

Planning Renewable Energy Communities in Intermediate Areas. A Case of Study

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Abstract. Renewable Energy Communities (RECs) are a promising instrument for decarbonizing urban areas and reduce energy poverty. This contribution is part of a larger research program, where it was previously presented a methodology to identify priority areas in which to foster the RECs promotion through the Municipal Urban Plan. The specific objective of this work is to evaluate the transferability of this methodological path to the territorial context of intermediate areas, located halfway between urban poles and inland areas. So, the methodology is applied to the case study of Fisciano Municipality, in Campania Region (Italy), in the context of studies for the Municipal Urban Plan formation. From this application, it is possible to conclude that the transferability of the above methodology is also possible to intermediate contexts. However, the results obtained offer further insights, especially the need to diversify the incentives and reward mechanisms to be provided for the RECs development in the plan, in relation to the different territorial contexts in which the planning activity is carried out. In this way, it is possible to ensure a just energy transition in urban areas, avoiding the generation of further inequalities.

Keywords: Energy Poverty · Renewable Energy Communities · Urban Planning

1 Introduction

In the international scientific debate, as well as in recommendations and guidelines promulgated by public entities and global organizations, Renewable Energy Communities (RECs) are recognized as bringing innumerable social, environmental and economic benefits to the local areas in which they operate and to the populations living there. The main benefits concern the reduction of climate-changing emissions (environmental benefits) and energy poverty (social and economic benefits). These benefits derive indirectly from those that RECs directly bring: the increase in decentralised plants for the production of energy from renewable sources; the energy efficiency of existing buildings; the reduction of the bill cost for the community members [1–5].

According to the definition given by the European Commission with Directive EU/2001/2018, known as "RED II", RECs can be defined as spatially concentrated networks of users - citizens, small and medium-sized enterprises, municipal administrations - which, on a voluntary basis, aggregate to self-produce, self-consume and share

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energy, produced locally by plants powered by renewable sources, with the main purpose of receiving the aforementioned benefits, rather than economic profits [6].

Since RECs respond to issues that afflict urban and metropolitan areas with increasing intensity, they are a promising tool for planners to put into practice the concept of Sustainable Cities, as advocated by the 2030 Agenda.

Promoting RECs in urban planning is therefore a way to achieve goals 1 "No poverty", 7 "Affordable and clean energy" and 11 "Sustainable cities and communities" [7], but also to reach the carbon neutrality goals set by the European Union [8].

Yet, the topic is approached by researchers with a prevalent interest in energy, technological or cost-effectiveness issues, rather than urban planning. Only recently, the RECs tool has sparked interest in academic research in the field of planning [9–11].

In Italy, this trend should be read in the light of a historically difficult integration between sectoral energy planning and general planning for development, at various levels, both at regional and urban scales [12]. The reversal of this trend is necessary so that planning itself does not become an obstacle to the spread of RECs, slowing down the approval processes, as stated both by scholars and in the Italian Energy and Climate Plan [13–15].

The work is part of a larger ongoing research project, aimed at promoting RECs through general urban planning. As part of this project, a methodology was proposed to spatially identify priority areas, or target areas, in which to direct this action. The methodological proposal is only briefly described in Sect. 2 for greater clarity, while for its deeper knowledge reference should be made to Gerundo & Marra [16], which is the study in which it was applied for the first time.

2 Methodological Path and Aim of the Work

The *priority areas*, mapped at an infra-urban scale, are intended to be located where a minimization of constraints and a maximization of the benefits deriving from the RECs establishment is expected, with particular reference to the reduction of energy poverty. Therefore, the proposed methodology is divided into three main Macro-phases (I, II, III), which consist, respectively, in the construction of the following maps:

- *Energy Poverty Map*, representative of the most critical urban areas from an energy and social point of view (I);
- *Constraints Map*, summarizing all the urban and regional constraints existing to the RECs establishment, with regard to the areas not suitable for the installation of RES plants, i.e. for the production of Energy from Renewable Sources (II);
- *Priority Areas map*, built from previously obtained maps (III).

The *Energy Poverty Map* is obtained by selecting urban areas with the worst energy consumption and low-income urban areas (I). The most energy-intensive areas are defined as the districts with a building-residential stock characterized by high consumption for heating and domestic hot water production. The identification of these areas is carried out by tracing the stock of residential buildings of each census section to a typical building, or archetype, representative of the entire section, on the basis of the prevailing building type and age class, calculated in a GIS environment. The energy consumption is then estimated, in accordance with current legislation, on the basis of the

climatic zone and the stratigraphic, technological and plant characteristics of the identified archetypes. Existing Public Housing (ERP) and/or Social Housing (ERS) districts are instead intended to be representative of low-income urban areas.

The *Constraints Map* is constructed by selecting the constraint factors that characterize the so-called "no RES zones" according to the Italian reference legislation, Interministerial Decree (D.I.) of 10 September 2010, entitled "Guidelines for the authorization of plants powered by renewable sources": protected areas, forest areas, water bodies, areas with high agricultural potential, areas and buildings of landscape or cultural interest; areas of high hydrogeological hazard and/or risk (II).

In the last macro-phase, the *Priority Areas Map* is obtained through an overlay mapping between the Energy Poverty Map and the Constraints Map. This map makes it possible to identify different degrees of priority: urban areas characterized by critical energy and/or social performance and, at the same time, not affected by the areas where the installation of RES plants is not allowed, represent those areas where the greatest effectiveness is expected, thus presenting the highest degree of priority (III).

The source of the data for the application of the methodology described is represented by the graphic elaborations produced in the ordinary activity of municipal urban planning.

The proposed method has already been applied to the Municipality of Pagani, belonging to the populous conurbation of the Agro-Nocerino-Sarnese, in the Campania Region (Italy), and to the small town of Andretta, a typical inland area of the same region, as documented in two previous works, to which reference should be made for the respective in-depth studies [16, 17].

The specific objective of this paper is to evaluate the transferability of the proposed methodological path to a different territorial context, halfway among those examined above, in order to complete the testing phase of the model. To this end, the method is applied to the Municipality of Fisciano, a case study that can be defined as intermediate between urban poles and inland areas [18, 19] of the same region. The case study is presented in Sect. 3, while Sect. 4 describes the performed application and the main results, discussing them in relation to the aim of the work. Section 5 reports the conclusions and possible future developments of the research.

3 A Case of Study

The municipality of Fisciano, which covers 31.69 km^2, is located north of the city of Salerno, capital of the province of the same name, and on the border with the province of Avellino, in the Campania Region (Italy). Due to its strategic position, the municipal area was chosen as the location of the main campus of the University of Salerno, a reference point for higher education for the two provinces. In addition, there is an extensive Industrial Development Area (ASI), which extends for 2.4 km^2, including part of the territory of the neighboring municipality of Mercato San Severino.

These circumstances have led to a significant demographic evolution for the municipality, which has gone from 8,000 inhabitants in 1971 to 12,275in 2011, up to 14,064 current residents, according to data released annually by the Italian Institute of Statistics (ISTAT). The main inhabited centre of Fisciano, almost close to the university

campus, is characterized as a watershed between two very different geographical and socio-economic contexts, both within the municipality in question and in the wider area including the neighboring municipalities: to the south-west the conurbation of the Irno River valley, developed in the municipalities around the coastal city of Salerno, with increasing demographic dynamics, albeit less rapidly over the last decade; to the north-east the Picentini Mountains, which lap the southern part of the province of Avellino, occupied by numerous inland municipalities, characterized by a severe demographic decline (Fig. 1). This barrier is reflected in the variation in the altitude of the territory, from a maximum of about 1,550 m above sea level to a minimum of 132 m above sea level, and in the articulation of the settlement system, denser in the south-eastern part of the municipality, which falls within the climatic zone D (1669 degree days).

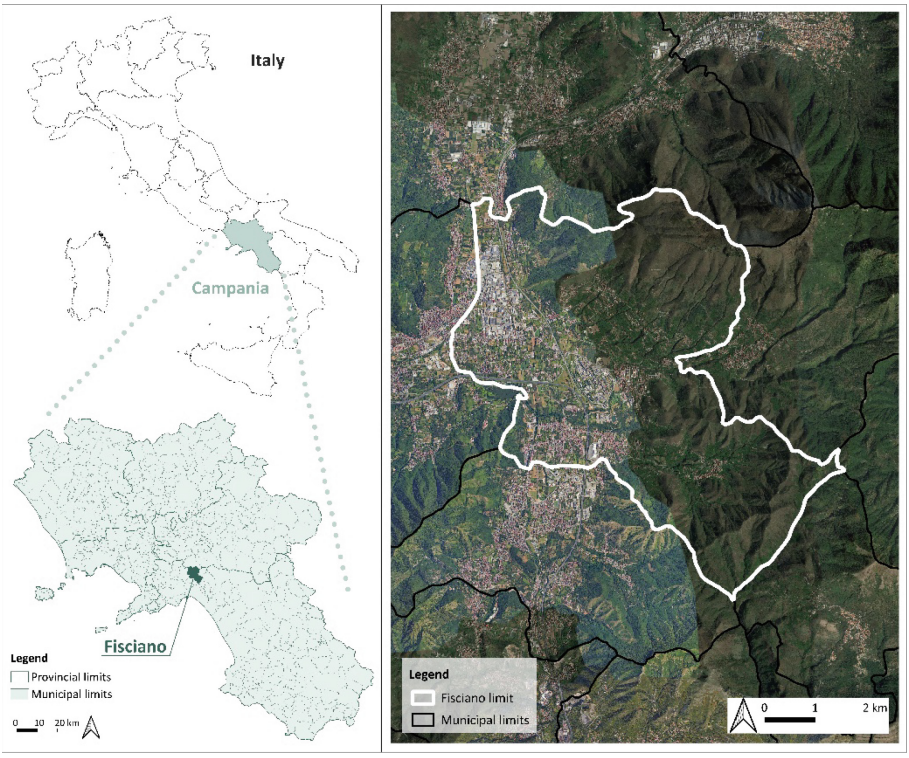

Fig. 1. The study case of Fisciano Municipality in Campania Region (Italy).

Fisciano has a General Regulatory Plan (PRG) approved in 2008. In 2018, the Municipality started the drafting of the new Municipal Urban Plan (PUC) to adapt to the changed regional legislation and to update the obsolete PRG, approving the preliminary proposal (Preliminary of PUC). In 2022, the Municipal Administration requested

technical-scientific support from the Department of Civil Engineering of the University of Salerno (DiCiv), for the drafting of the PUC final design [20]. The application experimentation covered by this paper is part of the studies carried out during the above-mentioned support activity.

3.1 Input Data and Processing

As anticipated in the introduction of this paper, the input data necessary for the application of the proposed methodology can be extrapolated from the graphic elaborations of Fisciano Municipal Urban Plan. In particular, the following documents were used for the Energy Poverty mapping:

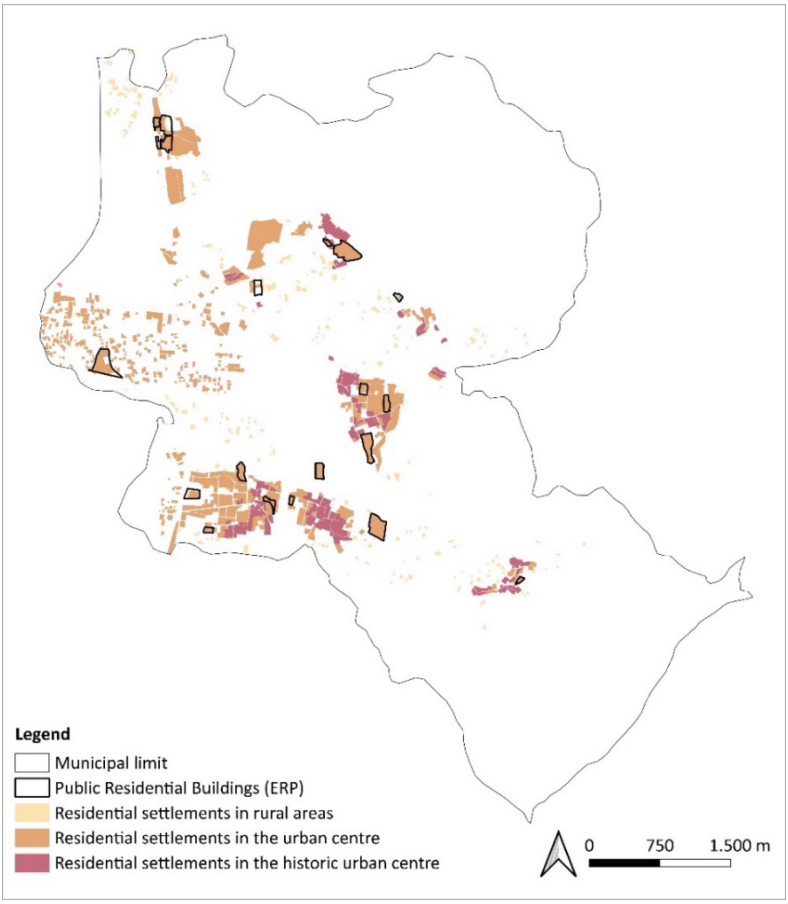

Fig. 2. Residential Urban Land Use Map. Source: Own elaboration on data from the "Urban Land Use Map" of Fisciano Municipal Urban Plan.

– Regional Technical Numerical Cartography, provided by the Campania Region to the Municipalities, from which to extract the information and geometric attributes of the buildings in the municipal area;
– Urban Land Use Map, from which to derive the prevailing use of the existing building, in order to isolate the mostly residential buildings from those for other uses. In addition, the 20 districts occupied by ERP housing, scattered throughout many of the municipality's urban centres, have been identified on that map (Fig. 2).

Subsequently, the data of some census variables were collected, selected from all census data provided by ISTAT [21], which divided the territory of Fisciano into 32 census tracts. However, it was possible to consider 27 of them in the analysis, as 3 lacked data and 2 had no residential buildings (Fig. 3).

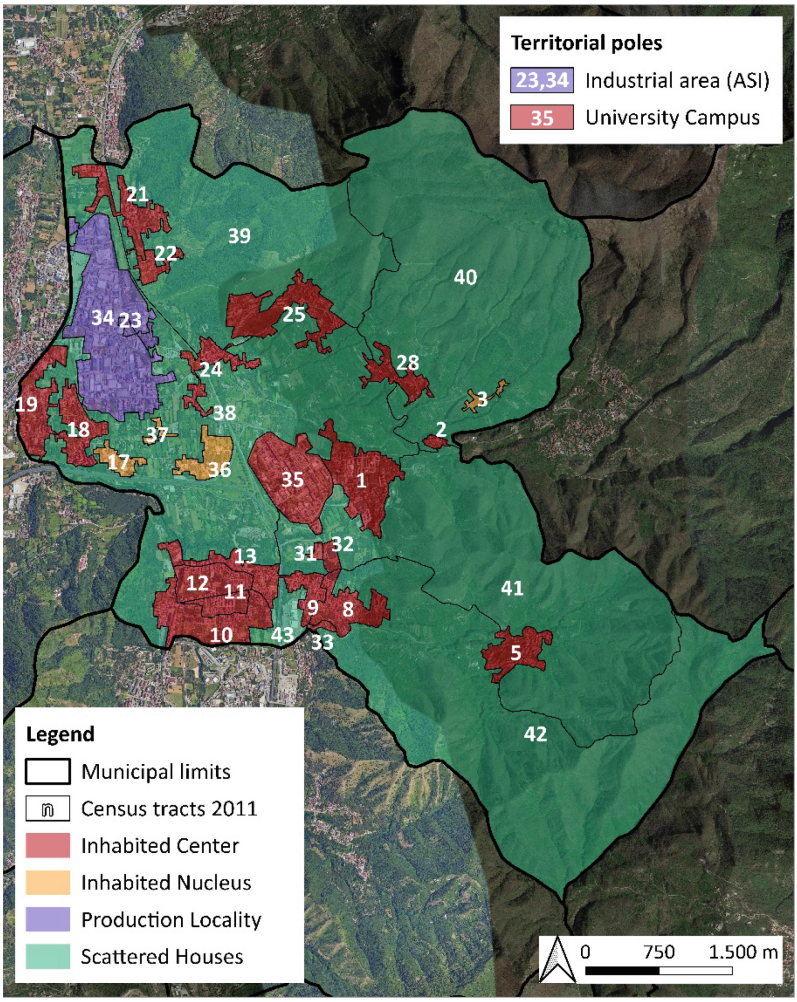

Fig. 3. Census tracts Map.

More precisely, the extrapolated data are as follows:

– number of residential buildings classified according to the number of floors;
– Number of residential buildings by age group.

Finally, for the identification of "No FER" areas and the mapping of Constraints, the data are extrapolated from the following graphic elaborations of the Fisciano Municipal Urban Plan:

– Hydrogeological hazard and risk maps, taken from the elaborations of the Hydrogeological Stability Plan, drawn up by the territorial competent Basin Authority, the one of the Sarno River;
– Map of agricultural land use, constructed on a preliminary basis by analyzing the Agricultural Land Use Map of the Campania Region;
– Protection system, a map made up of the constraints and buffer areas that insist on the municipal territory;
– Emergency system, i.e. resources of architectural and historic value;
– System of naturalness, inherent in the areas of environmental protection (Fig. 4).

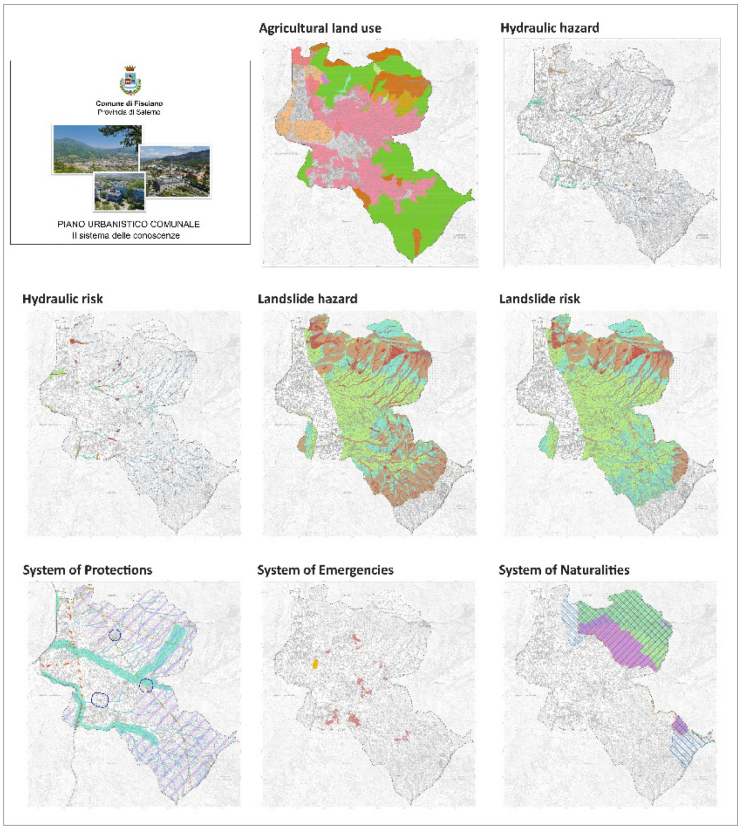

Fig. 4. Input data for Constraints Map. Source: Own elaboration on data from Fisciano Municipal Urban Plan.

The collected input data were processed in a GIS environment, using the commercial software ArcGis [22] and the open source software QGis [23].

4 Results and Discussion

The application of the proposed methodology to the Municipality of Fisciano involved the elaboration of the Energy Poverty Map (I), the Constraints Map (II) and the Priority Areas Map (III), as specified below.

4.1 Energy Poverty Map

From the analysis performed according to the first Macro-phase (I), it emerged how the prevailing building typology is that of multi-family buildings, more precisely buildings from 2 to 5 floors and up to 20 apartments. In addition, buildings for mainly residential use were built, on average, between the 1950s and 1990s, with a prevalence in the time interval 1961–1975. By intersecting the data relating to the building type and age class thus obtained, a building-type is associated with each census section, consisting of homogeneous stratigraphic, technological and plant characteristics.

For each building-type, the energy consumption for heating and domestic hot water production, expressed in kWh/m^2 per year, was assessed on the basis of the relevant technical literature [24].

The total consumption is calculated by multiplying the consumption value of the building-type representative of each section by the number of residential buildings in the same section. The resulted values were divided into five classes, from "Very Low" to "Very High", obtaining the map of the overall energy consumption. This classification was carried out in the QGIS environment using the Natural Breaks algorithm, which allows to identify natural groupings of the data, maximizing the variance between the classes [25].

The *Energy Poverty Map* is obtained by cross-referencing the Residential Land Use Map in Fig. 2 with the Map of the overall energy consumption. Of the latter, the 2 worst classes, "High" and "Very High", are considered.

From *the Energy Poverty Map* (Fig. 5) it is possible to deduce three types of priority areas, i.e. those most critical from an energy point of view, in the social dimension, or those where both profiles are problematic.

Compared to the case studies already analyzed, Pagani [16] and Andretta [17], the methodology proposed for Macrophase I was easily transferable to the case study of Fisciano. In fact, the input data necessary for the evaluation of energy consumption derive from official datasets, released and periodically updated by public bodies and entities, or from the Municipal Urban Plan ordinary elaborations.

It should also be noted that the complexity of the analysis is almost between those of the two cases previously analyzed. In fact, the Municipality of Fisciano has 32 census tracts, the spatial unit chosen for mapping, compared to the 125 into which the Municipality of Pagani is divided and the 15 of Andretta.

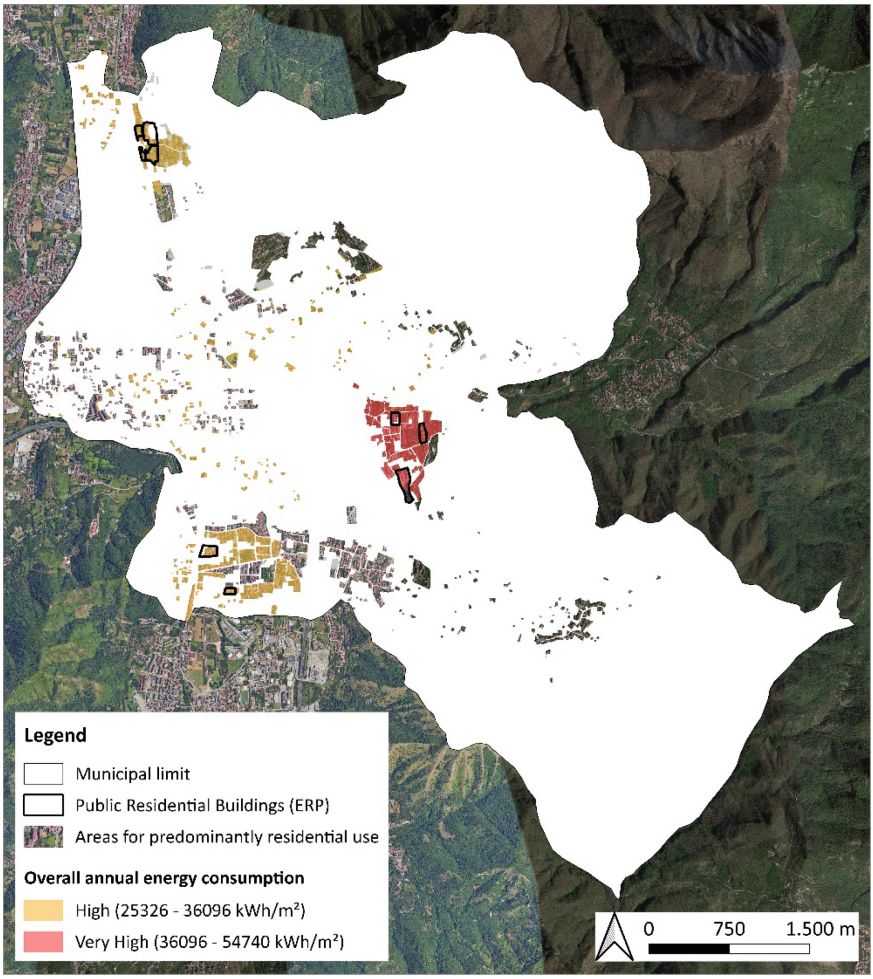

Fig. 5. Energy Poverty Map.

4.2 Constraints Map

The Constraints Map has been constructed considering the unsuitable areas for the localisation of RES plants, as mentioned in Annex 3 of the D.I. of 10 September 2010.

The map shows how the constraints are located mainly in the mountainous areas, home to the Monti Picentini Regional Park and the areas belonging to the Natura 2000 Network. In particular, the Municipality of Fisciano is crossed by the Site of Community Importance "Monte Mai and Monte Monna", and by the Special Protection Area "Picentini", which have a spatial relationship of partial overlap between them.

The areas at risk and hazard from landslides are also significantly extensive, even if only the worst classes have been considered (P3, P4; R3, R4).

In addition, most of the territory has areas affected by quality and/or particularly valuable agricultural-food production, especially in the types of orchards (Fig. 6).

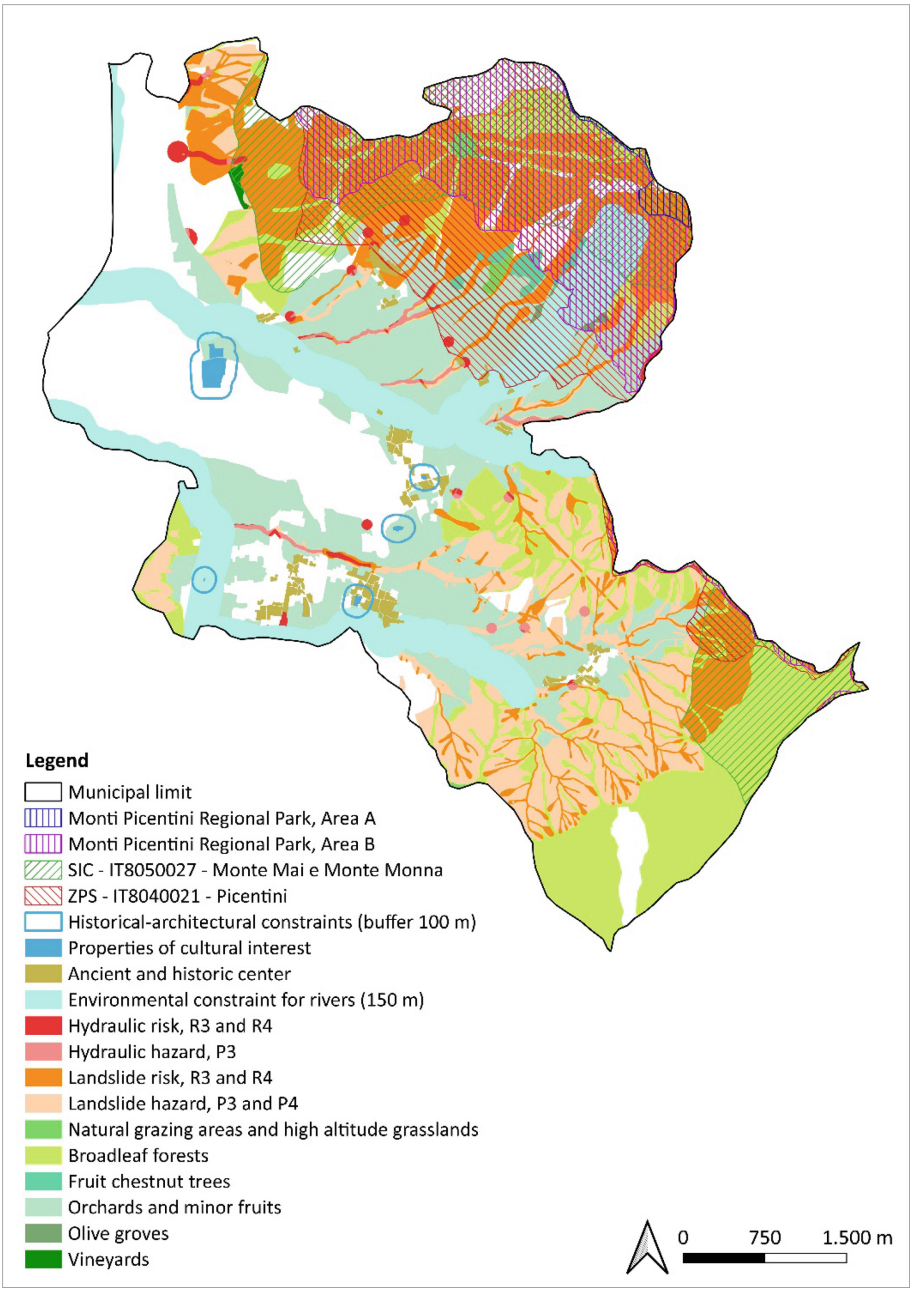

Fig. 6. Constraints Map.

On the contrary, historic centres and sites of cultural and architectural interest, as well as other types of cultivation, occupy a very small surface area, compared to the constraints mentioned above (Fig. 7).

From a constraint point of view, the case of Fisciano is more similar to that of Andretta, therefore to a typical context of the Italian inland areas, rich in natural and environmental resources. The difference is that the constraints are limited to the mountainous portion of the Fisciano territory, affecting the main inhabited centers to a limited extent. Exceptions are the areas at hazard and/or risk from landslides, which extensively involve the Fisciano municipal territory, also affecting numerous urban areas.

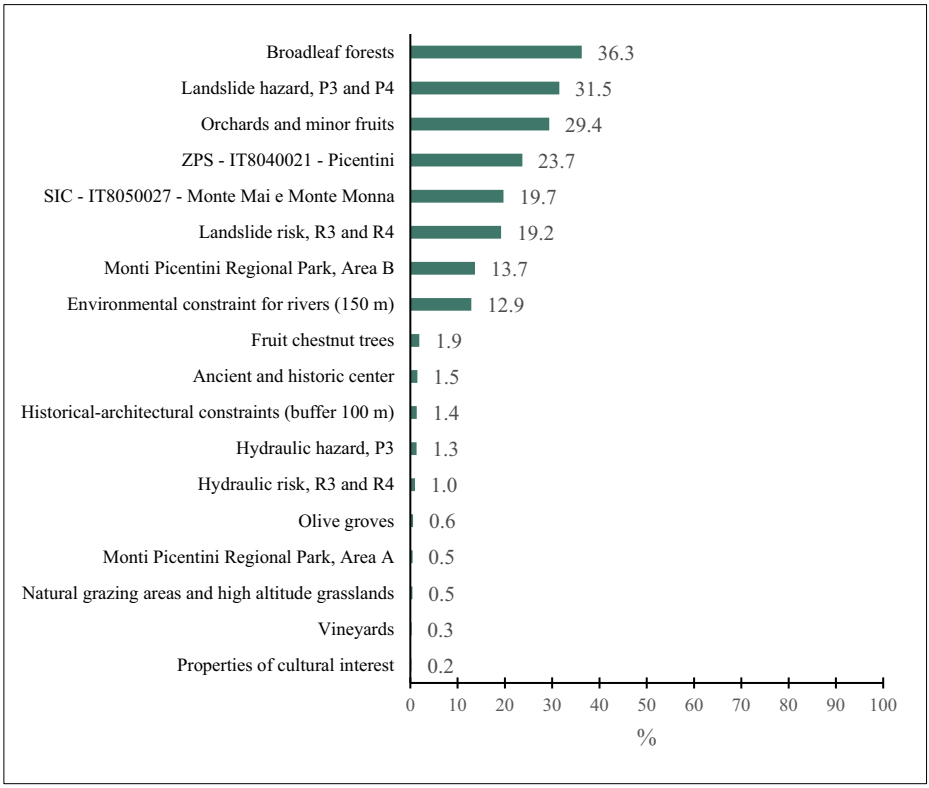

Fig. 7. Percentage of the area occupied by urban and regional constraints, compared to the surface of the entire municipal territory.

4.3 Priority Areas Map

The Priority Areas Map (Fig. 8) shows that the areas with the highest priority correspond to the low-income districts located in the urban centers of the localities of Fisciano, Soccorso and Bolano, included in census sections no. 1, 21 and 10, respectively. These are 7 districts out of a total of 20 ERP districts: 11 of them are located in areas characterized

by modest energy consumption, while only 2 are burdened by constraint conditions. The inhabited centre of Fisciano, which was found to be the one with the highest energy consumption, is instead affected by large portions of the territory excluded from the possibility of locating RES plants.

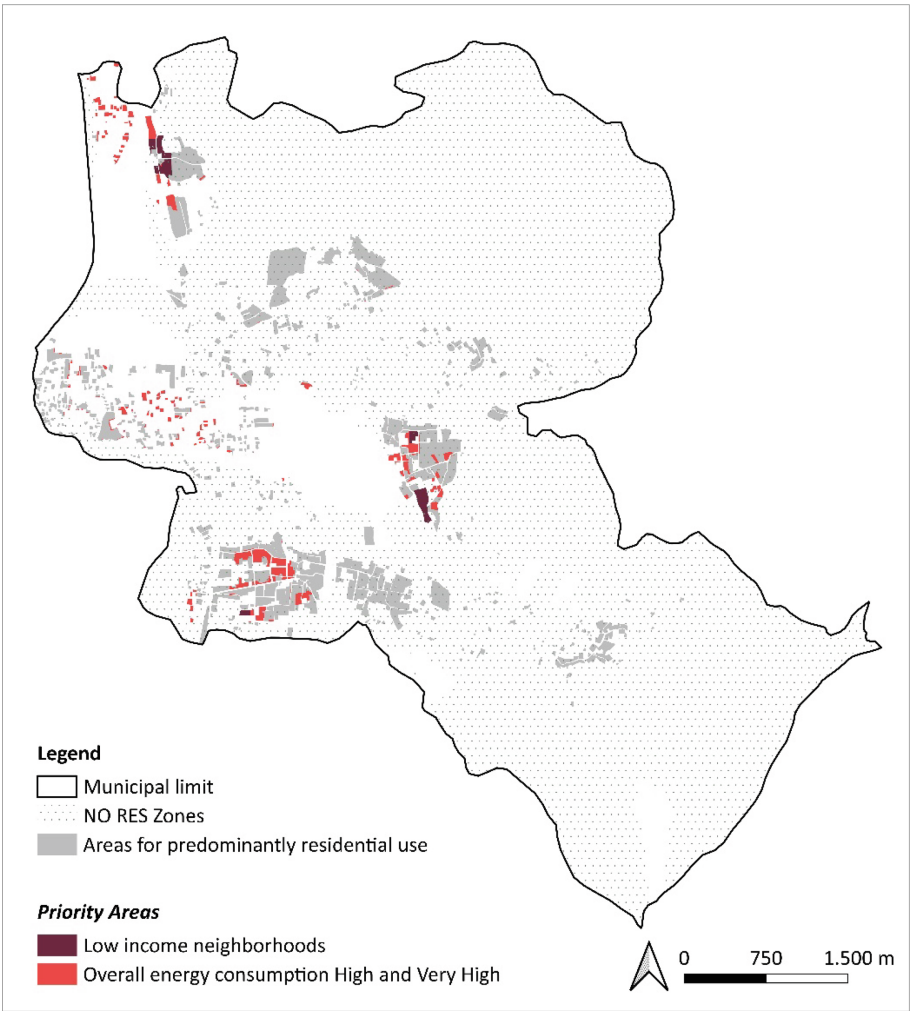

Fig. 8. Priority Areas Map.

In this scenario, it should be reiterated that this aspect does not represent a limit to the diffusion of RECs. In fact, the installations serving the RECs may be located in such a way as to admit to the community also members whose buildings are located in restricted areas.

Nevertheless, in order to receive state economic incentives, it is necessary to respect the spatial constraint that the energy produced is self-consumed within the area of the

"primary" substation (high-voltage substation) of reference, in accordance with the most up-to-date Italian legislation. These are, more precisely, Legislative Decree 8 November 2021 n. 199, which transposed the European Directive "RED II", and Ministerial Decree 7 December 2023 n. 414, in implementation of the transposition decree and state aid provided for by Next Generation Italy [26, 27].

As can be seen from the map of the areas served by the primary substations [28], the municipality of Fisciano falls within a portion of the region in which these areas have an inter-municipal dimension. This characteristic is common to Italian inland areas, even if the number of municipalities included in the areas served by the same high-voltage substation is higher than in intermediate contexts.

Moreover, Fisciano is not included among the "critical" municipalities, i.e. saturated in terms of connection to the existing national grid [29].

However, the main inhabited centre of Fisciano, home to the municipal hall, straddles two different reference areas, shared with the neighboring municipalities, located respectively north-east and south-west of the demarcation border. This particular location reflects its position as a watershed between the populous Irno Valley and the municipalities of Picentini, close to the inland areas of the province of Avellino. Unless in the future the boundaries of the areas served by the primary substations are harmonized with the municipal administrative limits, this circumstance foreshadows a possible locational disadvantage of some districts compared to others, in addition to the social and energy problems considered here: take, for example, the case of a priority urban area for high energy consumption and/or inhabited by vulnerable households, which is both unsuitable for the installation of RES systems and is part of a primary substation falling almost entirely within a municipality other than the one to which it belongs.

These 'proximity' disadvantages should be taken into account when promoting RECs through municipal urban planning instrumentation, for example, by providing specific incentive mechanisms for the areas affected by them, in order to promote a fair energy transition, not a harbinger of further urban inequalities [30]. In this direction, the prior direct involvement of potential communities is desirable, also in innovative forms [31-33] and by activating inter-municipal synergies.

5 Conclusion

This contribution concerns the application to the Municipality of Fisciano (Campania Region, Italy) of a methodology to spatially identify priority areas in which to promote the development of Renewable Energy Communities through the Municipal Urban Plan, already applied to the case studies of Pagani [16] and Andretta [17], inserted in completely different geographical and socio-economic contexts.

The Priority Areas Map carried out integrates the cognitive framework of the aforementioned plan and allows to support the public decision-maker in the definition of incentive mechanisms, which differ according to the different priorities of intervention found. From the results obtained for the case study of Fisciano, it is possible to conclude that the transferability of the above methodology is also possible to intermediate contexts between urban poles and inland areas.

However, the results of the application performed in this work have offered further insights, especially with regard to the need to diversify the incentives and reward mechanisms to be provided for in the plan, in relation to the different territorial contexts in which the planning activity is carried out.

The definition of these rewards is a possible future development of the work [34, 35], in order to assure a just energy transition of urban areas, avoiding the generation of further inequalities and societal issues.

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Authors Contributions. Conceptualization, A.M.; methodology, A.M.; software, A.M. and D.L.; validation, A.M.; formal analysis, A.M. and D.L.; investigation, A.M.; data curation, A.M.; writing—original draft preparation, A.M. (All Sections) and D.L. (Sects. 3, 4); writing—review and editing, A.M.; visualization, A.M. and D.L.; supervision, A.M.; project administration, A.M.; funding acquisition, A.M. All authors have read and agreed to the published version of the manuscript.

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