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Mixed-use neighbourhood to maximise urban energy community potential

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Abstract. Renewable energy communities (REC) are key drivers in promoting energy transition to renewable energy sources (RES). To maximise local potential for RECs, matching demand and local production requires the integration of different load profiles. Residential users prevail in urban areas while planning mixed-use neighbourhoods would contribute to having complementary loads towards urban RECs. Mixed areas can optimise the use of renewable production at different hours and limit demand pressures on the network. However, detailed spatial analyses are required to cluster building functions for long-term benefits. This work investigates which mix of building functions in urban blocks can maximise energy self-consumption and self-sufficiency. Five blocks combining residential with productive and tertiary activities are chosen, from a completely residential to a heterogeneous mix. The single loads use representative buildings for the Italian context. The integration of building functions flattens the energy peak loads in the district while increasing the use of PV production. The study identifies the residential and non-residential ratios to maximise energy self-consumption and self-sufficiency. Domestic users would mainly exploit the production from nearby non-domestic buildings, but adequate exchange mechanisms and upgrade of infrastructure still need to be implemented.

1 Introduction

The need to reduce greenhouse gas (GHG) emissions calls for a shift from an energy system centred on fossil fuel to renewable energy sources (RES) production. About 75% of global primary is consumed by urban areas, with a 7% annual growth of demand [1]. Improving the possibilities to produce renewable energy locally represents one of the key concepts towards sustainable and zero neighbourhoods [2]. An increasing number of cities decided to move towards a 100% renewable mix and carbon neutrality targets. Some cities introduced policy measures to motivate clean energy resources with developments, including rules that oblige utility companies to buy renewable power and building codes that require the installation of renewable technologies [3].

To improve the sustainability of the urban environment, photovoltaic (PV) has demonstrated the largest potential to contribute to the energy mix among the available micro-generation technologies [4], mainly through building integrated PV systems [5]. The

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increasing development of solar PV is mostly due to cost reduction and improvement of efficiencies, new government plans, increasing awareness of its potential, and rising electricity demand [6]. PV is a modular technology, which allows for a wide range of applications, from small residential roof-top systems up to utility-scale installations. However, a mismatch is recurrent between the intermittence of PV solar generation and the residential consumption profiles.

Renewable energy generation calls for the demand aggregation of different users through the concept of energy communities (ECs). ECs are new aggregation models of end-users which can combine and optimise the distributed generation of electricity and the share of energy locally used. Lowitzsch et al. [7] described ECs as the "governance model" of a "renewable energy cluster", through the diversity and complementarity of energy sources and demands, the presence of flexibility options and the bidirectionality of energy flows inside and outside the cluster. The recent European Directive 2023/2413 [8] updated the concept of Renewable Energy Community (REC). RECs promote the aggregation of energy customers for local renewable production and energy sharing leading to economic, social, and environmental benefits for the participants. The role of passive customers turns to active prosumers, who can consume and locally produce energy. According to ENEA guide to ECs [9], 264 million EU citizens will join the energy market as prosumers by 2050, generating up to 45% of the electricity from RES fed into the public distribution system. Italy introduced the collective self-consumption schemes and RECs in 2019 [10], while the revision of economic mechanisms is currently underway. The former can involve citizens who live in the same building or condominium, whereas REC participants can be citizens, small-medium enterprises (SMEs), local entities, and municipalities. In both cases, the main objective is to provide economic, environmental, and social benefits at a territorial scale, rather than purely economic profits. The Italian regulation promotes the local self-consumption of renewable energy through a virtual sharing model. The shared renewable electricity among REC members acquires a premium tariff, according to the 2020 Ministerial Decree. Requirements to access economic incentives for RECs are the installation of new renewable power plants by at least one member of the community, with a power limit within 1 MW, and the connection of all members to the same primary cabin of the existing national grid.

Existing RECs involve public and private subjects (consumers or companies) who join to self-produce and exchange among themselves renewable electricity. Recent studies estimate that Italian ECs will involve 1.2 million households, 200,000 offices and 10,000 SMEs by 2025 [9]. From this perspective, this paper aims to understand the most profitable aggregation of different prosumers for a REC. REC is composed of buildings with different functions. Each demand profile of prosumers represents the main commercial functions and residential, which can be found in a city. The first section describes the used data sources and methodology for the assessment of domestic and mixed-use RECs. In section two, the case study is briefly introduced. Section 3 shows the main results of the elaborations for energy-related indicators, considering domestic and non-domestic users. Discussions of outcomes and conclusions close the paper.

2 Methodology

This study assesses the energy-related advantages of incorporating various demand profiles for a REC in an urban area. The evaluation begins with the aggregation of residential buildings and then expands to include other activities. The integration of multiple building functions can enhance the complementarity of consumption and local production through user aggregation. The proposed methodology is based on open-source data and can be easily replicated in other contexts for REC assessment.

2.1 Energy consumption and PV production profiles

The first phase aims to define hourly profiles for electricity consumption, distinguished by building function. All the users can be prosumers in the project. The residential function prevails in urban areas, and it is the starting point of the evaluation. The hourly domestic profiles are retrieved from the ARERA website, which provides data for the average hourly electricity withdrawal (kWh). The ARERA dataset distinguishes consumptions by province, power installed by the user, and day (weekday or holiday) by month. Most domestic consumers have a power range between 3 and 4.5 kW [11], which is considered for the elaborations. Being in an urban context, the selected domestic configurations are apartment buildings (ABs), composed of multiple utilities. When selecting a specific AB, the number of utilities can be estimated from ISTAT census data, using the average number of families and the number of floors for each census area. The loads of ABs also include the consumption of common spaces, as elevators, emergency lights, stair lights, and intercoms. The electricity consumption and number of working hours for each application are retrieved from [12], for large-size condominiums.

Residential loads are integrated to non-residential consumption profiles. This study considers tertiary activities, namely food service, secondary schools, and local public administration (PA). Measured data for the average hourly consumption lack in this case. Therefore, the annual and daily electricity consumptions are retrieved from a previous study by RSE which analysed RECs in Italy [11]. The restaurant and school hourly profiles are then built on the ASHRAE schedules for these functions, while the PA office uses the schedule provided by the RSE study. The assumed load curves for community members take into consideration monthly and daily variations due to national, religious, and summer holidays. The restaurant consumes mainly during mealtimes, and it is considered with an installed power above 6 kW. The PA office is assumed with 15 employees. Consumptions are distributed among the working days while PA activities are closed at the weekends. The secondary school is closed on Sundays and during summer holidays.

The PV production uses PVGIS [13] to estimate the hourly solar output of PV panels. Using PVGIS, it is possible to calculate the hourly energy production up to 2020. The tool requires location (latitude, longitude, and elevation), radiation database, year of evaluation (from 2005 to 2020), PV mount type (fixed, vertical axis, inclined axis and two axes), slope and azimuth, PV technology, nominal power of the PV system and system losses. In this case, PV panels are crystalline silicon, fixed mounted to the roof, with 14% system losses. Slope and azimuth are optimised for each selected roof. The solar radiation data are based on PVGIS-SARAH2 for 2020. Different PV sizes are assumed for only residential RECs and mixed-use RECs. The former assumes an initial standard of 10 kWp installed on each AB, then extended to 20 and 30 kWp. For the latter, the PV system size starts at 10 kWp and then tests evaluate 20, 50 up to 100 kWp installed for the non-domestic user.

2.2 Energy flows for a REC configuration

Multiple energy flows occur in a REC. To be considered a REC, Points of Delivery (PODs) must be in the same conventional area of primary cabins. The map of these areas has been released by the Italian GSE [14], and a univocal code now identifies each cabin. Evaluations start with the electricity consumption and PV production by each REC member, according to the previous steps. PV production can cover a part of electricity consumption, but hourly PV production is not always fully consumed. Self-Consumption Index (SCI) is the share of renewable energy that is instantly self-consumed by each prosumer, while Self-Sufficiency Index (SSI) is the hourly self-consumed energy over the total electricity consumption [15]. The Uncover Demand (UD) is the share of consumption which is not satisfied by the local PV production, and it must be purchased from the national grid. UD occurs when the total consumption is greater than the total solar PV production. Overproduction (OP) is the share of PV electricity that is not instantly self-consumed, and it is injected into the national grid if the system is grid-connected. OP occurs when the PV production is greater than the hourly consumption. All these energy indicators are calculated on an hourly basis.

The evaluation by single building is the first step. The following analysis identifies the impacts and benefits of creating a REC. In a REC, the aggregation of multiple load profiles allows exchanges of energy production among participants. The Collective Self-Consumption (CSC) is the electricity exchanged among members, which consists of the OP generated by certain members sent to other participants with UD. This is the key component for energy exchanges in RECs. The CSC is equal to the hourly minimum between the energy fed into the grid by renewable plants (OP) and the energy withdrawn from the grid by all the REC members (UD). Seasonal and daily integration of different consumption profiles is fundamental to improve the energy performance of the cluster. At the community level, self-consumption and self-sufficiency consider both the self-consumed production by a single building and the collective self-consumption within the cluster. The REC Self-Sufficiency Index (REC SSI) is the share of locally self-consumed energy out of the total REC consumption. The REC Self Consumption Index (REC SCI) is the ratio between the share of locally self-consumed energy and the total RES production. Both indexes consider SCI by single building, collective Self-consumption (CSC), and total consumption and production of all the REC components. The REC configuration should increase the share of locally self-consumed electricity, but a portion of local consumption or production is still unsatisfied or unconsumed. The REC OP is the unused energy after the CSC which is sold to the grid. The REC UD is the unmet consumption after either the single-building SC and the CSC and requires to be purchased from the network.

2.3 Energy costs for a REC configuration

Different tariffs apply to each component of energy flows. The annual energy costs (AECs) consider the summation of expenses to purchase electricity from the network by the users and the summation of revenues by the energy fed into the grid. **Table 1** shows the electricity tariffs for Italy in 2022. The energy from the grid is purchased with ARERA electricity prices for domestic consumers for each trimester.

Table 1. Electricity tariffs from ARERA for domestic and non-domestic users. Source: [16].

Time period	Domestic (€/kWh)	Non-domestic (€/kWh)
1st trimester (January-March)	0.53	0.1892
2nd trimester (April-June)	0.24	
3rd trimester (July-September)	0.24	
4th trimester (October-December)	0.28	

For non-residential users, industrial and commercial annual tariffs are used because trimestral values are not available. The locally self-consumed energy by each building is considered free from charges because it is the share of renewable production directly consumed on-site. The OP sold to the national grid applies the Ritiro Dedicato (RiD) scheme, whose tariffs are defined by the GSE. The RiD tariffs vary by territorial market zones and hourly bands (F1, F2, F3), as defined by the AEEG 181/06. The interested members purchase the collective self-consumed electricity in a REC at the same price as grid electricity. The producers of the collective self-consumed electricity received a premium tariff, added to the RiD mechanism. The premium tariff is equal to 110 €/MWh for RECs, plus a unit compensation. The unit compensation includes the transmission tariff for low-voltage consumers, equal to 7.78 €/MWh in 2022, and the highest value of the variable distribution component for low-voltage consumers, equal to 0.59 €/MWh in 2022.

3 Case study

The study is located in Bari, Apulia Region, Southern Italy. Bari is in the climatic zone C, with 1,185 heating degree days (HDDs) established by the DPR. n.412/1993. However, the HDDs are likely to be updated due to the warmer projected climate compared to the year of the decree. The buildings are assumed to be located in the area of the primary cabin AC001E00350 by e-distribuzione S.p.A, which includes the Eastern part of the city centre (**Fig. 1**). Multiple load profiles are related to different functions and activities, namely domestic, commercial, educational and offices. In city centres, residential buildings are generally multi-family condominiums.

Two apartment buildings (ABs) with multiple units are indeed considered: one has 16 families distributed on four floors and one has 28 families distributed on seven floors. Each unit is connected to a different POD, whose consumption is assumed by the ARERA average hourly profiles for Bari. The other building types are assumed to be near the two ABs in a mixed-use neighbourhood and include a restaurant, a PA office, and a secondary school; these types of activities are common in urban areas.

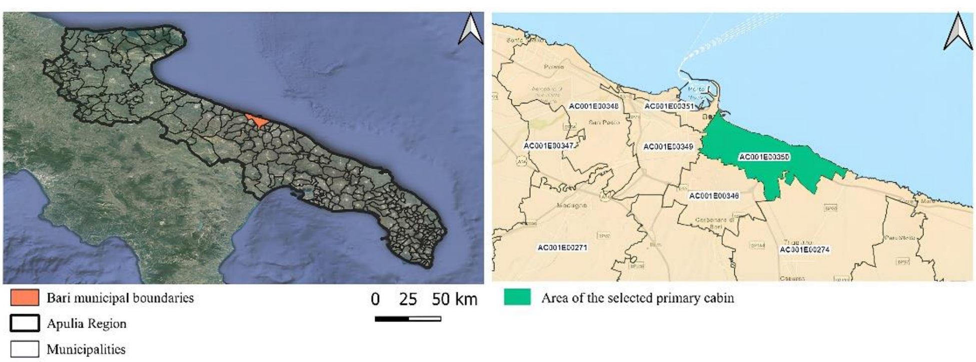

Fig. 1. Location of the studied area for the considered buildings.

4 Results

4.1 Residential scenario

This study shows how the integration of multiple load profiles can improve the energy performance for REC projects. Elaborations start from the definition of electricity consumption and production loads. The domestic consumption is retrieved from the ARERA average hourly withdrawal for Bari, and it distinguishes loads for working days, Saturdays, and Sundays. The initial installed PV power is 10 kWp, which is the standard threshold for residential installations. **Fig. 2** and **Fig. 3** display the load of an average working day, Saturday and Sunday for electricity consumption and PV production for an AB with 16 users in January and July, respectively. The consumption of common spaces in apartment buildings is retrieved from a previous study on condominium prosumers [12].

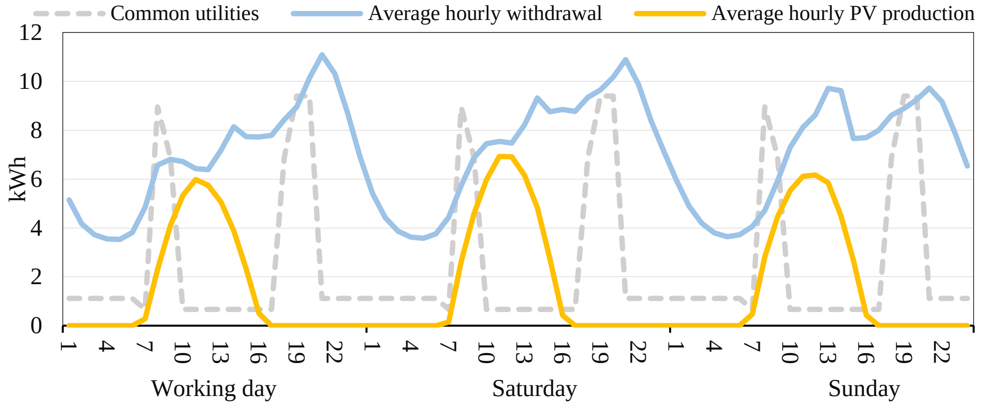

Fig. 2. Hourly average PV production (yellow) and electricity withdrawal (blue) by day types in January and consumption for common utilities in apartment buildings. Source: own elaboration [12], [13], [16].

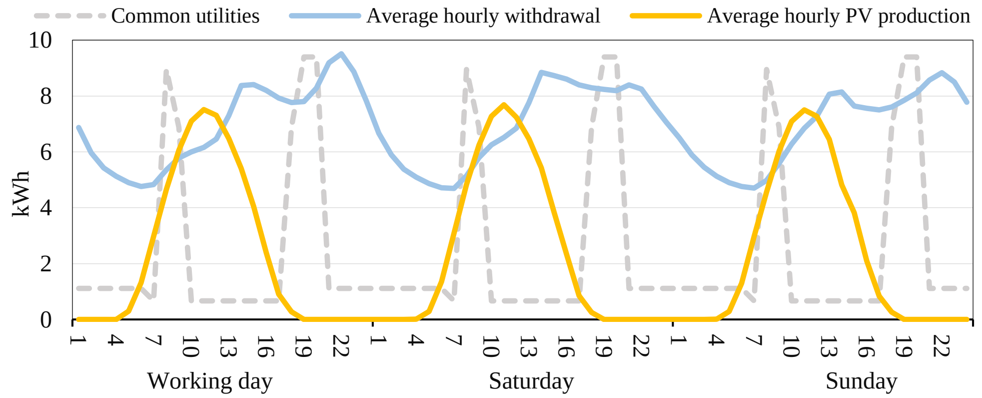

Fig. 3. Hourly average PV production (yellow) and electricity withdrawal (blue) by day types in July and consumption for common utilities in apartment buildings. Source: own elaboration [12], [13], [16].

Fig. 2 shows that working days register peaks above 10 kWh between 6 and 10 p.m., while Saturdays have a more homogenous load and Sundays have two minor peaks. In January, the PV output is generated between 7 a.m. and 4 p.m., even if solar peaks cannot satisfy the whole building demand. The total daily consumption is similar in January and July, but the latter has a withdrawal always above 4.7 kWh while the former is above 3.5 kWh. Indeed, the standard deviation is equal to 2.15 in January and 1.47 in July for a working day. Working days in July have two peaks above 8 kWh in the early afternoon (2 to 4 p.m.) and evening (8 to 11 p.m.). This could be due to the higher demand for space cooling on a summer day. The solar output for a 10 kW PV is higher than 6 kWh between 9 and 12 a.m. and leads to an overproduction before the afternoon peak.

Table 2 reports the energy impacts when installing PV panels with an increasing size for ABs only. Three PV system sizes are compared with configuration by single building and by CER, namely 10 kW, 20 kW and 30 kW. The solar output of 10 kW PV is almost entirely instantly consumed by the ABs, due to the high consumption, both for the configuration by single building and aggregated in a CER. The AB with 16 units would consume 50.507 kWh/y and the AB with 28 units about 88.388 kWh/y. A 20-kW PV REC registers the highest self-consumed share of solar production. Each residential REC configuration has an in-between value of REC SSI compared to the SSI of ABs individually modelled. Increasing the PV size does not proportionally increase self-sufficiency. A 40-kW REC reaches 40% higher SSI than a 20-kW REC made by 2 ABs, while a 60-kW REC reaches 6% higher SSI than a 40-kW CER. The OP is about one-third of CSC with a 20-kW PV CER, while it significantly overcomes CSC in other configurations. In the other two cases, OP is about 10% lower for the aggregation than the sum of single buildings due to the CSC contribution.

Table 2. Comparison of different PV configurations for apartment buildings, considered as single entities or aggregated in a REC.

Configuration	PV size (kW)	SCI	SSI	CSC (kWh/y)	UD (kWh/y)	OP (kWh/y)
AB with 16 units	10	0.94	0.22	-	56.300	922
AB with 28 units	10	0.99	0.15	-	93.258	0.32
CER: ABs	20	0.99	0.18	714	148.844	209
AB with 16 units	20	0.70	0.32	-	48.887	10.029
AB with 28 units	20	0.90	0.28	-	80.401	3.662
CER: ABs	40	0.81	0.29	1.090	128.198	12.601
AB with 16 units	30	0.53	0.37	-	45.540	23.201
AB with 28 units	30	0.73	0.33	-	73.601	13.382
CER: ABs	60	0.64	0.35	753	118.389	35.831

4.2 Mixed-uses scenario

After modelling only with domestic users, other building functions are included, namely PA, restaurant, and school. The integration of different consumption and production profiles can increase local independence from the network. The lack of measured data leads to estimates for the hourly consumption of non-domestic commercial activities. **Fig. 4** compares the electricity loads of the three considered cases for a working day, Saturday, and Sunday.

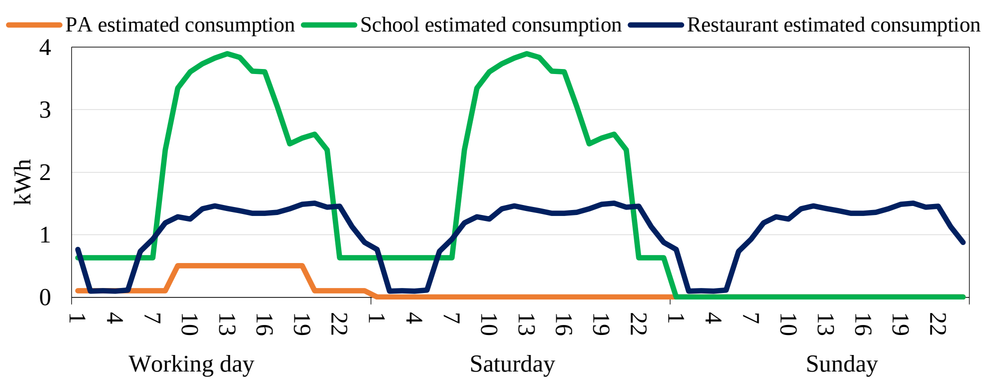

Fig. 4. Hourly estimated consumption for a PA office, school, and restaurant by day types.

The highest consumption is from the educational side, considering that a secondary school is open from Monday to Saturday. The restaurant is assumed to be open from Tuesday to Sunday, with a consumption profile distributed from the morning to late evening. The PA office has the lowest consumption from Monday to Friday, which is retrieved from [11].

Scenarios with PV installed for aggregations of multiple buildings are considered. The aggregation of multiple loads exploits the CSC by which the energy surplus of some buildings is sent to buildings with uncovered demand. The OP by tertiary functions is generally sent to the ABs with UD for the same time frame. For instance, for the weekly schedule, the school is closed on Sunday and the PA office all weekend long: therefore, their solar PV surplus can be used by the other ABs through CSC. **Fig. 5** relates the SSI and SCI values reached with domestic and mixed-use configurations. Higher power installed determines higher self-sufficiency and consequently independence from the national grid, but it decreases the level of self-consumed electricity. 2 ABs integrated to a restaurant reached the maximum REC SSI equal to 0.42, but the minimum REC SCI 0.32 due to the consistent OP which is sent to the network with RiD tariff. On the other hand, maximum SCI characterises the residential only cases, but having SSI lower than 0.2. Installing a larger PV system does not necessarily improve self-sufficiency in proportion to its size, as previously discussed for residential systems. The main increase rate of SSI would be between 10- and 20-kW PV installed for each building rather than with a bigger PV size.

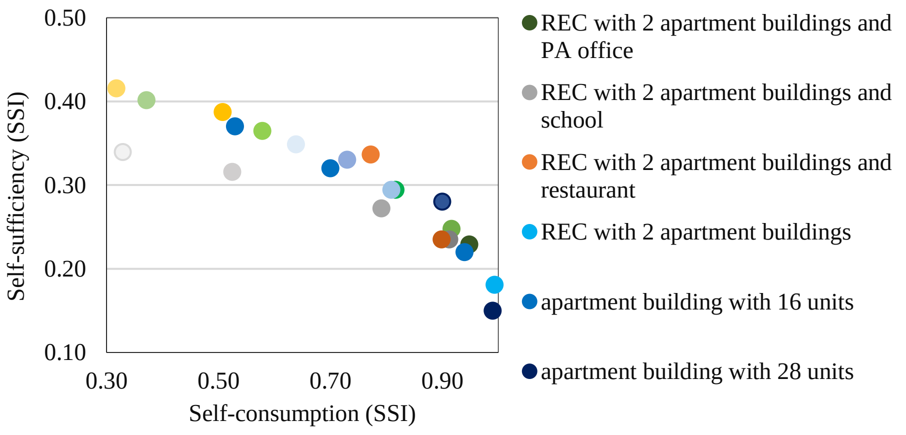

Fig. 5. SSI and SCI for different REC configurations and ABs. 2 ABs + tertiary have 10, 20, 50, and 100 kW installed for the non-residential function, while ABs have 10, 20, and 30 kW on each roof. Darker shades stand for a smaller PV size for the configuration, while lighter shades are larger PV size.

Bigger PV sizes reach higher CSC for the configuration, having its peak for 20-kW PV installed for residential and 100-kW PV installed for tertiary. A 40.135 kWh/y collective self-consumption occurs when integrating 2 ABs with PA due to closures during the weekends. Higher CSC values increase the local revenues due to the premium tariff for CSC and the RiD mechanism for OP, while the annual energy costs decrease. However, CSC does not cover a prevalent role in the increase of revenues with larger PV sizes. **Fig. 6** compares the amount of CSC and OP by increasing the installed PV size for non-domestic functions. CSC represents a marginal share compared to the overproduction when installing oversized PV systems. Indeed, with an overall 120-kW PV, CSC is about one-third of the total REC OP, whereas it overcomes OP with a 30-kW and 40-kW PV installed for the REC. All hypotheses register higher CSC and lower OP integrating the apartment buildings with PA offices.

The tendency of increase of revenues or reduction of AECs is less significant increasing the size of the PV system as well as for CSC. **Table 3** compares the trends of growth or reduction of collective self-consumption in relation to revenues and annual energy costs. For

2ABs + PA, CSC is the highest and registers a 41% increase from 10-kW to 20-kW PV installed for the PA office, 38% increase from 20-kW to 50-kW PV installed and only 17% increase from 50-kW to 100-kW PV. The maximum variation for revenues is between 20-kW and 50-kW PV installed for non-domestic functions, except for school, whereas the annual energy costs progressively decrease having bigger PV system sizes. All the mixed-use configurations can reduce annual energy costs from -21% for 2 ABs + PA with 70-kW PV installed up to -71% for 2 ABs + restaurant with 120-kW PV, while with only residential function, the reduction ranges from -17% to -41%.

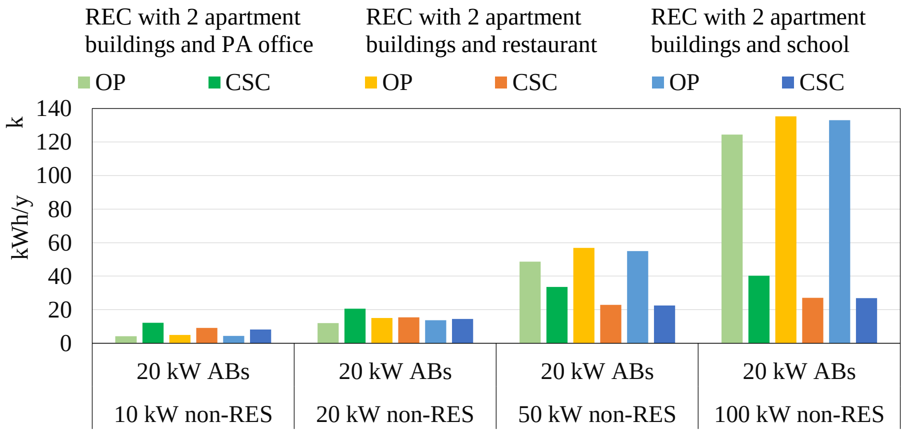

Fig. 6. Comparison of overproduction (OP) and collective self-consumption (CSC) for each mixed-use REC configuration and PV size.

Table 3. Increase or decrease of CSC, revenues, and annual energy costs for different REC configurations. CSC = collective self-consumption; AEC = annual energy costs.

Configuration	**Variable**	**20 + 10 kW PV**	**20 + 20 kW PV**	**20 + 50 kW PV**	**20 + 100 kW PV**
2 ABs + PA	CSC	46.095 kWh/y	+41%	+38%	+17%
	Revenues	3.356 €/y	+47%	+54%	+44%
	AEC	46.095 €/y	-7%	-21%	-42%
2 ABs + restaurant	CSC	9.151 kWh/y	+41%	+33%	+15%
	Revenues	2.742 €/y	+49%	+55%	+46%
	AEC	34.290 €/y	-9%	-27%	-71%
2 ABs + school	CSC	8.119 kWh/y	+49%	+30%	+16%
	Revenues	2.384 €/y	+58%	+51%	+47%
	AEC	35.117 €/y	-11%	-24%	-68%

5 Discussion

This study investigates the impacts of aggregating different load profiles in an urban Renewable Energy Community. The creation of RECs in urban areas implies the integration of multiple energy consumption profiles. Hourly and weekly demand schedules can be complementary for different functions with PV production. Residential users in cities generally occupy multi-family buildings, which register significant energy demand. Apartment buildings should be balanced with other non-domestic functions to increase self-sufficiency by exploiting the PV solar output.

Domestic users in apartment buildings are initially assessed for the installation of PV systems. The hourly withdrawal is retrieved from the measured data of ARERA for a 3-4.5 kW utility. Based on the ISTAT data, an AB with 16 families and an AB with 28 families are considered. The high electricity consumption of each structure entails that almost the whole PV local production is instantly consumed having a 10-kW PV system for each building. SCI decreases while self-SSI increases having larger PV sizes. Clustering two ABs in a REC with the same PV size for each roof can marginally improve both energy indexes due to the low share of CSC. The potential CSC is limited due to the high self-consumed energy for each building. Indeed, increasing the PV size for a REC with only residential users marginally decreases the values of uncovered demand compared to single-building installations. Daily and hourly complementarity cannot be achieved with homogeneous residential blocks.

Matching demand and production require the introduction of non-residential functions with their energy loads. Considering an urban context, tertiary functions are included, namely educational, office and restaurant. Their hourly energy profiles are retrieved from previous energy reports in Italy, due to the lack of measured data. The monthly distribution of consumption considers holidays and weekly schedules, which differ for each activity. The integration of domestic and non-domestic users improves the energy indexes if the system is not oversized. The highest CER SSI is calculated for ABs integrated to restaurant and PA, while it is lower with a school. 2 ABs with a PA register the highest CER SCI for a 10-kW PV system installed for each building. The assumed PA consumption is lower than schools and restaurants and its PV output can satisfy the domestic demand during the day. On the other hand, restaurants consume more homogeneously while schools mainly in the morning, therefore self-consuming their solar production in working days.

The CSC exploits the hourly overproduction to be sent to buildings with UD in the same time frame. The share of exchanged CSC is remunerated with a premium tariff equal to 0.118 €/kWh for RECs, in addition to the RiD incentive. However, increasing the size of PV plants does not proportionally increase the CSC of the mixed-use cluster, but rather the share of overproduction. CSC increases more than 40% enlarging the PV size of the non-residential building from 10 to 20-kW PV, but then the increase slows down for 50-kW PV and especially for 100-kW. Revenues keep rising and annual energy costs decreasing due to the purchase of overproduction. This is because the electricity locally produced overcomes the demand in some hours, while in other time frames the solar output cannot satisfy the electricity consumption. The uncovered demand interests the late afternoon or evening when residential utilities register their daily consumption peaks (see **Fig. 2** and **Fig. 3**)but daylight is no longer available. Therefore, electricity needs to be purchased from the network if short-term storage is unavailable. If the PV plant is significantly oversized, then the overproduction is sold applying the RiD scheme only, without the premium tariff. In this regard, CSC becomes less important in oversized configurations despite representing the main criteria and economic incentive for energy exchanges in RECs.

6 Conclusions

Energy communities are key drivers in energy transition and progressively need to be implemented in urban areas. Residential consumers prevail in urban areas, where mixed-use neighbourhoods combine different building functions. The mismatch of demand load profiles can be exploited when clustering utilities for RECs to maximise the self-consumption of locally produced energy and self-sufficiency from the national grid.

The study analysed resident load profiles for two apartment buildings individually and then integrated them into non-residential functions. The hypothesis of a renewable energy community (REC) composed of apartment buildings would not fully utilise collective self-consumption, which is a key aspect of a REC. Self-consumption was about 99% when a 20-kW PV system was installed due to high electricity consumption but decreased with larger systems. In a residential REC, overproduction with larger system sizes greatly exceeded collective self-consumption. The following step was to increase energy performance and CSC in residential buildings by integrating different building load profiles. Collective self-consumption did not proportionally increase with the growth of the PV size. The most significant improvements were between 10 and 20 kW installed on the tertiary building. The selected non-residential functions had holidays and daily schedules which differently exploited the local PV production, and their surplus can cover part of the domestic demand. An oversized PV plant would favour OP sent to the network instead of shared electricity within the REC boundaries. The annual energy costs are significantly reduced due to the contribution of the overproduced solar electricity, rather than collective self-consumption. Similarly, the share of self-consumption decreases, and self-sufficiency increases slowly with a system larger than 50 kW PV.

Future studies should aim to consider a wider range of building functions and model energy profiles based on measured data rather than hypotheses. The distribution of distinct hourly loads from building functions could significantly impact the energy performance and economic feasibility of energy communities. The combination of energy loads has the potential to increase the share of self-consumed renewable energy within the cluster. Starting from the current demand schedules, tools to optimise consumption profiles can contribute to changing user behaviour, maximising the share of self-consumption and increasing self-sufficiency, resulting in significant improvements. Additionally, RECs should identify the optimal integration of building functions to exchange energy surpluses with more energy-demanding buildings.

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