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Urban Regeneration and Renewable Energy Communities: The Case of the Ex-Caserma Stamoto in Bologna

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ABSTRACT

Growing competition for urban land reveals the urgent need to reconcile economic development, environmental protection and equitable access to high-quality urban spaces. In this scenario, the adaptive reuse of abandoned infrastructure within consolidated urban fabrics emerges as a strategic approach to limiting land consumption while enhancing urban resilience and sustainability. Addressing this challenge, the University of Ferrara developed an integrated regeneration proposal for the Ex-Caserma Stamoto area in Bologna, redefining this disused military complex as a catalyst for student and social housing and for the regeneration of the San Vitale district. The project was grounded in the regulatory framework for disused public assets, municipal planning policies and current sustainability agendas, while pursuing solutions capable of minimising public financial burdens. The research adopted a multidisciplinary methodology based on thematic mapping, which combined the analysis of urban morphology, mobility, green and blue infrastructure, energy sources and consumption patterns with a comparison of five urban fabrics of Bologna. This evidence-based approach supported the formulation of an urban strategy able to balance environmental integrity, spatial efficiency and social liveability. The proposal introduced a Renewable Energy Community (REC) as an operational tool to promote local energy self-sufficiency, circular resource management and collective participation. The analyses identified public buildings, car parks and industrial roofs as the main surfaces available for energy production, and the proposal was organised in successive phases, reaching photovoltaic capacities of 5,394 kWp, 6,734 kWp and 17,577 kWp in the San Vitale district, complemented by geothermal systems beneath the car parks of the complex. By integrating renewable technologies, the reuse of existing structures and the morphological adaptation of the site, the study demonstrated how underused urban voids can be transformed into sustainable and socially cohesive environments. The research ultimately contributed an integrated planning model for the ecological and energy transition of contemporary cities.

KEYWORDS Urban redevelopment, Sustainability, Renewable energy, Community planning, Environmental efficiency

1. Introduction

The high population density of urban areas, combined with high rates of land consumption and the presence of vacant or underused spaces, highlights the need to optimise the use of urban land (Istituto Superiore per la Protezione e la Ricerca Ambientale 2025). This context offers opportunities for the implementation of innovative urban planning and design strategies aimed at the efficient use of resources and the integration of sustainable energy systems (Barragán-Escandón *et al.* 2017). In this sense, the production and sharing of energy by local communities are relevant strategies for promoting a more sustainable and collaborative approach to urban development, favouring the use of available resources and the alignment of environmental, social and economic objectives.

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Renewable Energy Communities (RECs) are an instrument for enabling this approach, allowing different local actors to take part in the production and sharing of renewable energy (Italia 2021; Autorità di Regolazione per Energia Reti e Ambiente 2022). Beyond their economic benefits, these communities can contribute to reducing CO_2 emissions, strengthening local energy autonomy and promoting more participatory models of energy management. Their implementation can also support the regeneration of disused or underused urban areas, contributing to more sustainable and resilient spaces, in line with the objectives of the 2030 Agenda.

In this context, the regeneration of the Ex-Caserma Stamoto area in Bologna offered an opportunity to explore innovative approaches that integrate urban planning with the implementation of a Renewable Energy Community. The proposal developed by the University of Ferrara sought to transform this former military complex into a catalyst for the regeneration of the San Vitale district, combining student and social housing with recreational areas, sports facilities and commercial activities.

The project was based on an analysis of the urban, environmental and regulatory context, taking into account the guidelines of the Agenzia del Demanio, municipal planning policies (Comune di Bologna 2024) and contemporary sustainability objectives (Ministero dell'Ambiente e della Sicurezza Energetica 2023). At the same time, it sought to identify solutions capable of optimising the use of available resources, limiting environmental impacts and reducing the financial burden on the public sector, creating favourable conditions for the involvement of public and private partners.

The integration of urban regeneration and energy transition was therefore the central axis of the proposal (Sijmons 2014; Pasqualetti and Stremke 2018). The implementation of a REC was considered a strategy capable of linking local energy needs with the reuse of existing structures (Fabian *et al.* 2012), the enhancement of urban spaces and the participation of different actors in building a more sustainable model of development.

2. Methodology

In order to define urban intervention strategies and identify renewable energy solutions suited to the social, environmental and economic characteristics of the area, a multidisciplinary methodology based on the production and analysis of thematic maps was developed (Moura 2005).

The analyses covered different dimensions of the urban context, including morphology, mobility, ecosystem, energy sources and the characteristics of the built environment. The approach sought to understand the relationships between these dimensions and the specific features of the study area, respecting pre-existing natural elements and the consolidated characteristics of the urban fabric.

In addition, five urban fabrics of Bologna were compared: the rural plain fabric, the residential fabric, the industrial fabric, the Stamoto fabric and the rural hill fabric. This comparison made it possible to identify differences in spatial organisation, land occupation, building typologies and the distribution of infrastructure, providing input for the definition of regeneration strategies compatible with local characteristics.

The investigation also considered the integration of urban, environmental and energy aspects, seeking to identify opportunities for the installation of renewable energy systems and the use of existing infrastructure. The analyses were complemented by collective discussions aimed at defining urban regeneration strategies, taking into account economic feasibility, resource optimisation and the possibility of generating energy to meet the needs of the buildings and the local community.

This approach established an analytical basis for the development of an integrated proposal, in which urban regeneration and the implementation of a REC were treated as complementary processes.

2.1. Urban morphology

The analysis of urban morphology identified the differences between the fabrics that make up the city of Bologna, considering the relationships between the built environment, topography, occupation patterns and land uses.

The rural plain fabric consists of smaller units, organised according to a grid defined by the morphology of the agricultural landscape. Buildings mostly have one to three storeys and are characterised by mixed uses.

The residential fabric is formed by groups of buildings which, linked together, create a relatively compact structure crossed by transverse streets. Disused areas mainly correspond to abandoned buildings within the consolidated built fabric. In this context, large vacant areas similar to Stamoto are rare, with the exception of some military complexes with comparable characteristics.

Most buildings have one to three storeys. However, along the main radial roads connecting the historic centre to the peripheral areas, there are buildings of six to eight storeys. The fabric is characterised by a predominance of residential and mixed-use buildings.

The industrial fabric has larger units, more widely spaced and surrounded by gardens, storage areas and large car parks. Buildings mostly have one to three storeys and are mainly used for industrial activities, although services requiring large surfaces, such as recycling facilities, are also present.

The Stamoto fabric is characterised by a combination of smaller units and larger buildings, reflecting the overlap between the structures of the former peripheral fabric and the development of residential estates. This configuration includes buildings of one to three storeys and others of six or more storeys, as well as residential and mixed-use buildings, sports facilities, hospital structures and public services.

The presence of numerous public buildings in the surrounding area is a relevant aspect for the regeneration proposal, since these structures can support the provision of services and the establishment of social and functional connections between different urban sectors.

The rural hill fabric, in turn, is made up of smaller units distributed along the roads, following a spatial organisation shaped by the topography. Low-rise buildings predominate, generally with up to three storeys, used for residential, mixed and agricultural purposes.

The comparison of these fabrics showed how different morphological configurations influence the possibilities for intervention, the availability of surfaces for the installation of energy systems and the integration of new functions into existing structures (Figure 1).

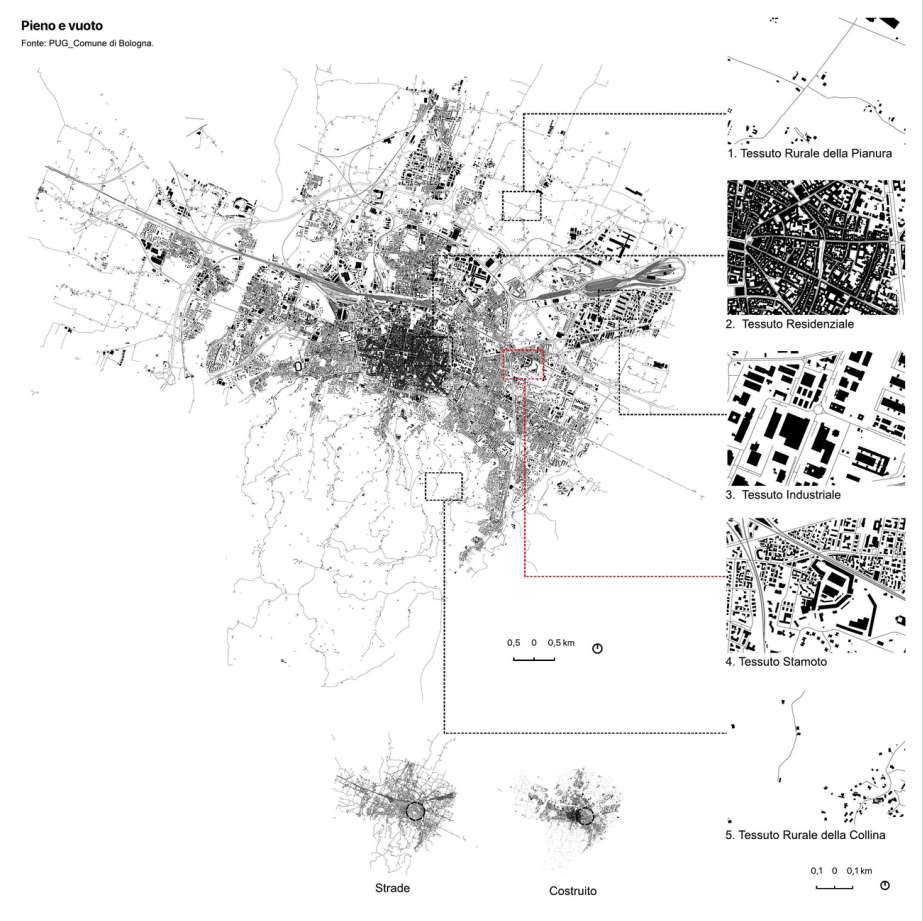

Figure 1. Figure-ground analysis. Source: Comune di Bologna (2024).

2.2. Urban mobility

The city of Bologna is structured by an extensive road network, which includes important regional routes such as the E45 motorway. The territory is also crossed by railway infrastructure that is relevant for connections between urban centres, including the corridors linking Milan and Florence.

Within the city, the road network combines grid-pattern streets, radial roads and fast-traffic corridors, forming a system that serves different modes of transport.

In the rural plain fabric, roads for vehicle traffic between agricultural areas predominate, connecting these areas to the main road infrastructure and the urban core, particularly for the transport of goods.

The residential fabric is characterised by a radial road network, complemented by narrow streets that favour local mobility. Movement is served by public transport, pedestrian routes and cycle paths, as well as larger car parks located mainly on the edges of the historic centre.

The industrial fabric has roads designed for fast traffic, with a relatively regular layout and large parking areas. There are also cycle paths connecting it to the historic centre.

In the Stamoto area, mobility is structured by roads for vehicle traffic, associated with parking areas distributed among the residential estates. This configuration offers opportunities to assess the integration of mobility infrastructure with local renewable energy production, particularly through the use of parking surfaces.

One of the main environmental impacts associated with transport infrastructure in the study area is noise pollution caused by the proximity of the railway line. This highlights the need to consider environmental conditions when defining urban regeneration strategies.

The rural hill fabric, in turn, is characterised by roads whose layout follows the contours of the terrain, connecting the higher areas with the urban centre.

The mobility analysis identified the relationships between accessibility, infrastructure, land occupation and environmental quality, providing input for the definition of interventions capable of improving the integration of the Stamoto area with the rest of the city (Figure 2).



Figure 2. Urban mobility analysis. Source: Comune di Bologna (2024).

2.3. Ecosystem and green infrastructure

The territory of Bologna is crossed by a branched water network, with no single large watercourse running through the urban centre. At the same time, green infrastructure is distributed across neighbourhoods, central areas and public spaces, performing environmental functions that are important for the ecological balance of the city.

The rural plain fabric includes green areas classified by the General Urban Plan (PUG) as rural territory (Comune di Bologna 2024), used mainly for agricultural activities. These areas are subject to restrictions on use and transformation and must be taken into account when defining planning strategies.

In the residential fabric, small gardens, generally private, and shrub vegetation along the streets predominate. In the industrial fabric, larger private gardens surrounding the company buildings stand out.

The Stamoto area features a combination of private gardens, public green areas and community gardens. A particularly relevant element is the ecological corridor located along the north-east axis of a former railway line used for logistics activities.

This corridor is an important environmental infrastructure, contributing to ecological continuity and to the regulation of the local microclimate.

According to the classification adopted in the research, the area has medium microclimatic fragility (Comune di Bologna 2024). The PUG guidelines indicate the need to preserve existing tree

cover and avoid unnecessary interventions, in order to reduce impacts on local environmental conditions.

The rural hill fabric also includes green areas subject to protection and conservation guidelines, whose configuration is related to natural features and to local networks of protected areas.

The ecosystem analysis identified environmental elements that should guide the regeneration project, including the preservation of existing vegetation, the maintenance of ecological corridors and the consideration of microclimatic conditions. These factors are essential to ensure that the introduction of new urban functions and energy systems is compatible with the conservation of natural resources (Figure 3).

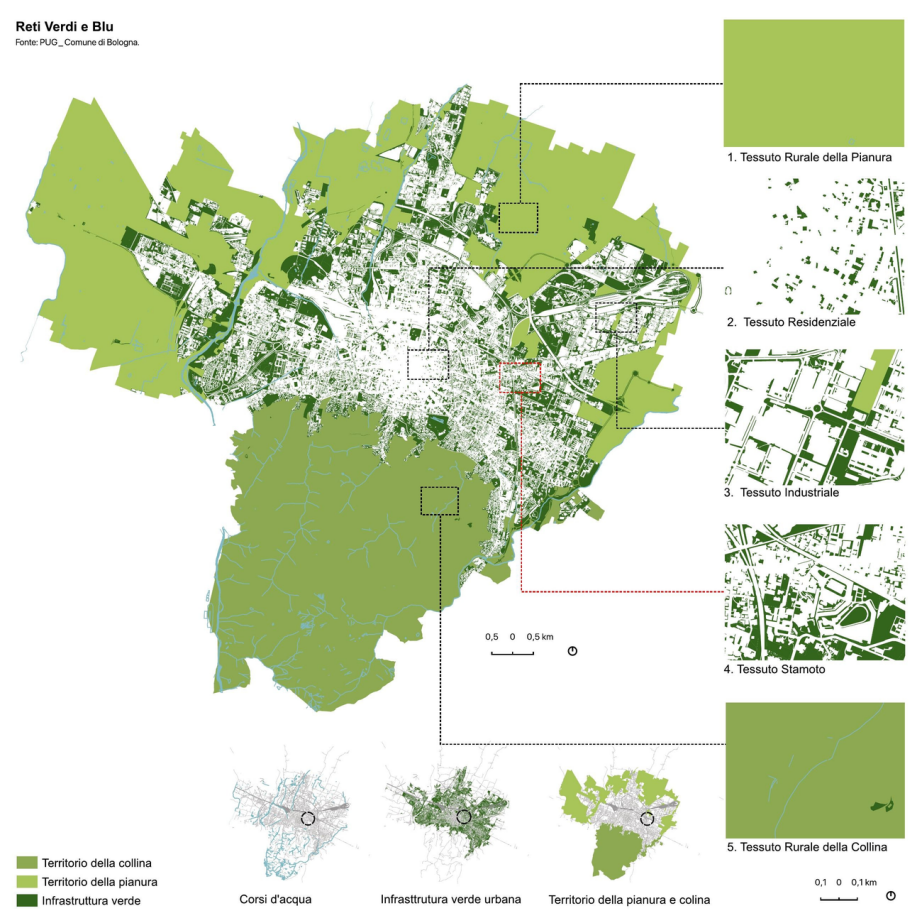

Figure 3. Ecosystem and green infrastructure analysis. Source: Comune di Bologna (2024).

2.4. Energy and energy consumption

The energy analysis focused on the territorial distribution of energy sources, consumption patterns and the possibilities for integrating existing infrastructure with renewable production systems.

In this context, the distribution of energy sources did not show a direct and exclusive relationship with the morphological configuration of the urban fabrics. Infrastructure and installations are scattered across the territory, reflecting different conditions of occupation, consumption needs and production opportunities.

According to the data analysed, solar thermal and photovoltaic energy, mini-hydropower and biogas are among the main renewable sources used locally to meet the energy needs of the city.

The growth of installed photovoltaic capacity in the municipal territory during the period in which the national incentive schemes for solar energy production, known as Conti Energia, were in force is particularly notable.

The distribution of final energy consumption by macro-sector shows the predominance of the civil sector, followed by the other economic sectors. According to the data considered in the research,

more than 73% of the city's energy consumption is concentrated in the civil sector (Comune di Bologna 2024).

Specifically, the residential sector accounts for 61% of Bologna's natural gas consumption, while the services sector accounts for 55% of total final electricity consumption (Comune di Bologna 2024).

The consumption of petroleum-derived fuels is also significant, mainly due to the circulation of petrol-powered vehicles.

In the Stamoto area, some public services are already supplied by photovoltaic installations. The energy infrastructure of the San Vitale district includes four electrical substations, whose function and relationship with energy production and distribution facilities must be considered in the planning of the future energy community.

The analysis of consumption patterns, the distribution of existing installations and the characteristics of the buildings identified opportunities to expand local renewable energy production and to integrate different users into a shared energy system.

These results form the basis for defining strategies that combine photovoltaic production, the use of available surfaces and the participation of public, residential, commercial and industrial buildings in a possible REC (Figure 4).

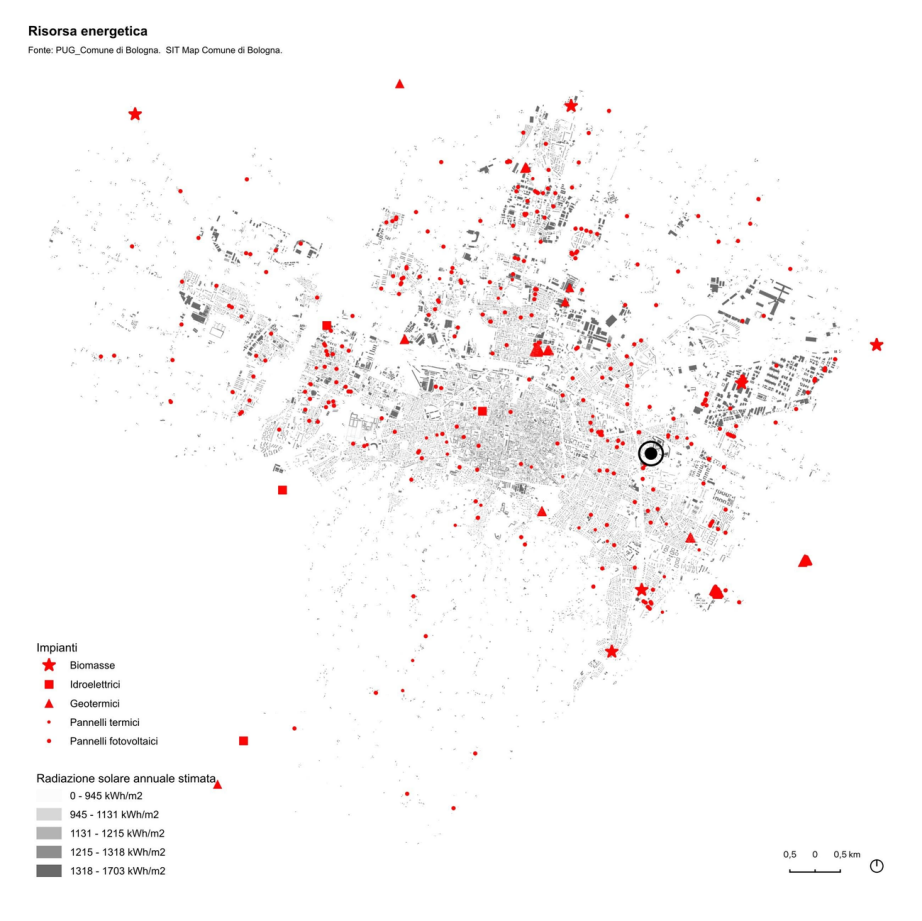

Figure 4. Territorial distribution of energy sources. Source: Comune di Bologna (2024).

3. Results

The research provided relevant input for the development of a Renewable Energy Community proposal in the Ex-Caserma Stamoto area, demonstrating the importance of integrating urban analysis with energy sustainability strategies.

The morphological analysis identified vacant spaces and surfaces potentially available for the installation of renewable energy systems. At the same time, it helped to recognise the features that

should be preserved, so that the proposed interventions respect the identity of the urban fabric and establish a balanced relationship between pre-existing structures and new functions.

The survey of building heights also provided important information for understanding built density, the configuration of the urban skyline and the conditions that may influence energy production and consumption. These data contribute to assessing the potential use of the available surfaces and the energy needs of the surrounding area.

The mobility analysis highlighted the importance of establishing connections between existing services and the new functions planned for the Stamoto area. The presence of public buildings, social facilities and services is a strategic element for structuring the REC, since these spaces can encourage the participation of different actors and the integration of the social, economic and energy dimensions of the project.

The investigation also identified the considerable occupation of urban land by parking areas. These surfaces represent an opportunity for the installation of photovoltaic systems, which can contribute to local renewable energy production and to the reduction of the environmental impacts associated with urban energy consumption.

The ecosystem analysis identified relevant green areas, ecological corridors and elements that are essential for maintaining the local microclimate. These components should be incorporated into the regeneration strategies, ensuring that the introduction of new infrastructure and urban functions respects existing environmental conditions.

The assessment of water resources also helped to define the possibilities for water-related energy use, highlighting the need to consider local characteristics and limitations when selecting the technologies to be adopted.

Finally, the analysis of energy sources and consumption patterns was fundamental for understanding the territorial distribution of energy demand, identifying existing infrastructure and recognising opportunities for renewable production. The integration of this information makes it possible to guide the definition of distributed generation and energy-sharing strategies, taking into account the characteristics of the buildings and of the different users.

From an infrastructural point of view, the connection between production and consumption facilities is a central aspect of REC implementation. In the Stamoto area, the presence of electrical substations and existing photovoltaic installations is a starting point for assessing the possibilities of integration with the distribution grid, in compliance with the applicable technical and regulatory conditions (Italia 2021; Autorità di Regolazione per Energia Reti e Ambiente 2022).

Based on these results, the proposed development strategy sought to combine urban regeneration and energy transition through the participation of public and private buildings, parking areas and industrial facilities.

Public buildings could act simultaneously as producers and consumers of photovoltaic energy, while parking surfaces could be assessed for the installation of solar generation systems. Similarly, industrial activities could use building roofs and other available surfaces to increase local renewable energy production.

The integration of these different possibilities makes it possible to conceive the REC as part of a broader urban strategy, in which energy is no longer considered merely a technical resource but becomes a structuring element of territorial regeneration (Pasqualetti and Stremke 2018).

4. Conclusion

The proposal explored in this research sought not only the aesthetic and functional revitalisation of the Ex-Caserma Stamoto urban area, but also the creation of a more sustainable, efficient and resilient environment. The results showed that integrated planning, based on the analysis of the morphological, environmental, energy and functional characteristics of the territory, can help to transform disused or underused urban areas into spaces capable of responding to the contemporary needs of the city.

In this context, the production and sharing of energy by local communities are relevant strategies for promoting a more sustainable and collaborative model of urban development. The implementation of a Renewable Energy Community can foster the efficient use of available resources, the participation of different local actors and the alignment of environmental, social and economic objectives (Figure 5).



Figure 5. Implementation phases of the REC: photovoltaic and geothermal installations in the Ex-Caserma Stamoto and the San Vitale district, and photovoltaic production by project phase.

Beyond their economic benefits, RECs can contribute to reducing CO_2 emissions, strengthening local energy autonomy and building more participatory management models. Their integration into urban planning broadens the scope of energy policies, linking renewable production with the reuse of existing structures and the enhancement of underused urban spaces.

From an infrastructural point of view, the integration of production and consumption facilities into the electricity grid is a fundamental element for implementing the REC in the Stamoto area. In this sense, the proposed strategy sought to promote not only economic and social but also urban transformations, through the integration of public and private buildings into the local energy system.

Public buildings could act both as producers and as consumers of photovoltaic energy, helping to exploit the energy potential of the area and strengthening the participation of public institutions in the energy community.

Mobility infrastructure could also play a relevant role in this strategy, particularly through the installation of photovoltaic systems in parking areas. This option links renewable energy production with the use of surfaces already devoted to specific urban functions, contributing to a more efficient use of land.

Likewise, industrial activities could use their roofs and other available surfaces to increase local energy generation. The participation of these different actors could foster links between the residential, public, commercial and productive sectors, expanding the possibilities for energy sharing and territorial cooperation.

The proposal therefore highlighted the potential for integrating urban regeneration and energy transition. The implementation of a REC in the Ex-Caserma Stamoto could become an instrument for combining the reuse of existing structures, the enhancement of public spaces, local renewable energy production and collective participation.

In conclusion, energy can play a structuring role in the process of urban regeneration, helping to transform disused areas into multifunctional, environmentally qualified and socially integrated spaces. The experience of the Ex-Caserma Stamoto thus provides a basis for reflecting on planning models capable of incorporating Renewable Energy Communities into strategies for the sustainable transformation of contemporary cities. The main limitation of the study was that the energy assessment was carried out at a preliminary design stage, so the proposed capacities should be verified through detailed simulations and the involvement of the future members of the community.

Declarations

Author contributions. Karla Cavallari: Conceptualization, Methodology, Investigation, Writing (original draft), Writing (review and editing).

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Conflicts of interest. The author declares no competing interests.

Data availability. The data supporting this study are included in the paper. The base cartographic and energy data were obtained from publicly available sources of the Comune di Bologna (PUG and SIT); the thematic maps derived from them are presented in Figures 1–5.

Ethics. Not applicable

Generative AI. Generative AI (Claude, Anthropic) was used to assist with formatting the manuscript according to the conference template, checking reference formatting, and translating the text from Portuguese into English. The author reviewed and edited all output and takes full responsibility for the content of the paper.

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