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Renewable Energy Communities: the redevelopment of urban areas and redistribution of energy sources

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Disclaimer:

The following work has been realized in team with Cristiano Brambilla, student of Building Engineering at Politecnico di Milano, by further developing the project started during the internship at "STRUTTURE ENERGIA srl".

The part concerning the analysis of the Italian law on energy communities and the key elements at the basis of the new production and consumption system, the analysis of energy redevelopment modelled on Termus BIM and the preliminary study of the ventilated wall were developed by Cristiano Brambilla.

Meanwhile the parts concerning the historical context and the energetic aspect have been carried out by Claudio Camarri, including the energy balance of the buildings and the storage systems, with the sizing of the heat pump and the photovoltaic plants, and the economic analysis of the renewable energy communities.

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ABSTRACT

With a view to raising human awareness of reducing carbon dioxide emissions, the objective of this paper is to study the European law on renewable energy sharing (RED II) and the method of its transposition by the Italian state in the RILANCIO decree (13 May 2020). In this way it was possible to investigate new production and distribution systems that will characterize the energy market in the future with the aim of achieving the Paris agreements and the Kyoto protocol towards global decarbonization.

Through the analysis and study of the law it was possible to highlight the setting of new user systems that act as the basis of the new process of production and consumption. In this new reality, the citizen and end customer actively participate in the production and localized consumption of energy: the figure of the prosumer, producer and consumer of energy, is thus born and the energy that each of them produces and consumes is incentivized.

On this basis of localized sharing of renewable energy, Energy Communities and Collective Self-Consumption are based, allowing a community to participate in producing and consuming energy, avoiding grid charges and losses that affect final costs and above all CO_2 emissions.

The study not only gives a basic idea of how “Renewable Energy Communities” (it will be named also RECs from now on) can be developed, but also provides an idea of integrated design based not only on sharing and producing energy but above all on reducing the consumption and needs of individual buildings. The aim is to create a design strand that allows whole neighbourhoods to be redeveloped into large renewable energy communities. The methods described in this work highlight the goal of electrifying buildings, using ventilated wall insulation methods, electric compression heat generators (heat pumps) powered by photovoltaic panels. In order to demonstrate this, two case studies were taken into account that were in the process of being realized by exploiting the incentives of the "Superbonus 110" in order to demonstrate not only the reduction of requirements but also the economic feasibility of energy requalification. Subsequently, it was possible to simulate an energy balance to size the storage batteries and energy sharing within a building that benefits from the cumulative self-consumption.

The analysed case studies show how an integrated design process can create interesting and economically feasible solutions for all by exploiting the available incentives.

1 Introduction

This thesis will evaluate different types of interventions to be applied on energy efficiency projects in residential buildings in order to lower their energy demand.

Considering the period in which this analysis is being carried out, different types of incentives made available by the Italian state will be considered, and above all attention will be paid to the application of collective self-consumption.

In private homes, by installing renewable energy systems, it is possible to benefit from the energy instantaneously produced and consumed to reduce consumption, and the energy taken from the grid, thus having an economic benefit on the bill.

Unfortunately, this is not applicable to condominiums, since the energy produced by the renewable energy system, typically a photovoltaic system, cannot be distributed among the individual building units that make up the building, but according to the previous legislation, it can only be used for common areas, typically the condominium lights, the lift, or other similar elements. Obviously, the energy demand will never be comparable to that of a family of 3 or 4 people, and therefore, especially when dealing with a block of flats made up of many houses, this limit would lead to undersize the photovoltaic system in order to avoid feeding almost all the energy produced into the grid, and therefore benefit less than self-consumption.

It is precisely at this stage that we will talk about collective self-consumption, which was recently introduced by the "Milleproroghe" (1) decree, and which goes beyond the limit previously explained by allowing the distribution of the renewable energy produced to individual households, comparing: the times when energy is produced and fed into the grid; the times when energy is withdrawn from the grid.

The law provides for an incentive mechanism to reward individual citizens who behave in a virtuous manner, so who consume energy when the plant is producing, thus lowering grid losses and decentralising energy resources. In fact, the main idea is to create energy communities, so genuine energy districts, which will one day achieve self-sufficiency and further increase the share of renewable energy in the national energy mix.

Two case studies will be analyzed: a private house and a block of flats.
The projects were carried out on "Termus BIM", an energy analysis software from the "ACCA" package, and the individual models were created in their actual state (after an inspection) by inserting stratigraphies of the vertical walls and floors, fixtures, boiler for domestic hot water and heating, and then the terminals, to then create a project state, carrying out the energy efficiency measures, therefore applying a thermal coat, replacing the fixtures, boilers in favour of a heat pump and installing a photovoltaic system.
All these aspects will be dealt with individually later in this paper.

In conclusion, this project will demonstrate the strong reduction of energy needs and will finally bring economic analyses to show the benefits in terms of savings, and in some cases gains, in the case of the application of collective self-consumption and thus the implementation of energy communities in the future.

In addition, it was possible to assess the economic feasibility of the intervention, ensuring that all end-customers have access to available incentives to apply and carry out energy upgrading that brings them economic and environmental benefits for an emission-free and energy-independent future.

The study of greenhouse gas emissions has been on the European Union's radar for years, during which time measures have been taken to limit their production and safeguard the health of the planet and its inhabitants.

In 2009, a European directive (Directive 2009/28/EC) (1) was produced that established guidelines to promote the use of renewable energy, imposing mandatory national targets for the spread of renewable sources in energy consumption and transport.

Each member state had to adopt an action plan and provide it to the European Commission, indicating the path that would be followed to achieve the targets imposed by 2020, specifying strategies, actions, and legislative measures.

1.1 The Kyoto Protocol

It is worth starting with the Kyoto Protocol, an international agreement to combat global warming associated mainly with human activity on the planet.

The treaty was signed on 11 December 1997 but only came into force later in early 2005 thanks to the participation of Russia:

- The participation of at least 55 nations.
- These nations represented at least 55% of global production of CO_2.

These prerequisites are justified by the fact that action must be at the global level, as local restrictions would not solve the problem, which is of greater proportions.

Among the non-party countries, the most prominent is the United States, which continues to contribute 36.2% of global emissions of CO_2, the main constituent of the human ecological footprint.

The protocol required a reduction in emissions of climate-changing gases from the levels reported for each participant in 1990, with different limits depending on the country.

The gases in question are:

- CO_2 mainly produced by the use of fossil fuels.
- CH_4 produced largely from landfill, livestock. and crop production.
- N_2O produced by the agricultural and chemical industry.
- HFC and PFC products in the chemical and manufacturing industry.

This study will mainly focus on the former, as it will concentrate more on the civil sector, where emissions are mostly due to electricity and heat consumption.

In general, we always refer to CO_2, thus we consider a cumulative value that takes into account all the emissions produced, comparing the individual heating powers with that of CO_2.

As far as Italy is concerned, the targets set were to reduce emissions by 6.5% in the period between 2008 and 2012 (i.e. by about 33.9 MtCO2eq), a result that was not achieved, limiting us to 4.6% and thus bringing the production of climate-changing gases down from 519 to 460 MtCO2eq.

From the data reported in the NIR (National Inventory Submissions) Italy contributes to the production of climate-changing gases from different sectors, and as far as the civil sector is concerned it is around 18.5%, so the third most influential sector in this context, below only 'Transport' and 'Energy Industries'.

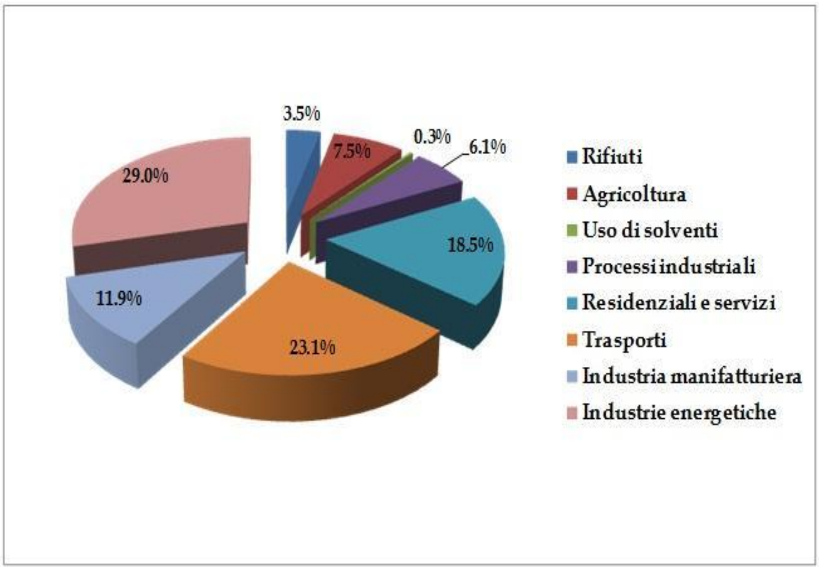

Figure 1-1 -National Italian Emissions of 2012 (26)

These latter sectors have already been targeted by the authorities by imposing increasingly stringent constraints to be respected in recent decades. Just consider the decarbonization policies that we are still following today, reducing the production of electricity from fossil fuels, which have a greater impact on the environment, such as coal, or the increasing diffusion of electric vehicles or vehicles powered by alternative fuels to the traditional ones on the market.

For the civil sector, on the other hand, the focus has been on optimizing the current state, so on energy efficiency aimed at reducing consumption and improving the energy performance of a building. Many incentives have been proposed recently (replacement of windows and doors, facade bonus, boiler replacement, installation of solar and photovoltaic panels, etc.) heading for achieving the primary goal of reducing consumption and therefore emissions, but it is only recently that we have begun to talk about “Renewable Energy Communities”, a mechanism capable of shifting energy production in situ, in places where there is a high demand for energy, thus reducing network losses and increasing the self-consumption of individual homes.

Specifically, the Kyoto Protocol on climate mitigation suggested measures to prevent and reduce greenhouse gas emissions, and also the promotion of compensatory forest uptake CO_2, as forest areas operate as carbon sinks, since they use their natural capacity to absorb carbon and immobilize it in the form of biomass.

It was envisaged that the achievement of the targets would be reached either through direct activities (such as those mentioned above), at national level, or also through 'Emission Trading', so exploiting the sale of carbon credits by other more virtuous entities.

This mechanism has been applied for example in Italy through the Green Certificates, introduced by the decree to liberate the electricity sector known as the “Bersani Decree”, which allowed companies producing energy from conventional sources, which were unable to meet the imposed limits of production from renewable sources (at least 2% of the energy produced from conventional sources in the previous year), to compensate for this shortfall by purchasing certificates issued by the state to virtuous producers, who guaranteed production from renewable sources, so as to reward them by increasing their revenues and facilitating competition on the market.

Article 2 of Legislative Decree no. 387/2003 defines renewable energy sources by limiting them to non-fossil sources (wind, solar, geothermal, wave, tidal, hydraulic, biomass, landfill gas, residual gases from purification processes and biogas). In particular, biomass means the biodegradable part of products, waste and residues from agriculture (including plant and animal substances) and forestry and related industries, as well as the biodegradable part of industrial and municipal waste.

The “Bersani Decree” (Legislative Decree N.79 of 16 March 1999) was the result of the transposition of Directive 96/92/EC of the European Parliament and of the Council of 19 December 1996 concerning common rules for the internal market in electricity. This introduced the free movement of electricity, while at the same time strengthening security of supply and industrial competitiveness.

The aim of liberalizing production is to introduce competitive mechanisms and management methods to encourage production efficiency, cost optimization and lower tariffs, all of which are entirely beneficial to the environment.

The Kyoto Protocol has therefore indirectly influenced climate change by increasing the international application of renewable technologies and reducing future emissions.

Furthermore, although some countries did not have strict restrictions, the introduction of an international agreement nevertheless stimulated a shift to new technologies in these countries, spurred on by an expectation of increased restrictions in the years to come.

1.2 The Paris Agreements

Until 2020, emission reductions were regulated by the Kyoto Protocol and were only mandatory for industrialized countries. Subsequently, other agreements were made to continue to incentivize emission reductions and technological upgrading.

The 21st meeting of the Conference of the Parties (Cop 21) to the Convention on Climate Change, held in Paris in December 2015, was attended by 195 states along with many international organizations to conclude the Paris Agreement on 12 December 2015. (2)

This agreement commits to keep the temperature rise as low as possible below 1.5°C compared to the pre-industrial level and entered into force with the signature of the European Union on 5 October 2016, thus reaching at least 55 countries that cover at least 55% of global emissions (share corresponding to the main emitters: China, USA, European Union, Japan, Brazil and India), and have deposited their ratification.
The next United Nations Climate Change Conference (COP26), postponed from 2020 due to the pandemic, is scheduled to take place in Glasgow in November 2021, with the aim of having every country adopt a transition plan to zero emissions by 2050.

Decarbonization of the energy sector is the most important component to take care of as 65% of global CO_2 production comes from burning fossil fuels. As can be seen from the figure, by 2015, electricity production had shifted to cleaner resources.

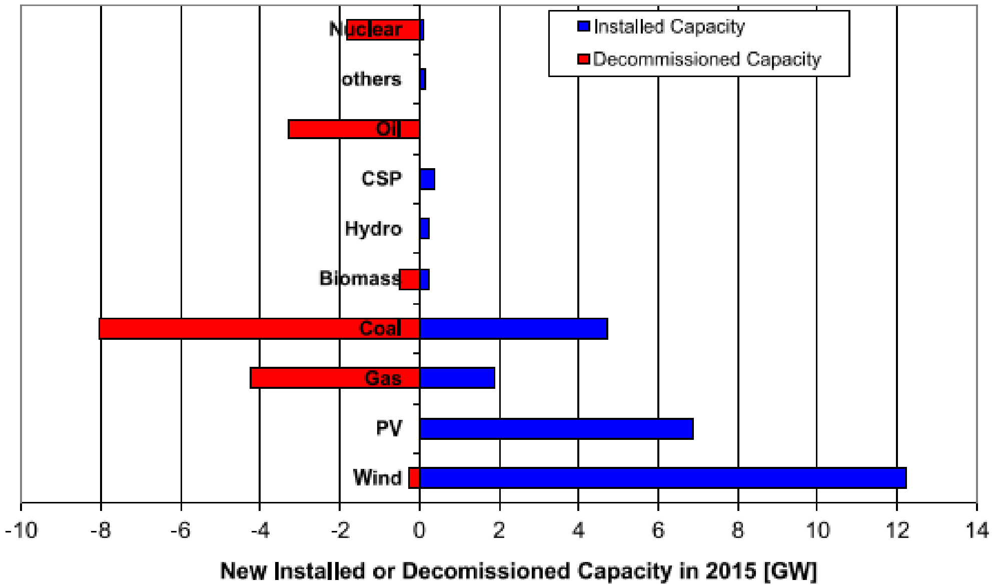

Figure 1-2 - New Connected or decommissioned electricity generation capacity in EU in 2015. (1)

Unfortunately, however, there are several structural obstacles to the use of all renewable sources, as the current European system promotes centralized production of energy from traditional sources, which risks not having a well-defined place in an energy transition scenario towards sustainable energy sources; furthermore, the electricity distribution system has been designed to operate unidirectionally from centralized units to consumers, while decentralized production, especially from renewable sources, requires bi-directional power flows.

In systems where the traditional infrastructure is well established, where there is no carbon tax, it is virtually impossible to expect a natural growth of the renewable market without the presence of policies that require renewable generation targets to be met by certain dates.

Within the European community, some support schemes were unable to keep up with the rapid growth of the renewable market, leading to strong changes of direction by governments in terms of both legal requirements and incentive schemes.

This led to installation peaks before the allocated deadlines and to a climate of uncertainty for investors, as several retroactive variations were also presented, obviously lowering the security for investment.

At the same time, however, one of the consequences of the ever-increasing installations of renewable systems (Figure 1-3) has been an increase in jobs and the local economy. The photovoltaic industry led to more than 260,000 jobs, or 38% of global employment in the photovoltaic sector in 2011 (3).
Much of this work was related to the installation and ancillary operations of photovoltaics and contributed to Europe's gross domestic product (GDP).

The European Union is currently aiming to achieve 27% of energy consumption covered

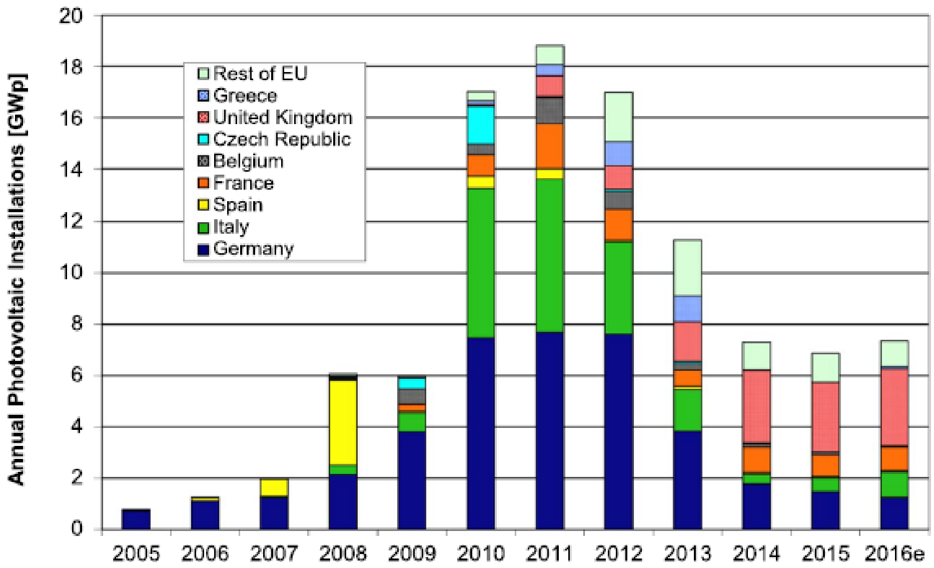

Figure 1-3 - Annual installations in the European Union. (3)

by renewable energy sources by 2030, which should reach around 1'700 TWh of production by that year, so around double the amount produced in 2014, and considering the development of costs in this sector, this is feasible both in economic terms and in terms of applicability.

1.3 The Italian Context

As mentioned above, there are many incentives proposed by the Italian government to increase renewable energy sources and energy efficiency in the civil sector.

Since the subject of this work is the study of RECs and cumulative self-consumption, paying more attention on the implementation of the last one, it is appropriate to focus more on the incentives of recent years that have contributed to the diffusion of renewable resources, especially for photovoltaic panels. As a matter of fact, renewable energies in Italy currently contribute to about 35% (4) of the national energy mix, one of the best results in Europe and in the world, but unfortunately without guaranteeing the total coverage of the national energy needs, thus leading to a demand of about 12% (5) from abroad.

Hence, encouraging self-consumption and the deployment of photovoltaic arrays on more and more buildings can help to close this gap in national demand, thus achieving energy independence.

It is therefore appropriate to make a brief summary (6) of the incentives proposed by the Italian State in this field, summarizing them as follows:

1. “Bonus Ristrutturazione”
2. “Ecobonus” e “Superbonus 110”
3. “Comunità Energetiche Rinnovabili” & “Autoconsumo Collettivo”

Details of the legal references listed above which are useful for the project are given:

1) Bonus Ristrutturazione 50% - art.16 bis del T.U.I.R. DPR 917/1986 (7)

Still in force and one of the main incentive mechanisms, it repaid 50% of the work carried out that fell under the decree, repaying it in 10 annual instalments.

Subsequently, the "Transfer of the tax credit" was introduced in the Growth Decree (August 2019), meaning that whoever buys the installation can transfer the right to receive the deduction to the company and the company makes an immediate 50% discount.

This, however, favored the large operators, distorting competition, to the detriment of small companies and damaging consumers, since not all small companies are able to provide this service, so that, by losing competition, there is a risk of entering a monopoly managed only by large companies (in addition, the final prices were raised to guarantee liquidity to companies, thus a counterproductive result in economic terms).

To solve this problem, the state has taken steps to include banks in the process, so that even small entrepreneurs can provide this service to end customers.

2) DECRETO RILANCIO 13 Maggio 2020:

It introduces the enhancement of the “ECOBONUS”, incentive mechanism for energy efficiency and building renovation, converted into “SUPERBONUS 110”, for expenditure between July 2020 and 31 December 2021 with certain conditionalities (8)

- Tax deduction spread over 5 years with availability of credit assignment to supplier or third party (banks) (9)
- Stand-alone systems excluded, so it is mandatory to connect to the national electricity grid.
- Expenditure must be incurred between 1 July 2020 and 30 June 2022.

- Incompatible with “Scambio sul Posto” but only with “Ritiro Dedicato”

3) DECRETO MILLEPROPROGHE - COMUNITA’ ENERGETICHE RINNOVABILI (REC)

The decree explains how the benefits of implementing a REC are to be divided into two main components:

- Tariff: Transport on higher voltage networks is avoided (avoided cost), transmission costs and part of the distribution cost are avoided, as production moves closer to consumption.
- Incentive: Citizens' virtuous behavior is rewarded in collective terms, i.e. for the energy that is fed into the grid when it is simultaneously consumed, they are entitled:
  - 100€\MWh for shared energy in an apartment building.
  - 110€\MWh for shared energy in RECs.

These above mentioned are some of the support schemes foreseen for the installation of photovoltaic panels, but together with these there are also schemes for the transfer of energy, which can be compared with the energy community:

Scambio sul posto:
It can be considered as a "partial refund" of the bills paid, in relation to the energy fed into the grid. It results as an economic compensation between input and withdrawals. The on-site exchange ultimately provides for two forms of contribution:

1. The contribution in “Conto Scambio” (Cs)
2. Any surplus, if the energy fed in is greater than the energy withdrawn in the current year.

To calculate the contribution of the on-site exchange, only two "readings" are needed, one for the energy fed in and one for the energy withdrawn.
The GSE uses the formula (1) to calculate the amount of contributions:

$$\mathbf{Cs = \min(Oe\ ;\ Cei) + CUsf \times Es} \qquad (1)$$

where:

Cs	"Contributo in Conto Scambio"
Oe	"Onere dell'energia prelevata dalla rete."
Cei	"Controvalore dell'energia immessa in rete."
CUsf	"Corrispettivo Unitario di scambio forfetario."
Es	"Quantità di Energia scambiata"

Table 1-1 - Explanation of each term of the formula above.

The "**Onere energia"** (Oe) is expressed in euros and is the price of the energy paid in the bill (the "energy share" only), i.e. the PUN, the Single National Price, which is an hourly and zonal average of the variable prices recorded day by day on the Power Exchange. The PUN varies between 4 and 6 cents per kWh on average.

The "**Controvalore dell'energia immessa"** (Cei) is also the price of energy, expressed in euros, but calculated in the reference area and according to the times at which it is fed into the grid. It too is on average around 5-6 $^{c€}/_{kWh}$, but can vary considerably depending on the region and the times at which the energy is fed into the grid.

The "**Corrispettivo Unitario di scambio forfetario"** (CUsf) on the other hand, is a parameter, expressed in euro cents, which quantifies certain grid costs and general system charges normally paid in the bill. This is the parameter that "identifies" the advantage of on-site exchange, reimbursing part of the "fixed" costs paid in the bill by the user. The fee is indicated in tables published by the Authority (year 2018) and, for the small LV domestic user, ranges from 5 to 20 $^{c€}/_{kWh}$.

Finally, the **energia scambiata"** (Es) expressed in kWh, is simply the minimum value between inputs and withdrawals.

Ritiro Dedicato:

The sale takes place through the "Gestore dei Servizi Energetici" (GSE), which acts, in this context, as buyer and intermediary between the producer and the energy market. Obviously, the owner of a photovoltaic system can choose whether to sell the entire amount of energy produced or to use part of it for his own domestic needs and sell the excess to the GSE.

This mechanism provides "guaranteed minimum prices" as a method of remunerating energy (hourly zonal average price).

This service has a cost that depends on the installed power and covers the management, verification, and control charges (10).

The price paid to producers depends on the type of plant and any additional incentives recognized on it, if the plant is:

- renewable source, not incentivized, with a capacity of up to 1 MW.
- incentivized photovoltaics with a capacity of up to 100 kW.
- incentivized hydroelectricity with an efficient power output up to 500 kW.
- the producer can request the application of the Minimum Guaranteed Prices (MGAs), which are set annually by the Authority for Electricity, Gas and the Water System and are differentiated by source and energy bracket. In all the other cases, so if the plant is:
- incentivized, based on renewable energy sources with a capacity of up to 1 MW (excluding the above cases);
- incentivized or not, based on renewable energy sources with a capacity exceeding 1 MW.

The price recognized is the hourly zone price (PO), i.e. the price formed on the electricity market which varies according to the time at which the energy is fed into the grid and the market zone in which the plant is located.

For plants for which PMGs are applied, an annual adjustment, if positive, is foreseen with the application of POs; in this way producers are in any case remunerated with the most advantageous price.

1.3.1 Energy Sharing In Italy

Having said that, the European and Italian context is now the most important topic. This paper stems from the need to address an urgent, necessary, and pressing issue: the energy transition, understood as the construction of a new model of social organization based on the production and consumption of energy from renewable sources. For this to be effective, cultural changes, both material and immaterial, must be triggered, based on energy saving and consumption efficiency.

New sustainability and decarbonization objectives play a key role in the evolution of energy infrastructures.

In such a scenario, the activation of new forms of collective action and collaborative economies (in which production and consumption give rise to new systems of exchange), together with the opportunities offered by new digital technologies, are the cornerstones of the energy transition, as well as representing an opportunity for the creation of new green economy models.

While the energy transition is necessary in terms of environmental sustainability, it will not be fully realized without a joint management of environmental, social and economic issues using a co-evolutionary and interactive approach, given the inseparability and mutual influence of social and technological change.

All this leads us to reflect on how it is possible to live together with our 'neighbors' and the environment that hosts us, seeking new methods that are increasingly complex, but which take their cue from basic and simple models such as that of community: peaceful cohabitation between people and the environment.

Evolution is pushing towards more sustainable modes of production and consumption based on distributed generation and reversing the current pattern of a high-carbon society that has led to geopolitical instability, inequality, and social inequity.

However, what interests us is that this new transformation of the model constitutes the system in a different way: user system as energy infrastructure.

By exploiting technological opportunities, private citizens have the chance to unite to regain relevance in the energy sector, putting themselves at the forefront as energy prosumers for a fairer and more sustainable system.

The European Commission on 28 November 2018 adopted a long-term strategic vision for a prosperous, modern, and competitive zero climate impact economy by 2050, basing this development on network infrastructure linked to the decarbonization process to optimize the process.

This innovative scheme underpins energy evolution, and in view of the reduction of carbon emissions in the electricity sector, it is estimated that 264 million EU citizens will join the energy market directly, generating up to 45% of the system's total renewable electricity within 30 years.

The importance of user systems based on achieving decarbonization targets, and of energy production and consumption models, which are a non-negligible variable in the evolution of the system, will be the basis for innovation in the coming decades. All this will happen if energy increasingly takes on a local connotation, based on models of user systems and original markets, which cooperate and exchange energy between users, according to the logic of territorial proximity.

The issue is that energy is increasingly taking on a local connotation, as nearby energy is needed to achieve the objectives: solar must be developed locally, to avoid transport and the losses associated with it.

The new development of the infrastructure system is a system with direct participation of citizens thanks to the user systems: in the standard model, different tariffs are paid (grid charges, system losses), while in the new scheme individuals are part of the development, thus saving part of the tariffs and reducing system losses. Consumers are involved in managing their energy production and consumption in a conscious way, thus becoming prosumers.

The term prosumer is used to refer to the user who does not limit himself to the passive role of consumer, but actively participates in the various stages of the production process (producer). In practice, the prosumer is someone who owns his own energy production plant, of which he consumes a part. The remaining energy can be fed into the grid, exchanged with consumers physically close to the prosumer or even stored in a appropriate system and then returned to the consumer units at the appropriate time. The

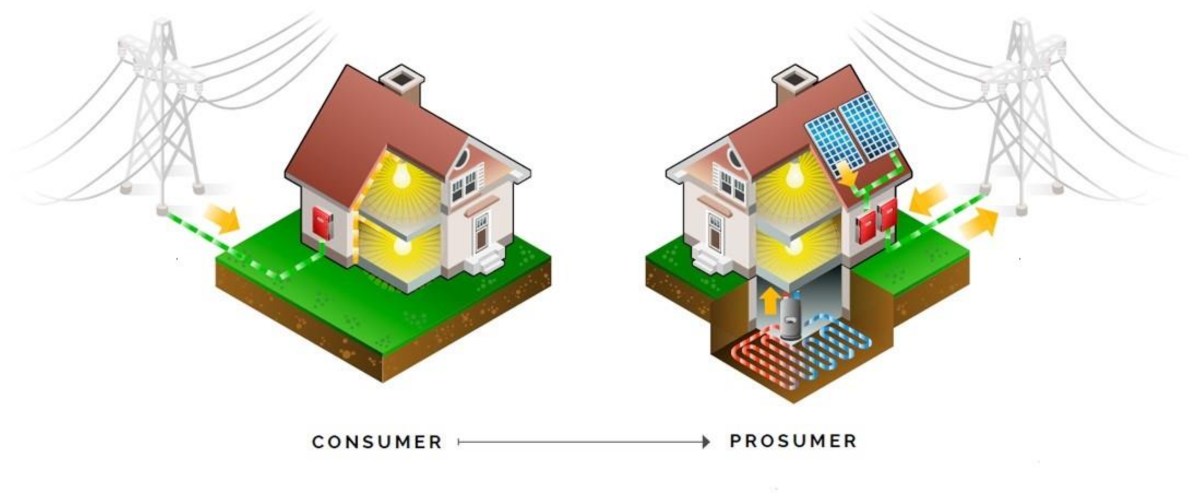

Figure 1-4 - Consumer (Consumatore) vs Prosumer (Producer-Consumer) prosumer is therefore an active player in the management of energy flows and can enjoy not only relative autonomy but also economic benefits (11).

This innovative “presumption” project (end-customer producing and consuming energy) can be implemented through Energy Communities (EC), so a set of users who, through an internal statute based on open and voluntary participation, collaborate with the aim of producing, consuming, and sharing energy through one or more local facilities.

The concept of community that underpins this innovative project is based on the principles of sharing within communities of interest and communities of place the development of renewable energy production and the economic and social benefits derived from it. On this basis, energy communities are all united by a single objective: to provide renewable energy at affordable prices to their members, without basing their business on economic profit but on the environmental and social benefits that follow.

1.3.1.1 The Role of Self-Consumption

Energy communities, changing the structure of the current energy model, base their energy production on decentralization and localization, involving citizens, businesses, and enterprises in the area, with a view to producing, consuming and exchanging energy, based on the concept of self-consumption and collaboration.

Self-consumption is a concept of consuming energy directly produced on site by a local generation plant to offset the energy needs of the community. The prosumer, who produces, stores and consumes local energy, has the opportunity to directly contribute to the sustainable development of the country towards a transition and development of renewable energy.

Currently, self-consumption can be implemented either privately or collectively in apartment blocks (collective self-consumption) or energy communities. All this is supported by the wide diffusion of distributed generation, thanks also to many incentives (as previously mentioned) that allow the diffusion of photovoltaic systems, making more and more possible the production and consumption of energy within neighborhoods and districts, always based on the principle of electrical proximity: energy communities that fall within the same medium and low voltage network (all connected users must be subtended to the same MV/LV transformation cabin).

In Italy, the law in force establishes a general system for the payment of grid and system charges, which uses as a basis only the electricity exchanged with the grid, thus establishing a method of sharing the energy exchanged.

Upstream of the point of exchange (POD: Point of Delivery) with the grid on the user's side, systems for the direct production and consumption of production (self-consumption systems) can be set up provided that these systems are "simple", i.e. involving of a single user and a single producer (even if different from the user). Simple systems consist of a single user and a single producer and energy sharing is allowed as long as the system does not constitute a network.

This means that complex systems, so a distribution network, which directly connect several users and producers, cannot be set up, except for closed distribution systems (CLS), which are electricity distribution networks. TSOs, which are defined in Directive 2009/72/EC (EU) and Directive (EU) 2019/944, are to all intents and purposes distribution networks for which production and distribution enjoy their own tariff incentives. They are a system that distributes electricity within a geographically limited industrial, commercial or shared services site and, subject to certain special conditions (mentioned in Article 38(4) of the Directive) and does not supply household customers except in certain special cases (12).

1.3.1.2 Self-Consumption of Renewable Energy

The end customers, electricity consumers, can now join together to produce locally, through renewable sources, the electricity necessary for their needs, "sharing" it. This is thanks to the entry into force of Decree-Law 162/19 (Article 42bis) and its implementing measures, such as ARERA's Resolution 318/2020/R/eel and MiSE's Ministerial Decree of 16 September 2020.

A self-consumer of renewable energy is defined as a "final customer who, operating on its own sites within defined boundaries, produces renewable electricity for its own consumption and may store or sell self-produced renewable electricity provided that, for a self-consumer of renewable energy other than a household, these activities do not constitute its principal commercial or professional activity". The production installation of the self-consumer of renewable energy may be owned and/or operated by a third party, provided that the third party remains subject to the instructions of the self-consumer of renewable energy (13).

1.3.1.3 Final Customer

The end customer is the consumer who purchases electricity and/or natural gas for his own use and is connected to a distribution network with access to third parties. The end customer is characterised by the characteristics of the electricity or natural gas supply and on this basis the following types of end customer are envisaged (14):

- final customer of low voltage (LV) electricity - subject of energy communities.
- non-domestic low voltage (LV) electricity end-customer.
- final customer of medium voltage (MV) electricity.
- low-pressure natural gas end-customer (BP).

- end-customer of electricity (LV domestic, LV non-domestic or MV) and natural gas (BP) with a single contract (dual fuel).
- Finale Customer "multisito".

The plant typology known as "Efficient User System" was introduced by Legislative Decree 115/08 and subsequently Resolution 12 December 2013, 578/2013/R/eel was issued, regulating the related connection, metering, transmission, distribution, dispatching and sale services. In particular, the SEUs, which will be described in the following paragraph, are the basis on which new models of energy sharing such as collective self-consumption and energy communities are developed.

Efficient User System (Seu)

The Authority for Electricity and Gas (the Aeeg) defined SEUs in Resolution 578/2013/R/eel (12/12/2013). This resolution actually regulates the "more generic" simple production and consumption systems (SSPC), which include Efficient User Systems (SEU).

The efficient consumer system is by definition "a system in which one or more electricity production plants, installed on the same site, powered by renewable sources or in high-efficiency cogeneration mode, operated by the same producer, possibly different from the final customer, are directly connected, via a private connection with no obligation to connect third parties, to the consumption unit of a single final customer (natural or legal person) and are built within an area [...], owned or fully available to the same customer and made available, in part, to the producer or owners of the relevant production plants. owned by or fully available to that customer and made available, in part, to the producer or owners of the relevant production facilities” (13).

Thus, the SEU is to be considered an electricity grid and the self-consumer is realized through this scheme. If in the absence of this model, the producer sold electricity to the authorities (in the Italian case the GSE), and the GSE sold the purchased energy to the general electricity market, now the producer can sell directly to the final consumer with the advantage of bypassing the grid, some intermediaries and part of their usage costs.

Thus, using the SEU scheme is convenient both for the producer, because the distributor is not obliged to charge a tariff service described by the authorities, and for the final consumer who buys at a convenient price. However, SEUs are simple distribution systems consisting of large, ground-based installations available to major users, such as factories and energy-intensive companies (15).

Definition Of Consumption Units

The consumer unit (CU) is the set of electricity consumption facilities connected to a public grid such that, the total electricity withdrawal, related to the already mentioned set, is used for a single use or production purpose. It is normally the same as the individual building unit.

It is possible to aggregate several building units into one consumption unit in the following cases:

- real estate units in the full possession of the same natural or legal person that are linked together by an appurtenance bond (main building unit and its appurtenances) and that insist on the same cadastral parcel or on contiguous parcels.
- appurtenant building units (attics, garages, cellars), even in the possession of different natural or legal persons, which are part of a single condominium. This set of appurtenant building units may in turn be included in the consumption unit relating to condominium utilities.
- real estate units at the full disposal of the same legal person, possibly made available by the latter to third parties, located on contiguous cadastral parcels, within a single site and used for the production of goods and/or services intended primarily for the realization, on that same site, of a single final producer and/or service.

From this last definition it is visible how the concept of SEUs is at the basis of new models of sharing such as energy communities: SEUs are at the basis of CERs.

The SEU site may involve several contiguous cadastral parcels (parcels are defined as contiguous if they are adjacent to each other) provided that, they are owned by the same natural or legal person. Ownership is defined by the full availability of an area:

- right to property
- other titles such as right of superficies or usufruct, or contractual title such as a commodity loan or lease contract
- the easement title is not capable of holding an area in full availability.

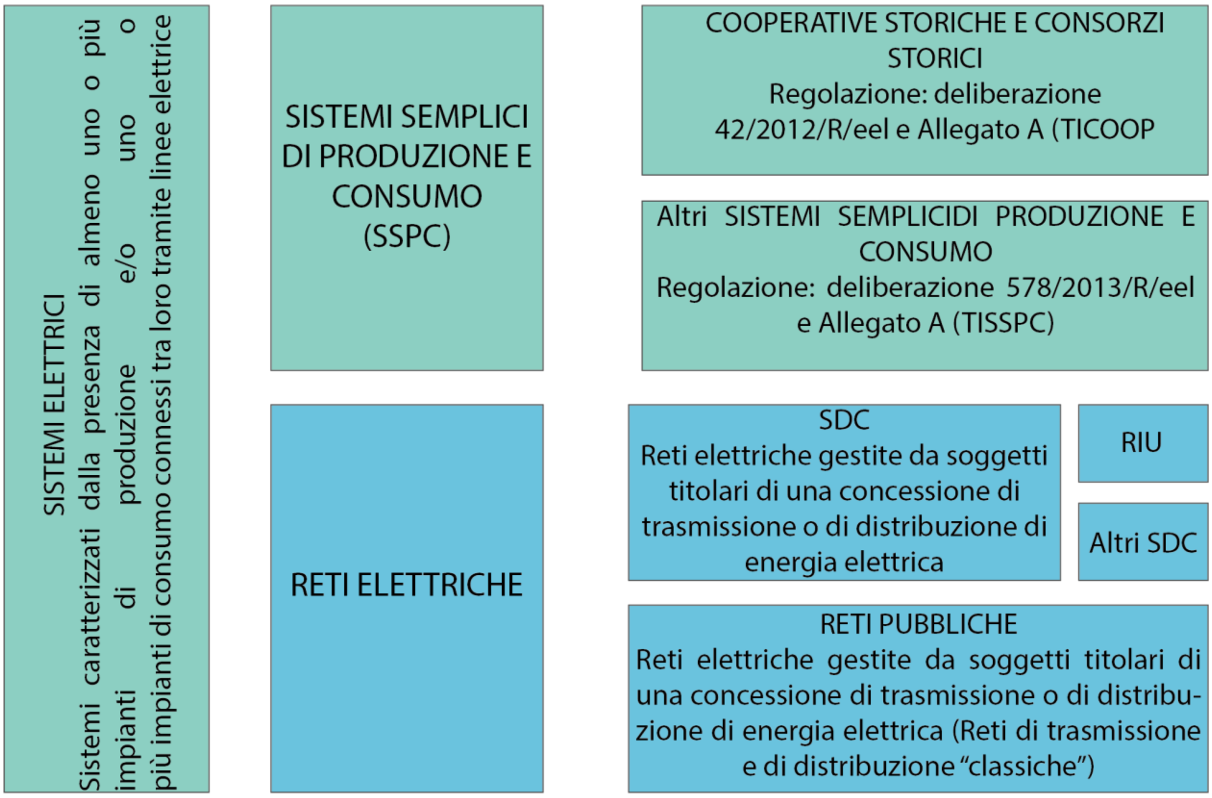

Figure 2-1 - Electrical systems defined in DCO 644/2012

These already mentioned networks, which constitute the national network, have, by definition, two important obligations to comply with, which also apply to new REC configurations. In particular, they describe the "freedom" of consumers to connect and choose their distributor. The obligations to be met are as follows:

1. Third-party connection obligation network: a network operated by an operator who has an obligation to connect all parties who request it. All public networks are must-connect networks. TSOs are must-connect networks limited to connectable users, so those users that do not result in the TSO definition being no longer met.

2. Compulsory Open Access Network: An electricity network operated by an operator that has an obligation to allow users connected to its network to exercise their right to free access to the electricity system. All TSOs are networks with an obligation of free access to the electricity system. This obligation is fulfilled by guaranteeing each user of a TSO, as an alternative:
    a. access to the free electricity market only and the possibility of being able to use a sales company other than the one historically operating in the TDC, while remaining a TDC user.

b. access to the electricity system in all its parts, becoming to all intents and purposes a user of the public network (guaranteeing access to the tariff treatment in force on the public networks, the technical connection rules laid down on them, as well as all the other services that are compulsory on them, including access to the free market).

Free access to the market is the core concept of the new experimental schemes underway that will give rise to the innovation of energy communities and models of collective self-consumption.

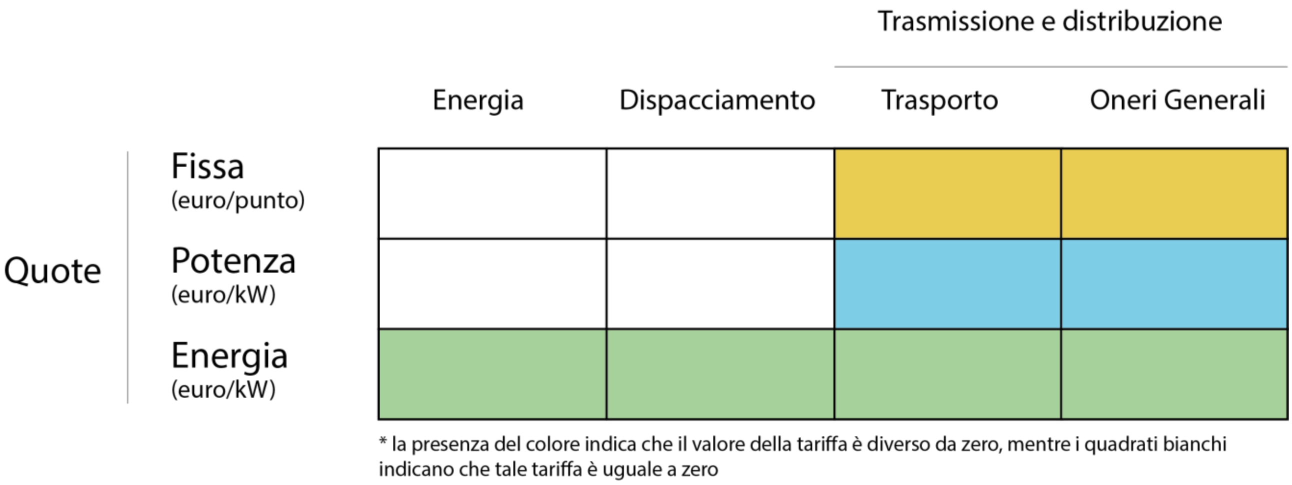

Figure 2-2 - Electricity tariff structure in Italy

The innovative development of these new electricity system models also includes avoided charges due to self-consumption, which are as follows (as seen in the white boxes in the figure):

- variable components of the transport service (transmission/distribution)
- the dispatching charge
- variable components of general charges

Similarly, the charges avoided within a TDI are all but dispatching.

2.1 New Context and Perspectives

The European Union guidelines are based on the "Clean Energy Package for All Europeans" (CEP) which consists of eight Directives regulating energy issues based on the concepts governing the electricity market of energy performance and efficiency in buildings and renewable energy.

The aim of these EU directives is to put in place the appropriate frameworks to enable the achievement of the objectives of reducing emissions and consumption by putting citizens first in the energy sector. Each country must transpose these directives into national law and for Italy the deadline is June 2021.

Among the eight directives of the CEP, the two that affect energy-sharing communities are the following:

- the Renewable Energy Directive (16), in which the definitions of collective self-consumption and Renewable Energy Communities (RECs) are given.
- the Directive on the internal electricity market defining the Citizens Energy Community (CEC).

The main difference between CERs and CECs is based, as far as CERs are concerned, on the principle of autonomy between members and the need for proximity to generation facilities. Moreover, the energy produced can be in different forms (electricity, heat, gas) as long as they are generated from renewable sources. On the other hand, as far as the CEC is concerned, the concept of proximity does not exist, and it manages electricity produced from both renewable and fossil sources.

In particular, Article 21 of the Renewable Energy Directive (2018/2001) defines the concepts of collective self-consumption in a condominium context based on providing electricity to more than one consumer. When self-consumption goes beyond the concept of a single building or condominium, energy communities (CERs) are addressed.

The result of these directives, in addition to achieving the set objectives, is to involve individual users in an active way and thus unite 'small' consumers to join the energy market.

Italy transposed the EU Directive 2018/2001 with the “Decreto Milleproroghe” (converted into law n.8/2020 on 29 February 2020), describing the concept of collective self-consumption and energy communities in Article 42-bis and launched an experimental scheme to test the functioning of this law.

2.2 Individual and Collective Self-Consumption

According to the “Decreto Milleproroghe”, collective self-consumption is made up of several consumers of renewable energy located in the same building and the generation plants can also be third parties.

In particular, the RED II Directive (17) defines individual or collective self-consumers as follows:

- A self-consumer of renewable energy is a final customer who, operating on its own sites within the defined boundaries or, if allowed by a Member State, on other sites, produces renewable electricity for its own consumption and may store or sell self-produced renewable electricity provided that, for a self-consumer of renewable energy other than a household, these activities do not constitute its principal commercial or professional activity.
  Thus, the self-consumer is the final customer who corresponds to the consumption unit that coincides with the building unit.
- Self-consumers of renewable energy acting collectively: are a group of at least two self-consumers of renewable energy acting collectively within the meaning of point 14 (describing the definition of self-consumer) and located in the same building or condominium.

Several subjects within a building are classified as a set of self-consumers, but are never defined as a single subject.

In the landscape of self-consumption and energy sharing, it is important to define the figure of the "active customer", which is described in EU Directive 2019/944. It is effectively a final customer or a group of pooled final customers that consumes or stores electricity produced on their own premises within a defined area or, if allowed by a Member State, on other premises, or sells self-produced electricity or participates in flexibility or energy efficiency mechanisms, provided these activities do not constitute their main commercial or professional activity.

The active customer is not defined by the type of energy produced, so it does not necessarily have to be renewable energy.

2.2.1 Benefits Of Collective Self-Consumption

In Italy, to promote energy sharing, the "Decreto Milleproroghe" (18) defined, as mentioned above, two different benefits agreed by ARERA and MISE: a tariff benefit and an incentive benefit.

The tariff benefit is due to the concept of electrical proximity avoidance and electrical compensation (as there is no change in flow). Thus, the transport of this energy on higher networks, which entails losses, is avoided, except in case of flow reversal. General system charges apply to energy withdrawn from the public grid by final customers, including shared energy (the benefit of self-consumption is only applicable to that achieved individually by each person).

ARERA identifies the value of the regulated tariff components, as well as those related to the cost of the energy raw material, which are not technically applicable to shared energy, as energy instantaneously self-consumed on the same portion of the low-voltage grid and, for this reason, comparable to physical self-consumption on site.

The MISE defines an incentive tariff for a maximum period of use aimed at rewarding instantaneous self-consumption and the use of storage systems in a modulated manner among the different configurations eligible for incentives to ensure the profitability of investments.

The avoided cost is not quantifiable in advance, but is based on different voltages and averaged over the transport, transmission, and distribution section: transmission is avoided in total, distribution is avoided in part. All avoided costs have been assumed by the authorities.

The premium incentive described by MISE for energy sharing is 100 $€/MWh$ in the context of collective self-consumption.

More specifically, the unit amount to be refunded is defined, on an approximate and lump-sum basis, as the sum of the TRASE component defined for low-voltage users (equal, for the year 2020, to 0.761 c€/kWh) and the highest value of the variable distribution component defined for BTAU users (equal, for the year 2020, to 0.061 c€/kWh).

The amount of avoided losses recognized is 1.2% in the case of plants connected to medium voltage networks and 2.6% in the case of plants connected to low voltage networks. The avoided losses that will actually be recognized are valued at the hourly zonal price.

Thus, the total amount to be refunded is equal, on an hourly basis, to the sum of two terms:

- The product of the unit amount to be refunded (totaling, for the year 2020, 0.822 c€/kWh) and a quantity of electricity injected by the production plants and the total electricity withdrawn from the connection points forming part of the same building or condominium owned by end customers belonging to the group of self-consumers acting collectively or who have issued a release for the use of their measurement data.
- The product of the coefficient of avoided losses (1.2% or 2.6%), the hourly zonal price and a quantity of electricity equal to the minimum between the electricity fed in by the production plants and the total electricity withdrawn from the connection points referred to in the previous point and connected at a voltage level equal to or lower than the voltage level of the production plant.

The formula (2) is used for calculating the contribution for shared electricity valorization (C_{AC}):

$$C_{AC} = CU_{Af,m} \times E_{AC} + \sum_{i,h} (E_{AC,i} \times C_{PR,i} \times P_z)_h \qquad (2)$$

In which:

- "E_{AC}" is shared electrical energy.
- "$CU_{Af,m}$" is the monthly flat-rate self-consumption charge.
- "$C_{PR,i}$" represents the coefficient of avoided losses.
- "P_Z" is the hourly zonal price.
- "i" is the reference voltage level.
- "h" is the reference time.

2.3 Energy Community

On the other hand, the provisions concerning energy communities describe that, participating entities must produce energy for their own consumption with renewable energy installations of not more than 200 kW. The energy is shared using existing distribution networks using forms of virtual self-consumption. In addition, renewable energy communities have the constraint of being formed by consumers located in the low voltage electricity grid, under the same low/medium voltage transformation cabin.

In particular, in the same way as for collective self-consumption, the EU Directive 2018/2001 (RED II) defines the energy community which has the obligation to respect certain constraints imposed by law. Indeed, the energy community is a legal entity:

- Which, in accordance with the applicable national law, is based on open and voluntary participation, is autonomous and effectively controlled by shareholders or members who are located in the vicinity of the renewable energy production facilities owned and developed by the legal entity in question.
- Whose shareholders or members are natural persons, SMEs or local authorities, including municipal authorities.
- Whose main objective is to provide environmental, economic or social benefits at community level to its shareholders or members or to the local areas in which it operates, rather than financial profits.

As the energy community is a sub-set of the citizens' communities, the EU Directive 2019/944 (as summarized in the figure 2-3) defines the latter as containing the definition of Renewable Energy Community.

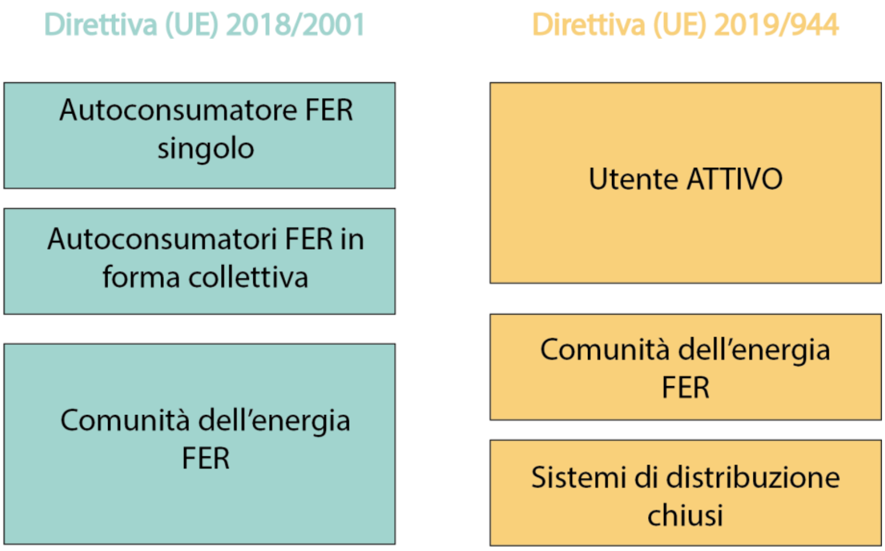

Figure 2-3- Definitions within EU Directive 2018/2001 and EU Directive 2019/944

In fact, the community of citizens (19) is a legal entity that in addition to the characteristics of "REC" allows participation in energy generation also from nonrenewable sources.

Since the energy community is defined as a legal entity, it must respect the aims and principles of governance, which assign powers to the shareholders and members of the community, as well as the principle of proximity of production and consumption facilities: the principle of electrical proximity.

The relationship between the energy community and the participants is important and is based on the community's key elements such as the voluntary nature of participation, the maintenance of the right of free access to the system, and the incompressibility of the rights and obligations of the participants with regard to their profile as end customers. The element that unites all these three key concepts is the public network. The above is achieved by maintaining a point of connection to the network with an obligation to connect third parties at each user.

2.3.1 Benefits Of “REC”

The energy shared within the energy community is equal to the minimum, in each hourly period, between the electrical energy produced and fed into the grid by the community plants and the electrical energy withdrawn by all associated members. Energy is considered to be shared for instantaneous self-consumption also through storage systems (20).

The premium incentive described by MISE for energy sharing is 110 €/MWh within energy communities.

As in the case of collective self-consumption, the unit amount to be refunded is defined, on an approximate and flat-rate basis, as the sum of the TRASE component defined for low-voltage users (equal, for the year 2020, to 0.761 c€/kWh) and the highest value of the variable distribution component defined for BTAU users (equal, for the year 2020, to 0.061 c€/kWh).

The amount of avoided losses is not recognized in the RECs.

The total amount to be refunded is equal, on an hourly basis, to the amount of:

- The product of the unit amount to be refunded (totaling, for the year 2020, 0.822 c€/kWh) and a quantity of electricity injected by the production plants and the total electricity withdrawn from the connection points forming part of the same building or condominium owned by end customers belonging to the group of self-consumers acting collectively or who have issued a release for the use of their measurement data.

In conclusion, the evolution of the Italian energy structure has undergone several transformations aimed at increasingly localizing the energy market. Thanks to various national directives, it has been possible to establish energy production and consumption while maintaining a relationship of electrical and geographical proximity. This makes it possible, on a large scale, for user systems to reduce energy costs but above all to reduce losses and cut consumption in order to achieve the objectives set by the European Union. The appendix summarizes the legislative process and the evolution of the law that has led us to energy communities.

3 INTERVENTIONS TO REDUCE ENERGY REQUIREMENTS AND URBAN RENEWAL

This chapter will be devoted to the study of the type of interventions that facilitate or increase collective self-consumption and contribute to urban regeneration. In today's increasingly complex society, the process of urbanization of the territory generates the need to organize a development process that can accommodate different cultures and communities. New smart city models must be based on the concepts of a safe, efficient, sustainable, and citizen-friendly city. This innovative development takes into account climate change, the rapid rise of the urban population and the need to reduce consumption leading to scarcity of energy and water resources and a disproportionate increase in CO_2 emissions.

The use of new technologies to address environmental issues and achieve the emission reduction targets set by the European Union must be supported by integrated planning. Sustainable development, low environmental impact and energy efficiency are the fundamental characteristics of the city of the future. Exploiting photovoltaic technology to produce renewable energy is a step towards renewal, but it must coexist with other technologies that support intelligent development.

Installing photovoltaics and taking advantage of tax deductions can lead to a halving of the payback time on the investment or, in other words, a halving of the actual costs. On the other hand, those who install heat pumps, change their windows and doors, or put in a thermal coat, can obtain even greater advantages. These energy savings can lead to a clear improvement in the performance of the building, lowering its energy needs and increasing the final value of the property.

Based on current incentives, it is possible to install technologies powered totally or partially by renewable sources, but the most important thing is to be able to make different forms of integrated production coexist.

The innovation process must start from the existing as increasing the built-up area is not the right way to urban regeneration. Neighborhoods in urban areas must be regenerated and integrated with innovative technologies based on renewable energy production. The energy community model is the starting point for localizing energy and reducing losses and consumption. Based on this development, other supporting technologies must be integrated to achieve electrification of buildings. The technologies to be integrated on the basis of energy sharing are mainly heat generators such as heat pumps, which are powered by solar energy, and, for urban and architectural redevelopment, the ventilated wall to reduce the needs of the building system. If an integrated design is applied with the aim of achieving the nZEB model, emission reductions are possible within the set time frame.

In the following chapters we will introduce the technologies of ventilated walls, heat pumps and solar panels to support urban and architectural regeneration by exploiting incentives and benefits to accompany social and economic development.

3.1 The Ventilated Wall

The ventilated wall is a closure system technology consisting of an external cladding layer, a cavity, an insulation layer and a support layer. The application of a ventilated façade improves the thermal performance of the envelope and the technical and architectural characteristics of the façade. Generally used to improve thermal and acoustic insulation and as a barrier to weathering, it can also change the architectural image of a building through the use of innovative cladding.

The technological system of the ventilated wall consists of an external cladding which can be of various shapes (slabs, panels, tiles, staves) and materials (stone, brick, ceramic, concrete, wood, metal, plastic). This cladding is supported to the load-bearing masonry by means of a secondary mullion and transom structure, which in turn supports, in some cases, the insulating panels. In other cases, the insulation layer is supported by dowelling or gluing directly to the masonry of the building.

Between the insulating layer and the external cladding panels there is an air cavity that allows natural (sometimes forced) circulation, activated by the temperature difference between the upper and lower parts of the cavity. The air flow, which depends on the external climatic conditions and the technical and dimensional characteristics of the system, determines various benefits to the hygro-thermal behavior of the building. In fact, this technology allows the reduction of unwanted heat input during the summer season, the limitation of heat loss due to thermal bridges and the formation of water vapor and interstitial condensation during the winter season (20).

Ventilated wall cladding systems, depending on how they work, can be divided into two main categories:

- Medium or strongly ventilated walls (ventilated veneers) provide both the advantages of high resistance and low sensitivity to the action of driving rain and make it possible to implement and optimize the thermo-energetic performance of the opaque wall, especially in the summer season and to a lesser extent in the winter season. The advantages have their effect if the sizing of the cavity, based on the external conditions, is correctly carried out guaranteeing the movement of air in and out, giving rise to the "chimney effect". In the winter season, on the other hand, the advantages of the ventilated wall consist of faster evaporation or disposal of water and humidity, reducing the probability of surface and interstitial condensation.

- Micro-ventilated veneers: these also provide high resistance and low sensitivity to driving rain and have the same thermal and energy performance as heavily ventilated walls, but a more generous insulation layer must be considered. In addition, the design is simpler as there are no air inlet and exhaust grilles in the cavity.

The performance and requirements of the ventilated wall are described below.

3.1.1 Ventilated Wall Characteristics and Performance

The main features of the benefits and advantages of installing a ventilated wall are summarized in the points below and explained in more detail in the following chapters:

- Water Shielding
- Sound insulation and absoprtion
- Thermal insulation
- Hygro-sensitivity
- Seismic Resistance
- Durability, maintainability, and sustainability

3.1.1.1 Water Shielding

Ventilated wall cladding systems have the function of protecting the building, particularly the masonry, from the action of driving water. In fact, they have a good propensity to shield the building from the action of wind and water, thanks both to open joints between the cladding elements and to the physical discontinuity between the solid masonry and the cladding: the air gap (not less than 2-3 cm).

This technology prevents rain from consistently wetting the layer of insulation on the wall behind, thus preventing a reduction in physical performance and the formation of deterioration on the wall.

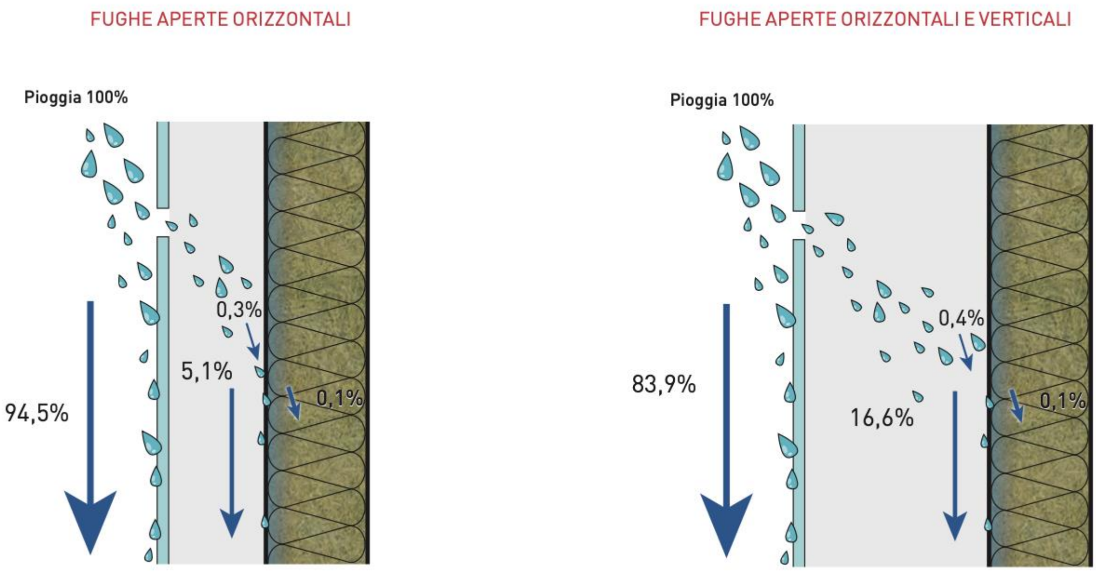

Figure 3-1 - Example of a micro-ventilated wall and the percentage of water that can penetrate.

In order to perform these functions, the air space must be continuous in its vertical development and, importantly, it must not be subject to a pressure significantly lower than that present on the external face of the cladding.

Otherwise, the water would be easily sucked in, ensuring exactly the opposite result.

To equalize the pressure between the interior (in the cavity) and exterior, it is important to leave the vertical and horizontal joints between the cladding elements open.

However, in the event of heavy rainfall, a small amount of water may penetrate and reach the insulation layer. For this reason, the panels behind must be continuous on the façade without interruption, and then, thanks to the moving air in the cavity, the moisture is easily evaporated.

3.1.1.2 Sound Insulation and Absorption

Among the comforts required in a building, the acoustic well-being of the interior is of great importance. In Italy, since the entry into force of the D.P.C.M. 05/12/1997, certain requirements must be respected, such as the evaluation index of the acoustic insulation of the façade normalized with respect to the reverberation time ($D_{2m,nT,w}$). This parameter, which depends on the soundproofing power, is calculated as the difference in sound pressure outside (2 meters from the façade) and the sound pressure inside, and basically measures the ability of the cladding to shield sound waves.

In particular, the UNI EN ISO 140-5:2000 standard "Acoustics - Measurement of sound insulation in buildings and building elements - In situ measurement of airborne sound insulation of façade elements and façades", provides for the measurement of airborne sound insulation of a façade according to two methods: global with road traffic and with a loudspeaker. The sound insulation between the external and internal environment depends on the soundproofing power of the individual components that make up the shielding or cladding.

However, in order to evaluate the soundproofing power of a complex covering analytically, it is necessary to quantify its compound apparent soundproofing power in relation to the soundproofing power of each element. This index, R'_W, is obtained by comparing the experimental curve of the solution with the standard reference curve, given by the UNI EN ISO 717-1:2013 standard (21).

However, due to the great complexity of determining the exact transmission of airborne sound through a closure element in an analytical manner, it is possible to divide closures into three categories:

- Single or single-layer elements: a single solid and relatively homogeneous element such as solid, semi-solid, perforated, hollow brick walls, precast reinforced concrete panels.
- Double elements with air chambers as dry stratified curtain walls separated by an air gap.
- Multilayer elements: made of layers of medium or even high mass, interspersed with sound-absorbing, damping, and disconnecting elements.

In conclusion, ventilated wall cladding systems contribute significantly to the reduction of sound transmission due to the 'sound trap' construction technology.

The reduction of sound pressure levels is achieved through the partial reflection of the incident acoustic wave by the cladding slabs, the absorption and dissipation of a part of it through the vibration of the individual elements (possible thanks to the special method of fixing the cladding elements to the substructure) and the absorption and damping also determined by the cavity and the layer of thermal insulation when it has sound-absorbing properties (as in the case of rock wool) (21).

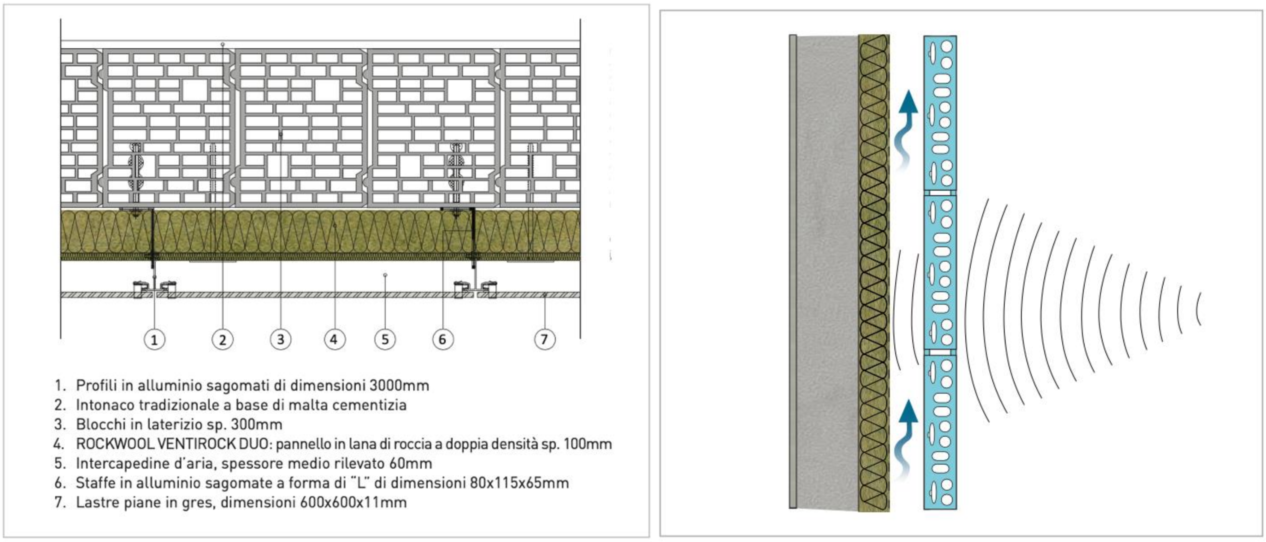

Figure 3-2– Sound performance of a ventilated wall

The figure 3-2 shows the acoustic insulation performance against airborne noise that can be obtained with the application of a ventilated wall cladding system on a 10 cm thick honeycomb brick wall, externally insulated with 10 cm thick double-density rock wool, with a 6 cm thick micro-ventilated cavity and 1.1 cm thick porcelain stoneware cladding, as indicated in the legend, is around 56 dB.

3.1.1.3 Thermal Insulation

During the summer season, the ventilated wall reduces the inward transfer of energy incident on the façade due to the partial reflection of solar radiation by the cladding and ventilation in the cavity. The reflected component is higher if light-colored and glossy materials are used as cladding.

For these reasons it deserves to be designed and built in such a way as to guarantee low energy consumption for winter and summer air conditioning and uniform and constant performance over time. The main parameter for controlling the thermal insulation of a ventilated façade is its thermal transmittance. It is defined as the heat flow through the surface and is calculated as in the formula (21):

$$U = \frac{1}{R} = \frac{1}{[\frac{1}{h_e} + \sum_{i=1}^{n} \frac{Si}{\lambda} + R_{int} + \frac{1}{h_i}]} \qquad (3)$$

Where:

- h_e is the external convective-radiative surface heat transfer coefficient [W/m²K]
- s_i is the thickness of the i-th layer [m]

- λ_i is the thermal conductivity of the i-th layer [W/mK]
- h_i is the internal convective-radiative surface heat transfer coefficient [W/m²K]
- R_{int} is the thermal resistance of any air gaps [m²K/W]

While, the value of the heat flow through the ventilated wall is calculated according to the expression (4):

$$\emptyset = A \; x \; U \; x \; \Delta T_{ml} \quad (4)$$

Where:

- A is the area of the portion of wall considered [m2]
- U is the thermal transmittance value of the closure package [W/m2K]
- ΔTml is the logarithmic mean temperature difference between inside and outside [°C]

The effect of ventilation is optimized and functions properly when the cavity is sized correctly according to thermodynamic variables. In addition, it is important to install the thermal insulation according to the rules of the trade by covering and paying special attention to crucial nodes such as the junction between beam and pillar or at window frames.

In Italy, the limit values are currently determined by two regulatory decrees that describe the incentive components and consequently the compliance with the limit transmittances as listed below:

- In the case of the “Ecobonus”, to the limit values of the useful thermal transmittance (U_{lim}) reported in the table 2 of Annex b of the Ministerial Decree of 11 March 2008, as amended by the Ministerial Decree of 26 January 2010.
- In the case of “Superbonus 110”, to the limit values of thermal transmittance (U_{lim}) reported in Table 1 of Annex E of the implementing decree of Decree-Law no. 34 of 19 May 2020, converted, with amendments, by Law no. 77 of 17 July 2020.

However, in this way the effective thermal transmittance value is calculated by means of a stationary calculation using the insulating layer as the last layer. From an energy point of view, neglecting the air gap has less influence, but the overall dimensioning does not take into account the protective contribution that the cladding can make as an external shield.

Otherwise, if the external shading of the cladding and the presence of the air gap are to be taken into account, the calculation should be carried out dynamically considering the variation of external and internal climatic conditions in the air gap.

In this way, it is possible to consider the behavior in summer and in winter.

During the hot season, the screen is able to reflect part of the direct radiation, absorb part of it and transmit the rest. The temperature of the cladding increases, while the transmitted part is disposed of due to the effect of ventilation, which results in lower temperature values in the cavity. In the winter season, however, it is important to inhibit ventilation in the cavity so that direct radiation can heat the cladding, creating favorable conditions in the cavity as can be seen in the figure 3-3.

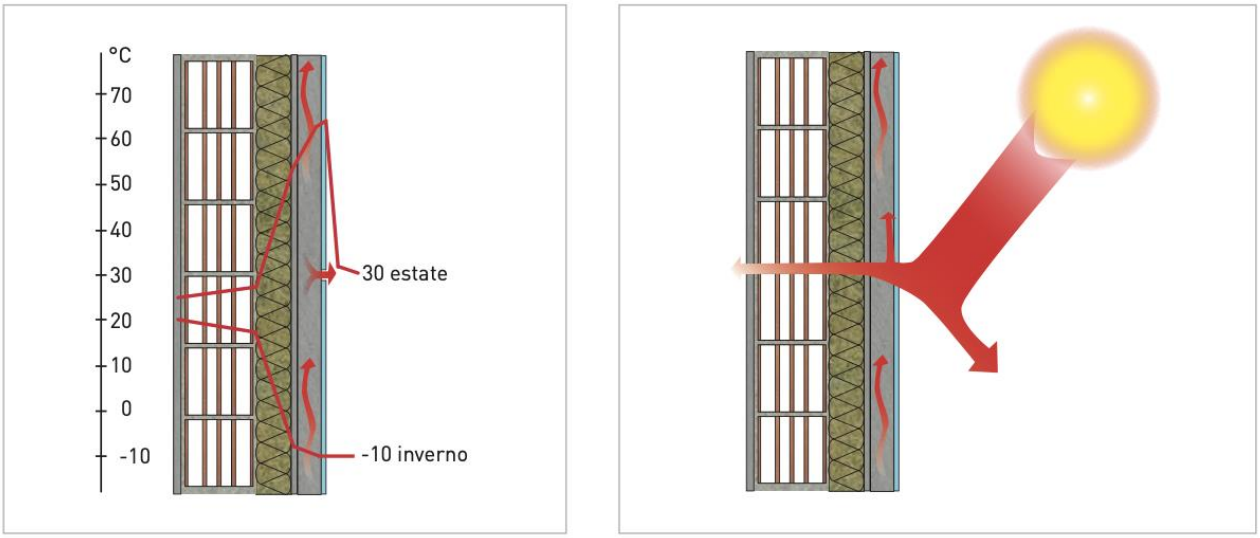

Figure 3-3 - Temperature behaviour in winter and summer of the ventilated wall and the effect of solar shading.

In ventilated walls, therefore, the air flow rate in the cavity, which depends on the inlet and outlet openings, is of considerable importance. The calculation procedure is defined in the technical document DTU P 50-702 Janvier 1997 "Règles Th - K: Règles de calcul des caractéristiques thermiques utiles des parois de construction", paragraph "2.14 Parties courantes comprenant une lame d'air ventilee" and in standard UNI 11018:2003 - "Cladding and anchoring systems for mechanically assembled ventilated façades - Instructions for design, execution and maintenance - Stone and ceramic cladding".

With reference to the type of cavity ventilation it is possible to identify three types on which to base the design calculations:

- Very weakly ventilated wall (micro-ventilated)
- Lightly ventilated wall
- Strongly ventilated wall

The cavity ventilation is determined by the ratio:

- In the case of vertical walls or similar that make an angle of more than 60° with the horizontal, the total area of the lower and upper openings s (m2) and the length of the wall L (m)
- In the case of walls forming an angle of 60° or less with the horizontal, the total area of the ventilation holes s (m2) and the wall area A (m2)

The ventilated wall has a considerable impact during the summer season, which is why the contribution of the cavity is important during this period. The incoming thermal load, in fact, is given by the contribution of the reflection from the cladding and that of the ventilation in the cavity.

However, for a precise calculation a "Computational Fluid Dynamics" calculation software should be used, but for design purposes it is possible to use simplified parameters that make it possible to evaluate the performance of the ventilated wall solution. The scheme reproduced proposes the method according to ISO 15099:2003 "Thermal performances of windows, doors and shading devices - Detailed calculations", in which the thermal exchanges due to convection, conduction and radiation in the cavity are calculated. In the figure 3-4 it is graphically illustrated how the heat flow in an air gap of the ventilated wall behaves.

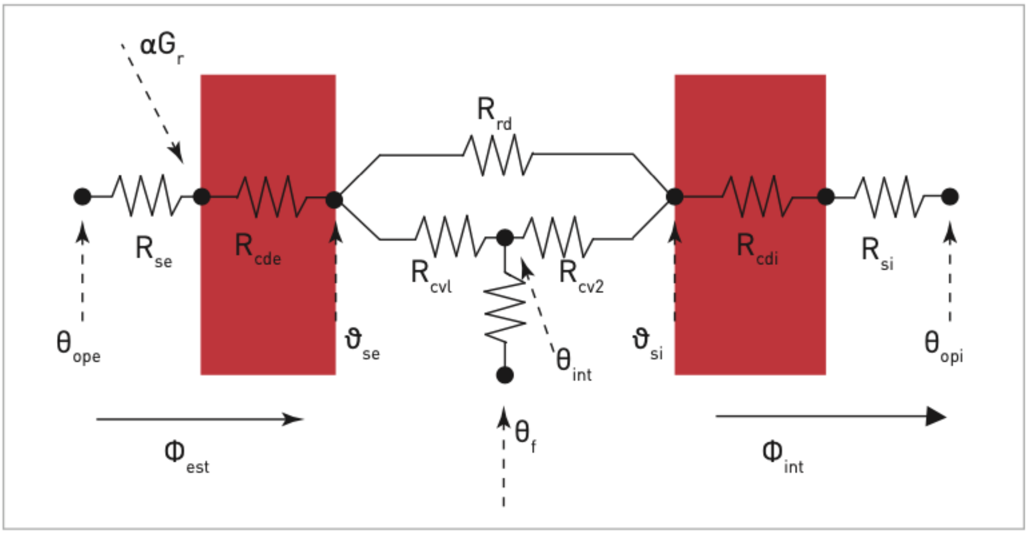

Figure 3-4 - Representation of the heat trasnfer flow in a ventilated wall

where:

- R_{cv1}, R_{cv2} are the resistances (related to convective heat exchange) of the air layer in the gap.
- Φ_{est} is the heat flow between the external environment and the cavity.
- Φ_{int} is the heat flow between the external environment and the cavity.
- αG_r is solar radiation.
- Θ_{ope} is the outdoor operating temperature.
- Θ_{se} is the surface temperature of the face of the cladding element facing the gap.
- Θ_{opi} is the temperature operating inside the building.
- R_{cde} is the resistance (related to conduction heat transfer) provided by the outer skin layer.
- R_{cdi} is the total resistance provided by the layers at the intrados of the ventilated air duct (usually insulation layer and supporting layer, also related to conduction heat exchange).
- R_{rd} is the resistance related to the phenomenon of heat exchange by radiation that occurs in the air layer.
- R_{si} is the internal surface resistance.
- R_{se} is the external surface resistance.

Whereas, from standard UNI EN 13792:2012 - "Thermal performance of buildings - Calculation of the summer internal temperature of a room in the absence of air conditioning systems - Simplified methods", it is possible to create a simplified procedure to calculate a ventilated wall type closure.

However, actual evaluations of the energy performance of a ventilated wall can be assessed through specific laboratory, experimental and field tests.

In conclusion, the benefits of a ventilated façade cladding are obvious and give the possibility to achieve high energy saving standards and to reach nZEB buildings. In particular:

- reduce the thermal load on the building in the hot season, thanks to the partial reflection of solar radiation incident on the façade by the cladding and the possible presence of ventilation in the cavity. In the summer season, the amount of energy accumulated by the external cladding is a function of the particular material used, its colour and thickness. The absorbed energy is transmitted from the external face to the internal face of the cladding, in contact with the ventilation space, with a delay and attenuation that depends on the characteristics of mass, density and specific heat of the external screen (in general the times are however limited). The real summer benefit of the ventilated wall is obtained on faces directly affected by direct solar radiation and with a continuous ventilation space, with thicknesses between 3 and 7 cm.

- create a homogeneous and continuous layer of thermal insulation, easily connected to the lines of the frames of the transparent closures, for total control of thermal bridges on the various façade fronts. Particular attention must be paid to the laying of the insulation, in order to create a continuous layer, well bonded and connected to the support, without discontinuities and/or voids.

- increase the thickness of thermal insulation by up to 15-20 cm without encountering any particular technical difficulties or cost increases. In this way, thicknesses can be adopted which give the building a very conservative energy behavior, minimizing dispersion and favoring thermal storage and, in short, reducing energy requirements to a minimum. However, it should be borne in mind that a considerable increase in the thickness of the thermal insulation means that the plane of the cladding is also removed from the rustic masonry and the structure of the building. This can lead to an increase in the stresses within the elements making up the substructure, particularly the brackets, due to the weight of the cladding and the action of the wind to which the façade is subjected, an increase in the depth of the window frames which, especially in the case of renovation work, could cause a reduction in the degree of natural illumination of the interior spaces (if the size of the window frames is not increased) (21).

3.1.1.4 Hygro-Sensitivity

An extremely important element of envelope solutions is controlling the formation of surface and interstitial condensation. As well as creating discomfort in dwellings, it can cause degradation in building materials and their durability and energy performance. Condensation is created when the flow of water vapor that laps or permeates a building component, following a reduction in temperature, reaches saturation and changes phase: from vapor to liquid.

Condensation, therefore, occurs when the surface temperature of a material is below the dew temperature. However, the dew temperature is not a fixed value but depends on the temperature and relative humidity of the environment.

On the other hand, interstitial condensation occurs when the diffusive mass flow of incoming vapor in a portion of the wall exceeds the diffusive mass flow of outgoing vapor, as a result of the vapor pressure in this portion exceeding the saturation pressure. In both cases, the presence of water in the materials leads to performance degradation and consequently to energy and structural performance problems.

The Glaser diagram can be used to analyze the internal pressures in the elements. In this diagram, as can be seen in the figure 3-5, the values of partial vapor pressure and saturation pressure are represented and compared in relation to the temperature profile in its cross-section.

At the design level, the UNI EN ISO 13788:2013 standard proposes a calculation procedure and establishes for each type of material the admissible limit quantity of condensate.

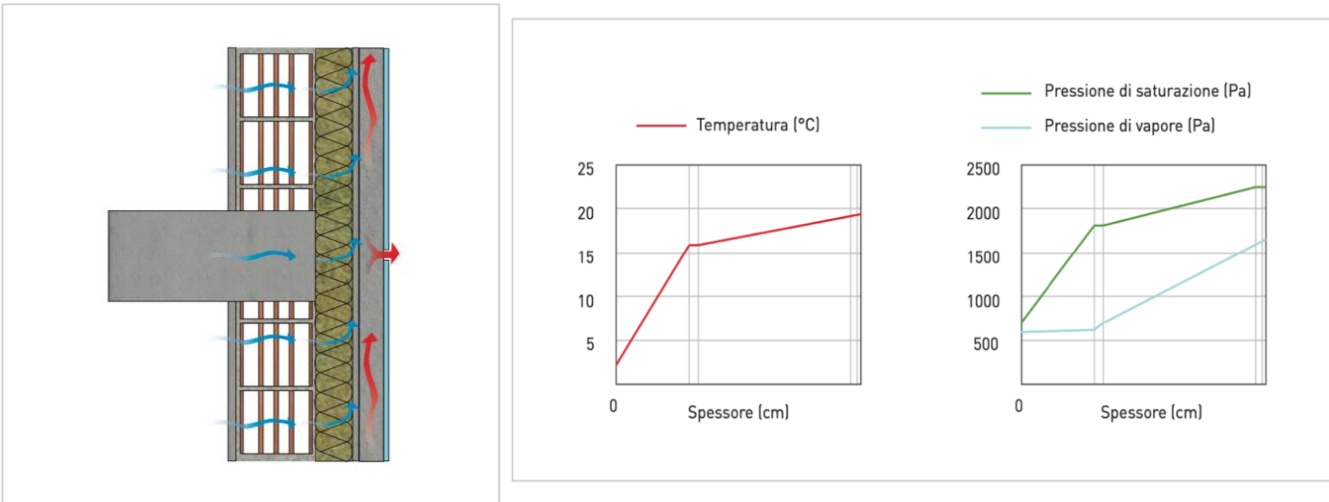

Figure 3-5 - Interstitial moisture in ventilated walls

The diagram in the figure 3-5 illustrates the pressure and temperature trends in a ventilated wall covering. In these types, due to the presence of a moving air space, the removal of moisture from the interior is greatly facilitated. Moreover, even in the first periods of service of the buildings, excess construction moisture creates discomfort, which would be solved with a ventilated wall system.

3.1.1.5 Seismic Resistance

According to the Technical Standards for Construction (Ministerial Decree of 14 January 2008) "Design criteria for secondary structural elements and non-structural elements" ventilated walls are included as secondary non-structural elements. Thus, calculation and verification methods are based on static and dynamic (earthquake) analyses.

The most important element, as far as ventilated walls are concerned, is the safety against possible breakage and fall to the ground of portions of the envelope during an earthquake. According to this principle, as described in the NTC 2008 standards, these envelope elements must be designed in accordance with verifications at the Operating Limit States (SLE) and at the Ultimate Limit States (SLU), which define the dimensioning of each of its elements (anchorages, anchorage brackets and bracing, substructure, cladding elements, and relative fixings, etc.).

Since the ventilated wall is a secondary element, whose mechanical strength depends on the supporting masonry, the pull-out and shear resistance test of the anchoring dowels is of great importance. In this regard, based on the degree of risk and possible spatial stresses (seismic response spectrum), the elements that make up the cladding must be sized, such as: the method of connection of the cladding to the wall face, materials to be used for the substructure and cladding, the type of anchoring and fixing of the cladding, whether or not additional fall protection systems are required, etc.

The design of the ventilated façade has as its first objective, to achieve conditions of mechanical independence between the individual cladding elements, avoiding the interaction of individual elements with each other. Furthermore, the cladding elements are connected to the masonry by means of a secondary structure, which has the task of transferring loads from the final cladding to the load-bearing masonry. In particular, an envelope with a ventilated wall cladding must react as a well-integrated and appropriately integrated or disassociated element with respect to the load-bearing system, mainly by using certain tricks:

- The masonry must be adequate to support seismic stresses.
- It is preferable to use a mullion and transom substructure rather than a mullion-only substructure as the connection points are larger and better distributed.
- Lightweight cladding elements with low mass per unit area are recommended.
- Additional safety systems against breaking and falling of cladding elements.

3.1.1.6 Durability, Maintainability and Sustainability

Ventilated wall cladding systems are generally considered to have a long lifespan, which, if designed correctly, reaches a useful life equal to that of the building (approx. 50 years).

Thanks to their dry, mechanical, on-site assembly, they can be easily and promptly replaced when needed.

Therefore, the ventilated wall solution, being fully demountable, guarantees the recovery for reuse and/or recycling of its components at the end of its service life. In addition, the prefabrication of the elements, the dry installation method and the high thermal-energy performance guarantee high energy efficiency values against a favorable overall Life Cycle Cost (LCC) and a generally very low environmental impact (LCA - Life Cycle Assessment).

3.2 Heat Pump

In residential dwellings, especially in blocks of flats, it is possible to find a system consisting of a central unit, typically a boiler fired by traditional fuels which has to cover the needs of all the individual dwellings, acted upon by terminals, usually radiators (cast iron, alluminium, steel) or thermo-furnishings, which require high temperatures to operate.
Heat pumps are a viable alternative to replace these traditional systems due to their relatively low installation costs and ease of installation (22). Unfortunately, the radiators already present in homes usually require higher temperatures and are not usually changed in renovation operations due to their cost, and the unnecessary nature of the operation. This unfortunately affects the performance of the heat pump, which is expected to operate in a sub-optimal temperature range.

With the latest developments, high-temperature heat pumps have recently come onto the market with which it is possible to reach a flow temperature of over 65°C (23), thus solving the problem mentioned above, as it would make it compatible with traditional terminals and not limit it to use for domestic hot water only. This request for higher temperatures would lead to an increase in traditional electricity consumption, but this could be balanced by exploiting the energy produced by a photovoltaic system. In this configuration, the electricity consumption would fall on the condominium users, so it would be possible to increase self-consumption without necessarily having to set up an energy community to benefit from it.

Heating systems of this type consist mainly of 3 elements:

- Heat pump
- Water-based thermal energy storage system
- Photovoltaic system

Where the thermal storage system can be considered as an alternative to electrical storage systems, which are generally much more expensive and perishable, it can be used both for the production of domestic hot water and for covering the heat demand.

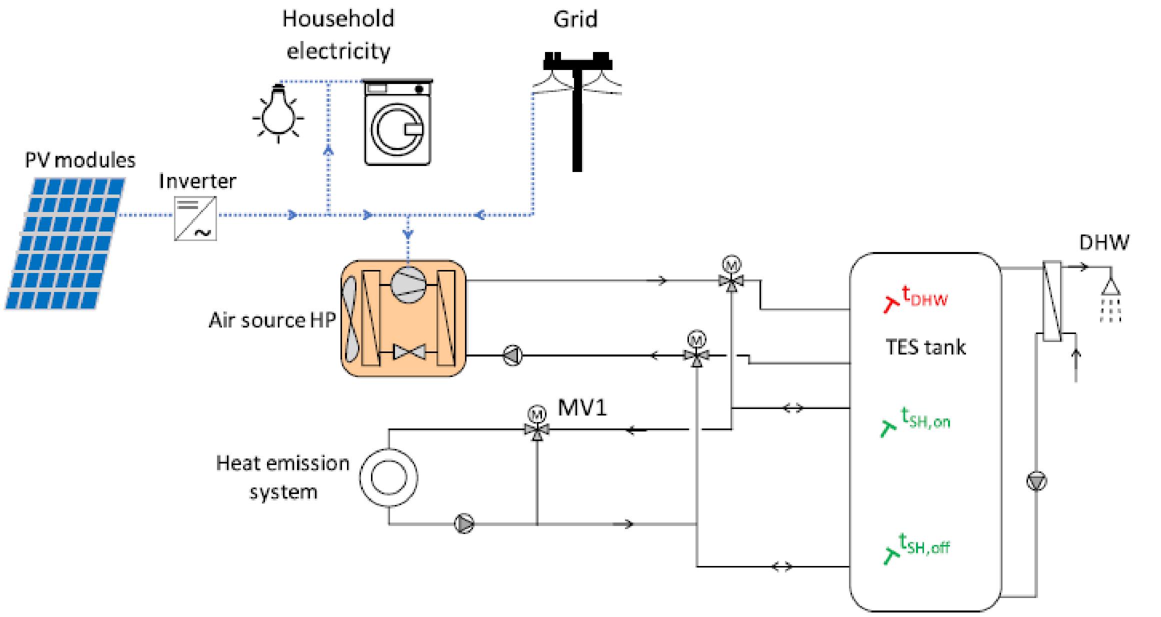

Figure 3-6 - Electrical and plumbing scheme consisting of photovoltaic panels, heat pump and thermal storage system.

As can be seen from the system diagram, the electricity produced by the photovoltaic system can be distributed for domestic use, such as lighting or various household appliances, and the surplus, rather than being fed into the grid, can be used to power the heat pump and possibly store thermal energy, so that it can be used in the event of zero production from the photovoltaic panels.

There are also different strategies to optimize system efficiency in order to make more use of photovoltaics and reduce demand from the grid.
The basic configurations take care to ensure comfort for the users, so it always guarantees a domestic hot water temperature of not less than 45°C and the heat pump works independently of the photovoltaic system, so the renewable energy is only used if the heat pump operates during production hours.
The next configuration is to overheat the storage system when excess renewable energy is available. Thus, higher temperatures are reached than in the standard case, always within the maximum permissible temperatures of the storage tank, which are also influenced by the limits of the compressor, meaning that depending on the outside temperature, different maximum temperatures can be reached.

It is possible to add an additional control on the energy absorbed by the compressor, so that it does not exceed the energy produced by the photovoltaic system and therefore does not require a share of energy from the grid.
Alternatively, instead of overheating the storage system, one could exploit the thermal inertia of the building and overheat the rooms.

By increasing the complexity of configurations, it is possible to further lower the costs on the bill and thus also the payback time.

However, there are some problems that accompany heat pumps, even the new generation. The maximum usable power that can be delivered by a heat pump is highly dependent on the source temperatures, and in particular it decreases as the temperature of the cold source decreases. As can be seen in the figure, the manufacturer always defines temperature limits within which the heat pump guarantees flow temperatures, and outside these limits the heat pump will stop.

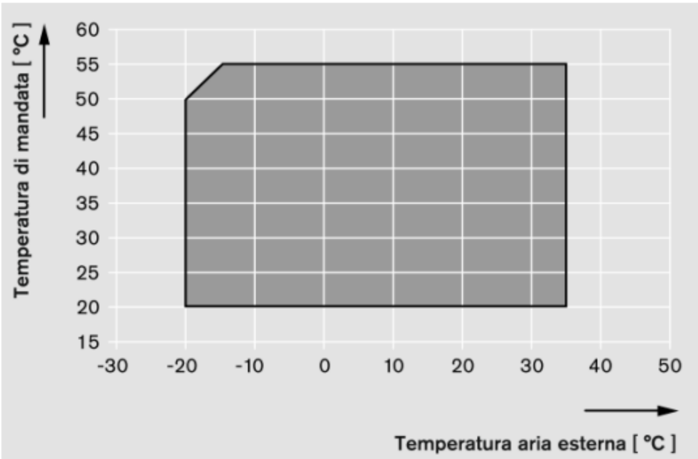

Figure 3-7 - Typical operating limits of a heat pump

Another typical problem is the formation of ice on the evaporator, which draws heat away from the ambient air. When the exchanger is at a temperature between 7°C and -5°C, condensation (due to air humidity) can form on the exchange surfaces, which turn to ice at these temperatures. This process is typically monitored by the machine which, to remedy this, initiates the defrosting process, i.e. a reversal of the cycle takes place to briefly remove heat from the internal environment or from the thermal accumulator if present, and send it to the evaporator which will then melt the ice which will be discharged as condensation water, restoring the operation of the heat pump, alternatively it is possible to use electrical resistances rather than reversing the cycle. This criticality therefore arises especially in wet areas or with heavy rainfall, where it is therefore desirable to use a system optimized for these cases.

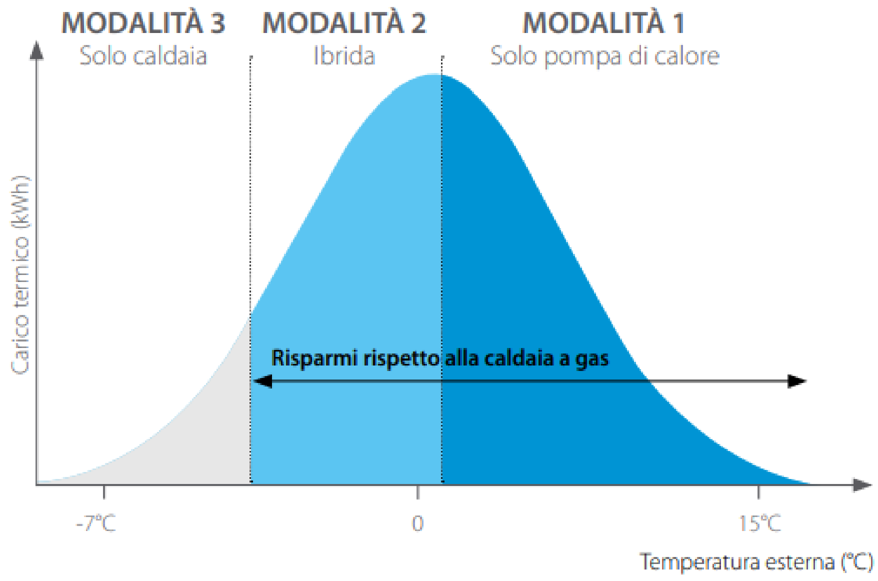

Figure 3-8 - Heat produced by the Heat Pump (28)

Hybrid systems have been designed to solve these eventualities, as they exploit a coupling with a fossil fuel condensing boiler to ensure optimized consumption, to be shared between the two components.

As can be seen from the figure, the boiler starts to operate in the temperature range near zero degrees, where the heat pump starts to suffer from the lowering of the COP and is unable to cover the thermal demand of the house. By doing this it is possible to save on fuel consumption, reducing the use of a conventional boiler and taking advantage of the high efficiencies of the heat pump at temperatures above zero degrees.

3.3 Photovoltaic System

The last component to be introduced that is indispensable for reducing emissions and increasing the share of renewable energy is the photovoltaic system.

The sizing of this component depends on a series of climatic, technical, economic, and architectural factors, which must be seen in their interaction, and it must also be defined whether it is to be designed on the basis of self-consumption or on the feeding of energy into the grid. In the latter case, the design will be of a general nature, in the sense that we will try to fill all the space available on the pitches with a southern, eastern, or western inclination. (24)
The latest generation of panels can provide considerable power while occupying an area of less than 2 m^2, which means that considerable power can be achieved even with little space available.

The first piece of information to look for when dimensioning a system of this type is the solar resource available at the site of installation. The average solar irradiance, typically expressed in kWh/m^2, must be obtained from a solar atlas in order to estimate the actual energy production of the system.

The data obtained will only serve as a reference, because it is then necessary to take into account the angle of inclination of the panel with respect to the geographical south, known as the azimuth angle, and the angle of inclination with respect to the horizontal plane, known as the tilt angle, as well as other factors such as shading or the presence of important obstacles that hinder solar illumination.

It is well known that the ideal inclination for photovoltaic panels is towards the south, as surfaces facing this way receive more solar radiation and receive more hours of light (at least in our hemisphere). Unfortunately, this condition is not always possible to apply during installation, as typically residential buildings do not always have a pitch arranged in this direction. However, this is not a problem, as even roofs facing East - West can achieve considerable performance. However, it is desirable to install with at least a partial south-facing orientation, if possible, in order to maximize the hours of light the panel can produce.

The other important factor is the tilt angle, which on average is optimal at around 30°, although this depends on the latitude of the chosen location. However, again, this is not always verifiable, as typically, for residential applications, panels tend to be installed coplanar to the slopes, which imposes a fixed tilt, not a variable one.

Another criterion to follow is according to the need that the system has to satisfy.

If, for example, the need is exclusively for the winter period, it is more appropriate to install the panels with an inclination towards 50°-60° to make greater use of solar irradiance, as the path of the sun remains low on the horizon during the winter.

On the contrary, if you want to maximize summer yield, you should install the panels with a lower inclination, between 10°-20° as, in this case, solar radiation is almost always perpendicular to the horizontal plane.

3.4 Storage Systems

Typically, the photovoltaic system, like many renewable resources, is characterized by being random, therefore difficult to program and consequently does not guarantee reliability.
For this reason, the installation of a renewable energy system is often coupled with the installation of storage systems or batteries, which solves the above-mentioned problem and brings with it several advantages:

- Increased self-consumption.
- Possibility of having an emergency energy resource in the event of a blackout.

These advantages are more relevant in the residential case, as the times when energy needs and photovoltaic production coincide are less likely in private homes than in the industrial sector, where the work shift is usually scheduled during the day, when the photovoltaic system has maximum production, and therefore self-consumption is maximum. As for the possibility of having an emergency system for black-outs, again, industries, being more energy-intensive realities, have a much higher energy demand that cannot be met with a simple storage system, and therefore would not justify the price.

Grid connected storage systems are known as Energy Storage Systems (ESS) and are generally composed of a battery pack and management and control equipment, which monitor the charging and discharging phases of the batteries.

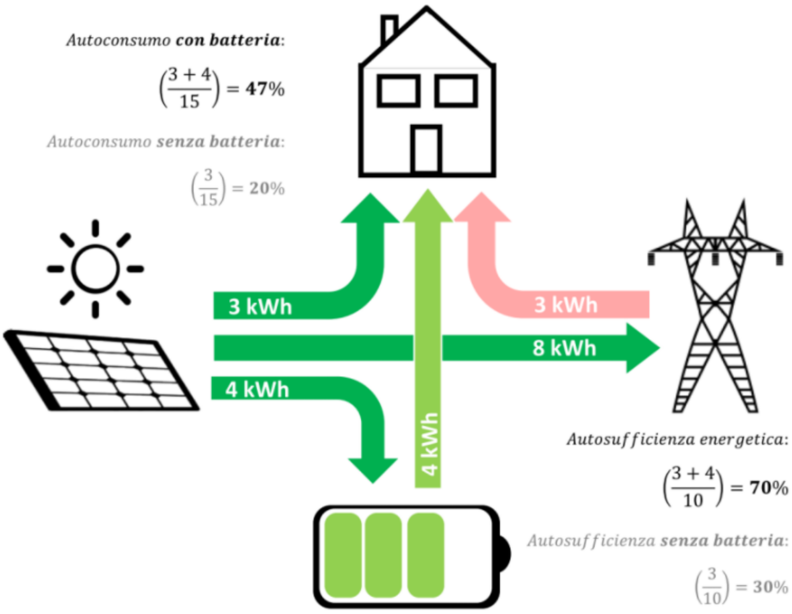

Figure 3-9 - Increased self-consumption with the presence of a storage system (29)

This last component allows the accumulator to be recharged directly from the energy produced by the photovoltaic system, taking the surplus quota with respect to our needs,

thus preventing it from being fed into the grid, reducing its value (typically the monetary value of the self-consumed kWh is almost double that of the kWh fed into the grid).
Once charged, the management system will provide the stored energy in phases where the photovoltaic system is not producing or when it is not sufficient to meet demand, so typically in the evening hours.

The direct consequence of such a process is an increase in self-consumption, thus an economic advantage, since as can be seen from the figure, the load and production curves of the photovoltaic system differ greatly, especially at peak times.

Adding the storage system allows in the charging phase to store the excess energy (green area under the green curve) and reuse it in the discharging phase outside the PV production hours (green area under the pink curve).
This is the typical case of a family, where members leave the house during the day and return in the evening.

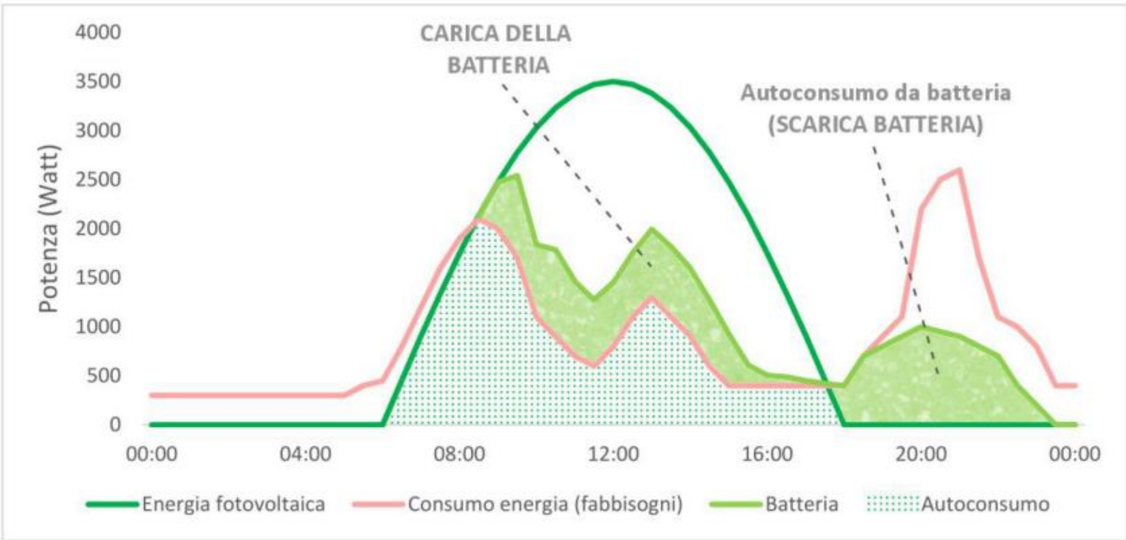

Figure 3-10 - Comparison between the load curve of a typical household and the production curve of a photovoltaic system (29)

The critical aspects to specify for a storage system are:

- High battery costs.
- Lifetime related to charging cycles, typically stated in years.

The latter feature is highly dependent on the variability of electricity requirements, as it prevents programmability, thus increasing charge and discharge cycles, leading to a reduction in battery life.

However, it must be made clear that it is almost impossible to achieve independence from the national grid, even if very large storage capacities are installed, because the electricity demand is highest in the winter period when photovoltaic production is minimal compared to the whole year round, so regardless of the storage system, it would not be possible to compensate the entire demand, but to compensate a part of it, thus achieving partial energy independence.

As far as sizing is concerned, the logic adopted is aimed at increasing the percentage of self-consumption, because otherwise the costs of the batteries could not be justified. Typically, the installed capacities range from 2 kWh to 10 kWh and are proportional to the size of the system, and there is a tendency to under-size in order to keep costs down rather than over-sizing by taking care of the heat flows throughout the year.

However, it will be seen in the case studies below, how one should proceed with hourly dimensioning for the case with a private house and for a block of flats.

4 METHODS AND MODEL OF ANALYSIS

Dealing with the model of analysis and the methods used to assess the actual state of the building and the revamping of it, the analysis that will be carried out in the next chapter will follow a main scheme, composed by different passages.

The buildings will be created and reproduced on "Termus BIM" and our task will be to reproduce the de facto state of the building in order to evaluate its starting energy class because, as long as the project use the incentives given by the "Superbonus 110", an improvement of 2 energy class is necessary to access the full incentive, so this condition will be verified to proceed correctly.

It will be described the interventions that facilitate the accomplishment of the target that will also be applied in four main aspects:

- Application of a thermal coat and installation of a ventilated wall.
- Substitution of old glass units.
- Substitution of conventional central heating system with a modern heat pump.
- Installation of a photovoltaic plant on the roof with a storage system.

Each building will be divided in different thermal zones according to the functions of the spaces. For each function, according to the ISO TS 11300, it will be defined the internal gain due to occupants, lighting and equipment and the minimum volumes per hour of air changes.

The aim is to determine the primary energy demand of the "de facto state" and the result after the intervention.

After that, the achievement of this paper is to demonstrate the benefits that could bring the cumulative self-consumption, and for doing so, two programs have been created in order to asses so: the first one provides the best suited storage system in order to maximize the self-consumption, considering a cost-benefit analysis and the second one will provide an economic analysis of the benefits that could come from many configuration of the support scheme treated before.

Concerning with the programs used to produce the result of this work it is shown the Excel Sheet created and there will be explain the passages to use it.

INPUT		
Numero Abitazioni 4 Persone	4	
Numero Abitazioni 2 Persone	9	
Numero Abitazioni 1 Persona	7	
TOTALE Unità Immobiliari	20	
Accumulo Dimensionato	30	kWh
Emmision factor Italia 2018*	408,9	gCO2eq/kWh
Emissioni Evitate	7,923775802	tCO2eq
Immissioni rete	1760,264	kWh
OUTPUT		
Riepilogo Copertura Consumi		
January	18%	16%
February	30%	19%
March	43%	24%
April	55%	26%
May	62%	28%
June	67%	31%
July	66%	31%
August	61%	25%
September	51%	25%
October	34%	18%
November	17%	13%
December	14%	13%
Totale (su 1200%)	518%	270%

*=fattori di emissione atmosferica di gas serra nel settore elettrico nazionale e nei principali paesi europei (EDIZIONE 2020)

Figure 4-1 - Output and Input of the spread sheet for the sizing of the storage system

The first one treats the sizing of the storage system and will provide the total coverage of consumption of the building analyzed. In this case, the only input is to specify how many apartments of a certain kind constitute the building, since in the same spread sheet were inserted 3 main possibilities:

- Apartments with 4 members family
- Apartments with 2 members family

- Apartments with 1 member

The behavior of each possibility, in terms of consumption per hour, was taken from the database of the software Solarius PV.

With the same software is possible to obtain the hourly production of the PV plant designed.

The last phase is to design the heat pump and obtain the consumption depending on the temperature. This was possible thanks to an online software designed by the company “Strutture Energia” which gives its contribute to go through this study. Going to “Rete Risparmio Energia” website is possible to size a heat pump and produce the following result, inserting only some characteristics of the building and of the selected heat pump.

Gradi	U.M.	gen	feb	mar	apr	mag	giu	lug	ago	set	ott	nov	dic
-8	kW_elet												
-7	kW_elet												
-6	kW_elet												
-5	kW_elet												
-4	kW_elet	6,53											
-3	kW_elet	6,04											
-2	kW_elet	5,58	4,93										5,68
-1	kW_elet	5,15	4,48										5,24
0	kW_elet	4,72	4,06										4,82
1	kW_elet	4,29	3,66										4,39
2	kW_elet	3,89	3,28	2,57									3,99
3	kW_elet	3,52	2,93	2,26	2,3	0						3,38	3,61
4	kW_elet	3,17	2,6	2	2,15	0	0	0	0	0		3,03	3,25
5	kW_elet	2,84	2,3	1,75	2	0	0	0	0	0		2,7	2,92
6	kW_elet	2,52	2,05	1,49	1,93	0	0	0	0	0		2,4	2,6
7	kW_elet	2,25	1,81	1,24	1,68	0	0	0	0	0		2,15	2,31
8	kW_elet	2,01	1,56	0,99	1,43	0	0	0	0	0	1,55	1,9	2,07
9	kW_elet		1,32	0,74	1,19	0	0	0	0	0	1,31	1,66	
10	kW_elet		1,08	0,49	0,95	0	0	0	0	0	1,07	1,43	
11	kW_elet			0,25	0,71	0	0	0	0	0	0,83	1,19	
12	kW_elet			0	0,48	0	0	0	0	0	0,6	0,97	
13	kW_elet				0,24	0	0	0	0	0	0,37	0,74	
14	kW_elet				0,01	0	0	0	0	0	0,14		
15	kW_elet												
16	kW_elet												
17	kW_elet												

Figure 4-2 - Performance of the heat pump of Pampuri's case study

At the end is possible to understand which is the contribute of the storage system, concerning the consumption coverage, varying its capacity.

The outputs are:

- Coverage of the consumption per month.
- Total coverage of consumption considering a year.
- Avoided emissions, considering the Italian emission factor.
- Energy sent to the grid, that is not self-consumed.

A picture of the over-all graphical user interface is provided in the appendix (figure 0.1).

The second program was also realized on Excel and deals with economic analysis of the REC.

It considers several configurations, and allows the user to make dynamic analysis changing the following inputs:

- Configuration of the incentives.
- Total installed power of the PV plant.
- The cost per kW of the panels chosen.
- Surface of the panel per kW (in order to consider other possible configurations).
- Possibility to consider a REC with more buildings or only one with self-consumption.
- Insert the energy available from the REC.
- Insert any emission factor.

All these inputs can be chosen wisely depending on the situation treated, and the spread sheet considers many other elements necessary for the calculation of the benefits of the self-consumption, which are for example:

- Tariffs of the network charges and grid losses. (BTAu and TRASe).
- PUN estimation for the "Ritiro Dedicato" considered for 2020 and 2019.
- Common consumption of a building taken from the condominium bills, with the possibility to add the consumption of a heat pump.

The program is able to value each contribution of the benefit, considering both the saving and the incentives, and provides different possibilities varying the percentage of the collective self-consumption.

Thanks to this it was possible to make some comparisons between different incentives configuration, and with the previous support scheme "Scambio sul Posto", providing a cumulative cash flow analysis and pay-back period of each configuration.

Also here, a picture of the over-all graphical user interface is provided in the appendix (figure 0.2).

5 CASE STUDIES

The following chapter deals with the modelling and energy study of a building located in the city of Trescore Balneario and in Milan. Since the two buildings have different properties, like the number of apartments and the size, it would be possible to understand which benefits it's possible to achieve in both the situations, in terms of energy saving, reducing the energy demand, and self-consumption,sizing the PV plant and the storage system.

5.1 Bombardieri's Case Study

The first project, located in Trescore Balneario, named "Bombardieri's case study", treats a building situated in an urban context, immersed in the city behind a not so crowded street. The geometry is irregular, with square plans with some differences on each side. Around the building there are no other houses so close, and the ones existing buildings have more or less the same height. The building is a private house, that consists of three floors out of ground and one underground: two floors of residential, one warehouse under the roof and one warehouse in the underground story.

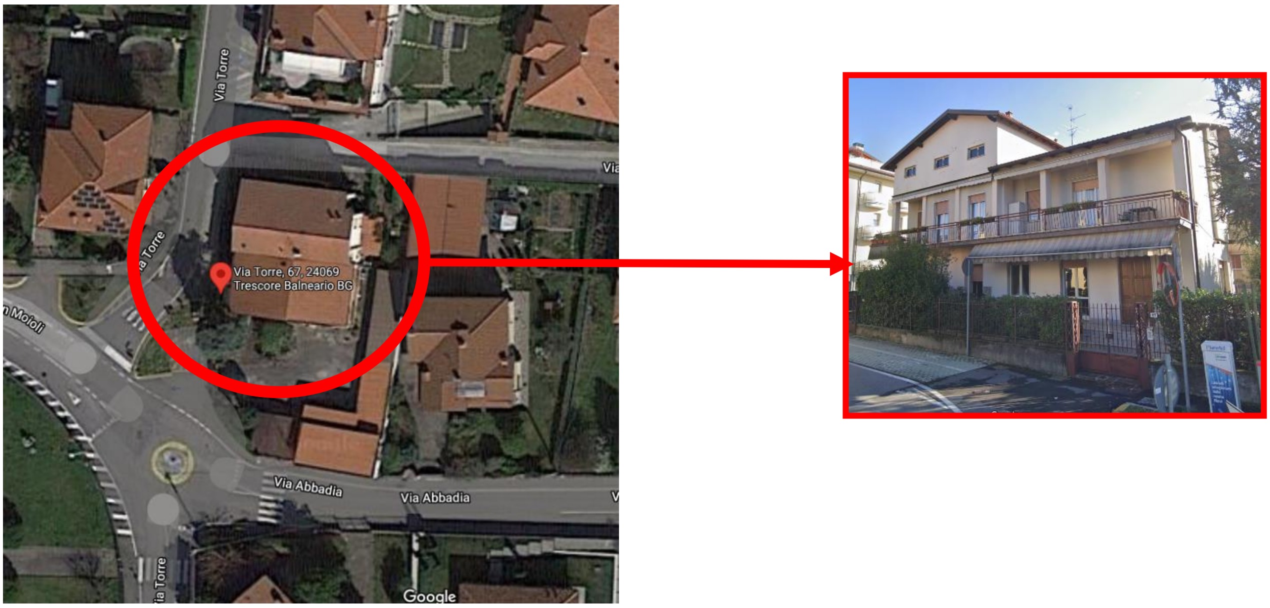

Figure 5-1 - Bombardieri's case study localization

The purpose of the study concerns the energy analysis of the two residential floors of the building that require air conditioning during the year with the aim of reducing the energy impact of the building through the use of insulation layer, ventilated wall and using more efficient windows, in order to reduce the cost of air conditioning (both for heating and cooling) and to have internal temperatures that can be considered of comfort between 20°C and 26°C.

The first aim, the most important one, is related to the problem of heating loads during the heating season that involves most of the year. It has been tried first of all, to reduce as much as possible the sensible heating loads needed by the whole building. According to this purpose, it has been tried to insulate according to the local construction technique in order to limit as much as possible any thermal losses through the envelope. Moreover, to reduce the energy consumption related to the thermal loads, it has been designed the heat pump and the photovoltaic field on the roof to feed electrically the consumption of the heat generator.

All these strategies are an attempt of reaching a *Nearly Zero Energy Building* defined in terms of properties and calculation methods in the UE Directive 2010/31. Despite, in Italy it has not been any directive for nZEB building yet, it has been carried out the analysis following the legislation ISO TS 11300 for the thermal loads to achieve the energy balance to discover the best energy storage size for photovoltaic production.

Figure 5-2 - Model reproduced on Termus BIM

The building has been divided in different thermal zones according to the functions of the spaces. In this way, it has been identified 4 main thermal zones:

- 1st Thermal Zone: warehouse at the underground floor (200 m^2 not warmed space);
- 2st Thermal Zone: ground residential floor (186 m^2 warmed space);
- 3st Thermal Zone: first residential floor (180 m^2 warmed space);
- 4st Thermal Zone: loft floor (200 m^2 not warmed);

The thermal zones under analysis are the 2st and 3st.

The building in its “the facto state” is composed by the stratigraphy of double bricks with air gap in the east side of the building and composed by one block of brick on the other sides of the building.

The first intervention is the application of EPS insulation layer and the ventilated wall. Due to the irregular shape of building, and the presence of balcony that runs on the two floors at the corner, the application of the ventilated wall is restricted on just a portion of all building’s side, where are not present the balconies. Under the energy analysis, the presence of ventilated wall with moving air is not so important for the result. So, for this reason, it has been carried out the analysis considering just the insulation layers that is placed usually behind the secondary structure of the ventilated wall.

The EPS layer is placed on all the envelope of the building, on the intrados of underground slab and on the pitched roof that it has been changed with a ventilated technology.

The figure5-3 is an example of adding the EPS layer on one of the walls and they show the facto and project state stratigraphy of perimeter front street wall.

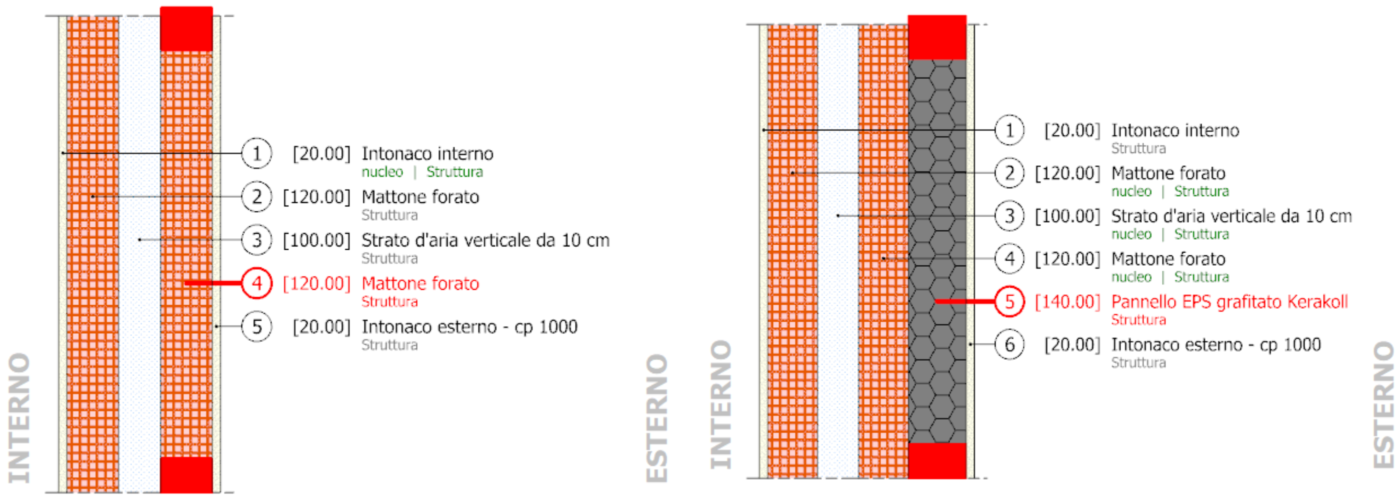

Figure 5-3 - Representation of the Stratigraphy on the east side before and after the intervention.

The roof in the facto state was composed by two simple layers: secondary wood structure and tiles. Due to the aim of retrain the loft, the stratigraphy of the pitched roof has been changed and increased its performance. Also, the installation of the solar PV panels without a strong resistant roof could not installed. Replacing the roof stratigraphy adding a XPS panel of 14 cm shows the increasing of the performance from U = 1.62 W/m²K to U= 0.20 W/m²K.

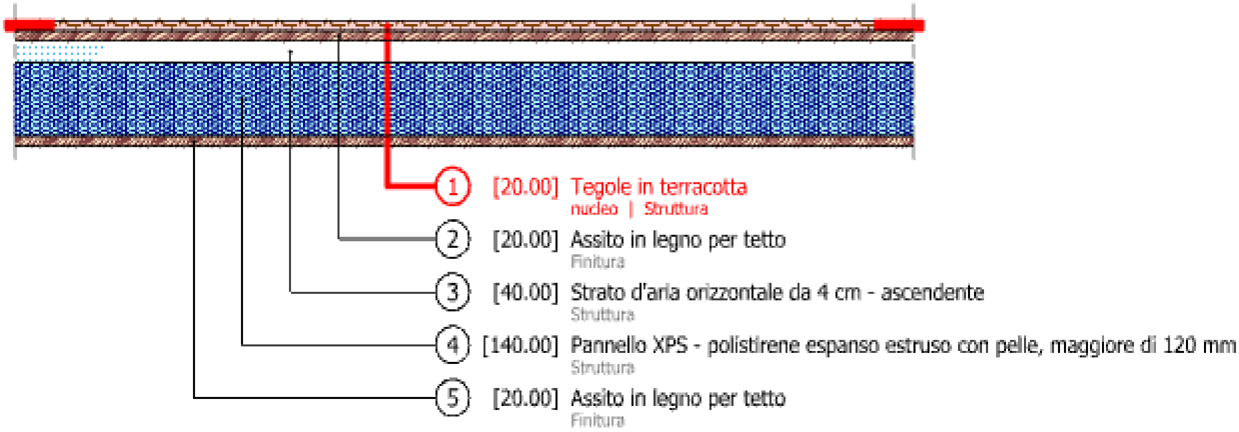

Figure 5-4 - Representation of the stratiraphy on the new pitched roof.

After that also a glass configuration has been changed. The main types of glass are composed by one glass and wood frame (Uw = 4.9073 W/m²K) replaced with a double glass with PVC frame and low emission coat (Uw=1.1438 W/m²K) to reduce the thermal losses. The influence of the glazed surfaces has a great impact on the internal temperatures due to the effect of the solar gains and the heat that is transferred through the glass. In fact, the changing of glass unit reduced the thermal transmission of 77%.

Furthermore to avoid the thermal bridge, it has been applied a layer of AreoGel (λ = 0.015 W/mK) around all the frame of the window. The table 5-1 shows how the adding of insulation EPS and XPS layer change and increase the performance of the envelope.

Application	**Layer thickness** (m)	**U_ANTE** (W/m²K)	**U_POST** (W/m²K)	**Increasing of performance**
EPS layer on the vertical walls	0.14	0.9798	0.19	**80%**
STIFERITE layer on intrados slab of underground floor	0.10	1.2	0.2	**83%**
Changing of pitched roof technology with XPS layer	0.14	1.62	0.2	**87%**
Replace of new glass unit	-	4.9	1.14	**77%**

Table 5-1 - Summary of the intervention on Bombardieri's case study.

Thanks to all these applications it has been possible to reduce the thermal loads of the building from 87,322 kWh to 23,179.37 kWh. In this way, the primary energy demand has been reduced of 74%.

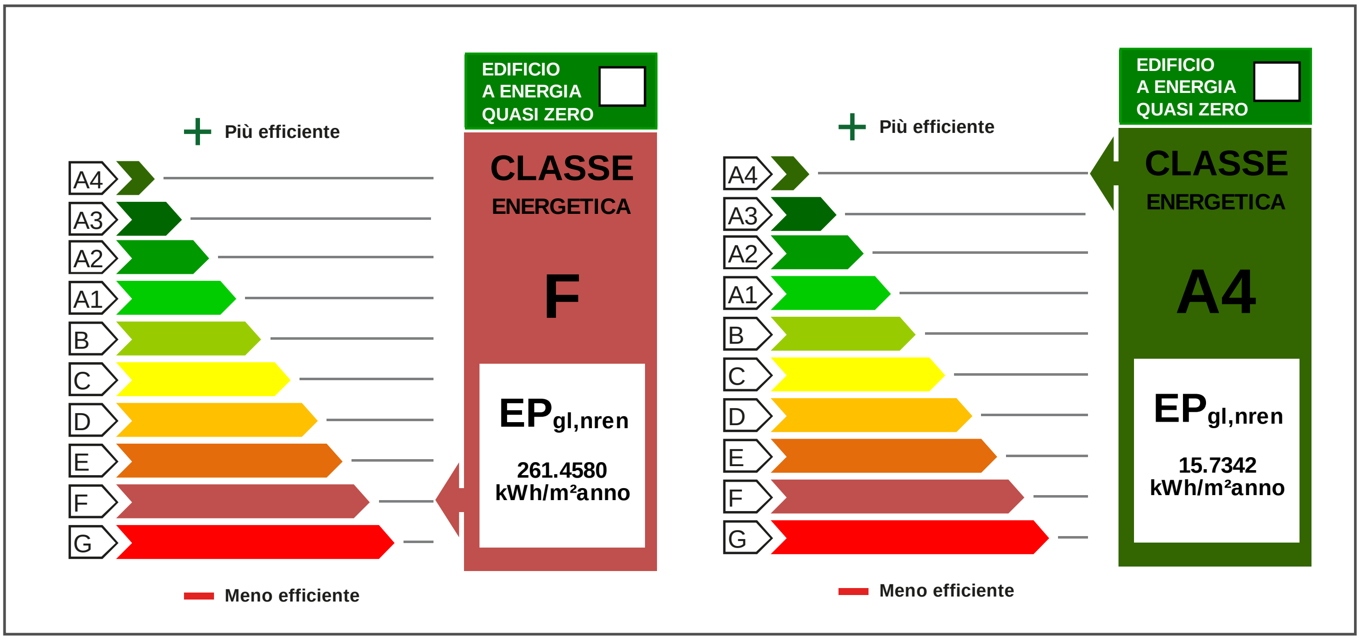

Figure 5-5 - Building's energy class of the de-facto state and the project state

Also, thanks to these applications it has been possible to increase the energy class of the whole building as it is shown in the figure 5-5. The result shows that the building reach the classification really close to nZEB.

According to the purpose of reducing the gas consumption, a heat pump of 8.6 kW has been designed in line with the new reduced loads. In the facto state of the project, there were two standard boilers of 25/30 kW that produced heat for all the building. In the new configuration, thanks also to the photovoltaic field, the electrical energy needed by the heat pump for heating and domestic hot water is given by the photovoltaic production.

5.2 Pampuri's Case Study

After having treated previously a private residential building of only a few building units, a larger case will be dealt. The project that is going to be explained was applied to a condominium named "Condominio Pampuri" composed by 20 building units. In the same way, it will propose some energy efficiency solution which are incentivized by "Superbonus 110", mentioned in the first paragraphs.

This building is situated in a residential district in the south part of Milan, and it was commissioned to improve the energetic performance of the external envelope and revamping the heat production and distribution system.

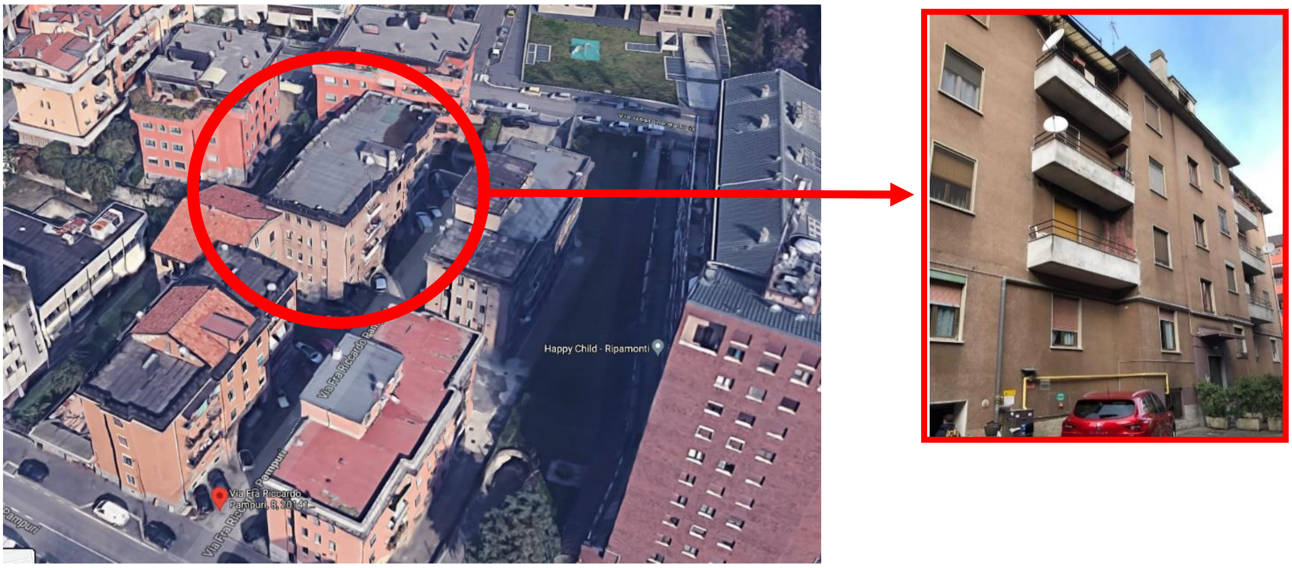

Figure 5-6 - Urban framework of the building

The procedure of energy analysis is the same of the Bombardieri case study and to achieve aim of the project can be summarized in a few points. In this case study, the main aspects will be:

- Application of a thermal coat and installation of a ventilated wall.
- Substitution of old glass units.
- Substitution of conventional central heating system with a modern heat pump.
- Installation of a photovoltaic plant on the roof with a storage system.

As for the case study of Bombardieri's house, the building was created and reproduced on "Termus BIM" and our task was to reproduce the de facto state of the building in order to evaluate its starting energy class because, as long as the project use the incentives given by the "Superbonus 110", an improvement of 2 energy class is necessary to access the full incentive, so this condition will be verified to proceed correctly.

Figure 5-7 - Model reproduced on Termus BIM

In this project, the thermal zones evaluated are 20 as the units of the buildings.

The main intervention is the application of 14 cm of insulation EPS layer to improve the envelope's performance, that leads the wall performance from U = 1.077 W/m²K to U = 0.188 W/m²K increasing the thermal transmission of 82%. Also, the underground intrados and the flat roof have been insulated with EPS and XPS of 14 cm.

The second intervention was to substitute the old windows of each apartment with new generation windows (the model selected was a PVC double glazing window with low emission coat characterized by a transmission coefficient below U_W = 1.3 W/m²K) and to apply a layer of AeroGel, that is a type of synthetically amorphous silica, behind the frame of the windows as well as the upper surface of the balcony (under the concrete slab) in order to remove the thermal bridge.
These operations are fundamental to maintain an isolated environment inside the building, reducing the thermal dispersions and nullifying the risk of mould formation. But, in order to apply these, since it concerns the private parts of the building, it is required a disclaimer from the owners of the apartment, which was provided in advance in order to start with the simulation of the project on the software.

Differently from Bombardieri's project, no relevant problems were found regarding the installation of the ventilated wall, thanks to the regularity of the perimeter surfaces and to the reduced length of the balconies, that may create an interruption of the flow inside the frame of the ventilated wall.

Concerning the central heating system, the installed configuration consisted of a floor-standing boiler of 180 kW, and it was required to fulfil the energy demand for heating, which was estimated to be about 172.70 kWh/m² per year by the simulation created on the software. According to the new thermal energy demand of 39,770.91 kWh, the project thermal load of 33 kW and the efficiency of the whole system that increase the power needed to balance the thermal demand, it has been designed two heat pump of 29,8 kW. They have been designed separately and oversized due to the fact of ensure a correct and continuous performance of heating.

Moreover, for the DHW (Domestic Hot Water), that are independent for each building units, it has designed a condensing boiler of 24 kW.

The last intervention, using the "Superbonus 110", was to install 60 modules of 330 kW on the roof to produce 23 173.98 kWh. The restriction of the incentive force to design at least 19.8 kW of photovoltaic field to produce renewable energy.

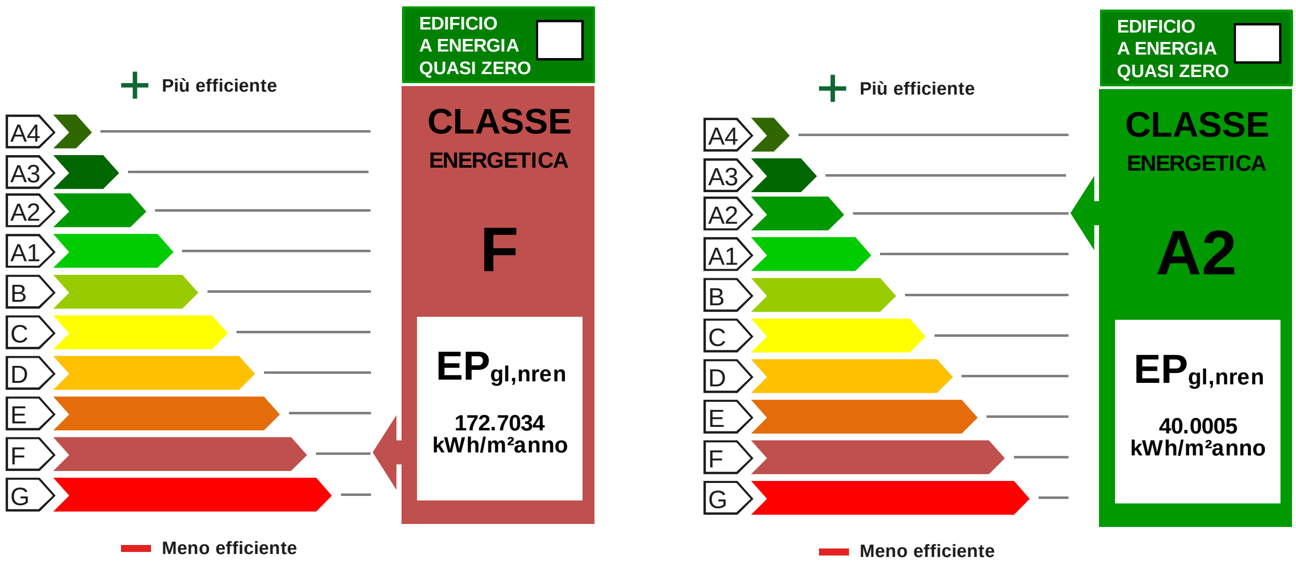

Figure 5-8 - Building's energy class of the de facto state and the project state

After all the above steps have been performed, is possible to make a comparison between the Ante-Operam and the Post-Operam and be sure to make the improvement of 2 energy class as shown in the figure 5-8.

As it is possible to see, the performance of the building rises a lot, significantly reducing the energy demand, the power capacity necessary to fulfil it, and so also the emissions of pollutants. The final result shows a reduction of not renewable energy of 76%.

Starting from these results is possible to proceed with some other analysis concerning the selection the sizing of the photovoltaic plant with the storage system, finding its best capacity to enhance the collective self-consumption and value the possibility to create a "Renewable Energy Community".

5.3 Energy Balance and Storage System Sizing

The aim of this chapter is to provide a general overview about what may be the advantages of installing a photovoltaic power plant on a residential building and it will show the benefit of installing a well sized storage system.

The target is to reduce the energy withdrawals from the grid, and in order to do so, the contemporaneity between energy production and consumption it's a key aspect, but it is not always easily achievable since the load curve typically doesn't match at all the production curve (as seen in the previous chapter in the figure 17).

Fortunately to solve this problem is possible to adopt different solutions, but the simplest one is to install a battery capable to store energy when it is produced, and not consumed instantaneously, and release it when necessary.
Since this project take advantages of the "Superbonus 110", this solution is completely incentivized, solving the problem of the high investment cost that characterizes this system.

Figure 5-9 - Panel layout of Pampuri's Building

In the figure 6-2 the graph represents the energy need covered by the PV plant installed on the roof. The considered capacity is 19.8 kW, composed by 60 Panasonic panel of 330 W each (HIT module: VBHN330SJ53) oriented to the south with a tilt angle of 30°, since the building has a flat roof surface, so these parameters could be chosen without any constraint of any sort.

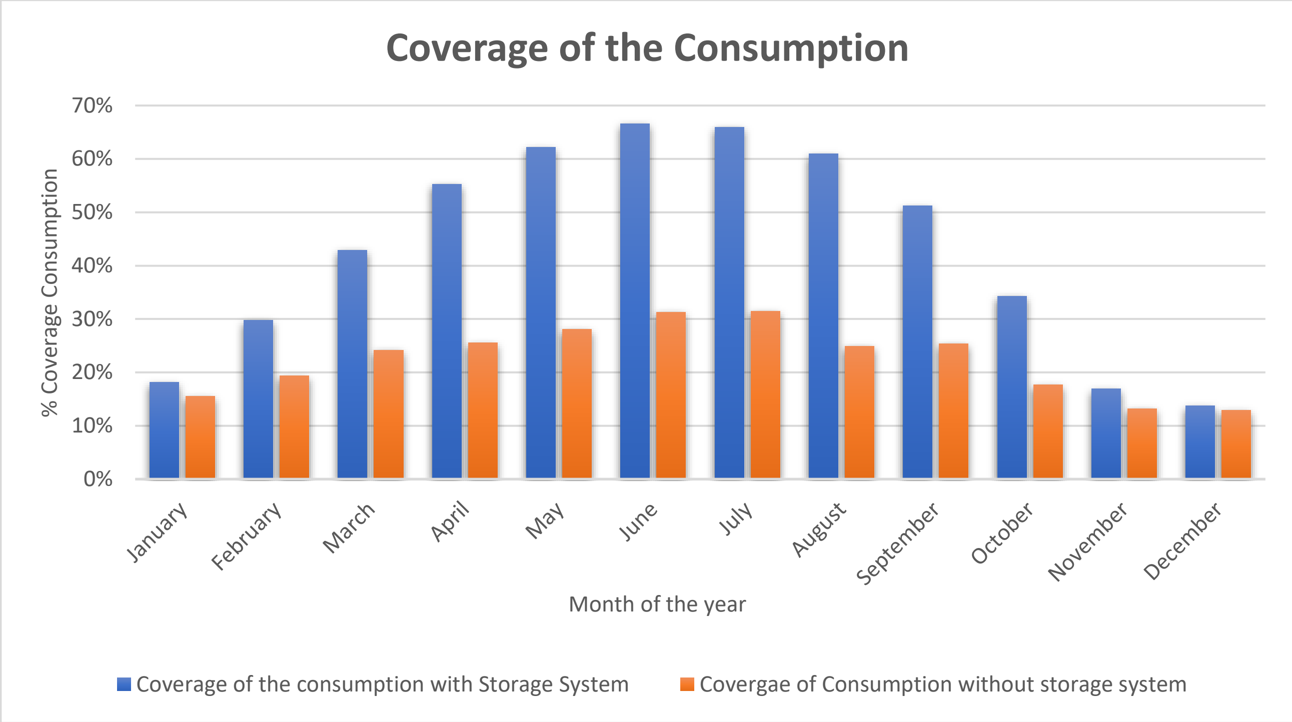

Figure 5-10 - Coverage of the consumption of Pampuri's Case study

As it is possible to see, it's nearly impossible to reach the energy self-sufficiency, since the building is composed by many apartments and the PV plants itself is not able to produce the same amount of energy required by the whole building to fulfil its energy demand.

To estimate it, the temperatures of a typical week of each month were evaluated to be able to estimate the consumption of the heat pump, having the availability of the electricity consumption of the latter based on the outside temperature and moreover, in order to take into account the possibility of the "collective self-consumption", it was considered the energy demand of each apartment depending on the number of people it is composed of.

As it can be seen by the graph, the coverage of the consumption is almost doubled thanks to the storage system, and it was noticed that the influence of the max capacity of the storage system has a logarithmic trend:

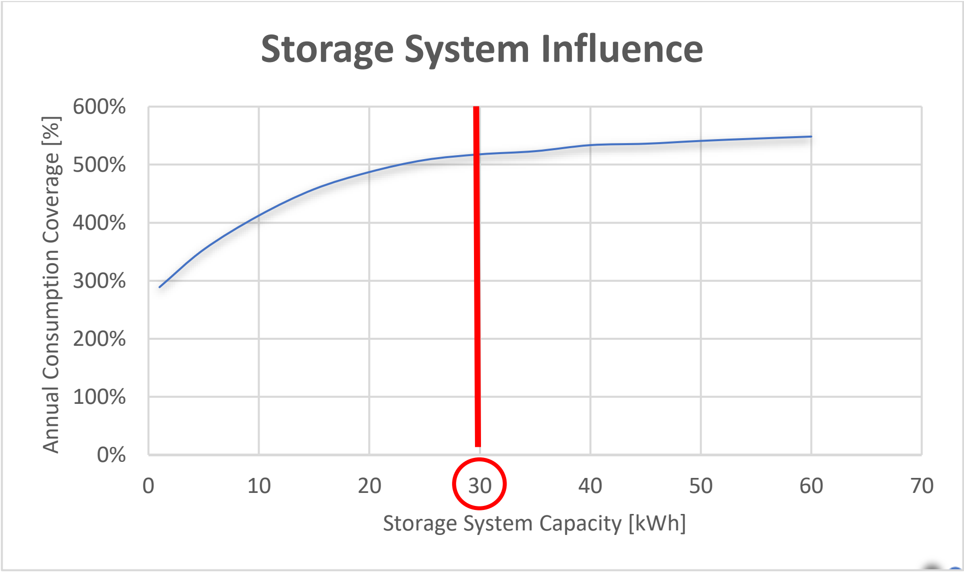

Figure 5-11 - Storage System Influence on annual consumption coverage (Pampuri)

In fact, the best solution that may be proposed for Pampuri's case study is to install a capacity of 30 kWh, since the more it would be installed the less it could benefit from the store of the energy from this point on. And in this way, the electricity fed into the grid is significantly reduced, since from the total production that was estimated through a software (ACCA Solarius PV) used to makes these analyses, which was 23,173.98 kWh, only 1,760.264 kWh are fed into the grid, where are obviously less valorised with respect to the self-consumption.

But the aim of this project is still to achieve the lowest impact on the electrical system concerning the grid withdrawals, thus in order to do so it's appropriate to analyse also the first case study.

The Bombardieri's case study has a dimension that is radically smaller than the Pampuri's case study, since it is composed by only 2 apartments with respect than the 20 apartments considered before.
Also in this case, it has been installed a total capacity of 19.8 kW, composed by 60 Panasonic panel by 330 W each, but now the configuration of the panel depends on the roof geometry, in fact the plant was divided in 3 sections (as shown in the figure 6-4) oriented to South, Est and

West.

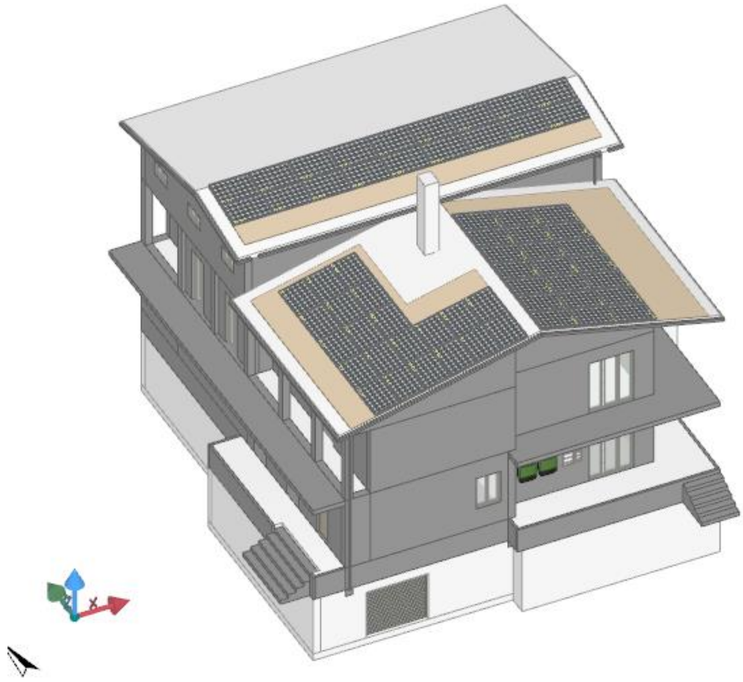

Figure 5-12 - Panel layout on the Bombardieris's Roof

With this configuration, the plant is able to produce 20,294.41 kWh, which can be used to cover all the energy need of the building.
As it is possible to see in the graph of the figure 6-5, the plant itself is able to cover almost 60% of the energy demand of a year, considering the request of 2 apartments composed respectively by 4 and 2 people, moreover it has been planned an installation of a heat pump to provide for the heating system, and as before the performance and the consumption of it, have been valued through the external temperatures measured for a typical week.

Thanks to the installation of a storage system, almost the totality of the energy need is covered by the energy produced on site, in fact the annual coverage moves from 60%, without a storage system, to around 85% that is a good result considering the De-Facto state of the building and the request of energy before the intervention.

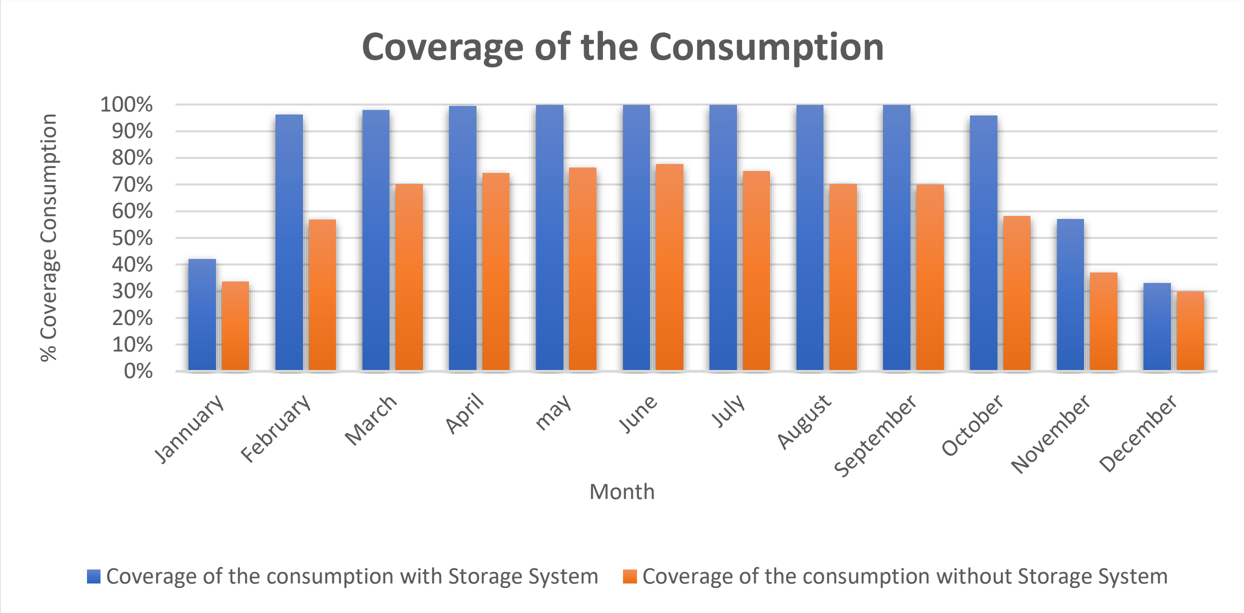

Figure 5-13 - Coverage of the consumption for the Pampuri's case study

In this case, it was considered to install a capacity of 8 kWh for the storage system, since, as shown before, the curve has a logarithmic slope and for this case study this capacity is enough to maximize the benefit without paying too much for the batteries.

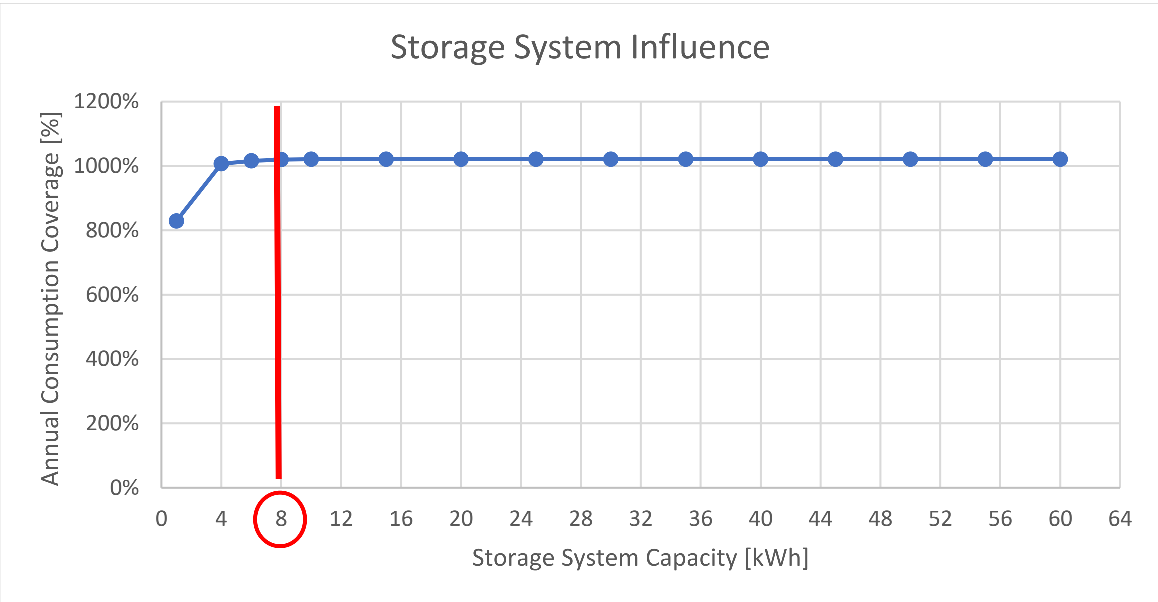

Figure 5-14 - Storage System Influence on annual consumption coverage (Bombardieri)

It was valued that 11,553 kWh, that is the 57% of the total production, are sent directly to the grid, because they cannot be self-consumed, rather than the previous case, where only 1,760 kWh of the total 23,173.98 kWh produced by the PV plant are sent to the grid.
This is a significant result because demonstrates that, concerning a residential building composed by plenty apartments, a power plant of 20 kW is not sufficient to ensure the zero impact on the grid. It has been considered a 20 kW plant mainly because is the

maximum capacity that is allowed to be installed with the “Supebonus 110” support scheme, but also because the surface required to install this capacity with the actual technology available in the market is around 100 m^2 and hardly this surface is available on the roof with a good orientation and inclination, so rarely it’s possible to install more.

So, basically whether the building evolves primarily in width rather than height it may be more probable to have more surface over which install PV panels and increase the max capacity of the plant, and in this situation, it may be useful to value other support scheme to install the PV plant.

Anyway, the result previously shown are allowed thanks to the most recent support scheme “Decreto Milleproroghe – articolo 42-bis”, in which it is introduced the concept of “collective self-consumption” as seed previously, in fact the energy produced by the PV plant can be used not only for the common expenses, but also for the consumption of the single apartments, making an hourly cross check of the energy sent to the grid and the one withdrawn.
The law provides an economic remuneration for the people how are able the consume when the energy is actually produced, but in the law it’s written also that this kind of contribute can be taken exploiting the storage devices (Comma 4; Lettera C;), solving the problem of simultaneity, for this reason it was thought to propose as a solution the installation of a storage system rather than trying to change the behaviour of individual users with home automation devices for example.

But the law aims to create a bigger scheme where this mechanism concerns not only a single condominium, but a series of residential buildings close to each other. In fact, as shown before, a lot of energy is sent to the grid when the PV plant is installed in building with only a few apartments, and this energy could be exploited to improve the situation of a building like Pampuri’s one, in order to create a “renewable energy community” and so an energy district that is almost self-sufficient or at least reduces a lot the energy request from the grid, decentralizing energy production consequently.

6 RESULTS

In conclusion we managed to provide an economic analysis of what it might be to constitute a renewable energy community, and how the collective self-consumption could be enhanced.

Since in both projects it has been considered an installation of a heat pump, it was possible to increase the self-consumption of the energy produced from the PV panel, allowing a considerable energy saving, in fact in one year is able to reduce the cost of the electricity bill of almost 3,500€ in case of Bombardieri's project (if we consider the same electricity asked from the grid) and even more for Pampuri's one.
The other contribute that is possible to see from the figure 7-1 is linked to:

- Energy sent to the grid sold at the market price.
- Costs of Tariffs saved.
- Incentives given to enhance the "shared energy".

As it is possible to see, this contribute is a lot lower rather than the previous one and does not depends on the percentage of self-consumed energy. This is caused by the fact that the plant is incentivized by the "Superbonus 110", and this allows to take advantage of only some of the components mentioned above, but at the same time, it allows to make an investment with zero pay-back time since all the cost of the interventions can be immediately covered with the credit assignment, reducing all the cost to zero for the clients.

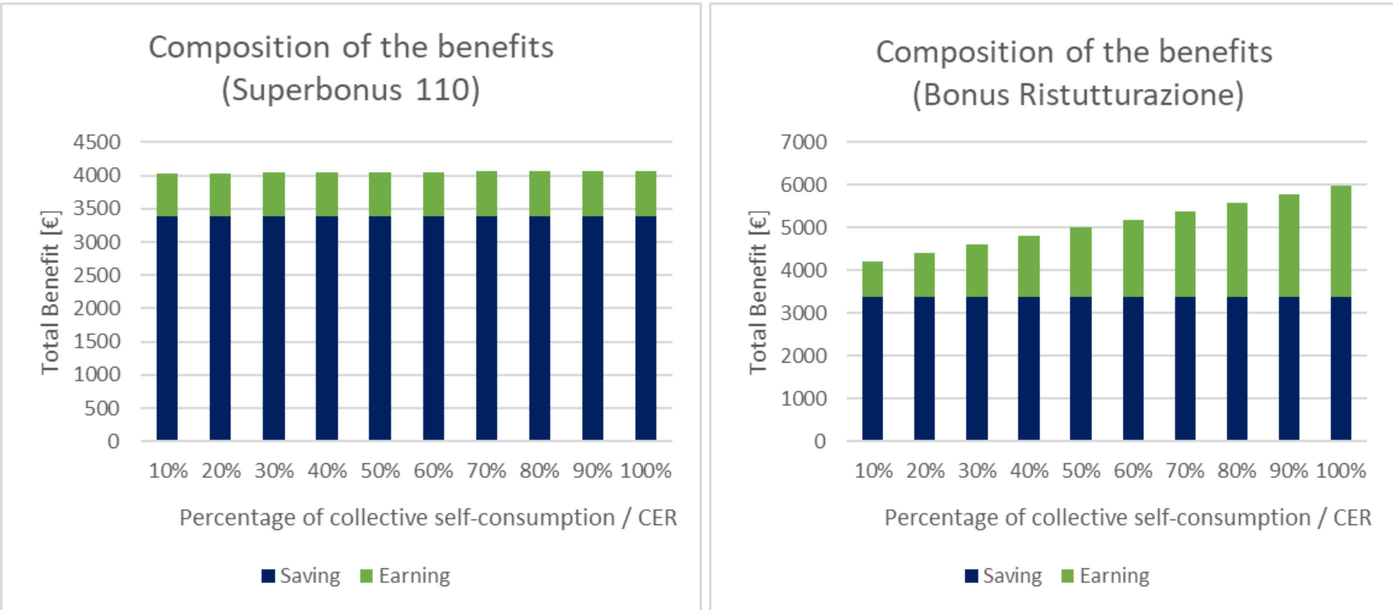

Figure 6-1 -Composition of the benefits in different cases

From the figures shown before it is evident that, depending on the type of support scheme, the benefits from the cumulative self-consumption changes consistently, and the earning part of the benefit rises a lot using the “Bonus Ristrutturazione” as the main support scheme, leading to almost 2,000€ more to the revenues.

Anyway, considering Bombardieri’s project, it was analysed that almost 11,000 kWh of renewable energy is sent to the grid and this energy could be exploited for the Pampuri’s project.

As it was designed a storage system of 30 kWh, the problem of contemporaneity could be solved easily, and the participants of the “Renewable Energy Community” could benefit from this energy. Starting from this, some economic analyses were made to quantify the earning that could guarantee a configuration like that (some moving from the “cumulative self-consumption” to the realization of a REC, composed by more than one building), considering the energy need that is not covered by the PV plant installed on Pampuri’s building, and the energy sent to the grid by Bombardieri’s PV plant.

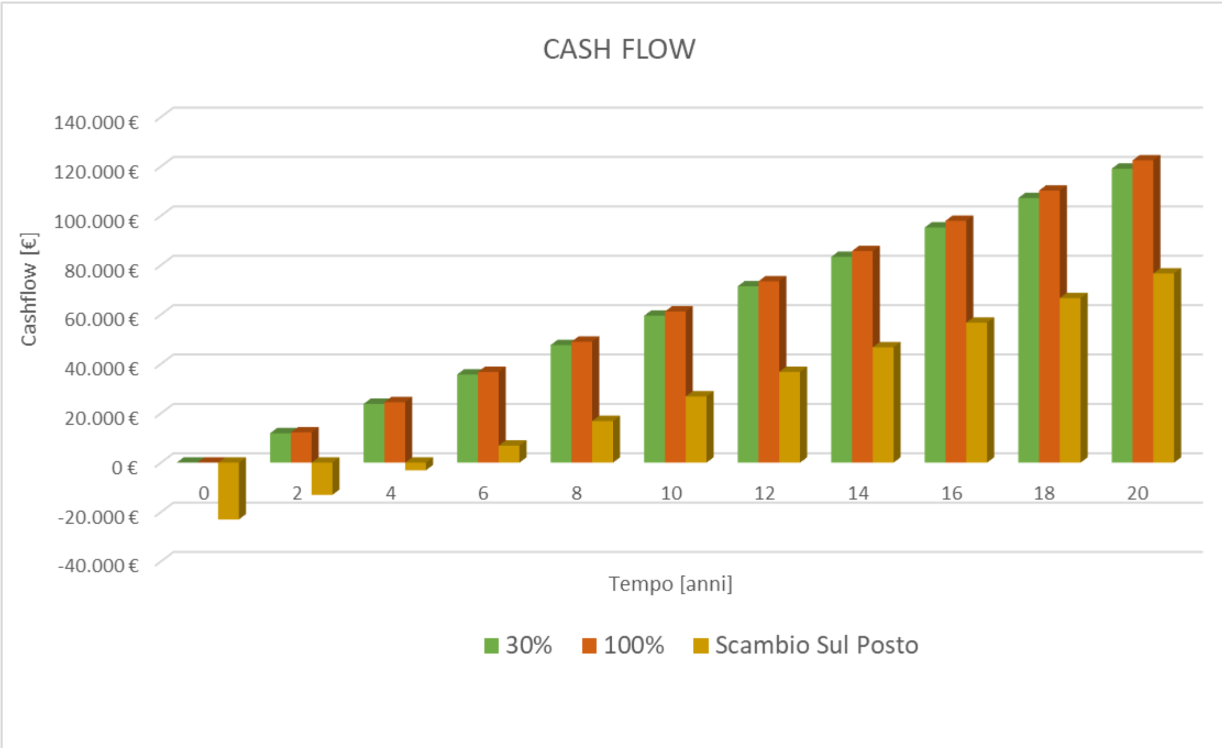

Figure 6-2 - Cash Flow in case of REC with "SUPERBONUS 110"

As it is possible to see, since both the plants have benefited from the Superbonus 110, there is no significant result depending on the collective self-consumption percentage (the cumulative cash flow reached with both the self-consumption percentage, is almost the same), so the main contribute comes only from the energy saving associated to the heat pump and the common uses consumption (elevators, building lights).

It was interesting to compare this configuration with the other incentive scheme proposed composed by "Bonus Ristrutturazione" and "Scambio sul Posto". With this configuration the investment cost moves from 0€ to 23.000 €, assuming a cost per kWp of 2.300€ and that half the cost of the plant is covered by the incentive mentioned above, that is the main different with the first configuration. The second aspect concern the enhancement of the energy sent to the grid, that has a different value in this case, but it is evident that in a 20 year span, considering the Pampuri's project it is not worth the effort, because it leads to almost half the revenues of the first configuration.

In the appendix are shown the excel sheet of the calculation done to produce the graph in the figure 7-3.

Furthermore, it is interesting to see that, other configurations can be considered that lead to different results. In fact, it can be considered:

- 20 kW – Superbonus 110.
- 20 kW – Bonus Ristrutturazione.
- 20+ kW – Superbonus 110 (20 kW) and exceeding kW with Bonus Ristrutturazione.

The "Renewable Energy Community & cumulative self-consumpiton" incentive last for 20 years, so the comparison of these configuration will be done in this period of time, even if "Scambio sul Posto" support scheme could last even for 30 years.

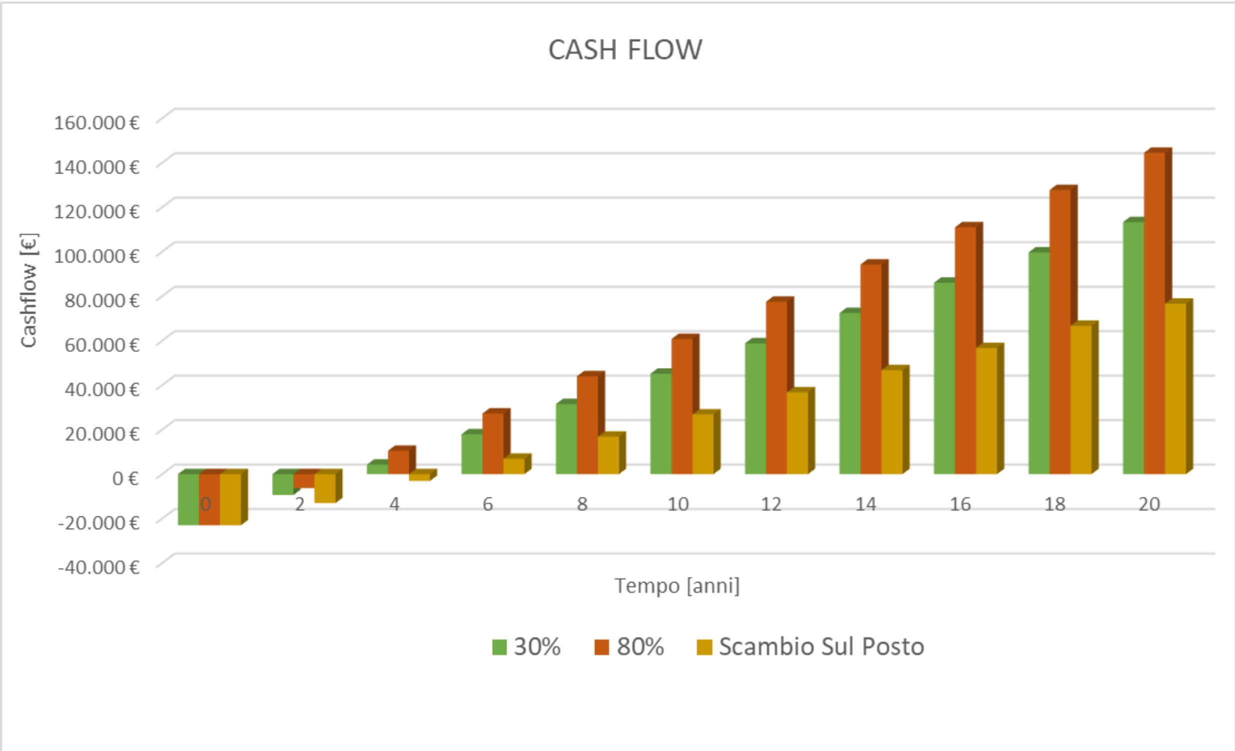

Figure 6-3 - Cash Flow in case of REC with "Bonus Ristrutturazione" as a main support scheme

Starting from the second possibility, it is shown in the figure 7-4 the cash flow of the same plant treated earlier, using “Bonus Ristrutturazione” as a support scheme instead of “Superbonus 110”.

In this situation, it is possible to achieve almost 140,000 € revenues among the participants of the “renewable energy community” and, differently from before, all the parts of the incentives could be exploited as a benefit in terms of earning, in fact the influence of the percentage of “shared energy” it’s consistent (difference between red and green column). This value could be distributed among the participants in different way, but the most important result is that, considering both the first and the second configuration, even if Pampuri’s building has an total energy demand of about 50,000 kWh, it can be covered almost entirely, reducing the energy request from the grid to only the 20,000 kWh, where around 20,000 kWh comes from the Pampuri’s PV plant and the storage system installed, and the other 10,000 kWh could come from a configuration like Bombardieri’s one, where almost half of the production of energy from the PV plant is sent into the grid.

It is evident, in the figure 7-3, that the configuration with “Scambio sul Posto” is not relevant, comparing with the other possibility. This is due to the fact that this support scheme was thought for the private buildings, and it has a low yield for the residential building composed by many apartments.

Before going to the last configuration, it is important to pay attention to the fact that the payback time of this configuration with every percentage of shared energy, stands around 4 years, making the reliability of this investment very high and secure. Moreover, this leads to the conclusion that the incentive concerning the “renewable energy community & cumulative self-consumption” fits better with the “Bonus Ristrutturazione” support scheme in terms of economic advantages.

At last, in is interesting to value a configuration with a bigger power capacity installed, that is allowed only if a sufficient surface is available on the roof of the building treated. This is not the case treated, but it is interesting in terms of possibilities that may be considered in the first steps of the sizing of the PV plant connected to a building that benefits from the “cumulative self-consumption”.

It was proposed to install a 40 kWp PV plant composed by 2 sections: one of 20 kWp supported by "Superbonus 110", and one of 20 kWp supported by "Bonus Ristrutturazione". This allows to install a higher capacity from the first cases with the same expenses of the second configuration, and to benefit from the total contributes of the incentives of the REC for the energy produced by the section supported by the "Bonus Ristrutturazione". So, basically, it is a mix of the previous configuration.

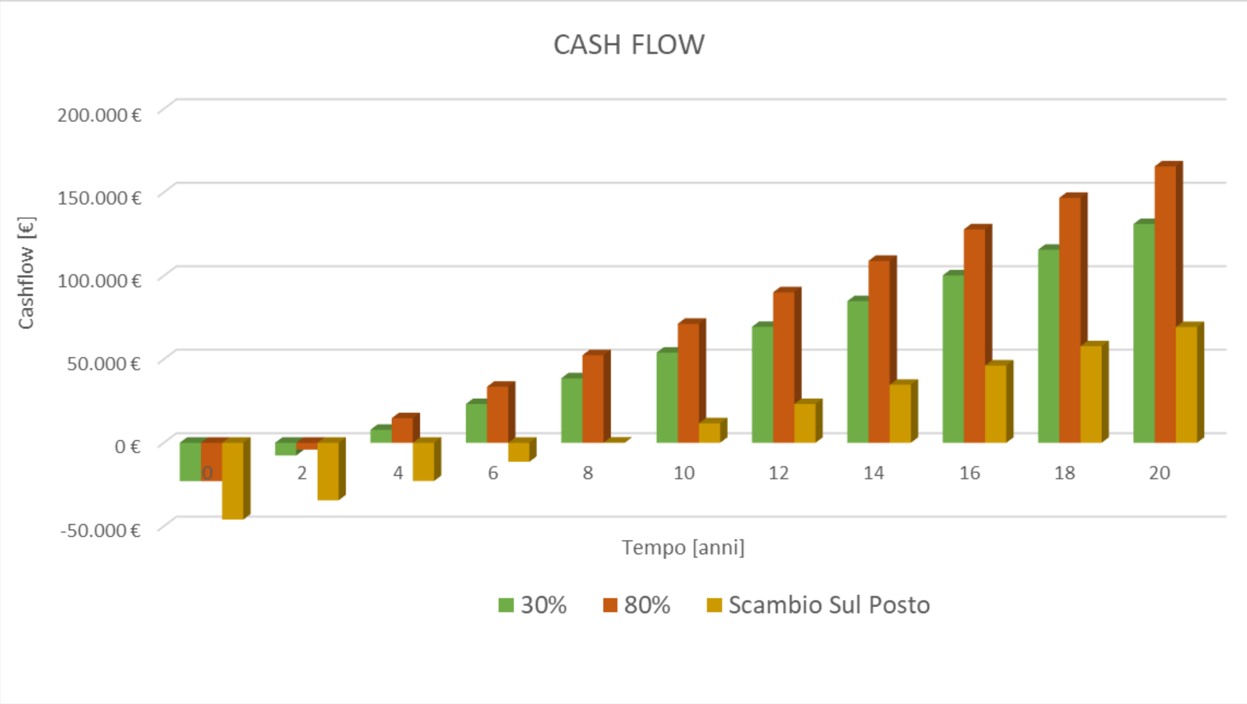

Figure 6-4 - Cash Flow in case of REC with 40 kWp installed with both "Superbonus 110" and " Bonus Ristrutturazione"

In this case, it is possible to reach even higher profit in terms of earning, reaching more than 160,000 € in a 20 years span, which would be divided by all the shareholders of the energy community, but the most important aspect is that by doing this the production of renewable energy from a building like Pampuri's one, could be doubled (more than 40,000 kWh per year), and thanks to the support taken from the energy sent to the grid by a PV plant like Bombardieri's one (around 11,000 kWh sent to the grid from a 20 kWp plant), it may be possible to fulfil the totality of the energy demand of the building, so almost nullifying the request of energy from the grid outside the REC.

Even in this case, the "scambio sul posto" support scheme is not comparable with the other possibilities, confirming the fact that it fits better for private houses, and the payback time is reduced from 3 to 2 years.

7 CONCLUSIONS AND FUTURE DEVELOPMENTS

In the last chapter it was proposed a possible “Renewable Energy Community” that may be constituted with the two cases study treated in this paper. It is evident that there are plenty benefits that can be achieved from this scheme, starting from the revenues that it could generate for the shareholders of the community, and in terms of environmental impact, because it could reduce the impact of the energy demand from residential sector, that could be covered with a local renewable energy production.

It has been considered an emission factor for Italy of 408,9 $^{gCO_{2,eq}}/_{kWh}$ (25) and considering the first case study of a residential building of only 2 apartments it was valued around 2.743 $tCO_{2,eq}$ of avoided emission, since the energy demand covered by the renewable energy was around 6,700 kWh considering the heat pump consumption. While, for the second case, it has been estimated an avoided emission of 7.92 $tCO_{2,eq}$that derives from 19,378 kWh of energy provided by the PV plant installed on the roof.

These results come from the possibility of share the energy produced by the PV plant among the apartments of a residential building, and use it not only for the common consumptions, that are really low compared to the first one.

It was shown that the “Superbonus 110” support scheme it is not the best one to exploit the full potentiality of a “renewable energy community” and the benefits of the “cumulative self-consumption”, but on the other hand, the “Bonus Ristrutturazione” fits better the aim of REC incentive, since calls for an increase in collective self-consumption, providing more contribute to the shareholders if they behave in better way, consuming energy while it is produced or without asking it from the grid, thanks to the storage system installed.

Since this paper focused more on the collective self-consumption of a single building, without any interaction among others, it could be useful to improve the energy balance of the storage system, taking into account the energy production of an external plant, in order to size more correctly the storage system and increase consequently the possibility of higher collective self-consumption. By doing so, it is possible to create a starting point for establishing a properly designated renewable energy community by ensuring a high coverage of consumption, without take any action on the people ‘s behaviour. It was evident that, in order to achieve the zero impact on the grid for a building like Pampuri’s one, the presence of smaller buildings like Bombardieri’s one is necessary, because at least half of the production of the PV plant energy, that is not self-consumed, may be sent to the grid in order to support the first building.

On the other hand, since the storage system has the problem of high investment cost, disposal difficulty and limited duration, it could be managed a research on the home building automation, that could change the load curve of each single apartments, improving the contemporaneity of production and consumption, and limits the quantity of energy that could be sent to the grid from the PV plant.

It has emerged, as it was explained clearly by the law itself, that the “Renewable Energy Community & cumulative self-consumption” have not been designated to generate profit, because they stand to creates benefits for the shareholders in terms of saving, but mainly to produce a less impact for the environment from the anthropic activity.

Furthermore, it emerged from the analysis of the energy balance and the hypothesis that the two case studies could be part of an energy community that the urban fabric in which such an energy community arrangement is considered must be analysed in advance. In fact, as the study shows, small buildings, such as the Bombardieri private house, can support larger buildings, as in the case of the Pampuri apartment building. In this way, it is possible to design a totally independent energy community thanks to the contribution that buildings, which produce more energy than they consume, can make to larger buildings. In fact, according to current legislation, the neighbourhoods that could benefit most from energy savings are those with a diverse urban fabric, with buildings of different sizes and able to balance energy demands where they are greatest. However, as described above, the study is based on design that aims to exploit incentives to achieve an economically sustainable result. In fact, both case studies were carried out trying to have a zero-investment cost, taking full advantage of all available incentives.

In conclusion, the result of the work has led to the awareness of how indispensable it is to plan in an integrated way, exploiting the best technologies and achieving important improvement objectives both from the energy point of view, reducing emissions, and from the social point of view, succeeding in laying the foundations for energy and urban redevelopment that can improve the lifestyle of citizens and actively involve them in the production and smart use of renewable energy.

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APPENDIX

Summary of the development of the laws about the REC:

2008	Sistemi efficienti di utenza SEU: They are not distribution systems, but it is a single end-customer who is self-producing energy from RES or CAR [Legislative Decree 115 of 2008]. The topic of self-consumption has always existed (law 9/10 1991) but since 2008 there is the definition of the law.
2009	Reti interne di utenza RIU: They are distribution networks between producers and industrial users existing on August 15, 2009 (high voltage connection).
2011	Sistemi di distribuzione chiusi SDC: They are distribution networks between producers and commercial users existing on August 15, 2009 (they are RIU but for commercial users). From here onwards come the resolutions of the authority - ARERA resolution 578/2013/R/eel and ARERA resolution 539/2015/R/eel.
2013	The first regulation of SEUs takes place
2015	Regulation of the SDCs
2018	Initiating the operation of RIUs
2019	Start of operations of TDIs other than RIUs

Table 0-1 - List of the laws concernig the REC

Settimana Gennaio	[kWh]
Produzione	217,739
Consumi Totali	-1.200,040
Consumi Senza accumulo	-1013,87
Consumi Con accumulo	-982,30
Copertura Consumi	16%
Accumulo Max	10,60
Accumulo Consigliato	30
Consumi Con accumulo Dimensionato	-982,30
Copertura Consumi	18%
Immissione in Rete	0,00

Settimana Febbraio	[kWh]
Produzione	308,420
Consumi Totali	-1.035,440
Consumi Senza accumulo	-834,88
Consumi Con accumulo	-727,02
Copertura Consumi	19%
Accumulo Max	24,86
Accumulo Consigliato	30
Consumi Con accumulo Dimensionato	-727,02
Copertura Consumi	30%
Immissione in Rete	0,00

Settimana Marzo	[kWh]
Produzione	436,100
Consumi Totali	-973,110
Consumi Senza accumulo	-737,68
Consumi Con accumulo	-537,01
Copertura Consumi	24%
Accumulo Max	45,03
Accumulo Consigliato	30
Consumi Con accumulo Dimensionato	-555,71
Copertura Consumi	43%
Immissione in Rete	18,70

Settimana Aprile	[kWh]
Produzione	532,980
Consumi Totali	-905,27
Consumi Senza accumulo	-674,33
Consumi Con accumulo	-372,29
Copertura Consumi	26%
Accumulo Max	60,86
Accumulo Consigliato	30
Consumi Con accumulo Dimensionato	-405,19
Copertura Consumi	55%
Immissione in Rete	32,90

Settimana Maggio	[kWh]
Produzione	588,840
Consumi Totali	-886,37
Consumi Senza accumulo	-637,60
Consumi Con accumulo	-298,89
Copertura Consumi	28%
Accumulo Max	66,89
Accumulo Consigliato	30
Consumi Con accumulo Dimensionato	-335,31
Copertura Consumi	62%
Immissione in Rete	37,78

Settimana Giugno	[kWh]
Produzione	688,940
Consumi Totali	-886,37
Consumi Senza accumulo	-609,26
Consumi Con accumulo	-205,94
Copertura Consumi	31%
Accumulo Max	83,87
Accumulo Consigliato	30
Consumi Con accumulo Dimensionato	-296,28
Copertura Consumi	67%
Immissione in Rete	98,85

Settimana Luglio	[kWh]
Produzione	712,040
Consumi Totali	-950,0526667
Consumi Senza accumulo	-650,84
Consumi Con accumulo	-246,64
Copertura Consumi	31%
Accumulo Max	77,24
Accumulo Consigliato	30
Consumi Con accumulo Dimensionato	-323,86
Copertura Consumi	66%
Immissione in Rete	85,85

Settimana Agosto	[kWh]
Produzione	619,920
Consumi Totali	-806,857
Consumi Senza accumulo	-605,71
Consumi Con accumulo	-283,38
Copertura Consumi	25%
Accumulo Max	112,53
Accumulo Consigliato	30
Consumi Con accumulo Dimensionato	-314,80
Copertura Consumi	61%
Immissione in Rete	127,86

Settimana Settembre	[kWh]
Produzione	547,820
Consumi Totali	-950,053
Consumi Senza accumulo	-708,89
Consumi Con accumulo	-402,23
Copertura Consumi	25%
Accumulo Max	61,17
Accumulo Consigliato	30
Consumi Con accumulo Dimensionato	-463,68
Copertura Consumi	51%
Immissione in Rete	61,44

Settimana Ottobre	[kWh]
Produzione	314,720
Consumi Totali	-903,020
Consumi Senza accumulo	-743,30
Consumi Con accumulo	-588,30
Copertura Consumi	18%
Accumulo Max	33,61
Accumulo Consigliato	30
Consumi Con accumulo Dimensionato	-593,53
Copertura Consumi	34%
Immissione in Rete	5,23

Settimana Novembre	[kWh]
Produzione	180,740
Consumi Totali	-1.068,060
Consumi Senza accumulo	-926,94
Consumi Con accumulo	-887,32
Copertura Consumi	13%
Accumulo Max	10,78
Accumulo Consigliato	30
Consumi Con accumulo Dimensionato	-887,32
Copertura Consumi	17%
Immissione in Rete	0,00

Settimana Dicembre	[kWh]
Produzione	164,920
Consumi Totali	-1.201,070
Consumi Senza accumulo	-1046,10
Consumi Con accumulo	-1036,15
Copertura Consumi	13%
Accumulo Max	3,62
Accumulo Consigliato	30
Consumi Con accumulo Dimensionato	-1036,15
Copertura Consumi	14%
Immissione in Rete	0,00

Figure 0-1 - Summary of each month of consumption, production and coverage of the consumption.

INPUT DATI

SCELTE INCENTIVO	SUPERBONUS (> 20 kW) - 110%	
	110%	
Potenza Impianto 1 (Superbonus)	20	kW
Potenza Impianto 2 (No Superbonus)	20	kW
Costo Unitario Impianto	2300	€/kW
Incentivo Energia Condivisa	11	c€/kWh
Valore Unitario Energia Prodotta (PUN)	3,890433333	c€/kWh
Costo Totale Impianto	92.000,00 €	
Costo coperto dall'incentivo	69.000,00 €	
Costo Residuo Impianto	23.000,00 €	
Superficie Pannello/kW	5	m²
Valore Energia Condominio	86,516	c€/kWh
Valore energia condivisa (tariffario)	0,822	c€/kWh
Valore di mercato del 2,6% dell'energia condivisa (Tariffario)	0,101151267	c€/kWh
CER	Si	
Energia dalle CER	11553	kWh
Italian Emission factor	408,9	gCO2eq/kWh

RIEPILOGO DATI DI PARTENZA

Potenza	40	kW
Ore Medie Produzione	1010	ore/anno
Produzione annua	40400	kWh
Energia Prodotta Impianto 1	20200	kWh
Energia Prodotta Impianto 2	20200	kWh
Consumi Servizi comuni	5623	kWh
% produzione destinata ai servizi c	13,92%	
produzione destinata ai servizi co	5623	kWh
Produzione Immessa in rete	34777	kWh
Costo Impianto	92000	€
Superficie Necessaria	200	m²
Fabbisogno annuo (Casa Privata)		kWh
Valore Autoconsumo (costo energ	0,2	€/kWh

COMUNITA' ENERGETICHE RINNOVABILI

QUOTA ENERGIA CONDIVISA	Energia condivisa /A.Collettivo	Risparmio per servizi comuni - autoconsumo	Beneficio risparmio di Oneri di rete	Beneficio Risparmio perdita di rete	Valore dell'energia (RITIRO DEDICATO)	Incentivo (CER)	Contributo Guadagnato	TOTALE
	[kWh]	[€/anno]	[€/anno]	[€/anno]	[€/anno]	[€/anno]	[€/anno]	[€/anno]
10%	2894,15	4864,79468	23,79	2,93	1802,437763	318,3565	2147,51	7012,31
20%	5788,30	4864,79468	47,58	5,85	1802,437763	636,713	2492,59	7357,38
30%	8682,45	4864,79468	71,37	8,78	1802,437763	955,0695	2837,66	7702,45
40%	11576,60	4864,79468	95,16	11,71	1802,437763	1273,426	3182,73	8047,53
50%	14470,75	4864,79468	118,95	14,64	1802,437763	1591,7825	3527,81	8392,60
60%	17364,90	4864,79468	142,74	17,56	1802,437763	1910,139	3872,88	8737,68
70%	20259,05	4864,79468	166,53	20,49	1802,437763	2228,4955	4217,95	9082,75
80%	23153,20	4864,79468	190,32	23,42	1802,437763	2546,852	4563,03	9427,82
90%	26047,35	4864,79468	214,11	26,35	1802,437763	2865,2085	4908,10	9772,90
100%	28941,50	4864,79468	237,90	29,27	1802,437763	3183,565	5253,18	10117,97

SCAMBIO SUL POSTO

Fabbisogno annuo energia elettrica	Energia Immessa in Rete [kWh]	Energia Prelevata [kWh]	Energia Scambiata [kWh]	Rimborso "Quota Energia" [€/anno] (Oe)	Rimborso "Quota Servizi" [€/kWh] (Cusf)	Valore Autoconsumo [€/kWh]	Totale Benefici Annui [€]
40400	34777	-5623	-5623	1352,98	-449,84	4864,79468	5767,93

Figure 0-2 - Spread sheet for the economic analysis of the REC.