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Mainstreaming Energy Communities in the Transition to a Low-Carbon Future: A Methodological Approach

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Abstract: Innovations in technical, financial, and social areas are crucial prerequisites for an effective and sustainable energy transition. In this context, the construction of a new energy structure and the motivation of the consumer towards a change in their consumption behaviours to balance demand with a volatile energy supply are important issues. At the same time, Consumer Stock Ownership Plans (CSOPs) in renewable energies sources (RESs) have proven to be an essential cornerstone in 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. Prosumers provide benefits by (1) generating a part of the energy they consume, (2) reducing their overall expenditure for energy, and (3) receiving a second source of income from the sale of excess production. Supporting Consumer Co-Ownership in Renewable Energies (SCORE) is an ongoing Horizon 2020 project with the aim of overcoming the usage of energy from fossil sources in favour of RES, promoting the creation of energy communities (EC) and facilitating co-ownership of renewable energies (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 EC creation. In particular, this paper focuses on the description of the methodological approach in implementing the CSOP model which consists of three main phases: the identification and description of selected buildings (preparation phase), the preliminary and feasibility analysis phase, and finally the phase of target group involvement. SCORE first started in three pilot regions in Italy, Czech Republic, and Poland, and later, with the aim of extending the methodology, in various other cities across Europe. In this study, Italian pilot study sites were chosen as a case study to develop and test the methodology.

Keywords: energy community (EC); renewable energy sources (RESs); citizen involvement; co-ownership in renewable energies

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1. Introduction

Nowadays, due to global environmental problems (e.g., climate change and the increase of greenhouse gas emissions) it is necessary to follow a "decarbonization process" for an energy transition. Energy transition means not only a move 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 an awareness of energy consumption by building users and citizens [1,2].

In this regard, energy community (EC) initiatives seem to be the way through which it is possible to provide a concrete response to the aforementioned environmental issues. Moreover, the EC represents a new model which considers energy as well as economic and social perspectives. This emerging concept leads to positive implications in different areas such as global CO_2 emission reductions with the reduction of local pollutants for an improvement in external air quality, and economic developments (e.g., creation of 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 (RESs), in this emerging system the consumer plays an active role. The consumers' willingness to actively participate in decisions together with the production, distribution, and consumption of energy from RESs represents a key element in the EC definition. The EC emerges from bottom-up willpower in which municipalities, small and medium-sized enterprises, and citizens, located in a specific area, share the willingness to self-produce, self-consume, and exchange energy from renewable energy sources among different users in different end-use buildings [3,4].

It is clear that 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 undertaken by men who are middle aged with a higher income, whereas the involvement of women, low-income households, and vulnerable groups affected by fuel poverty is uncommon and as a rule these groups are excluded from renewable energies (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 areas, 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 (Figure 1).

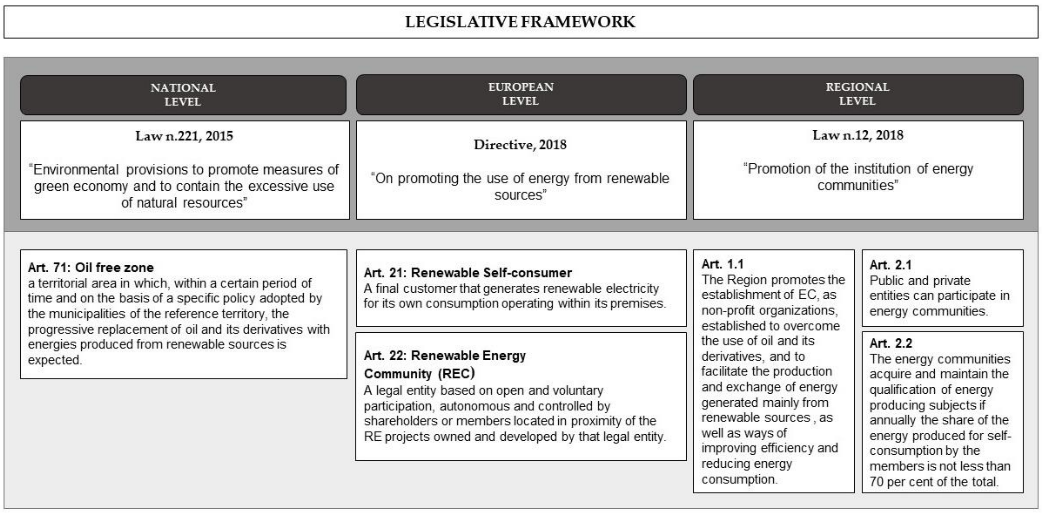

Figure 1. The legislative framework of energy communities.

In this context on 30 November 2016, the European Commission presented the "Clean Energy for All Europeans" package, also known as the "Clean energy package", which includes several measures in the fields of energy efficiency, renewable energy, and internal energy market power [6]. Among all, two directives are important since they significantly address EC issues: (1) Renewable Energy Directive II (RED II, 2018) and (2) the new directive on the new rules of electricity market (2019). The RED II overall target is for 32% of energy consumption to be supplied by RESs. 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 defines how to reach the targets through 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 the national level, recognition of 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 be used 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, Law 221 of 2015, "Environmental provisions to promote measures of green economy and to contain the excessive use of natural resources", within article 71 establishes the possibility of creating areas free from dependence on fossil fuels, in a so-called "oil-free zone". These territorial areas have the possibility of encouraging experiments, including those on new forms of association.

Following the new regulatory framework, the Piedmont Region has displayed the willpower to "promote the birth of energy communities as non-profit organizations". Indeed, the Piedmont Region is the first Italian region, through the Regional Law of 3 August 2018, n. 12 ("Promotion of the institution of energy communities"), that encourages the new paradigm related to 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 RESs 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, has committed to financially support the establishment of energy communities. This may also involve agreements with Italian Regulatory Authority for Energy and Networks (ARERA – Autorità di Regolazione per Energia Reti e Ambiente), 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 the delegation of 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 as follows:

- 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 of delivering 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, 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 results of an ongoing research project, which focuses mainly on the engagement of private and/or public consumers towards sustainable energy transition. The purposes could be summarized as follows:

- Facilitating consumers to become prosumers of RE, firstly in three pilot regions (Italy, Poland, and the Czech Republic), and secondly in cities across Europe after the pilot projects. This involves the application of Consumer Stock Ownership Plans (CSOPs), utilising established up-to-date best practice by inclusive financing techniques combined with energy efficiency measures.
- Encouraging local authorities and consumers, demonstrating the positive impact co-ownership has on consumer behaviour, and showing the ability of this democratic participation model to include women as well as those of low-income households, in particular the unemployed.
- Empowering 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, and the Czech Republic).
- Formulating 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 through a real case study application, and reflecting 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 the CSOP model, which consists of three main phases: the identification and description of selected buildings (preparation phase), the preliminary and feasibility analysis, and finally target group involvement. Supporting Consumer Co-Ownership in Renewable Energies (SCORE) first started in three pilot regions in Italy, the Czech Republic, and Poland, and later, with the aim of extending the methodology, was carried out in various other follower cities across Europe. The Italian pilot studies 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 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 preparation, which includes 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 ones, 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. The final phase (III) is target group involvement, in which citizens and public and private entities will be a part of financial model. It is helpful to break the study down into the main elements that frame it to understand the research process steps employed. 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.

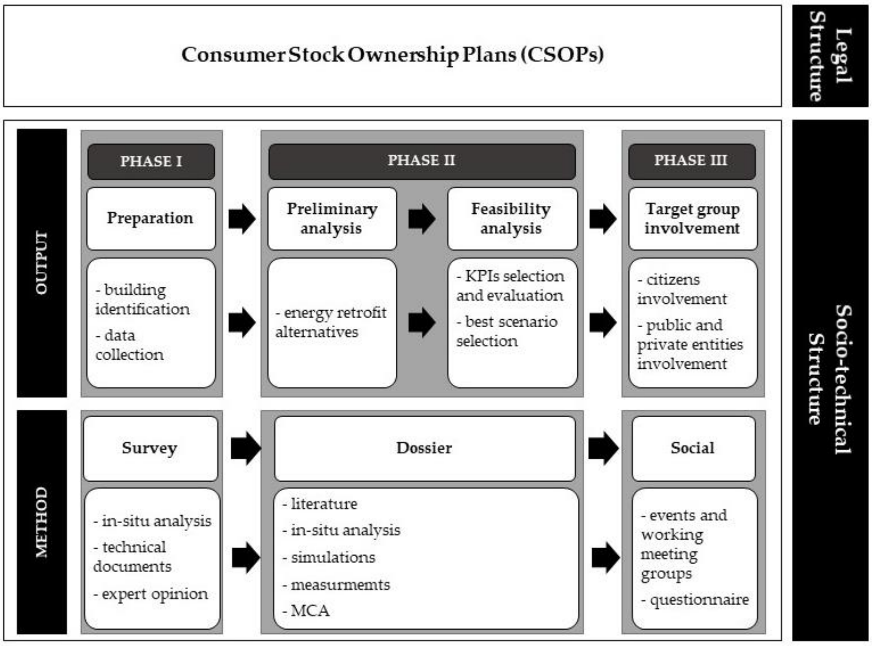

Figure 2. Flow-work: different steps of work. MCA: multi-criteria analysis; KPIs: key performance indicators.

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.

(1) The first survey regards the investment identification of RESs, which is composed of five main sections [7]. This survey collects a general description of the buildings considered for each pilot study case, describing the current situation (i.e., geometry and energy plant systems) 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 domestic hot water (DHW) distribution system operator, average of consumption expenses, total number of dwellings or offices, total official number of inhabitants/employees, number of floors, total usable area, and total roof area). The second section 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 RESs, for example the type of energy sources and installed power. In the fourth part, the planned RESs are investigated. Finally, the fifth section is dedicated to the planned structure of financial sources for RES investment (e.g., type of financial sources and percentage of overall costs). Since the target is on a local scale, the definition of the building's database is crucial.

(2) 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, average consumption fee data (€/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 consists of preliminary and feasibility analysis, is investigated within the specific document, called the "dossier" [8]. The 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 pilot building. Additional data are collected for defining different refurbishment measures, which are described in dossier using simulation and measurements approaches. Issues addressed in the detailed dossiers are as follows:

(1) Energy impact assessment of 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 the building energy simulation model. At least two different refurbishment alternatives (for each case study) have been proposed. The retrofit alternatives concern the envelope system, the energy system installing RES, and the control system.
(2) Environmental impact assessment illustrates the strategies to minimize the environmental impact with each alternative.
(3) Economic and financial assessment of the investment costs.

Finally, in order to select the best scenario, 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 is made as per 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 is reduced as a result of five internal discussion rounds among relevant experts. In 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 us to define the best alternative considering different indicators, in order to determine 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 us 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 consumers 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 (1) confer ownership rights in RE projects, (2) involve "active" consumers with the specific attention on vulnerable ones, and (3) and consider local or regional areas. Since user 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 complete [5]. Moreover, these types of projects are usually performed by men who are middle aged and with a higher income, whereas vulnerable groups (affected by fuel poverty), women, and low-income households are excluded from RE investments [5]. As such, a social analysis will be conducted through a specific action plan to collect information through, first of all, (1) events and a work 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 drivers that favour/hinder their participation. As mentioned before, the citizens' involvement took 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 method allowed us 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 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 were alternated with 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 method, the interviewees were 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 the EC project;
    b. Feeling related to community identity information: level of feeling related to trust, satisfaction, pride, hope, disgust, shame, fear, boredom;
    c. Technical information: building type and age, type of heating system, efficiency of the energy plant or building envelope;
    d. Socio-economic information: personal and family income, family composition, building construction year, and building ownership;
    e. Socio-demographic information: age, gender, education level, nationality, marital status, and municipality.

The questionnaire was given citizens in a specific context and the data analysis produced a division of citizens into population segments that shared common features. The study allowed us to understand and, subsequently, to promote the users' cooperation to become co-owners of the new energy plant system. The definition of different population segments highlighted the clusters that were interested in or would like to be part of community project but, for different reasons, did not have the possibility of participating (e.g., women, low-income households, 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 was 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.

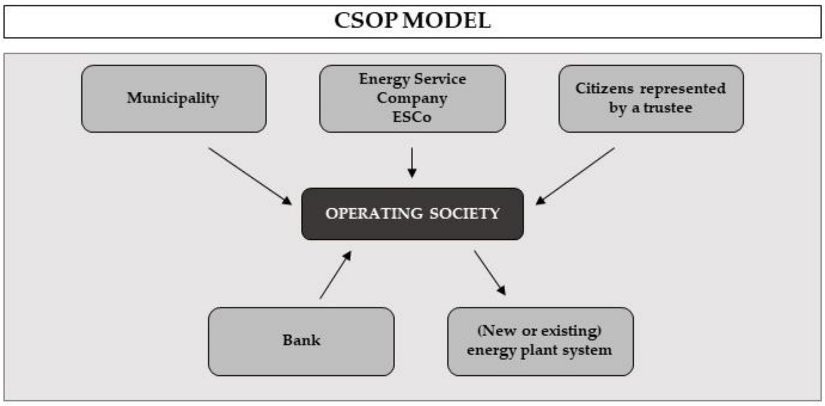

Figure 3. Financing of a renewable energy (RE) plant and energy efficiency (EE) measures through a CSOP, authors' elaboration.

Once all the three above mentioned phases (socio-technical structure) were concluded, the financial CSOP model (legal structure) could be implemented. The creation of CSOPs enables consumers, especially the vulnerable, to have 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 through investment 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 3, and the main elements are as follows:

- 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 of consumer-centred investment for general services, providing participation both financially and in regard to management decisions.
- Municipalities, small and medium-sized enterprises (SMEs) and other local stakeholders are permitted as co-investors. CSOPs avoid personal liability for consumer-shareholders.
- The Operating Society invests in new or existing RE plants and operates on behalf of different actors as co-owners.
- It is possible to demand loans from banks;
- New RE plants supply energy to consumers at fixed price and generate revenues from excess production sold to the grid.

3. Case Study

The Susa Valley (45°8′12″ N, 7°3′29″ E, from 300 to 3.612 m asl), was selected as a pilot case study. It 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 been 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: the Oulx area, Susa area, Condove area, and Avigliana area. The population is over 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 involves 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 10 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. DH: district heating; LGP: Liquid Propane Gas.

No.	Municipality (City)	Number	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. RESs in Susa Valley

Currently in the Susa Valley, 75% of the pilot projects originate from fossil fuels, while 25% of energy is produced by RESs, mostly from biomass. Although there is a 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, 11 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 a difficulty in paying for necessary energy, which leads to a decline in living conditions [14]. Groups vulnerable to energy poverty are not located in a particular area, but are 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 in these areas since the rent or the housing costs are low. Some associations work with these vulnerable groups. For example, Consorzio Intercomunale Socio-Assistenziale (Con.I.S.A.), Cooperativa Sociale Amico (COOPAMICO), and Caritas are three entities that operate on the Susa Valley territory, dealing with people in difficulty in order to help them with issues involving poverty, unemployment, and access to 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 an 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 (1) lower costs for energy, (2) a high share (>80%) of energy cost remaining on the territory, and (3) lower CO_2 emissions (closed 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 10 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 study in San Giorio di Susa with activities at the city scale deals with residential buildings, and is of 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 of phases and methods to obtain the final results. This phase, "Building identification and data collection", illustrates how the methodology is applied on one out of the 10 case studies. Oulx was the pilot study chosen due to the prior approval and engagement of the municipality, and the variety of possible refurbishment alternatives proposed. The aforementioned aspects will enrich the procedure of selection. The first phase involved the preparation, and therefore, the collection of data and information, as 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 study building (detailed in Table 1) in Oulx has been described through the following information: building ownership (private or public) and building function (residential or non-residential), building construction year, the latest refurbishment year, average heat and domestic hot water (DHW) expenses, total number of building zones (dwellings or offices), total number of users (inhabitants or employees), total usable area, and finally, average annual energy consumption.

Table 2. Oulx data and information collection.

No.	Ownership and Function	Construction Year	Latest Refurbishment Year	Average Heat and DHW Expenses (€/year)	Total Number of Zones	Total Number of Users	Total Usable Area (m^2)	Average 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	5585	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) conditions. nZEBs are buildings that have very high energy performance, pursuant to Directive 2018/844 on the energy performance of buildings. As per 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 renewable energies sources (RESs), including RE produced on-site or nearby (cf. recital (7) and Annex I point 2 of the Directive). DHW: domestic hot water.

4.2. Phase II: Preliminary and Feasibility Analysis

4.2.1. Preliminary Analysis (Energy Retrofit Alternatives)

As mentioned above, Phase II, preliminary, and feasibility analyses were performed through dossier documents. This phase started 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) were acquired. Specifically, the Oulx dossier investigated the school complex that is the subject of energy retrofitting in order to access the "Conto Termico" (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). 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.

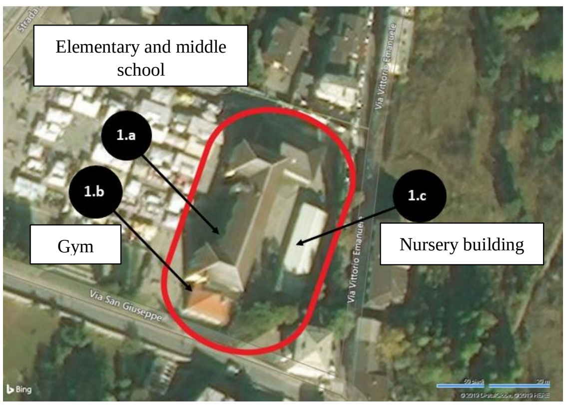

Figure 4. Buildings involved, source: www.bing.com/maps.

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 efficiency values 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 as follows:

- 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 over 10 years old);
- Not clean energy sources (diesel fuel) and consequent high emission levels of CO_2.

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

	Before	
Element	**Thickness (mm)**	**Thermic Transmittance (W/m^{2}K)**
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
Gym upper-attic slab	60	1.429
Nursery upper-attic slab	50	0.438

In addition, data in terms of energy costs and tariffs were collected for the actual situation, using non-renewable energy sources. Specifically, the information presented in Table 4 was provided by administrative municipal accounting, and current values are assumed to be the same due to the impossibility of accessing more recent information. Then, the litres of consumed diesel fuel in one year were calculated and a consumption of 57,746 litres/year was 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 that are the object of this study was created with software certified by the Comitato Termotecnico Italiano (CTI). The resulting values have been validated taking into account the trends of utilization of the buildings, as shown in 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 °C/16 °C
Gym	7	12	20 °C/16 °C
Nursery	5	12	22 °C/19 °C

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

Table 6. Oulx 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	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) were studied in order to improve the current energy situation and minimize the environmental impact. Since the main purpose of the project was to facilitate consumers to become prosumers of RE and to become owners of RE energy plants (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 lower. In addition, as mentioned previously, it is considered useful to reach nearly Zero Energy Building (nZEB) conditions and to obtain the incentives offered by the "Conto Termico". Table 8 shows the Oulx envelope system characteristics after intervention A4, where the results start to reach nZEB conditions. Consequently, through the energy simulation, Table 9 shows the 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 (https://www.mise.gov.it/images/stories/normativa/DM_requisiti_minimi_allegato1.pdf).

Table 7. Retrofit alternatives for Oulx pilot case study. nZEB: nearly Zero Energy Building.

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 slab insulation (18 cm).
A3	Simulation 2 and external walls insulation for the school and the gym (18 cm).
A4	Simulation 1 and nZEB conditions obtained with the upper-attic slab insulation (40 cm), external walls insulation for the school and the gym (30 cm), and the nursery's external walls (25 cm).
The A5	Simulation 1 and nZEB conditions obtained with the upper-attic slabs insulation (50 cm for the school and the gym, 40 cm for the nursery), external walls insulation for the school and the gym (40 cm), and the 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/m^{2}K), upper-attic slab insulation (15 cm for the school and the gym, 12 cm for the nursery), external wall insulation for the school and the gym (15 cm), and the nursery's external walls as built.

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

	After *	
Element	**Thickness (mm)**	**Thermic Transmittance (W/m^{2}K)**
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 reaching nearly Zero Energy Building (nZEB) conditions.

Table 9. Oulx energy simulation results.

Code of Simulation	Qp,tot	Qp,ren		Qp,nren		CO2 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%	9876	6.16%
A4	177,276	141,821	80%	35,455	20%	8864	5.53%
A5	177,213	141,771	80%	35,443	20%	8861	5.53%
A6	177,638	142,110	80%	35,528	20%	8882	5.54%

4.2.2. Feasibility Analysis (KPI Selection and Evaluation)

After defining the appropriate retrofit alternatives (Table 7), and consequently simulating their energy performance results (Table 9), the definition of the different indicators has been made. 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 indicator impact assessment, it is possible to identify the most feasible and sustainable project that will fit in each pilot study case. 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 in [7].

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

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.

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

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 were some of the inputs needed [9].
- ENV2—Global CO_2 emission reduction. The building's energy system CO_2 emissions are 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 NOx emission 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 PM_{10} emission 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 (1):
- EC2—Investment cost. Many studies consider investment costs as the most important criterion to evaluate energy savings interventions. The investment cost involves all the costs related to refurbishment of the building and/or new heating system; it includes the purchase of building

material, technological installations, manpower, and set up of the cost for each individual element of the renovation project (building envelope and energy systems), as demonstrated in Table 11 [21,22].

- EC3—Public incentives. This 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 nearly Zero Energy Buildings (nZEBs);
  - 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.).

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

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	6250	1	6250
Building site	20,000	1	20,000
Lean concrete	2500	1	2500
Foundation	15,000	1	15,000
Walls	3750	4	15,000
Slab	12,500	1	12.500
Waterproofing	1000	1	1000
Passages	5000	1	5000
District pipes	20,000	1	20,000
Biomass boiler	70,000	1	70,000
Plant 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

To have access to these incentives, there are some aspects to take into account such as 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, and certification of the pellets used 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—Labour cost. It includes the salary of employees who are directly involved in production activities, services (such as general repairs and maintenance performance), and supervision. It is assumed to be 40% of investment costs, as an expert in the field suggested during an internal meeting [24,25].

- EC6—Labour cost by a social cooperative. The part of labour cost which will be covered by the 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 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. The territory is intended to be the Susa Valley.
- EC9—Running cost. This involves the energy costs plus maintenance costs. The maintenance costs are assumed to be 2% of investment cost according to [26].
- EC10—Type Thermal Account Access (TAA) vs. Energy Efficiency Certificates (EEC). This represents the access to the thermal account and energy efficiency certificates, Italian public incentives carried out by energy services management.

Technical Indicators.

- T1—Increase of plant system efficiency. This is the increase in the efficiency of the new system plant compared to the existing one [9].
- T2—Installed power reduction. This 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. 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 MCA, called PROMETHEE (preference ranking organization method for enrichment evaluation), was chosen in order to outrank the different energy retrofit interventions proposed previously in each case study [28]. The target was 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 were 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 were two qualitative criteria. For the "Architectural impact" indicator it was decided to use the "5-points" ordinal scale.

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

For all other indicators, quantitative criteria were set. The criteria for which the maximization choice was made are: primary energy saving, global CO_2 emission reduction, local NO_x emission reduction, local PM_{10} emission 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 was 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 us to quantify the degree of preference, indicated as $\pi(a, b)$, of a generic alternative "*a*" compared to "*b*", calculated as in Equation (2).

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

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

$$P_j\,(a,\ b) = F_j\left[d_j\,(a,\ b)\right],\quad 0 \leq\ P_j\,(a,\ b)\ \leq 1 \tag{3}$$

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 $\varphi+$ and represents the measure of the robustness of the analysed alternative. The outgoing flow calculated as in Equation (4), varies between 0 and 1. The more $\varphi+$ approaches 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.

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

As far as the incoming flow is concerned, the notation $\varphi-$ 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 $\varphi- = 0$ means that the selected alternative has a degree of weakness equal to zero, and therefore represents the best alternative; on the contrary $\varphi- = 1$ represents the worst one. Equation (5) is used for the calculation:

$$\phi - (a) = \frac{1}{n-1} \tag{5}$$

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 us to directly compare the proposed alternatives and provide the ranking of alternatives as shown in Equation (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 14). This last part is useful to test the robustness of the model.

Table 14. Sensitivity analysis. w: weight; p: preference.

		ENV1	ENV2	ENV3	ENV4	T1	T2	S1
Baseline	w	0.0625	0.0625	0.0625	0.0625	0.125	0.125	0.25
	p	21,397	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	21,397	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	21,397	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	179,387	13	3637	41,397	10,349	137,990	48,296	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 in that category (Table 15).

- Each environmental indicator will get a weight of 0.0625 percent, obtained through the division of 25 percent by four 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 two indicators.
- Each social indicator will get a weight of 0.25 percent, obtained through the division of 25 percent by one indicator.

Change 1 proposes the same weight for each indicator (e.g., ENV1, EC1, T2), of 5.9 percent each (Table 16). This leads to different weights for each category of indicators:

- 23.5 percent for environmental indicators;
- 11.8 percent for technical indicators;
- 5.9 percent for social indicators; and
- 58.8 percent for economic indicators

Change 2 focuses on the two aspects that have more impact in the project, the environmental and economic categories. Taking into account the relevance of these two, a higher weight was assigned (30 percent each one), leaving the rest to social and technical aspects, divided equally (Table 17).

- 30 percent for the environmental category and 0.075 percent for each environmental indicator;
- 30 percent for the economic category and 0.03 percent for each economic indicator;
- 20 percent for the technical category and 0.1 percent for each technical indicator; and
- 20 percent for the social category and 0.2 percent for each social indicator

Table 15. 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

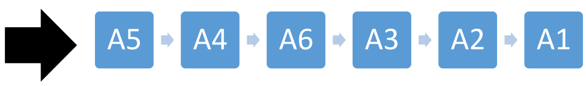

Table 16. Change 1 results.

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

A5 → A4 → A6 → A2 → A1 → A3

Table 17. 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

A5 → A4 → A6 → A3 → A2 → A1

From the model runs, by changing the weights, the best alternative is always A5 followed by A4 and A6, as shown in Tables 15–17. The main reason is because they reach nZEB conditions, obtaining a great 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 a biomass boiler).

4.3. Phase III: Target Group Involvement

4.3.1. Info-Events

During the months of November and December, 12 events were organized involving local institutions (e.g., mayors) and organizations that work in the area of Susa Valley. The purpose of these events was (1) to inform and share the research activities and the project results (mainly related to the technical analysis) with the Susa Valley community; (2) raise awareness among stakeholders about the energy community benefits and, finally, (3) 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 7 February 2020, the first workshop was organized in Almese with the collaboration of Deutscher Caritas Verband and Cooperativa Sociale Amico. Indeed, thanks to their contribution (these groups have close ties to local people), 20 citizens were invited (through personal communications) to attend this event. The duration was about half of day and the educational approach was alternated with three periods of debate and activities, in which the participants were called to express their thoughts and opinions.

After a first section in which the aim of the project and the meaning of "energy transition", "renewable energy sources", "energy community", and "CSOP (financing model)" were 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?"*

This process involved a free discussion, and the answers obtained showed that most of citizens were not satisfied with the energy expenditure since the heating bills were 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, and 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.

Subsequently, 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 through the question: "*What are the CSOP benefits you are most interested in?*". Specifically, the key elements were written on sheets (one per sheet). Participants were given a maximum of three dots, one red dot to stick on the sheet with the most important benefit for them, and two green dots to put on the sheets with some benefits for them. In this way, two elements remained unchosen, that is, those that were not important to them. The results showed that the "small source of income" benefit was not successful because on the one hand, the income was small and, on the other hand individuals were slightly sceptical about obtaining money. Indeed, this option was only chosen by 11.4% of individuals (75% red and 25% green). For this reason, "environmental issues" and "low investment", both with a preference of 28.5%, were the more successful options. Specifically, it has been said that if a low investment was required, they would agree to contribute as it was an interesting project from which the whole community could benefit. In addition, advantages with respect to the statements: "the trusted administrator helps and represents consumers" (8.5%) and "independence from the national energy supply" (22.8%) were 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 answers can be summarized in the three following points:

- Distrust because, being an innovative project, there is no one who can guarantee that 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 situations of greater representation with greater investment;
- Bureaucracy: navigating the process and the necessary documentation could be complicated for simple citizens not working in the legal field.

Therefore, the workshop allowed us 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 and explained which benefits of the CSOP they were interested in and the barriers they could encounter. The collection of these data was 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): (1) the identification and description of selected buildings (preparation phase), (2) preliminary and feasibility analysis, and finally (3) target group involvement in implementing the CSOP model. Specifically, Phase I and Phase II were described in detail. The first action was 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 an 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 was 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-related 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 completion 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 showed that the best alternative was always A5 followed by A4 and A6. The main reason underlying this result was because the achievement of nZEB conditions is linked to numerous public incentives. In addition, simulations 5 and 4 were very similar and differed in the thickness of insulation; for this reason similar values of net phi were obtained. The lowest values were associated with alternative 1 (just adding a biomass boiler).

A 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 (women, those of 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 drivers favouring/hindering participation in energy communities.

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