Renewable Energy Communities Monitoring, Optimization, and Planning. The RECMOP Research Project

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Abstract. The concentration of anthropogenic activities in cities has made them more and more energy-intensive, with an increase in climate-changing emissions and local temperature, seriously threatening the quality of life and, more generally, urban sustainability. Urban planning cannot fail to address these needs, which must be placed among its primary objectives. Renewable Energy Communities (RECs) are a promising tool for tackling these global challenges, as well as energy poverty. However, despite promotion policies at both European and national level, RECs are struggling to spread across Member States, mainly due to the absence of transparent and accessible data on the benefits provided, the territorializability of projects and the absence of incentives at local level. This contribution aims to describe an ongoing research project, titled "Renewable Energy Communities Monitoring, Optimization and Planning (RECMOP)", intended to design a monitoring network to address the above-mentioned open questions. It is aimed at optimizing the space-time configurations of RECs, in order to maximize its social, environmental and economic benefits. The same network will support urban planning through the construction of cognitive frameworks that provide transparent and accessible information, to citizens and stakeholders, of the relevant parameters for the optimization of existing and future RECs. The monitoring network is based on a WEB platform and GeoAI technology, integrated with data from satellites, in situ and shared by citizens and stakeholders.

Keyword: Renewable Energy Communities · GeoAI · Urban Planning

1 Introduction

Numerous international agendas call for urgent action to contain global temperature, reduce dependence on fossil fuels and promote renewable energy [1, 2]. In this framework, cities, which have doubled globally from 1975 to 2020, are increasingly energy-intensive, with a demand for energy from homes equal to 22% of the total needs for the building sector, second only to that of transport. In Italy, half of residential buildings are

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energy inefficient and, energy poverty, given by a combination of high energy expenditure, poor energy performance of homes and low income [3], is on average double that of Europe [4, 5]. The latter, amounting to about 31 million people in 2019, is set to increase due to the pandemic and the Russia-Ukraine conflict [6, 7].

Faced with these challenges, EU countries are obliged by 2030 to reduce emissions by 55% compared to 1990 levels, and to achieve carbon neutrality by 2050 [8]. In this scenario, urban planning becomes essential to increase sustainability and address climate-changing emissions and local temperature in urban areas [9, 10]. Therefore, it cannot fail to take into account these needs, to be placed among its primary objectives.

As a promising tool to combat these global challenges, Renewable Energy Communities (RECs) emerge. Intended as coalitions of citizens, SMEs and local authorities, capable of producing, consuming and sharing locally produced energy from renewable sources, RECs have the main aim of providing environmental, economic and social benefits to the community itself or to the areas in which it operates [11].

In support of this solution, experiments in the USA and Europe show the advantages of RECs obtained in specific areas, including the energy efficiency of existing buildings, the impact of the use of renewable energy, the consequent reduction of emissions and the fight against energy poverty [12–17].

The link with the areas in which they operate differentiates RECs from other configurations of collective self-consumption, making RECs an important tool for achieving the above-mentioned urban planning objectives.

Directive EU/2001/2018 (RED II), part of the Clean Energy for all Europeans regulatory package, obliges Member States to promote RECs, assessing their barriers and development potential in their territories, as well as facilitating them with an appropriate support framework [11].

In Italy, RECs were introduced by Decree-Law No. 162 of 30 December 2019, subsequently updated by Legislative Decree No. 199 of 8 November 2021, which implemented the aforementioned Directive. Italian RECs must comply with specific constraints to obtain economic incentives, such as connection to the same primary substation, i.e. medium-high voltage, and renewable plants with a power not exceeding 1 MW each. Some Italian Regions have anticipated European legislation, financing RECs establishment, often in the most disadvantaged areas. In addition, the National Recovery and Resilience Plan reserves additional incentives for RECs in municipalities with a population of less than 5000 inhabitants, to counter demographic decline [18]. In order to simplify the verification process about the eligibility for incentives and the feasibility in terms of energy capacity of REC projects, the National Energy Service Operator (GSE) has released the map of the areas served by the primary substations [19] and the map of the critical areas in terms of grid saturation [20].

In addition, several applications useful for the optimal RECs design are developed internationally, e.g. Procsimulator [21] and LoadProfileGenerator [22].

Examples of Italian design support platforms are the following: a simulator by GSE [23]; the RECON, DHOMUS, and CruISE applications by ENEA [24–26]; the e-360 platform by Sistematica company [27].

2 Barriers to the RECs Deployment in Europe and Italy

Despite the RECs promotion in the framework of the European Green Deal and Repower EU initiatives, their uptake in the Member States is limited.

As shown by a recent EU report on this issue, among the main obstacles are the following: the difficulty of involving potential community members; the lack of expertise to localize REC projects; urban planning obstacles, in terms of constraints, intended use and previous building rights, in the authorization process of projects; the absence of incentives at local level [28].

Notwithstanding these aspects, a review of the international literature has shown that energy/technological and cost-effectiveness aspects prevail in the search for optimal RECs spatial configurations, while those related to urban planning, as well as the phenomenon of energy poverty, have received little attention [29, 30].

This picture does not differ much from the Italian one, in which, despite the efforts made by both the national government and the Regions, there are still few RECs fully implemented [31], which are disconnected from planning processes. Furthermore, from the analysis of the municipal urban planning instruments of the 109 Italian provincial capitals, the concept of REC is included in only seven cases, highlighting an obsolescence of the plans examined with respect to this issue, particularly in the South [32–35].

These trends are also reflected in the currently available applications, which facilitate the optimal RECs design from an energy/technological and economic point of view, but do not support the pre-project or planning phase.

Exceptions are the maps of primary substations and existing grid capacity [19, 20]. However, the maps are drawn up at an inadequate level of spatial detail to address these issues at the local level.

Therefore, general urban planning is considered a probable obstacle if not properly updated on the subject [36–38].

On the contrary, it can play a relevant role in overcoming these barriers, especially if integrated with local energy planning, contrary to what happens historically [39, 40].

In particular, the general plan should be integrated with the Sustainable Energy and Climate Action Plan (SECAP), which pursues common objectives, such as the reduction of climate-changing emissions and the fight against energy poverty to ensure a sustainable and fair transition, providing for the citizens active participation in decision-making processes.

This path can also be followed by considering the role of Local Authorities both as potential members of RECs and as institutions that can lead the process of activating RECs, facilitating the involvement of citizens, even in the planning process of their competence [41, 42].

3 Open Questions and Scope of the Work

From the analysis conducted on the state of the art, some open questions emerge from a scientific point of view (OQ):

OQ1) in the experiments carried out there is often the difficulty of involving citizens as potential RECs members, due to their lack of information and/or perception about

the potential benefits brought by the RECs themselves - a problem that is not secondary since the ERC activation process is based on their open and voluntary participation;

OQ2) in the search for optimal spatial configurations of RECs there is a prevalent attention to energy/technological aspects and economic convenience, while aspects related to urban sustainability have received little attention, as well as the phenomenon of energy poverty, with the risk of a non-territorializability of projects, or of a limited RECs performance;

OQ3) RECs are disconnected from urban planning processes, making planning itself a possible obstacle to their development, as well as determining the lack of incentives at the local level.

As a result, it emerges that, despite promotion policies at both European and national level, RECs are struggling to take off in the Member States, mainly due to the absence of transparent and accessible data on the benefits brought by the territorializability of projects and the absence of incentives at the local level [28].

These trends are reflected in the currently available applications and maps, which do not support the pre-design phase, which is useful for the projects territorialization, planning and the involvement of potential REC members. This limitation represents the main technological gap found that can become a significant business opportunity.

This contribution aims to describe an ongoing research and development project, titled "Renewable Energy Communities Monitoring, Optimization and Planning (RECMOP)", intended to design a monitoring network to address the above-mentioned open questions from a scientific and technological point of view, in order to promote the rapid deployment of RECs, in line with European and national policies.

The scientific approach, with reference to OQ1, is to monitor existing RECs to measure their social, economic and environmental benefits, to increase the awareness of potential members about these benefits, through appropriate participatory processes, as well as to evaluate the impacts of RECs promotion policies in terms of achieving the expected results.

With reference to OQ2, it is necessary to optimize the RECs configurations from a spatial point of view, but also temporarily, both by minimizing the obstacles, also with reference to urban and territorial constraints, and by maximizing the benefits, not only in terms of technological or economic performance, but also with reference to the objectives of adaptation to climate change and reduction of energy poverty in urban areas.

With reference to OQ3, it is necessary to strengthen the role of Local Authorities and urban planning to promote RECs, aiming to overcome the historically difficult integration between energy planning and city planning (Fig. 1).

Overall, the main objective of RECMOP is to develop a RECs monitoring network, aimed at optimizing their spatio-temporal configurations, in order to maximize their performance, understood in terms of social, environmental and economic benefits. The same network will support urban planning through the construction of cognitive frameworks that provide transparent and accessible information, to citizens and stakeholders, of the relevant parameters for the optimization of existing and future RECs.

Based on a cyclical process of Monitoring-Optimization-Planning, the network represents a new technological solution, not present on the market, to effectively promote

RECs as tools for achieving the ambitious European decarbonization goals, as well as combating energy poverty.

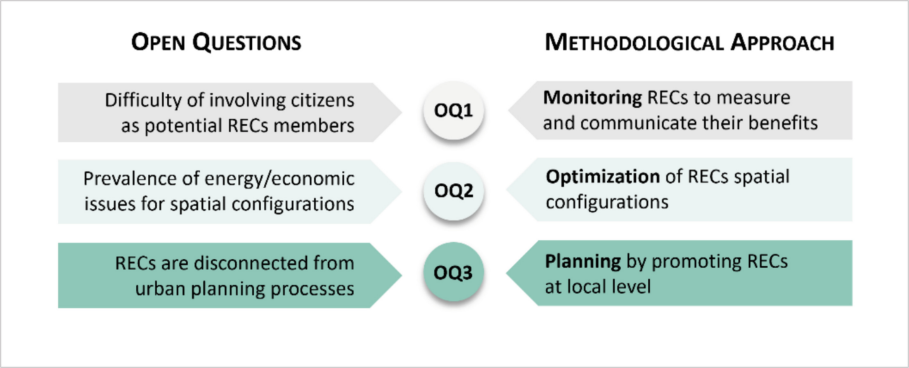

Fig. 1. The scientific approach behind the RECMOP project.

4 The Structure of the RECMOP Project

The monitoring network is based on a WEB platform and GeoAI technology integrated with data from satellites, in situ and shared by citizens / stakeholders, thanks to the partnership with the companies Latitudo 40 and Nexsoft. More precisely, the monitoring network will allow the drafting and consultation of cognitive frameworks, supplementary to those already available at national level [19, 20], which may concern the following parameters, by way of example:

- the spatial perimeter of existing RES plants;
- the suitable sites for the location of new RES plants or, in other words, the urban and territorial constraints on the location of new RES plants;
- the RES local potential, in terms of the most suitable renewable energy sources;
- the most energy-intensive buildings, with particular reference to predominantly residential urban areas;
- urban areas inhabited by low-income households;
- the areas of greatest energy poverty;
- any building and urban planning incentives differentiated by areas;
- any projects approved or under construction that may have shared objectives;
- the barriers faced by citizens who are REC members or who have failed to become members.
- The data necessary to build this knowledge will be taken from:
- official datasets periodically updated by public bodies and entities (e.g. Italian Institute of Statistics, Italian Institute for Environmental Protection and Research, Regional Agencies for Environmental Protection, Regions, Provinces);
- data ordinarily available in municipal urban planning processes;
- data derived from satellite images.

The overall structure of the project is divided into Work Packages (WP), within which specific Activities are envisaged, useful for the implementation and validation of the proposed methodology, which consists of the workflow described in subsequent sentences.

WP1 concerns the recognition of sources, the collection and analysis of the data necessary to build the cognitive frameworks.

Starting from these data, it will be possible, through appropriate processing already consolidated in the experience of the partnership, to build further data, through analysis and simulation algorithms, such as spatial analysis in a GIS environment and Machine Learning, in particular the use of innovative analysis solutions applied to satellite images (Sentinel 2 super-resolution at 1mt, models for the analysis of environmental phenomena and for the identification of solar panels), will allow the creation of an expert system to support the identification of the most suitable areas for the RECs establishment and to monitor their environmental benefits (WP3).

The aforementioned data will also be supplemented with data directly provided by citizens. The latter will be acquired through appropriate information and awareness of the population, involved through the same network and with the help of an integration of participation techniques, during the entire period of the project implementation, also in synergy with municipal authorities, professional associations and stakeholders (WP5).

The network will be designed and developed in its architecture (WP2) and functionality (WP3).

The network will be tested in a selected case study (WP4), but will be designed to be transferable to other geographical contexts (Fig. 2).

The cognitive frameworks built within the RECMOP project are intended to be useful to support:

- with reference to OQ1, participatory processes for the information and awareness of citizens, individually or in association, SMEs and institutions, as current or potential members of RECs, or even leaders who can lead the process of activating RECs, with particular reference to Local Authorities;
- with reference to OQ2, professionals and companies engaged in the ecological and energy transition in the pre-feasibility studies of REC projects, minimizing the risk of non-territorializability of the projects;
- with reference to OQ3, the choices of political decision-makers in the promotion of RECs in municipal, general and sectoral urban planning tools, also through incentive mechanisms, reducing the risk that urban planning that is not up-to-date on the subject or not integrated could be among the obstacles to the spread of RECs.

Examples of such incentives for private initiative in support of public action are the following: volume or surface increases; discount on urbanization charges; local tax advantages; green credits [43–45]. So, municipal authorities will be able to respond, at local level, to the European Commission obligation to identify the obstacles and development potential in their territories, promoting RECs dissemination through the provision of transparent and accessible knowledge frameworks, as well as through an appropriate support framework and incentives, to be made explicit in urban planning instruments. Finally, the updating of the knowledge framework (ex post) is a way to monitor the impacts of RECs on the territory with respect to the individual issues in

which this knowledge is articulated (ex ante), allowing the outcome of the political and technical choices made to be assessed, with particular reference to the achievement of the expected social, economic and environmental benefits, to be taken into account in the updating of plans and projects.

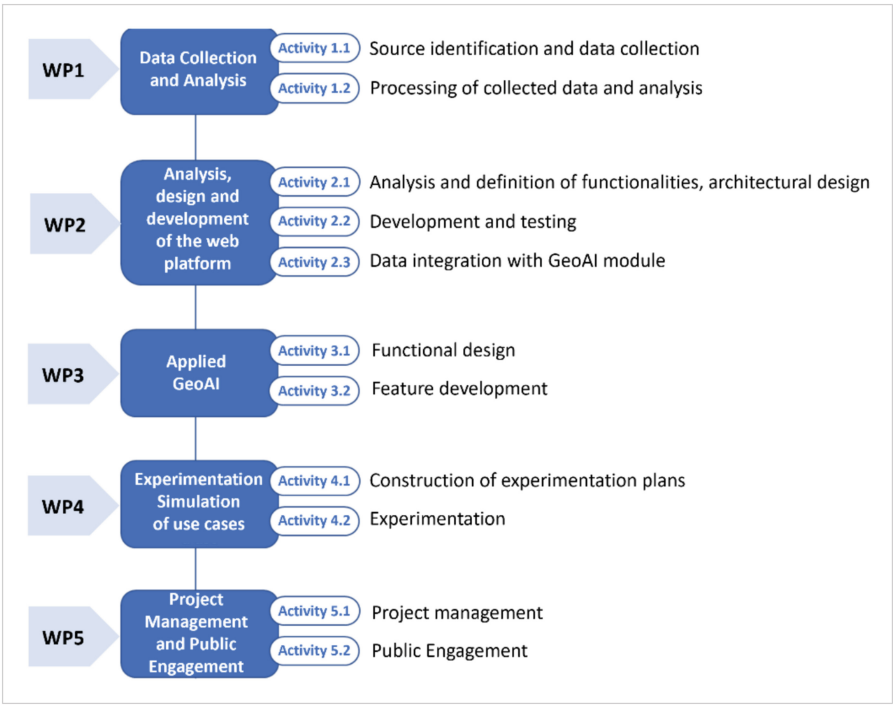

Fig. 2. The proposed workflow according to the WPs and related Activities.

5 Conclusion

The concentration of anthropogenic activities in cities has made them more and more energy-intensive, with an increase in climate-changing emissions and local temperature, seriously threatening the quality of life and, more generally, urban sustainability. In addition, the escalation of poverty, due to the recent pandemic, and the rise in energy prices are significantly increasing the risk of experiencing energy poverty, which was already a concern in Europe before the spread of Covid-19.

Renewable Energy Communities are a promising tool for tackling these global challenges.

Despite promotion policies at both European and national level, RECs are struggling to spread across Member States, mainly due to the absence of transparent and accessible data on the benefits provided, the territorializability of projects and the absence of incentives at local level, often due to urban plans not updated on the topic. This contribution

aims to present an ongoing research and development project, titled "Renewable Energy Communities Monitoring, Optimization and Planning (RECMOP)", intended to design a monitoring network to address the above-mentioned open questions. The monitoring network is based on a WEB platform and GeoAI technology integrated with data from satellites, in situ and shared by citizens.

The main expected results concern the repercussions of the knowledge framework produced, which will be made accessible through the platform, promoting:

- information, awareness and involvement of citizens, SMEs, institutions and stakeholders, all potential members of a REC;
- professionals and companies in the energy transition sector in pre-feasibility studies, reducing the risk of projects not suited to the territory;
- policy makers in the integration and promotion of CERs in urban planning, also through incentives and reward measures aimed at encouraging private initiative in support of public action.

The ultimate goal of RECMOP research and development project is to promote the rapid development of RECs, as tools to achieve climate neutrality and combat energy poverty in urban areas, in line with European and Italian decarbonization policies.

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