria.
- Measurability principle. The criteria should be measurable in quantitative value as possible or qualitatively expressed.
- Comparability principle. The criteria should be normalized to compare or operate directly.

After that, new modifications were introduced to arrive at the final list of indicators showed on Table 1. These last changes were emerging as the project progressed, and they were explicitly detailed and accepted by the partners.

Table 1: Key performance indicators matrix.

Category	Indicator	Description	Type Qualitative vs Quantitative	Data Source	Unit
Environmental	Primary energy saving	Primary energy that would be saved if the new plant was built (it is linked to the renewable nature of the investment and to the interventions on the building envelope).	Quantitative	Estimated or metered data	[$kWh_{primary\ energy}$/year]
	Global emissions CO_2 reduction	Reduction of CO_2 emissions guaranteed by the project plant compared to the current one.	Quantitative	Estimated or metered data	[kg]
	Local emissions NO_X reduction	Reduction of NO_X emissions guaranteed by the project plant compared to the current one.	Quantitative	Estimated or metered data	[kg/year]
	Local emissions PM_{10} reduction	Reduction of PM_{10} emissions guaranteed by the project plant compared to the current one.	Quantitative	Estimated or metered data	[kg/year]
Economic	Payback period (PBP)	Time in which negative and positive cash flows are equal. It represents the moment after which the expenses are amortized and there is the actual gain.	Quantitative	Calculation	[Years]
	Investment cost	Investment costs related to refurbishment of the building (efficiency investment) and/or new heating system (infrastructure investment).	Quantitative	Calculation	[Euro]
	Public incentives	Percentage of savings linked to the share of investment cost covered by administrative incentives.	Quantitative	Process documentation	[%]
	Savings on energy expenditure	Savings on annual expenditure.	Quantitative	Calculation	[Euro/year]
	Labor cost	Include the salary of employees who are directly involved in production activities, services (such as general repairs and maintenance performance), and supervision.	Quantitative	Estimated or metered data	[Euro]
	Labor cost by a social cooperative	Part of Labor cost done by social cooperative	Quantitative	Estimated or metered data	[Euro]
	Material cost	Costs of raw materials or parts that go directly into producing products or providing services.	Quantitative	Estimated or metered data	[Euro]

	Material cost purchased on the territory	Part of material cost that remains in the territory	Quantitative	Estimated or metered data	[Euro]
	Running cost	Energy costs plus maintenance costs	Quantitative	Calculatio n	[Euro]
	Type Thermal Account Access (TAA) vs. Energy Efficiency Certificates (EEC)	Access to the thermal account and energy efficiency certificates, italian public incentives carried out by Energy services management.	Qualitative	Process documenta tion	[TAA/ EEC]
Technical	Increase of plant system efficiency	The increase in the efficiency of the new system plant compared to the existing one	Quantitative	Estimated or metered data	[%]
	Installed power reduction	The reduction of installed power	Quantitative	Estimated or metered data	[kW]
Social	Architectural impact	The visual and architectural impact of refurbishments in the existing built environment	Qualitative	Process documenta tion	[-]

<u>Impact assessment</u>: After the appropriate selection and the definition of the performance indicators, it was time to proceed with the impact assessment. This step consists in filling the evaluation matrix shown in Table 3, which is fundamental to reach the final selection. It allows the comparison of each refurbishment alternative proposed in the preliminary analysis with the current situation, taking into account the selected KPIs. To complete it, the collaboration of different parties is necessary, since the indicators cover the different areas of the project, from the economic to the social, through the technical and environmental. With regard to environmental and technical aspects, it was necessary to carry out an analysis of the current energy systems in each case study, in order to calculate their efficiency and power, energy consumption and subsequently gas emissions. A software was used to simulate the alternatives and to obtain the data. In relation to the social section, the architectural impact that the different alternatives produced was determined with one of the previously named questionnaires. The economic aspect will probably be the most important when choosing the best alternative, due to the amount of KPIs involved. To complete the matrix of this section, it will be necessary to analyse the cost of labor and materials, and a precise investigation to involve different public entities in investment matters.

<u>Selection of best alternative:</u> To proceed with this step, an outranking Multi Criteria Analisys (MCA) will be used in order to rank the different energy retrofit interventions proposed previously on each case study called PROMETHEE. The target is to provide a comprehensive overview of the best alternative. Moreover, a sensitivity analysis will be carried out, modifying the weights and valuations of each alternative, in order to observe how their ranking varies.

<u>Users involvement and CSOP model</u>: As mentioned in the introduction, in the Energy Community, the citizens cover an important role and one of the purposes of the “SCORE project” is to encourage the active role of consumers. Indeed, the users will be not only simple consumers but a prosumers, participating actively in the phases of decision, dissemination, production and distribution of energy. In this context, the creation of a CSOP Operating Company would bring different kind of users, such as municipalities, small and medium-sized enterprises and citizens, to become co-owners of the new energy

plant system. In order to understand and promote the users' cooperation, two phases are necessary: the survey phase and the operational phase.

The survey phase consists in gathering opinions and attitudes, about the topic of energy community, of citizens in a specific context. The administration of a questionnaire allows to collect information about the citizens' willingness to engage in local energy initiatives and to understand which drivers favour/hinder their participation. The survey questions are divided in 4 parts: (i) socio-demographic, (ii) socio-economic, (iii) attitude and willingness to Energy Community and (iv) feeling related to community identity. The output phase will be a citizen's division in population segments that share common features. In the operational phase, the CSOP Operating Company is established including, also through ad hoc policies, of each population segment defined in the previous phase, paying particular attention to cluster that are interested or would like to be part of the project but for different reasons they do not have the possibility.

2.1. Case study

Ten pilot projects have been selected in Susa Valley where the implementation consists of substituting the existing heating system that is fuelled by diesel oil and natural gas. The Susa Valley is one of the widest and deepest Italian alpine valleys. The new systems will use local biomass as their heating source: wood chips instead of pellets or wood blocks that are the typical solution for small individual boilers. To avoid repetitions in this paper of these ten projects one representative project is analysed in the result section; the remaining projects have similar properties to those analysed. Table 2 shows the selected cases indicating existing and planned heating systems.

Table 2. Pilot case studies in Susa Valley, Italy.

Municipality (city)	Building
Oulx	School Social activity building Gym Building Touristic office Municipality
Novalesa	Abbey Private building 1 Private building 2
Rueglio	Municipality Retirement house
San giorio di susa (building scale)	Multi-use room and bar
San giorio di susa (city scale)	Private residential buildings
Villardora	School and gym Kindergarten
Susa	District heating network
Bardonecchia	District heating network
Bussoleno	District heating network
Almese	Sport (facilities) buildings Middle school Private buildings

3. Results

This section illustrates the results obtained of one out of ten cases study. Oulx was the municipality chosen due to the variety of possible refurbishment alternatives. Below is represented some information collected in the first step of the workflow (Data Collection), about critical aspects and the context of the current system, to determine the buildings involved (Figure 2).

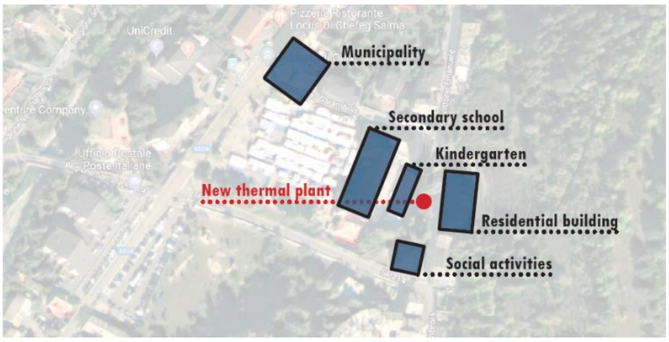

Figure 2: Context of Oulx

The constrains and critical issues that characterize the study are:

- A significant energy leakage through the opaque casing;
- The obsolete regulation and balance systems (simple regulation on-off with no internal temperature compensation);
- The obsolete heat generation technology (more than 10 years old);
- The presence of multiple generators with no integration between them;
- The use of an unclean energy resource (diesel fuel) and consequent high emission level of CO2.

Six alternatives of retrofitting were proposed. It is considered useful to reach nZEB conditions and obtain the incentives offered by the “Conto Termico” for public buildings. The Table 3 shows the simulations designed for this study and the values of energetic indicators for each simulation.

Table 3: Retrofit Alternatives for Oulx pilot case stusy

Code of simulation	Interventions
0.0)	As built simulation model
0.1)	As built simulation model from real consumption (benchmark)
1)	Simulation 0) and replacement of the boilers with a unique biomass-fired one and regulation retrofitting.
2)	Simulation 1) and the upper-attic slabs insulation (18cm)
3)	Simulation 2) and external walls insulation for the school and the gym (18cm)
4)	Simulation 1) and nZEB conditions obtained with the upper-attic slabs insulation (40cm), external walls insulation for the school and the gym (30cm) and nursery’s external walls (25cm)
5)	Simulation 1) and nZEB conditions obtained with the upper-attic slabs insulation (50cm for the school and the gym, 40cm for the nursery), external walls insulation for the school and the gym (40cm) and nursery’s external walls as built
6)	Simulation 1) and nZEB conditions obtained with the replacement of the windows with more efficient components (Transmittance: <1,0 W/m^2K), upper-attic slabs insulation (15 cm for the school and the gym, 12cm for the nursery), external walls insulation for the school and the gym (15cm) and nursery’s external walls as built

After the appropriate selection of the alternatives the indicator selection and the impact assessment have been proceed. These two steps are the keys due to the importance to then evaluate the mentioned scenarios through economical, technical, environmental and social categories. Below is the complete evaluation matrix (Table 4), ready to apply PROMETHEE method and define the best one.

Table 4: Evaluation Matrix

Category	Indicator	A.1	A. 2	A. 3	A. 4	A. 5	A. 6
Environmental	Primary energy saving [kWh/y]	525269	549640	577191	581242	581254	581169
	Global emissions CO_2 reduction [$kgCO_2eq$]	137.427	143.520	150.408	151.420	151.423	151.402
	Local emissions NO_X reduction [kg/y]	94,55	98,94	103,89	104,62	104,63	104,61
	Local emissions PM_{10} reduction [kg/y]	6,83	7,15	7,50	7,56	7,56	7,56
Economic	Payback period (PBP) [years]	8,3	11,7	16,5	16,3	16,3	16,3
	Investment cost [euro]	284.750	417.250	617.250	617.250	617.250	617.250
	Public incentives [%]	40%	40%	40%	65%	65%	65%
	Savings on energy expenditure [euro/year]	34.142	35.727	37.517	37.781	37.782	37.776
	Labor cost [euro]	136.250	136.250	136.250	136.250	136.250	136.250
	Labor cost by a social cooperative [euro]	34.063	34.063	34.063	34.063	34.063	34.063
	Material cost [euro]	148.500,00	281.000	481.000	481.000	481.000	481.000
	Material cost purchased on the territory [euro]	51.975	98.350	168.350	168.350	168.350	168.350
	Running cost [euro]	39.523	33.156	26.962	25.463	25.459	25.490
	Type Thermal Account Access (TAA) vs. Energy Efficiency Certificates (EEC) [TAA/EEC]	TAA	TAA	TAA	TAA	TAA	TAA
Technical	Increase of plant system efficiency [%]	9,80%					
	Installed power reduction [kW]	175					
Social	Architectural impact [-]	3	3	3	3	3	3

This is the current situation in which the project is located. The following steps are those defined in the workflow, which includes the selection of best refurbishment alternative with a multi-criteria decision method (PROMETHEE) and the user involvement applying CSOP.

4. Conclusions and future developments

This study has demonstrated how different energy alternatives are defined, how indicators have been selected and assessed, and how the SCORE project aims at involving the citizen in CSOP Model in order to create the energy communities. The next step is building an evaluative matrix, which later makes it possible to analyse the feasibility of the different case studies and choose the best retrofit alternative through a Multi-Criteria Analysis (MCA) of different Italian case study within the "SCORE" project. One of the interesting future developments is the use of PROMETHEE method, which is an outranking Multi Criteria Analysis (MCA) in order to rank a feasibility analysis of ten case studies pilots, taking into account the criteria weights defined by this study. This will allow defining the most convenient pilot project in a sustainable perspective.

Acknowledgments

This research project has been financially supported by the H2020 project, entitled Supporting Consumer Co-Ownership in Renewable Energies – "SCORE". Grant Agreement number: 784960-SCORE-H2020-EE-2016-2017/H2020-EE-2017-CSA-PPI.

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POLITECNICO DI TORINO

SCORE Co-own. Prosume. Renew.

APPENDIX 2: Visual Promethee software's screenshots.

OULX

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

	Change 3	Primary ener…	Global emissi…	Local emissio…	Local emissio…	Payback peri…	Investment …	Public incenti…	Savings on e…	Labor cost
	Unit	kWh/year	kg/year	kg/year	kg/year	years	€	%	€/year	€/anno
	Cluster/Group									
	Preferences									
	Min/Max	max	max	max	max	min	min	max	max	min
	Weight	8,33	8,33	8,33	5,88	3,33	3,33	3,33	3,33	3,33
	Preference Fn.	V-shape	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	absolute
	- Q: Indifference	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	- P: Preference	21397	5349	3,85	0,28	1,66	€ 179.387	13	€ 3.637	€ 41.397
	- S: Gaussian	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Statistics									
	Minimum	525269	137427	94,55	6,83	3,93	€ 350.675	40	€ 89.296	€ 80.925
	Maximum	581254	151423	104,63	7,56	8,18	€ 802.425	65	€ 98.813	€ 185.175
	Average	565961	147600	101,87	7,36	7,01	€ 680.550	53	€ 96.213	€ 157.050
	Standard Dev.	21397	5349	3,85	0,28	1,66	€ 179.387	13	€ 3.637	€ 41.397
	Evaluations									
☑	Alternative 1	525269	137427	94,55	6,83	3,93	€ 350.675	40	€ 89.296	€ 80.925
☑	Alternative 2	549640	143520	98,94	7,15	5,60	€ 522.925	40	€ 93.439	€ 120.675
☑	Alternative 3	577191	150408	103,89	7,50	8,18	€ 802.425	40	€ 98.122	€ 185.175
☑	Alternative 4	581242	151420	104,62	7,56	8,12	€ 802.425	65	€ 98.811	€ 185.175
☑	Alternative 5	581254	151423	104,63	7,56	8,12	€ 802.425	65	€ 98.813	€ 185.175
☑	Alternative 6	581169	151402	104,61	7,56	8,12	€ 802.425	65	€ 98.799	€ 185.175

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

	Change 3	Labor cost b…	Material cost	Material cost…	Running cost	Type Therm…	Increase of …	Installed po…	Architectural…
	Unit	anni	€	€	€	y/n	%	kW	
	Cluster/Group								
	Preferences								
	Min/Max	min	min	min	min	max	max	max	max
	Weight	3,33	3,33	3,33	3,33	3,33	0,00	0,00	33,30
	Preference Fn.	V-shape	V-shape	V-shape	V-shape	V-shape	V-shape	V-shape	Level
	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	1,00
	- P: Preference	€ 10.349	€ 137.990	€ 48.296	€ 8.627	2,00	2,00	2,00	0,76
	- S: Gaussian	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Statistics								
	Minimum	€ 20.231	€ 269.750	€ 94.413	€ 36.251	1,00	9,80	175,00	3,00
	Maximum	€ 46.294	€ 617.250	€ 216.038	€ 59.127	1,00	9,80	175,00	5,00
	Average	€ 39.263	€ 523.500	€ 183.226	€ 42.531	1,00	9,80	175,00	4,50
	Standard Dev.	€ 10.349	€ 137.990	€ 48.296	€ 8.627	0,00	0,00	0,00	0,76
	Evaluations								
☑	Alternative 1	€ 20.231	€ 269.750	€ 94.413	€ 59.127	yes	9,80	175,00	average
☑	Alternative 2	€ 30.169	€ 402.250	€ 140.788	€ 48.681	yes	9,80	175,00	very good
☑	Alternative 3	€ 46.294	€ 617.250	€ 216.038	€ 38.567	yes	9,80	175,00	very good
☑	Alternative 4	€ 46.294	€ 617.250	€ 216.038	€ 36.258	yes	9,80	175,00	very good
☑	Alternative 5	€ 46.294	€ 617.250	€ 216.038	€ 36.251	yes	9,80	175,00	very good
☑	Alternative 6	€ 46.294	€ 617.250	€ 216.038	€ 36.299	yes	9,80	175,00	good

VILLAR DORA

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

Change 3	Primary ener…	Global emissi…	Local emissio…	Local emissio…	Payback peri…	Investment …	Public incenti…	Savings on e…	Labor cost
Unit	kWh/year	kg/year	kg/year	kg/year	years	€	%	€/year	€/year
Cluster/Group	◆	◆	◆	◆	■	■	■	■	■
Preferences									
Min/Max	max	max	max	max	min	min	max	max	min
Weight	8,33	8,33	8,33	8,33	3,33	3,33	3,33	3,33	3,33
Preference Fn.	V-shape	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	absolute
- Q: Indifference	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
- P: Preference	4275	1177	0,45	0,31	1,87	€ 70.846	0	€ 428	€ 16.349
- S: Gaussian	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Statistics									
Minimum	346034	65799	37,03	24,91	10,10	€ 350.675	40	€ 34.603	€ 80.925
Maximum	356389	68673	38,13	25,66	14,40	€ 512.265	40	€ 35.639	€ 118.215
Average	351662	67301	37,63	25,32	12,70	€ 449.735	40	€ 35.166	€ 103.785
Standard Dev.	4275	1177	0,45	0,31	1,87	€ 70.846	0	€ 428	€ 16.349
Evaluations									
Alternative 1	346034	65799	37,03	24,91	10,10	€ 350.675	40	€ 34.603	€ 80.925
Alternative 2	352562	67431	37,72	25,38	13,60	€ 486.265	40	€ 35.256	€ 112.215
Alternative 3	356389	68673	38,13	25,66	14,40	€ 512.265	40	€ 35.639	€ 118.215

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

Change 3	Labor cost b…	Material cost	Material cost…	Running cost	Type Therm…	Increase of …	Installed po…	Architectural…
Unit	Euro/year	€	€	Euro/years	y/n	%	kW	
Cluster/Group	■	■	■	■	■	◆	◆	●
Preferences								
Min/Max	min	min	min	min	max	max	max	max
Weight	3,33	3,33	3,33	3,33	3,33	0,00	0,00	33,30
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	€ 4.087	€ 54.497	€ 37.094	€ 235	2,00	2,00	2,00	2,00
- S: Gaussian	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Statistics								
Minimum	€ 20.231	€ 269.750	€ 40.607	€ 40.607	1,00	3,00	249,00	1,00
Maximum	€ 29.554	€ 394.050	€ 130.918	€ 41.160	1,00	3,00	249,00	3,00
Average	€ 25.946	€ 345.950	€ 88.646	€ 40.929	1,00	3,00	249,00	2,33
Standard Dev.	€ 4.087	€ 54.497	€ 37.094	€ 235	0,00	0,00	0,00	0,94
Evaluations								
Alternative 1	€ 20.231	€ 269.750	€ 94.413	€ 41.160	yes	3,00	249,00	average
Alternative 2	€ 28.054	€ 374.050	€ 130.918	€ 40.607	yes	3,00	249,00	average
Alternative 3	€ 29.554	€ 394.050	€ 40.607	€ 41.020	yes	3,00	249,00	very bad

RUEGLIO

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

Change 3	Primary ener…	Global emissi…	Local emissio…	Local emissio…	Payback peri…	Investment …	Public incenti…	Savings on e…	Labor cost
Unit	kWh/year	kg/year	kg/year	kg/year	years	€	%	€/year	€/year
Cluster/Group									
Preferences									
Min/Max	max	max	max	max	min	min	max	max	min
Weight	8,33	8,33	8,33	8,33	3,33	3,33	3,33	3,33	3,33
Preference Fn.	V-shape	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	absolute
- Q: Indifference	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
- P: Preference	2540	695	0,46	0,03	0,62	€ 34.578	0	€ 432	€ 7.980
- S: Gaussian	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Statistics									
Minimum	273112	71262	49,16	3,55	7,60	€ 350.675	40	€ 46.429	€ 80.925
Maximum	279132	72940	50,24	3,63	9,10	€ 433.485	40	€ 47.452	€ 100.035
Average	276576	72186	49,78	3,60	8,43	€ 397.215	40	€ 47.018	€ 91.665
Standard Dev.	2540	695	0,46	0,03	0,62	€ 34.578	0	€ 432	€ 7.980
Evaluations									
Alternative 1	273112	71262	49,16	3,55	7,60	€ 350.675	40	€ 46.429	€ 80.925
Alternative 2	277485	72355	49,95	3,61	8,60	€ 407.485	40	€ 47.172	€ 94.035
Alternative 3	279132	72940	50,24	3,63	9,10	€ 433.485	40	€ 47.452	€ 100.035

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

Change 3	Labor cost b…	Material cost	Material cost…	Running cost	Type Therm…	Increase of …	Installed po…	Architectural…
Unit	Euro/year	€	€	€/year	y/n	%	kW	
Cluster/Group								
Preferences								
Min/Max	min	min	min	min	max	max	max	max
Weight	3,33	3,33	3,33	3,33	3,33	0,00	0,00	33,30
Preference Fn.	V-shape	V-shape	V-shape	V-shape	V-shape	V-shape	V-shape	Level
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	1,00
- P: Preference	€ 1.995	€ 26.599	€ 9.310	€ 965	2,00	2,00	2,00	2,00
- S: Gaussian	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Statistics								
Minimum	€ 20.231	€ 269.750	€ 94.413	€ 42.096	1,00	0,00	0,00	1,00
Maximum	€ 25.009	€ 333.450	€ 116.708	€ 44.371	1,00	0,00	0,00	3,00
Average	€ 22.916	€ 305.550	€ 106.943	€ 43.048	1,00	0,00	0,00	2,33
Standard Dev.	€ 1.995	€ 26.599	€ 9.310	€ 965	0,00	0,00	0,00	0,94
Evaluations								
Alternative 1	€ 20.231	€ 269.750	€ 94.413	€ 44.371	yes	0,00	0,00	average
Alternative 2	€ 23.509	€ 313.450	€ 109.708	€ 42.096	yes	0,00	0,00	average
Alternative 3	€ 25.009	€ 333.450	€ 116.708	€ 42.678	yes	0,00	0,00	very bad

SAN GIORIO

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

Change 3	Primary ener...	Global emissi...	Local emissio...	Local emissio...	Payback peri...	Investment ...	Public incenti...	Savings on e...	Labor cost
Unit	kWh/year	kg/year	kg/year	kg/year	years	€	%	€/year	€/year
Cluster/Group									
Preferences									
Min/Max	max	max	max	max	min	min	max	max	min
Weight	8,33	8,33	8,33	8,33	3,33	3,33	3,33	3,33	3,33
Preference Fn.	V-shape	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	absolute
- Q: Indifference	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
- P: Preference	1763	441	0,19	0,12	1,10	€ 33.891	0	€ 176	€ 7.821
- S: Gaussian	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Statistics									
Minimum	155215	29600	16,61	11,18	13,60	€ 350.675	40	€ 15.522	€ 80.925
Maximum	158741	30481	16,99	11,43	15,80	€ 418.457	40	€ 15.874	€ 96.567
Average	156978	30041	16,80	11,30	14,70	€ 384.566	40	€ 15.698	€ 88.746
Standard Dev.	1763	441	0,19	0,12	1,10	€ 33.891	0	€ 176	€ 7.821
Evaluations									
Alternative 1	155215	29600	16,61	11,18	13,60	€ 350.675	40	€ 15.522	€ 80.925
Alternative 2	158741	30481	16,99	11,43	15,80	€ 418.457	40	€ 15.874	€ 96.567

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

Change 3	Labor cost b...	Material cost	Material cost...	Running cost	Type Therm...	Increase of ...	Installed po...	Architectural...
Unit	years	€	€	€/years	y/n	%	kW	
Cluster/Group								
Preferences								
Min/Max	min	min	min	min	max	max	max	max
Weight	3,33	3,33	3,33	3,33	3,33	0,00	0,00	10,00
Preference Fn.	V-shape	V-shape	V-shape	V-shape	V-shape	V-shape	V-shape	Level
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	1,00
- P: Preference	€ 1.956	€ 26.070	€ 9.125	€ 2.964	2,00	2,00	2,00	2,00
- S: Gaussian	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Statistics								
Minimum	€ 20.231	€ 269.750	€ 94.413	€ 21.444	1,00	10,00	12,00	3,00
Maximum	€ 24.142	€ 321.890	€ 112.662	€ 27.371	1,00	10,00	12,00	3,00
Average	€ 22.187	€ 295.820	€ 103.538	€ 24.408	1,00	10,00	12,00	3,00
Standard Dev.	€ 1.956	€ 26.070	€ 9.125	€ 2.964	0,00	0,00	0,00	0,00
Evaluations								
Alternative 1	€ 20.231	€ 269.750	€ 94.413	€ 21.444	yes	10,00	12,00	average
Alternative 2	€ 24.142	€ 321.890	€ 112.662	€ 27.371	yes	10,00	12,00	average

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