Integrating Renewable Energy Communities into Historic Urban Landscapes: A Framework for Sustainable Conservation

Mara Ladu[1(✉)], Ginevra Balletto[1], Alessandra Milesi[1], Federica Isola[1], and Emilio Ghiani[2]

[1] DICAAR - Department of Civil, Environmental Engineering and Architecture, University of Cagliari, Cagliari, Italy
{mara.ladu,balletto,federica.isola}@unica.it, alessandra.milesi.unica@gmail.com

[2] DIEE - Department of of Electrical and Electronic Engineering, University of Cagliari, Cagliari, Italy
emilio.ghiani@unica.it

Abstract. The decarbonization of the European energy system to achieve climate neutrality by 2050 presents a significant challenge for existing building stocks, particularly within historic urban landscapes where conservation and modernization should coexist. This study presents the URB-REC project, funded by the European Union – NextGenerationEU, which explores Renewable Energy Communities (RECs) as an ecosystem for inclusive energy transition and urban regeneration. Using Masullas, a small municipality in Sardinia, Italy, as a case study, the research addresses the technical and regulatory complexities of integrating renewable energy into historic areas characterized by stringent landscape constraints and low energy performance. The proposed methodology adopts a multidisciplinary approach, integrating urban, energy, and sustainable mobility planning. To overcome the limitations of individual building-level interventions, the URB-REC model prioritizes the use of public real estate assets and strategic surfaces outside protected historic cores to host collective energy plants. This model enables residents to transition from individual to collective action, mitigating social inequity and energy poverty. The study introduces MyCER, a digital platform designed to monitor energy flows and optimize collective self-consumption in real-time. URB-REC demonstrates that technological innovation, when guided by participatory governance and inclusive design, can preserve cultural identity while advancing the Sustainable Development Goals (SDGs).

Keywords: Renewable Energy Communities (RECs) · Urban Regeneration · Historic Centers

1 Introduction

The decarbonization of the EU energy system to achieve climate neutrality by 2050 represents one of the main international and national challenges, drawing attention to the definition of a package of actions aimed at the energy requalification of the building

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O. Gervasi et al. (Eds.): ICCSA 2026 Workshops, LNCS 16760, pp. 569–583, 2027.
https://doi.org/10.1007/978-3-032-30521-3_36

stock [1]. Historic areas represent privileged contexts for investigation and action to combine conservation objectives with urban regeneration and community development needs [2]. Renewable Energy Communities (RECs), based on the availability of public real estate assets, enable the promotion of a shift from individual to collective action in the production of electricity from renewable sources, avoiding uncoordinated single interventions [3]. Furthermore, they can contribute to urban regeneration projects that address energy demand for residential, commercial, and other uses, including that arising from the transition to sustainable mobility [4, 5].

The URB-REC project (Call for the development of a Proof of Concept (PoC), within Spoke 7 of the e.INS - Ecosystem of Innovation for Next Generation Sardinia project) funded by the European Union – NextGenerationEU, considers RECs as an ecosystem for inclusive energy transition, based on participation between public and private entities, adopting as a case study Masullas, a small municipality in the Oristano province of central-western Sardinia (Italy).

URB-REC addresses various issues related to the decarbonization of the energy system and the sustainable regeneration of the existing architectural heritage, particularly in the historic centers of Sardinia's inner areas [6, 7]. One of the main issues concerns the low energy performance of much of the real estate included in historic cores, where stringent landscape constraints make the installation of plants for electricity production from renewable sources complex without compromising the value of the historic urban landscape. Buildings of high historical-testimonial value are often subject to constraints and planning regulations that do not allow the adoption of standard technological solutions, but rather the definition of types of interventions implementable in individual cases, consistent with the need to safeguard the complexity of the values at play [8]. This condition of social inequity in access to electricity production systems from renewable sources can also exacerbate the energy poverty of local communities.

National legislation in Italy, particularly the Code of Cultural Heritage and Landscape (Legislative Decree 42/2004), imposes precautions for changes in historic centers, but thanks to the Simplification Decrees (DL 17/2022, DL 199/2021) and Law 34/2022, simplified authorization procedures and incentives have been introduced that favor the installation of photovoltaic systems and the establishment of RECs even in constrained contexts, provided there is architectural and landscape compatibility. Superintendencies today cannot oppose systems in an absolute manner, and case-by-case evaluation is mandatory, with refusals only if truly justified (Guidelines for Improving Energy Efficiency in Cultural Heritage, MIBAC 2015) [9]. Recent case law shows an increasingly favorable orientation toward integrating renewable energies in historic centers, especially when systems are non-visible or integrated into architecture, in line with Legislative Decree 190/2024.

Parallel to the risk of potential inequality phenomena, the fragmentation of action toward energy production, typically entrusted to single buildings, often generates plant superstructures that negatively alter the overall landscape value of historic urban areas.

Within this framework, URB-REC promotes the decarbonization of the energy system, with particular attention to the existing building stock, especially in historic centers, approaching the socio-demographic and territorial challenges of Sardinia's inner areas—which are also characterized by poor accessibility, depopulation, and progressive

abandonment that accentuate peripherality and limit economic and social development opportunities—with a multidisciplinary approach. In this sense, URB-REC proposes the triple integration of urban planning, energy planning, and sustainable mobility planning to define a coherent and sustainable strategic vision of territorial development and favor a sustainable conservation and urban regeneration that respects long-consolidated cultural and environmental values.

URB-REC is based on the idea that RECs should be correlated with the availability of public real estate assets. This represents a concrete opportunity to favor an inclusive energy transition. In fact, the shift from autonomous to shared production, typical of RECs, can lay the foundations for planning capable of coordinating conservation aspects with those of energy transition. More precisely, the need to overcome regulatory difficulties to create shared and innovative REC models requires the active contribution of both public and private entities, particularly using public infrastructure as roof surfaces for renewable plants, to coordinate interventions and minimize visual impacts [10]. Finally, the need emerges for adequate technological and managerial tools to monitor, manage, and optimize energy production and distribution in RECs, ensuring transparency, participation, and effectiveness in inclusive energy transition processes.

Finally, the project aims to experiment with and validate innovative solutions by adopting a collaborative and interdisciplinary approach involving academia, businesses, and sector startups, with the objective of creating a virtuous and transferable energy transition model in similar territorial contexts.

The conservation and protection of historic heritage represent a responsibility for current generations, necessary to preserve a community's cultural identity and collective memory, which require careful architectural interventions capable of ensuring long-term conservation without compromising its integrity and authenticity. However, in a contemporary context marked by the growing need for environmental sustainability and involvement in energy transition, reflection is imposed on technological innovation that can coexist with conservative protection.

Within this concise framework, the present study proposes an inclusive REC model to develop innovative design solutions that integrate energy transition and urban conservation objectives in historic urban areas, in accordance with the Sustainable Development Goals (SDGs). After the introduction, the manuscript is structured in 6 sections: Materials (Sect. 2), which focuses on an overview of the ongoing transitions and sustainable spatial planning (Sect. 2.1), Sustainable Urban Regeneration (Sect. 2.2), and Renewable Energy Communities (Sect. 2.3); Method (Sect. 3), where criteria for managing the energy transition in historic centers (Sect. 3.1), a model for Renewable Energy Communities (RECs) (Sect. 3.2) and a digital platform MyCER to support the model (Sect. 3.3) are proposed; Case study (Sect. 4); Results (Sect. 5) and Conclusions (Sect. 6).

2 Materials

2.1 Ongoing Transitions and Sustainable Spatial Planning

The multiple ongoing transitions—energy, ecological, digital, and demographic—represent complex and interconnected processes of social, economic, and environmental transformation in Europe and Italy.

The energy transition focuses on shifting from fossil fuels to renewables (photovoltaic, wind, hydroelectric, etc.) with the goal of reducing greenhouse gas emissions and achieving climate neutrality by 2050, supported by digitalization that enables efficient resource management also through artificial intelligence, Internet of Things, and big data to reduce waste and emissions. Parallelly, the ecological transition aims to integrate biodiversity conservation and ecosystem protection into the development model, promoting a holistic and integrated vision that combines health, economy, social equity, and quality of life, essential for urban and territorial regeneration.

The digital transition is simultaneously an enabling driver that supports energy efficiency and environmental sustainability, facilitating smart management processes for urban services typical of the "smart city" while enhancing environmental monitoring and civic participation.

Finally, the demographic transition, characterized in Sardinia by depopulation and population aging mainly in inner areas, calls for renewing territorial planning and welfare policies, requiring strategies of inclusivity and equity [11].

These multiple transitions require renewed urban planning based on an integrated and multidimensional approach that includes multi-level governance tools, strategic programming with extended time horizons, and the use of well-being indicators, environmental and economic sustainability to assess impacts. Attention is focused on the territory and its communities as a privileged field of observation to grasp connections between different sectors and spatial disparities [12], placing particular emphasis on spatial justice and the need to promote urban regeneration projects.

Studies on the topic confirm that transition processes require integrating the environmental dimension with socio-cultural and economic aspects to promote models of cities and territories capable of adapting to contemporary challenges, particularly through the new paradigm of participatory governance.

2.2 Sustainable Urban Regeneration

Sustainable urban regeneration of historic centers is a multidimensional process that aims to improve livability, inclusion, resilience and sustainability, going beyond simple architectural restoration [13]. It seeks to enhance community quality of life, promote renewable energy use, optimize resources, foster sustainable mobility and revitalize the socio-economic fabric, integrating urban-planning, energy, environmental and cultural dimensions. The ecological transition has shown that the traditional separation between urban planning (focused on space and settlement functions) and energy policies (focused on supply and efficiency) is inadequate [14]. Climate change and the need to reduce energy-related emissions call for an integrated, interdisciplinary approach between urban and energy planning as a key strategy for the conservation of historic centers. At the EU level, the Green Deal targets climate neutrality by 2050, supported by the Energy Performance of Buildings Directive and RED II [15], both of which include specific exemptions for historic and cultural buildings, while national law imposes general energy-efficiency obligations with tailored provisions for historic centers.

In Italy, simplified procedures for PV installations on or near historic sites (Decree-Laws 76/2020, 17/2022, 181/2023) and specific landscape-authorization rules (Legislative Decree 190/2024) and the National Energy Strategy (SEN) [16], seek to

improve comfort and performance in heritage without compromising cultural value, though practical challenges remain [17]. Urban planning and energy planning are complementary: the first shapes city layout and development models, the second promotes energy efficiency, renewables and climate resilience through tools such as Sustainable Energy and Climate Action Plans (PAESC). Their convergence allows joint governance of urban functions, sustainable mobility, smart grids and resource flows, pointing toward systemic, interdisciplinary strategies.

Within the Next Generation EU framework, the Recovery and Resilience Facility support Member States' recovery, and Italy's PNRR [18] uses it to promote investments and reforms that make urban centers more sustainable, inclusive and resilient, with a focus on regeneration of historic and degraded areas. Two main directions emerge: energy-efficient retrofitting of historic buildings with low-impact technologies and the revitalization of public spaces, combined with cultural and commercial activities and active community participation. Public-sector investment and strategic planning are essential to align building renovation, technological innovation and socio-economic sustainability [19].

Historic cities are key sites of concentrated energy demand, and urban regeneration responds by integrating energy-saving measures and harmonious technological upgrades into the fabric [20]. Reusing existing buildings, including disused stock—adapted to current needs and regulations is more energy-efficient than demolition and supports identity preservation and depopulation-countering goals. Historic construction has proven resilient and adaptable, and its energy performance has been addressed through guidelines and incentives, such as the MiBACT Guidelines (2015) [21], which combines heritage protection with reversible, low-impact interventions, passive and active systems, and local-resource use. For photovoltaics, alternatives include external plants serving whole historic centers, integrated solutions like photovoltaic tiles, thin-film installations and solar canopies.

Community participation is crucial: energy autonomy and collective management of common goods strengthen local cohesion. Cooperatives and energy communities foster inclusive, place-based economies, while the prosumer model supports collaborative resource management. Effective governance and broad local involvement determine the success of these models.

The shift toward smart energy governance in historic centers is not merely a technological process, but primarily a political and social one. It requires self-governance tools, social capital, and a balanced relationship between innovation and heritage enhancement, consolidating a systemic, sustainable and inclusive approach to urban regeneration.

2.3 Renewable Energy Communities

Renewable Energy Communities (RECs) are associations of citizens, businesses, local authorities and other local actors that produce, share and consume energy—mainly from renewable sources, allowing participants to act as prosumers and share environmental, social and economic benefits [22]. This model supports generation diversification and decarbonization while addressing the "energy trilemma" of environmental sustainability, cost-effectiveness and supply reliability [23]. The European framework distinguishes two main types:

– RECs (Renewable Energy Communities), introduced by RED II, are open legal entities for citizens, local authorities and SMEs; they operate only with renewables, pursue non-profit environmental and social goals, and allow flexible, voluntary membership.
– Citizen Energy Communities (CECs), under the Internal Electricity Market Directive (IEM), are also voluntary but restrict participation to citizens, local authorities and small enterprises (no SMEs), and can handle both renewable and non-renewable energy, with broader activities from generation to distribution and EV charging.

RECs typically repurpose under-used spaces (public-building roofs, industrial sheds, abandoned land) into community energy infrastructure and foster cooperation among actors such as municipal administrations, parishes, third-sector organizations, small businesses and residents. Economically, members save on electricity bills through self-consumption, earn revenue from surplus energy fed into the grid and benefit from ARERA-based incentives tied to shared renewable generation. It is estimated that by 2030 up to 20% of a city's energy could come from RECs, meaning substantial savings and CO_2 reductions (about 950 kg per year for an average Italian household), and enabling the creation of Positive Energy Districts (PEDs). From a social perspective, RECs can combat energy poverty by installing PV on vulnerable households' roofs and redistributing benefits via fair-sharing algorithms, making clean-energy projects local, inclusive and socially innovative. RECs can also invest incentive-based revenues in energy-efficiency measures (insulation, efficient systems), further reducing demand and raising the value of self-consumption. Smart meters and shared apps foster energy-literacy, collective responsibility, and reduced social isolation, while enabling public authorities to design better-targeted social policies.

At EU level, the Clean Energy for All Europeans Package (CEP) package places consumers and local actors at the center of the transition, promoting energy efficiency, a higher share of renewables, better-integrated markets and consumer rights. Two key directives are RED II (2018/2001), which introduces collective self-consumption and RECs, and IEM (2019/944), which frames Citizen Energy Communities.

Italy has progressively aligned its rules with several directives [24]: Decree-Law 162/2019 (Law 8/2020); ARERA Deliberation 318/2020; the Ministerial Decree of 16 September 2020; the Legislative Decree 199/2021 and the Decree 210/2021; ARERA's TIAD (Deliberation 727/2022, updated 2024); Ministerial Decree 414/2023 (MASE). Overall, Italy combines tariff-based incentives, capital grants and increasingly flexible technical-and-geographic rules to promote Energy Communities and collective self-consumption as central levers of its energy transition.

3 Methodology

3.1 Criteria for Managing the Energy Transition in Historic Centers

Developing a model for Renewable Energy Communities (RECs) is essential for the shift toward a sustainable energy system, especially in Sardinia's context of rich, protected architectural and landscape heritage. REC development should therefore integrate landscape, environmental and social criteria, while preserving and embedding the historic environment in the energy-innovation process, thus combining protection, valorisation and innovation. Actors participate as producers, consumers or prosumers, sharing

renewable energy and environmental, social and economic benefits through cooperatives, associations or other legal entities.

In historic centres, RECs typically use public buildings and nearby sites for energy plants, promoting urban regeneration and enhancing historically valuable environments. This approach merges urban, energy and mobility planning into an innovative Spatial–Energy–Mobility model, including smart-community, sustainable-mobility and accessibility components. The main REC-development phases are: meetings with founders and participants to raise awareness; sizing and preliminary analysis of energy resources and plant characteristics; definition of the legal form (bylaws, regulations, elected bodies); training and dissemination to educate citizens and stakeholders on technologies and benefits.

Given that about 35% of Sardinian municipalities have around 1,000 inhabitants (like Municipality of Masullas, the selected case study) and an average age of about 52, the possibility for starting RECs is narrow. The Public Administration is therefore strategic in launching the process, later expanding it through private participation. The goal is energy autonomy for key public services in the historic center, using surfaces or adjacent areas akin to those required for urban-planning standards (e.g. parking, green areas). In historic-center contexts, historical, architectural and landscape protections limit on-site self-production, so RECs rely on nearby capture surfaces—such as public-buildings in the historic city and energy plants in surrounding low-consumption public areas to create an energy ecosystem that preserves the historic urban landscape while ensuring local self-production.

The methodology is structured into two main stages. First, it involves the identification and assessment of energy consumption patterns in key public buildings located within the historic core, including administrative, educational (e.g., schools, libraries), cultural, and tourism-related facilities. Second, it focuses on the identification of suitable surface areas for energy production, particularly for photovoltaic installations. These include both built and open spaces, such as rooftops of public buildings and designated public areas located outside the historic core, which are deemed technically feasible and compliant with existing planning regulations for hosting energy generation systems.

3.2 Definition of the REC Concept

Renewable Energy Communities (RECs) are encompassed within the self-consumption configurations defined by ARERA (Regulatory Authority for Energy, Networks and Environment in Italy). Widespread self-consumption refers to the possibility for final consumers to associate to share electricity generated within the same configuration. This approach helps meet their own energy needs while yielding economic, social and environmental benefits.

Within a given self-consumption scheme, several roles can be identified: consumers, who only withdraw electricity from the grid and hold a single Point of Delivery (POD); producers, who own a generation plant and focus solely on energy production. The intersection of these roles gives rise to the prosumer, who owns a generation plant, consumes part of the self-produced energy, and can feed the surplus into the grid, share it with other consumers in the same community, or store it in energy-storage systems. Prosumers

thus become active players in managing energy flows, contributing to a more decentralized and sustainable energy system, while gaining greater autonomy and economic advantages.

Self-consumption can occur in physical or virtual form. In physical self-consumption, generation plants are directly connected to consumption loads within the private network of a building or condominium, with a single point of connection (POD) to the public grid, shared supply contract and internal metering infrastructure. In virtual self-consumption, each user maintains its own POD and can freely choose the electricity supplier; physical energy exchanges occur over the public grid, ending at each user's withdrawal points, with the grid operator responsible for measurement.

A REC is defined as an autonomous legal entity, typically established as an association or cooperative and without a profit-seeking purpose. Its members commit to produce, share and consume clean energy generated within the community by entities classified as producers or prosumers. Membership does not limit the rights of the individual final customer, who retains the freedom to choose the electricity supplier and the right to exit at any time, subject to the bylaws and constitutive agreements. A REC should comprise at least two members and at least two distinct connection points, one for consumption and one for production, with no upper limit on participants. Eligible participants include private citizens, small and medium enterprises, territorial authorities (municipalities, provinces, regions, metropolitan cities), local authorities, research and training bodies, religious and third-sector associations, or environmental-protection organizations, if participation is not their main economic activity. Members can assume the roles of consumer, producer or prosumer: consumers use shared energy to meet part of their needs, producers generate renewable energy for the community, and prosumers combine production and self-consumption, covering their own loads and sharing surplus with other members.

REC plants should be fed exclusively by renewable sources such as photovoltaic, wind, hydro, biomass and biogas, possibly combined with storage systems. Within the community, energy is shared among producers and consumers connected to the same primary substation, using the national distribution grid. This is called virtual energy sharing: the shared energy corresponds to the minimum between the total energy injected into the grid by renewable plants and the total energy withdrawn by members, thereby maximizing collective self-consumption and promoting a more efficient and sustainable power system. A key role in managing the Energy Community is played by the Referente (legal representative), who handles the technical and administrative management of the REC. This function can be performed by the community itself through its legal representative, by a producer or a final-customer member, or by an external third-party producer holding a certified UNI 11352 ESCO licence, provided that its plant contributes to the community configuration. The Referente coordinates plant operation, ensures correct accounting of energy flows and production/consumption data, and serves as contractual counterpart with the GSE, submitting incentive-access requests and receiving related invoices.

3.3 The Digital Platform MyCER

Italy's Legislative Decree 199/2021 and the Ministerial Decree n. 414/2023 have enabled new Collective Renewable Energy Self-Consumption Communities, which require not only aggregating individual plants and loads but also continuous coordination, monitoring and regulatory compliance. Building on this framework, Higeco Energy—a company specializing in industrial and PV-plant monitoring—has used its robust cloud infrastructure to create a user-friendly front-end for end users unfamiliar with PV and consumption monitoring.

MyCER platform has been developed as a robust, scalable tool that helps RECs actively participate in electricity markets. In both standard and white-label modes, MyCER centralizes data from all PODs, ensures traceability and compliance with GSE incentive rules, and optimizes energy flows via dedicated algorithms to maximize collective self-consumption and reduce imbalances. It offers transparent dashboards for administrators, referees and members, improving trust and engagement, and supports scalable governance across multiple configurations—Collective Renewable Energy Self-Consumption Communities, collective self-consumption groups and remote individual self-consumers—on a single platform. In this sense, MyCER translates complex regulations into simple operations, turning energy data into economic and environmental value for all participants. For the URB-REC project, MyCER will be used for simulation, exploring multiple scenarios to recommend, before any investment, the configuration closest to the Referente's preferences, thereby reducing the risk of errors and improving the expected return on future investments.

4 Case Study

4.1 Geographical Context and Spatial-planning Framework

The Municipality of Masullas, a little town (~1,000 inhabitants) in Oristano province, central-western Sardinia (Fig. 1), serves as a case study representative of most Sardinian municipalities (characterized by a population of about 1000 inhabitants) and due to the energy-transition initiatives carried out by the municipal administration, including the ongoing update of the Local Plan. Spanning 19 km2 with a trapezoidal shape bounded by ridges and Monte Arci slopes (altitudes 81–409 m), it features diverse microclimates, hills, agriculture, natural areas, a hydrographic network, and a temperate-Mediterranean climate. Located in Monte Arci Regional Park, it boasts biodiversity, prehistoric obsidian sites, and trails for sustainable tourism/education.

The economy relies on agro-pastoral-silvicultural systems, diversifying into olives, vineyards, and crops with sustainable/self-production focus. Land use: herbaceous crops (45.7%), tree crops/natural areas; built-up non-urban $<2\%$; forests minimal.

The compact urban center blends a preserved historic core with expansions along Via Nazionale, offering distributed services (greens, sports, squares, public/religious buildings) and high-quality environment. Key sites: "Sa Gloriosa" parish church, "Palazzo Salis" (town hall/museums), historic churches. Well-connected via SS131 road, Uras railway, and local roads despite peripheral position, Masullas harmonizes natural/agricultural/urban elements with cultural heritage, supporting a rural model of

environmental protection, innovation, and tourism—ideal for a Local Plan-driven energy goals. Masullas' Local Plan, adopted in 1999 and last generally amended in 2011, defines the ancient urban core perimeter. The 2008 Historic Centre Detailed Plan (Fig. 1) implements the Local Plan goals: conserving public spaces, protecting monuments/relational areas, enhancing pedestrian quality, and linking key sites. Its "PROS 4 Energy and Sustainability" project promotes bioclimatic retrofits, solar optimization, and energy-efficient PV/solar system requiring certification, non-obtrusive integration (e.g., roof-fitting panels on hidden slopes, photovoltaic tiles in the historic center), and banning rooftop boilers (attic/courtyard placement only) to preserve historic forms.

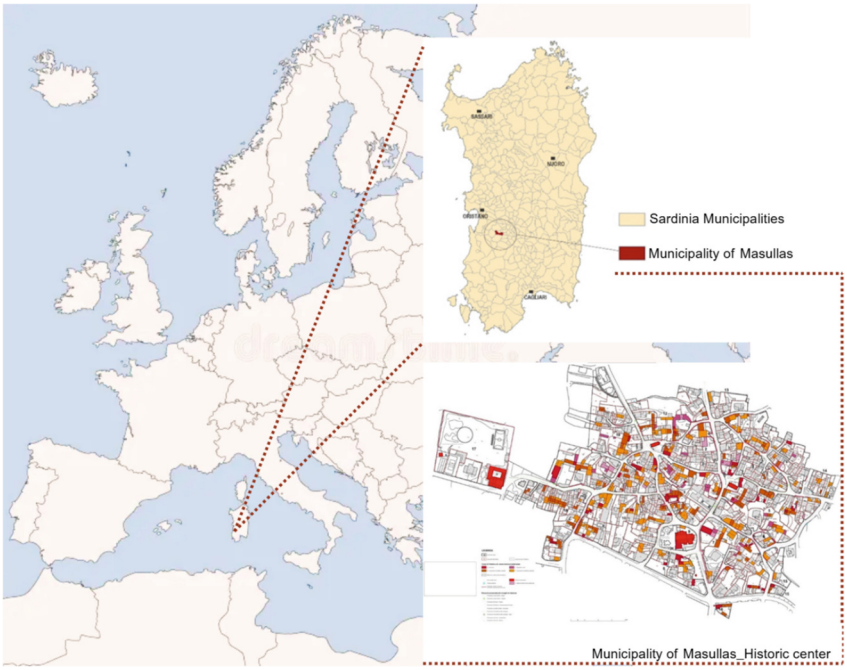

Fig. 1. The geographical context of the Municupality of Masullas (Sardinia, Italy), and an extract from the zoning table of the Historic Centre Detailed Plan.

4.2 Public Electricity Consumption

In accordance with the objectives of the URB-REC project, which aims to develop a REC model for the energy regeneration of the historic urban landscape, data on both public and residential electricity consumption were analyzed. Specifically, the local administration (the Municipality of Masullas) provided direct annual electricity consumption data for the main municipally owned properties used for public services in the historic center. The utilities studied include public buildings and spaces which can be divided into various categories: cultural and museum buildings, schools and sports facilities, and religious buildings.

In addition to the list of municipally owned properties and areas, the administration also provided the three PODs for public lighting systems, which were also studied.

To process the monthly and hourly electricity consumption data, necessary to characterize the demand profiles of the various users, historical withdrawal data provided by the grid operator for each POD were used. Consumption was further broken down into time slots F1, F2, and F3 to highlight load variations based on the consumption time slot.

Domestic electricity consumption, however, in the absence of direct measurements, is defined based on data provided by the ARERA portal to ensure a consistent and representative comparison.

The methodologies used to estimate monthly consumption, both for municipally owned properties and for residential users, allow user load profiles and identify peaks in demand.

5 Results

Consistently with the objectives of the URB-REC project, aimed at promoting electricity generation from renewable sources in an urban context by exploiting public real-estate assets, municipal properties in Masullas hosting the main public services in the historic center were selected, for which direct consumption data are available. The electrical supplies under analysis (2024) include cultural and museum buildings, educational and sport facilities, religious buildings, and the three PODs related to public lighting, which were also analyzed.

Consumption was analyzed on a monthly and hourly basis for each POD, reconstructing load profiles and identifying demand peaks. For some municipal buildings, missing data were estimated by correlating them with a reference building (e.g., the former Town Hall) equipped with a complete hourly profile; for domestic consumption, for which no direct measurements were available, a standard ARERA profile was applied and disaggregated by time band. The overall hourly profile was reconstructed by assigning the former Town Hall's profile to the various PODs and, where necessary, by applying specific profiles for public lighting and the municipal supply, integrating all hourly consumption values.

MATLAB was used to simulate energy flows for different photovoltaic capacities, starting from the hourly consumption data of municipal supplies and the solar irradiation data for the province of Oristano. The results indicate higher gains in the first 100 kWp, with load coverage approaching 35% above 500 kWp, leaving about 65% of consumption uncovered. To increase coverage, energy storage systems are therefore required (Fig. 2).

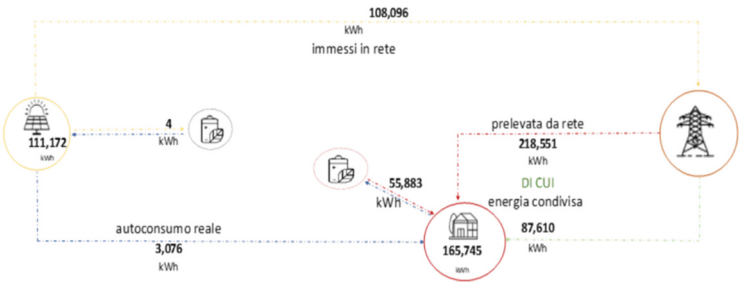

Fig. 2. Energy flows of the configuration with public administration supplies.

The available surface on buildings and public areas suitable technologically and compatible from an urban-planning perspective for photovoltaic installations was mapped, identifying, in agreement with the Municipality, areas potentially usable for a REC and preparing descriptive sheets for each one, including the following information: type of asset, location and geographical context, urban-planning classification, installation surface type, overall capture surface.

Finally, MyCER simulator was used to verify a Collective Renewable Energy Self-Consumption Communities configuration with a 60 kWp photovoltaic system and a 140 kWh storage capacity, capable of guaranteeing about 55% self-sufficiency. The hourly annual simulation shows that more than half of the community's consumption is locally covered, with flows of feed-into the grid, self-consumption and energy sharing that, combined with storage, increase coverage of the demand-side users. The cash flows, discounted over 20 years, show a progressive reduction of revenues over time due to discounting and the gradual decline in photovoltaic system efficiency, as well as a reduction in revenues from grid-injection and shared energy. The entire incentive, net of management costs, is allocated to the producing supplies (the Municipality), while the payback period of the investment is calculated considering both the photovoltaic installation alone and the overall Collective Renewable Energy Self-Consumption Communities system.

6 Conclusions

Renewable Energy Communities (RECs) emerge as a tool that links conservation-oriented urban planning with energy and mobility planning in a unified, systemic and interdisciplinary way, supporting a new model of sustainable historic city. They also help limit visually intrusive technical installations to protect landscape identity, but any new visible equipment must be carefully assessed for its visual and cultural impact to avoid disrupting the environment's formal balance and authenticity.

Growing demands for efficiency, connectivity, safety and smart services have led to uncoordinated, fragmented installations. To reduce this, a multidisciplinary approach is needed, combining regulatory rules, design guidelines and monitoring that specify materials, colours, positioning and size of plants, while favouring integrated or "camouflaged" technologies and coordinating actors to avoid overlapping interventions.

The URB-REC project develops this idea as a multidisciplinary proof-of-concept that integrates urban, energy and mobility planning to promote the sustainable conservation of historic centers through RECs, especially in Sardinia's inner areas. The model treats RECs as energy-transition ecosystems based on coordinated participation, mainly led by public institutions, which protect historic public buildings while decarbonizing through collective renewable-energy production. The project validated the legal framework (RED II, IEM, Italian Decrees 199/2021 and 210/2021), identified simplified procedures for PV in and near protected areas, and applied this approach in Masullas. Using the MyCER platform, the project also enabled savings and incentive distribution, user-level monitoring of consumption and generation, integration with storage and e-mobility infrastructures, and context-specific, white-label adaptation. Key benefits are collaborative, equity-oriented models that help combat energy poverty.

The URB-REC project and the Masullas case show this is technically and economically feasible, but its success depends on the political will to implement these changes. As a matter of fact, the model is viable and replicable but requires further regional-scale experiments to streamline landscape authorizations and spread digital management tools for RECs, in turn making them strategic instruments for urban sustainability and resilience in historic areas.

To turn RECs into transformative tools in historic centers, the study proposes a move from incentive-centered to governance-centered policies, building capacity through facilitation services, legal-technical support and training. It also calls for simplifying complex regulations, fostering community building and social-capital development, and embedding energy-justice principles that include vulnerable groups excluded from installing PV on their own buildings. Communication should stress collective, relational and environmental benefits rather than only individual savings, and policies should strengthen municipal leadership, support inter-municipal cooperation and invest in long-term institutional development via multi-year funding and adaptive learning.

Acknowledgments. This study was funded by the research project URB-REC "Managing the Historic Urban Landscape: Renewable Energy Communities for Sustainable Urban Conservation" – UNICA PoC Call (DR 268/2025 of 12/03/2025) for the development of Proofs of Concept (PoC) by researchers aimed at promoting technological innovation and the energy transition - within the framework of Spoke 7 of the e.INS project - Ecosystem of Innovation for Next generation Sardinia - MUR Code: ECS00000038 - CUP F53C22000430001. Principal Investigator (PI): Mara Ladu. Research Group: Ginevra Balletto, Stefano Matta, Emilio Ghiani, Francesco Puddu, Viola Gioi, Alessandra Milesi, Federica Isola and Corrado Zoppi (University of Cagliari), and HIGECO ENERGY srl.

Author Contributions. G.B. and M.L. wrote Sects. 1, 3.1 and 6; G.B. wrote Sect. 2.1; F.I. wrote Sect. 2.2; E.G. wrote Sect. 2.3, 3.2 and 4.2; M.L. wrote Sect. 3.3; F.I. and A.M. wrote Sect. 4.1; G.B., M.L., F.I., E.G., F.I. and A.M. wrote Sect. 5. The authors have read and agreed to the published version of the manuscript.

Disclosure of Interests. The authors have no competing interests to declare that are relevant to the content of this article.

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