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Techno-Economic Analysis of an Energy Community Based on PV and Electric Storage Systems in a Small Mountain Locality of South Italy: A Case Study

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Abstract: The ecological transition at the centre of the United Nations 2030 Agenda and the relevant EU policies are increasingly becoming an emerging issue in the political choices of most countries. It is an important challenge to ensure sustainable development and overcome the issue of energy supply. Italy produces 35% of its electricity consumption, a too low percentage that obligates the nation to purchase abroad to cover the overall needs. Energy communities can represent an interesting and viable option for businesses and citizens struggling with the abrupt rising of energy prices. In community energy systems, the energy demand of a group of households or public services is met by electricity collectively generated through renewable sources and this feature is particularly suggested in small towns to promote social benefits and environmental advantages. In this work, possible scenarios of an implementable energy community were investigated for the small mountain municipality of Soveria Mannelli, located in Southern Italy. A building stock made of four public edifices was used as a reference case for which heating needs were determined by dynamic simulations based on the EN ISO 52016-1 procedure. Other simulations carried out in the TRNSYS environment allowed for implementing different schemes of the energy community considering diverse building interaction modes, in which photovoltaic generators and electric batteries cooperate to supply heat pump systems to assure the maximum share of self-consumed electric energy. Indeed, this paper is targeted at the identification of the best solution in terms of technical and economic performance. Despite an evident study limitation is represented by the exclusive use of PV and electric storage systems, the results demonstrate a potential CO_2 emission reduction of over 80%. The more profitable solution for the Municipality was identified with an NPV of 11 k€ in 20 years with appreciable payback.

Keywords: renewable energy community; energy demand; dynamic simulation; TRNSYS; electrical storage; self-consumption; NPV; CO_2 emission

1. Introduction

The energy sector is constantly evolving to meet the reduction in CO_2 emissions and to contrast climate change, as stated by 2050 European targets. There are many measures and actions aimed at supporting the energy transition from fossil fuel to renewable resources, even though another crucial aspect is the limitation of energy needs [1]. Such measures are not only concerned with energy issues because environmental, social, and economic changes are also involved, constituting the three topics that lie at the base of sustainable development. The building sector plays an important role to reach sustainability goals and particular attention has to be paid to new edifices [2] and the renovation of the existing building stock [3]. In this scenario, renewable energy sources are becoming the key technology for the transition to a decarbonized society. The main driver for the reduction in buildings' CO_2 emissions is the combination of energy efficiency measures, with the electrification of building technical plants. In light of this, PV systems and electric heat pumps are nowadays well-consolidated technologies that allow for reducing primary energy consumption of buildings [4,5]. A recent interesting and appealing concept is represented by the Energy Community (EC), introduced in Europe by the "Renewable Energy Directive Recast 2018/2001" (RED II) [6], which is defined as "a legal entity autonomous that is based on voluntary and open participation" of all final customers, "members or shareholders are natural persons, local authorities, including municipalities, or small enterprises", also stating that "for private undertakings, their participation does not constitute their primary commercial or professional activity". The main focus of such a regulation is "to provide environmental, economic or social community benefits for its shareholders or members or for the local areas where it operates, rather than financial profits". It allows anyone to produce, consume, store, sell, and share electrical and thermal energy while preserving subjective rights and duties. The regulation does not require a minimum or maximum limit for the system's strength but accounts for the essential proximity between production and consumption. Different reasons should incite adhesion and participation in a such scheme: environment improvement, social relationship strengthening, and economical savings.

In [7], the objectives for joining an energy community were identified for a varied range of stakeholders. The results showed the elements that need to be considered when designing an EC, as well as when setting up policy initiatives to stimulate a large-scale EC. It was found that, for potential members, financial incentives are the main drivers of participation but often not the decisive objectives. Their decision to join is influenced by a variable combination of social, economic, technical, and environmental motivations. Local governments mainly want an EC to bring social and environmental advantages, and the local distribution system operator (DSO) only supports ECs when they can bring added value to their main grid and society as a whole, avoiding major grid investments. The opportunity to extend the "zero-energy building" concept to the neighbourhood scale was investigated, taking into account the impact of the urban form on energy needs and the onsite production of renewable energy, as well as the impact of location on transportation energy consumption [8]. A conceptual agent-based model for an urban neighbourhood in Iowa was proposed to predict household-level renewable energy adoption behaviours in the presence of multiple options [9].

One of the most important aspects in the implementation of a sustainable energy community is the freedom of the stakeholders' number and typology choice, and the organization is based on different reasons, objectives, and resources. The choice can change according to the size and type of buildings and according to their geographical location and the climate of the community. There are different renewable sources and different technologies that can generate electric and thermal energy but photovoltaic and wind turbines [10] are mainly contemplated. Some other interesting options can be the use of geothermal energy [11], hydrogen systems, wood biomass [12], and cogeneration systems [13]. Other studies explored how energy communities can mobilise ICT to enhance the agency on the energy transition. Two energy communities were closely followed for three years, collecting data during project meetings and semi-structured interviews [14]. Some investigations focused on the bcVPP (community-based virtual power plant) in different contexts [15]. Seven case studies in Belgium, Spain, the Netherlands, and Greece were analysed, where the multi-actor multi-criteria analysis (MAMCA) was applied in the design phase [16]. Researchers found that aspects such as emission reduction, community building, energy cost reduction, and grid stability were considered to be the most significant. In worldwide research, 23 case studies have been identified and analysed based on their design methodology, focusing on the technologies and measures used for energy consumption reduction and minimization of greenhouse gas (GHG) emissions, as well as the generation of electrical and thermal energy by renewable sources. The study revealed that all of the settlements mainly focused on onsite energy generation, while some of them also considered various adaptation techniques to lessen buildings' energy demand, and few of them incorporated mitigation strategies to lower the ambient temperature and diminish the GHG emissions and the energy demand of the community [17]. A community energy enterprise to increment the share of the energy supply, developed in the project "*Adotta un Pannello*" (Adopt a Panel), was developed in order to access a fixed capital for the PV installation [18].

Currently, in this field, there are no binding standard models and this produces strong flexibility because it can suit the territory, community, and its features, as shown by different case studies [19]. Nevertheless, it also represents a weak spot because it seems to be complicated to manage the members and distribute profits in an equal manner [20]. Moreover, regulations, misinformation, and socio-economic conditions are the main obstacles to the spread of EC.

In order to overcome these issues and to consider the mentioned aspects, in this study, the implementation of a municipal energy community in the small mountain town of Soveria Mannelli (Southern Italy, 39°05′ N, 16°22′ E) was proposed and analysed. The location is characterized by particular boundary conditions, both in terms of climatic context and socio-economic features, being the analysed town belonging to a disadvantaged and isolated area for which EC could represent a pragmatic solution for its development. The public building stock was analysed to identify the available surfaces for the implementation of PV systems. The thermal energy demand for heating was evaluated by dynamic simulations based on the EN ISO 52016-1 dynamic procedure to properly consider the energy balance of the building envelope [21,22]. These evaluations have been used to determine the design loads required for the implementation of the energy community in the TRNSYS 18 environment [23]. Different sizes of PV systems and electric storage have been analysed to identify the best solution in terms of self-consumed electricity and, in turn, environmental aspects. Technical-economic evaluations determined the revenues due to the EC implementation, which allowed for identifying the best solution for the municipality maximizing energy savings and economic gains.

The only use of PV systems is a limitation in the vision of the energy community because it does not embrace the vocation of the mountain territory; however, it represents the best choice due to the abundant availability of the free solar source in the considered territorial context [24,25]. Nevertheless, the next step of the research is the evaluation of other renewable systems to further enhance EC self-consumption. In particular, the employment of solid biomass, largely abundant in the mountain areas and available in the neighbourhood due to the forest maintenance, will be considered in a centralized cogeneration plant.

The study is the result of preliminary research carried out in the context of a doctorate at the University of Calabria. The Ph.D. is founded by the National Development and Cohesion Fund (FSC) on the issues of the National Strategy for the internal and marginalised areas of the country.

2. Materials and Methods

2.1. Case Study

The mountain city of Soveria Mannelli is located in Southern Italy, between the Sila plateau and Mount Reventino, at an altitude of 800 m above sea level. It occupies an area of 20.5 km^2 with a population (from the last census) of 2950 inhabitants [26]. It is made up of 5 fractions and has a population density of 143.9 inhabitants/km^2. Characterized by cold winters and mild summers, is in climatic zone E with 2.374 heating degrees-day (according to national classification); nevertheless, it is classified as a subtype "Csa" (hot-summer Mediterranean climate) in the Köppen Climate Classification [27].

The building stock selected for the EC analysis consists of five public buildings: a primary school, a secondary school and its canteen branch, a city hall, and the technical office. The locations of the considered buildings are depicted in Figure 1.

Figure 1. Aerial view of the considered buildings for cooperation in the EC.

All of the analysed buildings have been subjected to energy efficiency measures in recent years to reduce the prevailing heating requirements, sometimes only contemplating the renovation of the air-conditioning plants. However, in the case of the primary school, efficiency improvements were also carried out on the building envelope to limit thermal losses.

The city hall and the technical office are made of 70 cm thick stone masonry. The cover is made of wood with tiles to which an insulating layer of 16 cm EPS and cellulose fibre obtained from technical documentation from thetechnical office. The windows consist of wooden frames and double-low emissive glass filled with argon. The original heating generator, supplying both buildings, was powered by diesel with a nominal power of 150 kW. Successively, it was replaced with a heat pump using a geothermal source with six boreholes 32 mm in diameter and 100 m in depth. The geothermal probes are connected to two independent absorption heat pumps working with an ammonia-water mixture by air condensation.

The primary school has an enclosure consisting of poor-quality stone masonry, wooden roofing and tiles, and aluminium windows with a double pane. The cast iron radiators are powered by a diesel boiler. The energy renovation interventions have foreseen an internal coat of 3 cm thick rock wool. The mineral wool has been used also for the insulation of the dispersing ceiling towards the unheated attic. The old diesel boiler has been replaced with 2 condensing boilers working in master-slave mode supplying fan coils as emitters.

The building envelope of the middle school and the canteen is made of semi-solid bricks. The latest energy efficiency interventions have concerned the replacement of generators. In the power plants, there were two heat generators with diesel burners with single-stage blown air. These have been replaced with a new condensing generator with a 115 kW modulating burner for the middle school and with a heat pump and a VRF system for the detached site. Table 1 synthetizes the main features of the considered building-plant systems.

Table 1. Main features of the considered building-plant system.

	Envelope			Heating Plant
	Vertical Wall	**Roof**	**Window**	
City hall	70 cm of stone masonry lined	Wood with tiles and EPS insulating	Wooden frames and double low emissive glass with argon cavities	150 kW diesel boiler
Technical office	70 cm of stone masonry lined	Wood with tiles and cellulose fibre insulating	Wooden frames and double low emissive glass with argon cavities	150 kW diesel boiler
Primary school	Poor quality masonry and 3 cm internal coat in rock wool	Wood with tiles and wool rock insulating	Aluminium with double glazing	2 condensing boilers
Secondary school Branch-canteen	Semi-solid bricks	Concrete brick floors	Aluminium with double glazing	Condensing boilers Heat pump

2.2. Thermal Energy Demand and Dynamic Simulation

The analysis of heating requirements was evaluated for each of the buildings using hourly dynamic simulations carried out by a software tool. The software is based on the procedure described in the ISO 52016 standard and the modelling of structures is carried out by the 4R5C method (4 resistances, 5 capacitors) to consider the thermal behaviour of the building fabric. Compared to the classical assessment by the quasi-state model, based on the Italian standard UNI TS 11300-1 [28], the main advantage of the dynamic hourly method consists in the better modelling of the building-plant system, which is more reliable in considering capacitive effect affecting the system thermal inertia, obtaining reliable results.

In order to sett the schedules for activities and equipment use, a survey was made on the activities and habits that are carried out in the buildings so that standardization of a typical day was also made according also to the seasons and the intended use of the buildings.

For this study, it was assumed that the generators of the heating systems in the considered buildings are ideally replaced with air-water heat pumps. The aim was to make the buildings completely independent from natural gas and to rationalize the electric energy to be self-produced and shared within the energy community. After the evaluation of the thermal energy requirements, commercial heat pumps, sized following the design loads, were chosen for each analysed building.

The heat pump characteristic curves were plotted for a flow temperature of 45 °C, suggesting fan-coils as emitters, and COP trends were identified (see Figure 2). Through the correspondent equation, the COP can be calculated hour-by-hour as a function of the outside air temperature. Since the chosen devices are equipped with inverters and the chiller is opportunely sized, worsening of the COP due to the part-load mode was not taken into account. Finally, starting from the COP and the thermal requirement values, the hour-by-hour heat pump electricity requirement was evaluated, as well as the PV production, in order to determine the self-consumed share, the available rate to transfer into batteries, and the share absorbed from the grid. It has to be noticed that heat pumps have priority in the absorption of electricity.

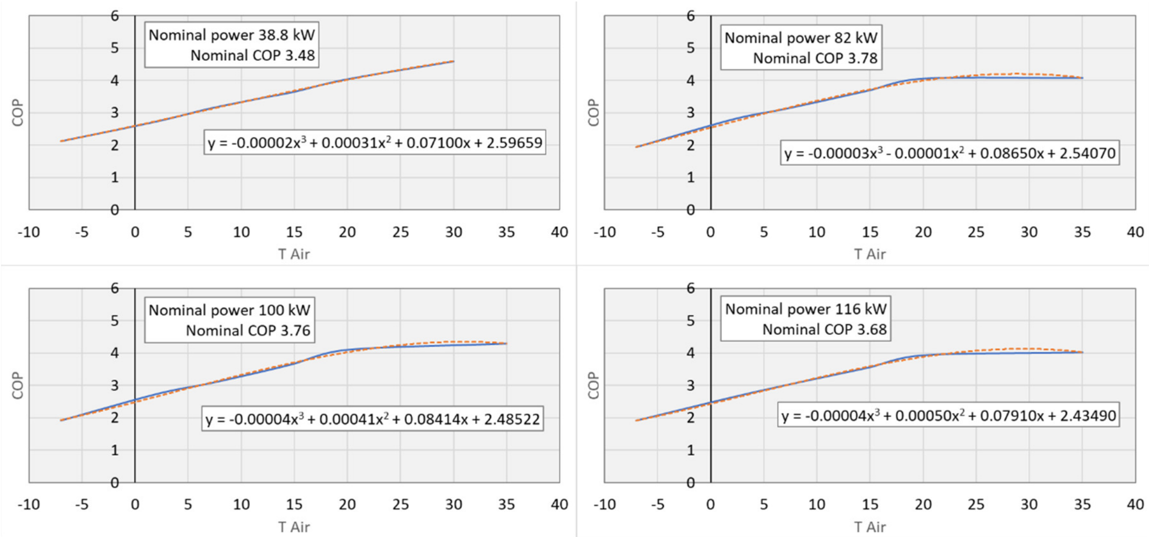

Figure 2. COP of the simulated heat pumps as a function of the outdoor air temperature by setting the supplied hot water to 45 °C.

2.3. The Parametric Study

After the electric needs were assessed, 21 parametric studies were carried out. The parametric studies involved the PV size and the capacity of the batteries.

For the choice of PV peak power, a preliminary analysis of the available roofs of the buildings constituting the energy community was made. In particular, the extension of the slopes facing south, west, and east was assessed, in order to identify the panel whose dimensions guaranteed the best utilization of the available roof space. Table 2 shows the surfaces available for the installation of the photovoltaic modules in the considered buildings. Successively, 5 types of commercial PV panels were identified among those that had high efficiency.

Table 2. Installable PV peak power among the considered buildings.

	Roof Area [m^2]	Modules [n°]	Peak Power [kW]
Branch-Canteen	230	129	54.18
Secondary school	246	98	41.16
Primary school	122	47	19.74
Technical office	43	15	7.05
City hall	280	76	31.92
School gym	188	72	30.24

In the case of the technical office, only a part of the roof was considered for the new installation, as the remaining part of approximately 121 m^2 is already occupied by a pre-existing system and which was considered in the EC configuration.

From evaluations on the technical feasibility, a PV poly-crystalline module with a peak power of 420 W was chosen. The maximum installable power was found to be 184 kW and, in light of this, it was decided to analyse 3 cases: the first case with a PV peak power of 100 kW, a second with a peak power of 150 kW, and the last case with the maximum installable peak power of 184 kW.

Additionally, the electric storage was chosen among different commercial products to have the technical info required for the battery modelling in simulations. The basic unit chosen for the analyses has a nominal capacity of 12.8 kWh and the first case considered a total storage of 64 kWh. For the other six cases, the storage system string of 5 modules was increased from time to time to reach a total of 35 modules and a global capacity of 448 kWh.

The size of the inverter was chosen by calibrating its size as a function of the installed PV peak power. Table 3 lists the different quantities varied in the parametric study.

Table 3. Values considered in the parametric study for the PV and inverter sizes and the battery capacity.

PV Modules [kW]	Battery Capacity [kWh]							Inverter [kW]
100	64	128	192	256	320	384	448	103
150	64	128	192	256	320	384	448	153
184	64	128	192	256	320	384	448	186

2.4. Energy Community and Dynamic Simulation

One of the novelties introduced in this work concerns the development of an integrated approach in the TRNSYS 18 software (Figure 3). This tool, in fact, was used for the energy simulation, but it does not include urban modelling. So, the interaction among the buildings was modelled by Type9c, which by an attached file provides the calculated electrical loads required to plan suitable management of the energy fluxes.

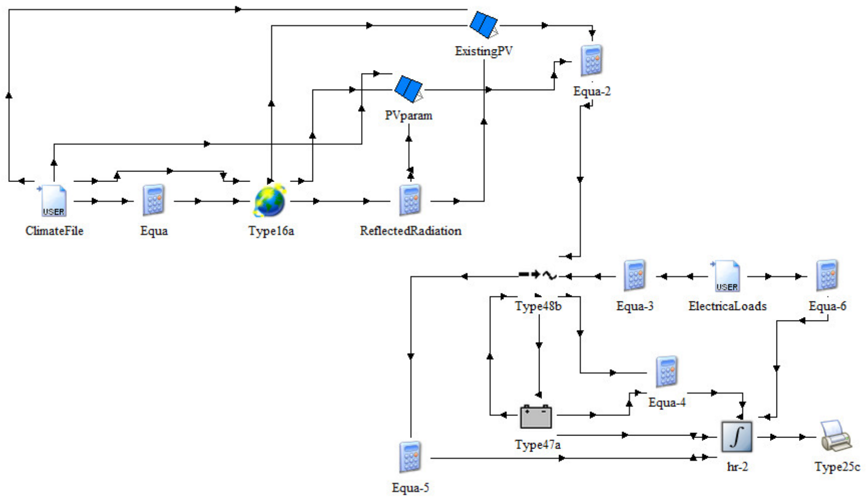

Figure 3. TRNSYS model considered for the electric sharing among the considered buildings.

External thermal stresses are applied through a link with a weather file. The climatic data provided by the Italian Thermo-technical Committee (CTI) are on an hourly basis and interpolated for lower timesteps. To complete the solar data entry, the radiator processor Type16a was used to project the horizontal solar radiation on tilted and exposed surfaces.

Two different blocks of PV systems were considered using Type103b. One of these is for the existing photovoltaic system integrated into the calculation. The second one represents the PV system on which the parametric analyses were carried out for the evaluation of the best EC configuration.

Type48b was used to simulate the control of electric chargers that manage the electricity produced by PV generators and to define the inverter output power capacity as a variable. The same type allowed priority for satisfying the heat pump electric loads and only then the surpluses can be exploited to recharge batteries.

The simulations were carried out with a timestep of 1 min; therefore, the quantity integrator Type24 returned the results at a monthly level for easier evaluation.

Basically, the main results provided by TRNSYS were PV electricity production, instant electric loads, storage of electric surplus, and the share provided by the national grid.

2.5. Tecno-Economic Analysis

Solar systems are often characterized by low operating costs and high investment expenses. For this reason, the sizing of a solar system requires methods of economic evaluation and optimization. In this regard, an analysis of costs and revenues was carried out throughout the expected lifespan, considering discounting and inflating rates to attain the actual revenues over the various years as outputs, considering initial costs (I_0), management, and maintenance costs (C_k).

The economic analysis of investments was carried out using discounting methods, which report all of the amounts at the same instant of time. The discounting of future revenues (R_k) was carried out using the customer's discount rate "d". The discounting method used is the NPV (Net Present Value), equal to the sum of the discounted net cash flows decreased by the value of the initial investment.

As usually adopted in the calculation of solar plants and considering the revenues discounted to the energy inflation rate "e" and the costs discounted to the general inflation rate "g", the NPV can be calculated as:

$$-I_0 + \sum_{k=1}^{n} R_k \cdot \left(\frac{1+e}{1+d}\right)^k - \sum_{k=1}^{n} C_k \cdot \left(\frac{1+g}{1+d}\right)^k \quad (1)$$

According to estimates on current economic data, the indices e, d, and g used in the economic analyses are listed in Table 4 and updated to the last available values in 2022.

Table 4. Financial indices employed in the economic analysis.

Financial Indices		
Rate of inflation of the cost of energy	e	0.27
Customer's discount rate	d	0.04
The general rate of inflation	g	0.08

The values reported in the national price lists were used to evaluate the installation costs, including all of the necessary services as listed in Table 5. In particular, a value of 1190 €/kW$_p$ was considered for the PV generators, 1000 €/kW$_p$ for the inverter, and 586.11 €/kWh for the electrical storage. In this preliminary analysis, available financial support was not considered. An annual cost of 2.5% of the initial total cost was considered instead for the maintenance as well as the cost related to the replacement of the inverter and batteries at the tenth year.

Table 5. Summary of costs and revenues for Italian energy communities.

	Cost			**Revenues**		
I_0	PV modules	1190	€/kW	Electric energy	0.40	€/kWh
	Inverter	1000	€/kW	Energy Community	119	€/MWh
	Storage	586	€/kWh	Power-to-grid	0.07	€/kWh
	Maintenance	2.5% of I_0				

The considered revenues were the premium tariffs envisaged for shared energy and the revenues due to the energy supply into the grid. For the first case, a revenue of 110 €/MWh is currently applied for the energy shared in the EC, fixed by the national regulation and in charge for 20 years. Another 9 €/MWh is considered to enhance the benefits brought to the system, setting it constant for 20 years. The revenue from the shared energy is reported in the technical rules for accessing the enhancement and incentive of shared electricity by the Manager of Italian Energy Services (GSE). Currently, revenues of 0.07 €/kWh were considered based on the current national energy price.

Finally, the most important share in an energy community context is the revenue obtained by considering all of the electrical energy that is not taken from the grid due to the self-consumed share. For this item, an average saving of 0.40 €/kWh was considered and it refers to the cost reported by the Italian regulatory authority for energy, networks, and the environment (ARERA).

By neglecting the lack of funding for the initial installation of the plant, the determined payback is in the worst case. Nevertheless, there are several support plans for small municipalities for the creation of energy communities that surely improve the economic analysis.

The technical-economic analyses were carried out over a period of 20 years.

3. Results and Discussion

The first analysis presented relates to the electrical needs assessed for the considered buildings. Figure 4 shows the total electricity requirements for each building. These needs include heating, lighting, and equipment. It can be appreciated that in each of the 4 graphs the greatest demand occurs in winter due to the electric absorption of the heating systems. In spring, the demand is very low and is around 25 kW. Moreover, the canteen has an obvious intermittent demand as the building is used only a few hours a week. The discontinuity produces a high heating power, which is not necessary if the system were kept in attenuation operation mode. The other buildings also have a similar issue but only after the weekend as the rooms are inhabited for the rest of the days.

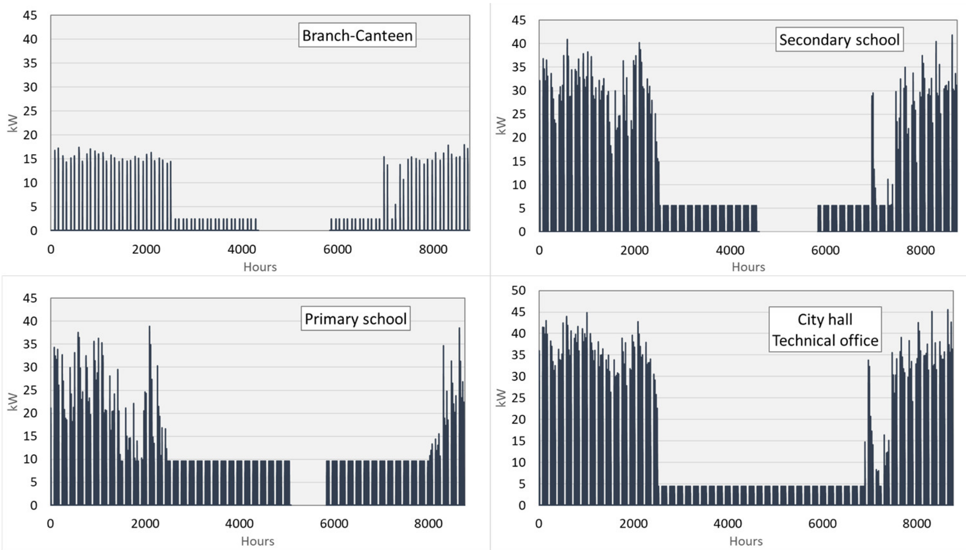

Figure 4. Total electrical needs for the considered building sharing the self-produced electric energy.

Figure 5 shows the percentages of self-consumed electricity from PV production, provided by the storage or withdrawn from the grid for three different sizes of PV plants and seven different battery capacities. In particular, considering the case of a PV plant with 100 kW_p, for any battery capacity, the electricity directly self-consumed from the PV modules amounts to 48%, whereas the electricity taken from the batteries moves from 9% in the case of a 64 kWh of storage capacity to 24% in the case of a 448 kWh capacity. The remaining share is taken from the grid and it amounts, in the worst case, to 29%. If the PV size is increased to 150 kW, the percentage of energy from the PV rises to 54%, showing a constant contribution by varying the battery size. The latter is able to provide almost 28% of electricity when the 448 kWh capacity is adopted.

Figure 5. Percentage shares of the different electricity sources as a function of PV size and battery capacity.

The share withdrawn from the grid ranges from 35% down to 18% in the most favourable case. When the maximum peak power of PV systems is installed on the roofs of municipal buildings (184 kW), even though the directly consumed electric energy rises by only three percentage points (reaching 57%), a higher reduction can be appreciated in the share taken from the grid that drops to 13% for the greatest battery size. As expected, in this scenario, the batteries provide the greatest amount of energy to the community, ranging from 11% to 30%. Even though an increasing contribution of the battery is appreciable with a higher storage capacity, it has to be noticed that 448 kWh was set as the maximum possible capacity both for technical and economic reasons. Indeed, the high costs to be incurred for larger capacity batteries are not justified, being the benefits of only 1–2%, suggesting a capacity growth from 348 kWh to 448 kWh.

The implementation of an energy community provides additional benefits aside from the energy savings in electricity consumption due to the limitation of CO_2 emissions.

CO_2 evaluations were carried out by using an emission factor of 0.46 $kgCO_{2eq}$/kWh as indicated by ISPRA (Higher Institute for Environmental Protection and Research operating in Italy) in its annual report on the atmospheric emission factors of greenhouse gases in the Italian power generation sector.

Figure 6 shows the trend of the equivalent CO_2 production in the current configuration of the municipality (without PV systems) and after the EC implementation.

Because of the drastic reduction in the energy withdrawn from the grid, the CO_2 emissions are also considerably reduced and, furthermore, the reduction increases with the size of the batteries. In all the considered cases, it is worth noting a drastic decrease in CO_2 emissions. In the current configuration, the Municipality contributes to approximately 30,919.6 kg_{eq} per year. Such value considerably drops after the EC implementation, reaching the minimum in correspondence with the greatest battery capacity, with emissions amounting to 8896.91 kg_{eq} for the PV peak power of 100 kW, and 4170.4 kg_{eq} for the most favourable case, with 184 kW of installed PV peak power. Regarding the current situation, the highest achievable CO_2 saving amounts to 26,749.3 kg_{eq} with a reduction of 86.5%.

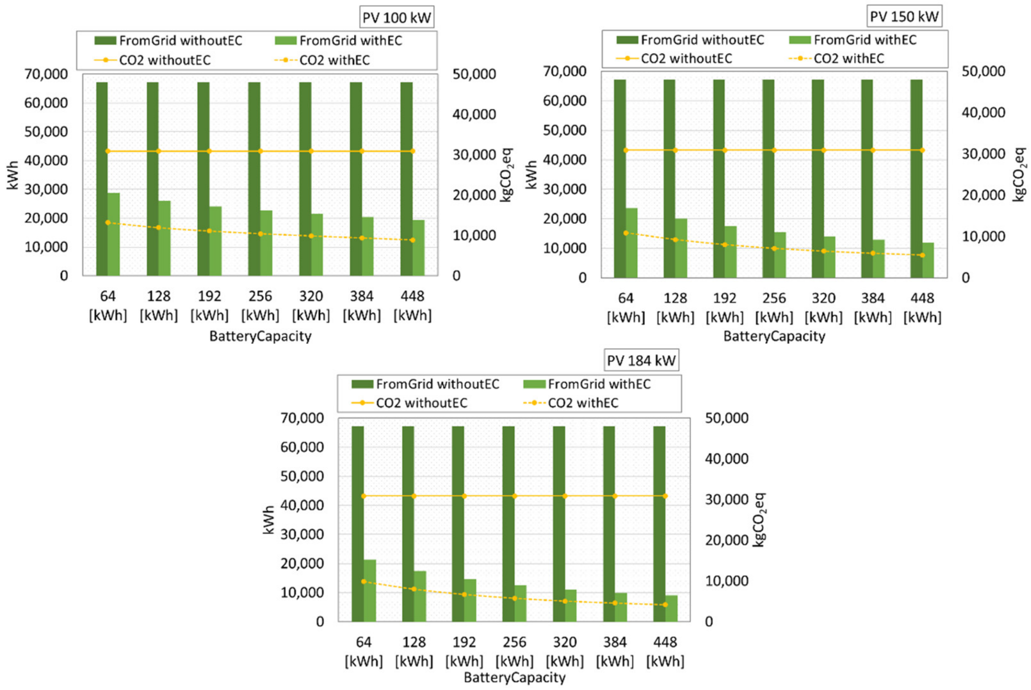

Figure 6. Assessment of the equivalent CO_2 before and after the implementation of the energy community as a function of the PV size and the storage capacity.

The economic analysis evaluated the profitability of each scenario. The results are reported in Figure 7, where the discounted payback is used as an indicator. The latter is reported against the different battery capacities for the three different PV peak powers. It can be appreciated that for any PV and storage size, the payback is acceptable, never surpassing 8 years, namely in the worst scenario, and included the period of 6–8 years. It is also interesting to observe that, for any PV size, the greater battery capacity produces almost the same result, whereas the employment of batteries with a capacity over 320 kWh is not recommended.

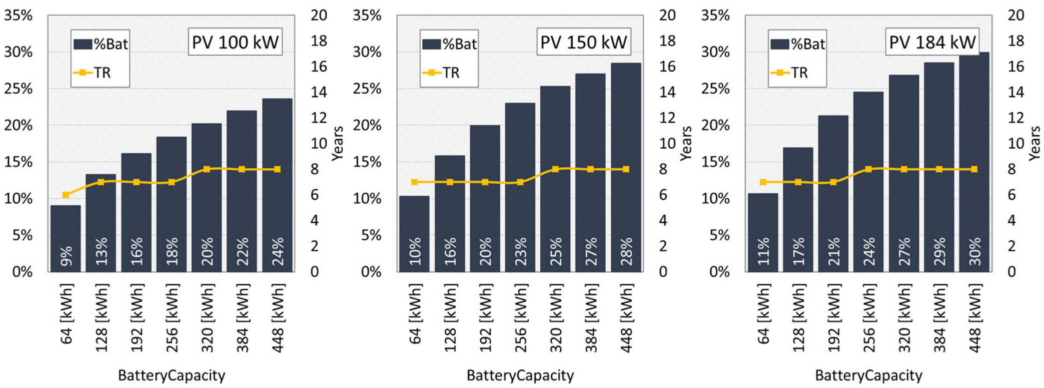

Figure 7. Payback time and average charge state as a function of the battery capacity for three different PV peak powers.

Finally, the NPV for each considered case is reported in Figure 8. Obviously, the investment cost increases with the size of the PV plant; nevertheless, the greater production and self-consumption of electricity produce the highest NPV values at 184 kW_p of installed PV. Interestingly, for the 100 kW_p plant, the NPV curve shows an almost flat trend after the battery capacity of 128 kWh indicating that, from an economic point of view, a further increase in the storage size does not improve the economic gains. Moving from 384 kWh to 448 kWh, in fact, the NPV slightly rises from 7803 k€ to 7819 k€. When increasing the PV size, the threshold value after which the NPV curve tends to become flat, moves toward higher battery capacities, and for 184 kW_p, it appears to be 256 kWh. Indeed, the last three battery sizes provide NPV equal to 10,980 k€, 10,996 k€, and 10,994 k€, respectively.

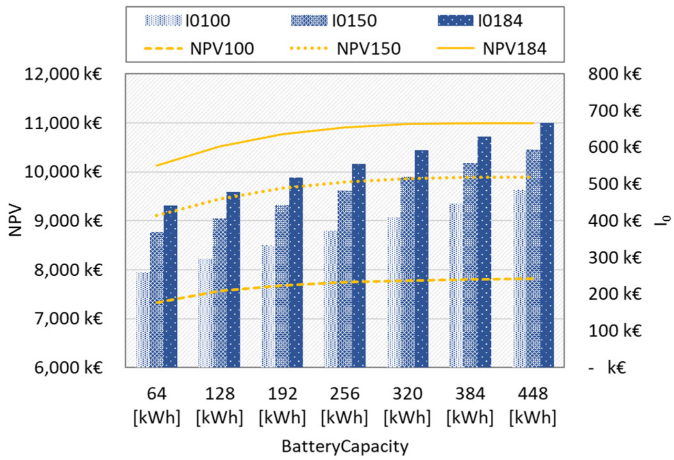

Figure 8. The 20-year NPV and initial cost I_0 as a function of the PV size and the battery capacity.

4. Conclusions

This research examines and analyses a real case study of a renewable energy community planned in a small town located in a mountain region of Southern Italy. It was assumed that the generators of the heating systems in the involved buildings are replaced with electric air-water heat pumps assisted by a PV generator and an electric storage system. The aim was to optimize the use of the energy produced and shared within the energy community, assuming that electricity can be accumulated also in adjacent buildings. After the evaluation of the electrical needs assessed for every building, a parametric study, including 21 scenarios, was carried out by varying the actually installable PV peak power and the battery capacity.

An increasing role of the battery was detected with a higher storage capacity: with a battery size of 448 kWh, in fact, a reduction of up to 30% of power absorbed from the grid, also in relation to the size of the PV systems, was observed.

Because of the drastic reduction in the energy withdrawn from the grid, the CO_2 emissions were considerably reduced and, furthermore, the reduction increased with the battery capacity. However, all of the considered cases produced a net decrease in CO_2 emissions.

The economic analysis carried out by using updated indices showed that, for any PV installed peak power and storage capacity, the discounted payback is more than acceptable, equal to 8 years in the worst scenario and, in any case, always included in the range of 6–8 years.

It is also interesting to observe how, for any PV size, the last three battery capacities showed almost the same payback, so the use of a battery capacity over 320 kWh is not recommended.

The results of this investigation indicate that the renewable energy community can significantly reduce the annual energy costs for the municipality, simultaneously CO_2 emissions are significantly limited when an optimal size of the plant technology is identified; nevertheless, renewable energies have to be transferred and shared among participants.

Future research work will include the extension of this study and consider replacing or adding additional renewable sources. Indeed, currently only PV systems have been considered due to the wider availability of solar radiation. Another interesting option is given by the abundant resource of solid biomass, provided by the maintenance of neighbouring forests, to use in cogeneration plants promoting induced activities, with a positive impact also from a socio-economic viewpoint. It will also be useful to evaluate the interaction of families within the energy community, who will certainly have different profile use of energy resources, even during those moments of the day when public buildings do not register significant consumption.

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