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EnerCmed Project: A Hybrid Paradigm Combining Energy Communities and Nature-Based Solutions to Enhance the Sustainability of Mediterranean Cities

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Abstract: Mediterranean cities are increasingly affected by climate change, energy inequality and environmental pollution. Rising temperatures, the effects of the urban heat island (UHI) and growing energy demand exacerbate socio-economic inequalities and energy poverty. To address these challenges, integrated strategies are needed, that combine effective energy system management with robust urban planning adapted to local climatic conditions. This manuscript aims to present the pilot actions implemented in the EnerCmed Project, an EU-funded project that aims to promote the sustainability in port cities by taking action in urban areas near the port, with the aim of enhancing and supporting their development. The project adopt a combined approach in which a renewable energy community (REC) or a self-consumption scheme (SCS) will be implemented through the installation of renewable energy production using Photovoltaic plant (PV) systems, to collectively generate, manage and share the energy produced from renewable sources. The key paradigm of the project consists in the development of the REC/SCS coupled with a nature-based solution (NBS) tailored to the area concerned, that increase the social acceptability and reduce UHI. This approach is oriented towards the reduction of dependence on fossil fuels, acting as a catalyst for a society in which energy autonomy and socio-economic well-being become central, thanks to actions that mitigate energy poverty and support social inclusion. This manuscript highlights the preliminary results of the EnerCmed project, demonstrating how the simultaneous implementation of REC/SCS and NBS contributes to improving energy efficiency, climate adaptation, economic and social inclusion in line with the objectives of the EU Green Deal.

Keywords: Energy transition; Energy poverty; Climate resilience; Renewable energy communities; Nature-based solution; EnerCmed project

1 Introduction

Mediterranean port cities are increasingly exposed to combined social and environmental pressures, particularly in peripheral, socially marginalised urban neighbourhoods [1]. These areas often combine aging buildings, energy poverty and limited access to green spaces, resulting in greater vulnerability to heat events due to the urban heat island (UHI) effect [2]. Although climate change adaptation and energy transition policies are receiving increasing attention in Europe, they are still unevenly implemented in disadvantaged contexts [3].

In this perspective, the EnerCmed project addresses these challenges by exploring an integrated approach combining renewable energy communities (RECs) [4] and self-consumption schemes (SCSs) [5] with nature-based solution (NBS) [6] to support sustainability and climate resilience in vulnerable urban areas. Despite the fact that Renewable Energy Communities and NBS are addressed in the literature as separate domains, they actually have important synergies in addressing climate mitigation. For instance, implementing both REC/SCS and NBS can reduce carbon emissions by utilizing renewable energies as energy source and the implementation of green islands with the inclusion of consistent vegetation. In fact, Razzaghi Asl [7] highlighted in the manuscript various possibilities to implement energy transition systems through NBS, such as the implementation of Photovoltaic plant (PV) and green roof, solar gardens or the implementation of PV in urban gardens. Finally, NBS can be considered as facilitators of the transition to urban sustainability, increasing social acceptance due to visible benefits (thermal comfort, health), co-benefits (aesthetic) [8, 9], and clean air and low carbon [10].

Renewable Energy Communities may face barriers too: in literature, were identified three main categories that represents possible barriers in REC implementation: regulatory barriers in terms of the REC legal model and PV plant dimensioning, technical barriers in terms of area restrictions and bearing load capacity of the building, and financial barriers [11, 12]. In this context, EnerCmed project analyses these barriers and develops context-specific solutions that explicitly take them into account, with the ambitious target of proposing a transnational model that combines decentralized governance of renewable energies with NBS designed to achieve the reduction of CO_2 emissions and a more sustainable energy production through the use of renewable sources. This, in turn, led to an improvement of the living conditions in disadvantaged areas in the Mediterranean port hinterland, often populated by economically vulnerable families. The project goals are aligned with the European Commission's priorities: the Green Deal initiative and the "just transition, no one left behind" principle [13].

The European Union supports the project through the Interreg-EuroMED funding program "Promoting green living areas". This mission, particularly, promotes projects that bring green development in local communities, promoting energy-positive and climate-resilient neighbourhoods.

The project partnership includes universities, companies, energy agencies and local authorities: nine partners from Italy, Spain, Croatia, Greece and Cyprus. Notably, in EnerCmed Project, local authorities and public entities are involved in implementing effective pilot actions, by installing renewable energy systems (PV panels) on public buildings. This manuscript aims to detail the project framework, along with the objectives and the expected outputs. Technical REC/SCS implementation and activation and NBS implementation will be detailed for each pilot, supported by a deep and rigorous analysis of the national policies.

2 Project Framework and Approach

The project approach involves the implementation of REC/SCS coupled with NBS to support vulnerable areas identified by Project partners. This paradigm is implemented through five pilot actions and one metareplicator action. The main components of the interventions are:

• Adoption of RECs and/or SCSs: Decentralized systems that enable local generation and consumption of renewable energy, empowering communities to actively manage energy flows and reduce dependence on conventional centralized suppliers [14].

• Implementation of NBS: Interventions such as green roofs and walls or urban gardens, and other green infrastructures increase urban vegetation and act to reduce external temperatures and the cooling energy demand. In addition, these interventions aim to improve air quality by reducing pollution and enhancing urban liveability [15, 16].

Before the actions implementation, a deep analysis of the stakeholders and residents involved, the national/regional policies and the financial modelling must be performed. Then, the technical evaluations take place, performing analyses on the PV plant location and potential, along with the NBS implementation.

The project structure takes into account four main aspects, illustrated in Figure 1, which are addressed and explored in depth through the development of two important tools: a Knowledge Sharing Platform and the Terms of Reference (ToR). The four key aspects addressed by the project are, in particular:

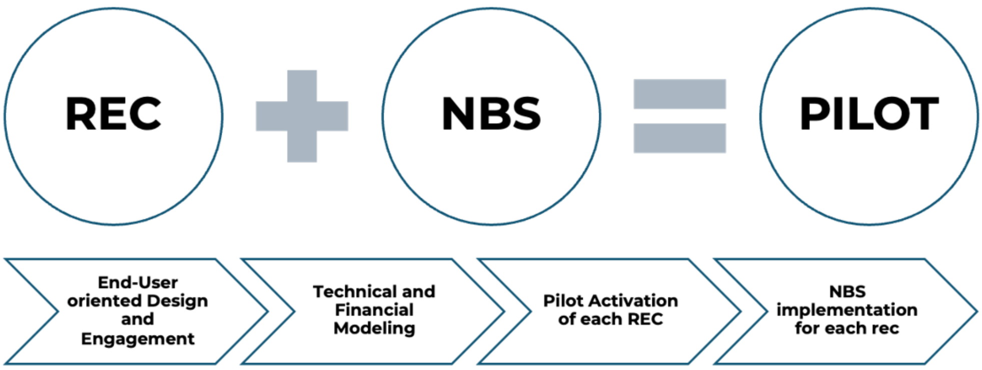

Figure 1. Scheme representing the main aspects of the project implementation

• End-user-oriented design and engagement: co-creation processes of the REC/SCS and NBS with residents, local authorities, and stakeholders, to ensure social awareness, engagement and acceptance of the hybrid intervention.

• Technical and Financial Modelling: Each pilot are defined business models, contract structures and technical specifications, tailored to the specific reality in which will be implemented, as a function of national/regional policies and available incentives/funding/grants.

• Activation of RECs/SCSs: The scheme to use and share energy becomes operational in the five pilot cities after the installation of new renewable energy power plants, to achieve a total estimated annual production of 278 MWh and a consequent reduction of approximately 160 tons of CO_2.

• NBS implementation: A NBS solution is integrated in each pilot city. This intervention aims to provide environmental and social benefits, such as contributing to UHI mitigation, optimizing building energy performance and gaining social acceptance by providing comfort to the involved population.

2.1 EnerCmed Project Pilots

Each pilot action developed within the EnerCmed Project emerged as a direct response to specific local challenges, whether environmental, social, or economic. Pilot sites are located within the port hinterland of Mediterranean cities, as shown in Figure 2. This transnational initiative presents a comprehensive overview of various governance models, technical approaches, and community mobilization strategies applicable to the region.

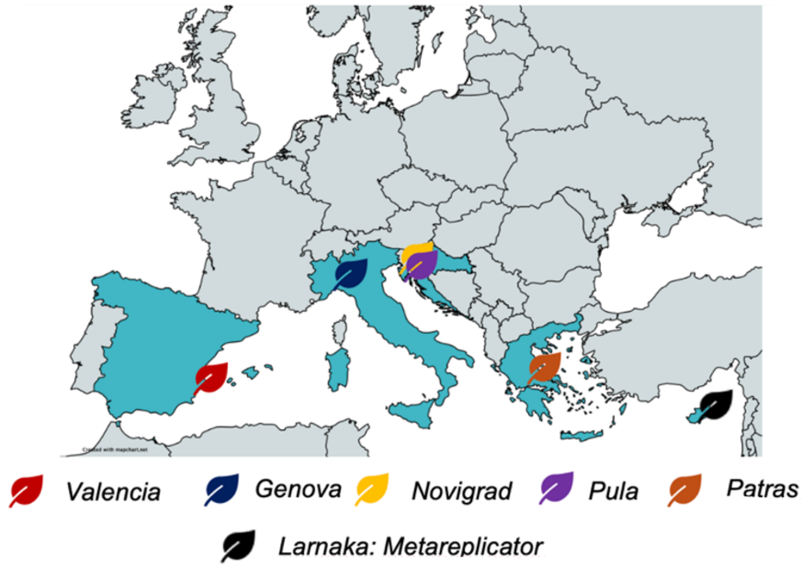

Figure 2. Map of the pilot actions and metareplicator

Genoa (Italy). The Cornigliano district was selected for the intervention because of its proximity to a densely populated area, historically associated with a heavy industry presence and its greater exposure to energy poverty. Given regulatory constraints on implementing RECs at the national level, this pilot action adopts a SCS model. The adopted approach focuses on the use of municipal buildings (schools) connected to the same primary substation (mandatory requirement, as will be explained below in the policy section). In the selected public schools, rooftop photovoltaic systems will be installed, combined with nature-based intervention, aimed to transform the terrace into a small green garden that will serve not only to mitigate the effect of solar radiation in hot seasons, but also to serve as an educational space for students in the school district. Although the regulatory landscape has posed challenges, the initiative has benefited from strong municipal leadership and access to existing energy audits. In the study by Bocanegra et al. [14], the numerical analysis of energy consumption and production data implemented to study the performance of the REC located in Genoa.

Valencia (Spain). The two RECs operate in two neighbourhoods (Nazaret and La Malva-Rosa) known for their high energy vulnerability and a difficult socio-economic situation, given the presence of many families with very low incomes. In this case, public buildings such as CEIP Ausiàs March and CEIP Ballester Fandos schools became the focal points for the interventions. These sites were selected for their social significance and technical feasibility, including suitable roofs and proximity to low-voltage power grids. The photovoltaic systems are combined with shading surfaces and cool roof initiatives. The social component, with significant citizen involvement through numerous local entities, made it possible to convey the project's message properly and effectively.

Patras (Greece). The pilot will be implemented in a school complex near the Dassilio Municipal Forest. Supported by Greek law promoting the implementation of RECs, a cooperative model was developed with residents, municipal staff and Non-Governmental Organization (NGOs). The technical analysis identified roofs with strong solar exposure and access to the existing grid. The REC acts as both an energy producer and reinvestment tool, supporting local repairs and heat mitigation activities in a heat-prone area with limited natural ventilation.

Pula (Croatia). The Monte Zaro neighbourhood was selected due to its high population density and the strong impact of UHI in the area. Additionally, the large concentration of vulnerable groups and the proximity to key public infrastructure played a crucial role in the site selection. Solar panels have been installed on the Children's Creative Center, which has already undergone a series of renovations aimed at improving its energy efficiency. The intervention creates vertical greenery around an existing bus shelter using planters and climbing plants to improve microclimate benefits and thermal comfort to the users. Tree planting campaigns in the vicinity and awareness-raising initiatives have been linked to the development of the REC. A network of users, including families and cultural centres, is being gradually integrated.

Novigrad (Croatia). The REC focuses on the Bikokere neighbourhood, with the main intervention involving the Home for the Elderly, a public building that serves low-income residents and seniors. Its sloped roof provides a suitable space for the installation of photovoltaic systems, while nearby public lots have been identified for potential solar canopies. This pilot project combines rooftop generation with green areas. The initiative directly addresses the rising energy costs in elderly care facilities.

Larnaca (Cyprus). The city of Larnaca is the first meta-replicator, serving as a test case to validate the proposed framework for implementing hybrid solutions before being applied to the large-scale amplification strategy. In the study by Bocanegra et al. [17], the impact of green roofs on energy consumption in Mediterranean climates, such as that of Larnaca, was analysed. The research demonstrated that energy vulnerability can be mitigated and urban sustainability enhanced through the use of passive design strategies like green roofs. Furthermore, Alexandrou et al. [18] focused on pedestrian-level radiative exposure in Cyprus. It emphasized that buildings, urban form, and the reflective properties of materials influence the extent to which incoming solar radiation is retained near ground level. The authors highlighted that reducing canyon depth or incorporating NBS can contribute to the mitigation of the UHI effect and promote improved thermal comfort.

In each case, the RECs/SCSs setup was shaped through co-design processes, stakeholder workshops, and cross-analysis of climate, regulatory, and socio-economic data.

3 Project Implementation and Results

3.1 EU and National Policy Framework

One of the main contributions of this research was the development of country-specific Policy Briefs that were aimed at curbing the regulatory differences due to the different ways the Renewable Energy Directive RED II was transposed across the Mediterranean basin and particularly for pilots in Spain, Croatia, Italy and Greece. Table 1 highlights the main differences in the national policy background and main available incentives for the implementation of the practicability of renewable energy communities in the nations involved.

Comparative analysis of the legislative regimes in Italy, Croatia, Greece and Spain shows that, even though the overall goals of the European Union are broadly similar, the channels by which the national governments address such goals are quite different, thus creating specific barriers to the pilot projects.

In Italy, the shift to the more detailed structural framework (DL 199/2021) alike to the experimental stipulation (D.Lgs 162/19) has expanded the perimeter of aggregation to include the primary substation, and, has raised the power limit to 1 MW. However, in small municipalities (with populations less than 5,000), as pointed out in the Policy Brief, the tariff incentive becomes not the decisive enabler but a non-repayable capital contribution, possibly in the form of PNRR measures, which can amount to 40% or even more.

The suggestion to the Genoa pilot, therefore, is to take advantage of the "Primary Substation" requirement to combine users above the single building scale, therefore, breaking the physical barriers of the tight historic center.

In particular, Tatti et al. [19] analysed the regulatory framework for REC development in Italy, highlighting that the majority of the RECs established in Italy are led by a local authority or no-profit organization. In the study by Zatti et al. [20], a further analysis of the REC framework in Italy was carried out, focusing on the design and operation of energy assets. Meanwhile, Pellegrino and Coletta [21] conducted an in-depth analysis of REC schemes arising from the Italian implementation of European regulations, examining how the RED II and IEM directives impact the electric distribution systems within Italian RECs.

The Greek regulatory framework (Law 5037/2023), on the other hand, is more segmented, dividing between RECs and Citizen Energy Communities (CECs). This analysis has found that the most effective tool for the Patras pilot can be Virtual Net Metering because it allows balancing the consumption without the physical connection lines.

However, the compulsory non-profit nature and strict profit-allocation measures, which demand that excesses be reinvested in local social initiatives as opposed to dividend payments are a form of governance that focuses more on social than actual financial payoff on investment. In the study by Sargentis et al. [22], a deep review about the energy policies in Greece in the last years is reported.

Table 1. National policy background

Feature	Spain	Croatia	Italy	Greece
EU Directives Transposed	Partial-full enabling framework still pending	Transposition completed (2023)	Transposition completed (2022)	Transposition completed (2024)
National regulation framework	Royal Decree 23/2020, and 244/2019	Law on the Electricity Market (ZOTE); RES & HE CHP Act (amended)	Legislative Decree 199/2021; Ministerial Decrees; ARERA Resolution 318/2020	Law 4513/2018 and amendments; law 5037/2023
Eligible Members	Individuals, SMEs, municipalities, local authorities, non-profits	Citizens, SMEs, public authorities	Individuals, SMEs, municipalities, local authorities, non-profits	Citizens, SMEs, local authorities
Legal Form Required	Associations or cooperatives	Cooperatives; mandatory formal registration	No single mandatory form; cooperative, association, or company	Cooperative structure required; public entities participate via cooperatives
Max Plant Power Support	100 kW per plant (effective limit for and most support schemes)	50–100 kW (small-scale installations only; no large REC projects currently supported)	1 MW per plant (clear and binding limit for REC incentive eligibility)	1 MW standard; up to 2 MW for municipal or special-purpose EC
Incentives Available	Surplus self-consumption compensation; regional tax incentives (time-limited)	Limited financial incentives; mainly administrative facilitation	Feed-in premium for shared energy; PNRR grants	Virtual net-metering; grants; strong support for municipalities

In the study by Antić et al. [23], the REC regulatory framework and policies at the EU level and the Croatia's perspective are deeply studied. The Croatian policy, which is regulated by the Law on Electricity Market (OG 111/2021) and the Law on Renewable Energy Sources (OG 138/2021), is a two-tier system involving Citizens Energy Communities (EZG) and Renewable Energy Communities (ZOIE). As the main obstacles, the Policy Brief of the pilots in Pula and Novigrad singles out the bureaucratic complexity of registration with HERA, and the technical restrictions (e.g. 30–50 kW dedicated to pilot installations) in particular. Based on this, the recommendation aims to facilitate the authorization processes of the public-private partnerships of municipal utilities.

Lastly, the regulatory environment in Spain is based on Royal Decree 244/2019, which is favorable to collective self-consumption. Despite the fact that the specially designed Spanish pilot-friendly decree on Energy Communities is still in draft form (as of 2023), the Spanish pilots still serve to bypass legal delays through the still-in-place so-called collective SCSs. In Valencia [24], the Valencian Community Government launched the strategy "One Local Energy Community in each of the Valencian Community municipalities for 2030. It this context of different national policies background, the Policy Briefs support the harmonization of licensing processes to claim that the technical feasibility introduced by the pilots can be abolished by the administrative lead times exceeding the time of the projects.

3.2 Social Engagement Strategy

In urban neighbourhoods near Mediterranean ports, vulnerable populations such as low-income families, older residents, migrants, and marginalized groups face significant energy poverty and climate challenges. They often lack access to reliable, affordable energy and have little influence over decisions that affect their lives. In order to ensure reliable identification, awareness, inclusion of the vulnerable population it was developed a social engagement strategy that consists in the following action presented in the Figure 3.

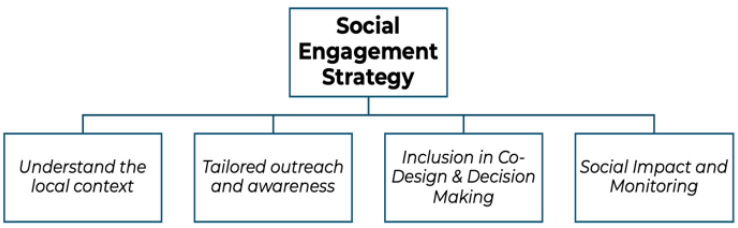

Figure 3. Social engagement strategy

The EnerCmed initiative begins with context-sensitive assessments that map demographic, cultural, and socioeconomic profiles to identify energy-related vulnerabilities. This approach ensures that project strategies are grounded in real lived experiences rather than assumptions.

Engaging vulnerable populations is a key pillar of the project, making it essential to raise awareness and provide knowledge about the energy transition and their vital role within it. Empowering these residents through accessible education is crucial for achieving transformation.

Evidence shows that increasing awareness of energy issues, such as the benefits of renewable energy, individual rights, and efficient usage, can turn passive consumers into active energy citizens. When communities understand their role, they are more likely to engage meaningfully with RECs.

Building on this foundation, the project extends into inclusive decision-making and co design: early involvement through dialogue, consultations, and participatory workshops ensures that energy-sharing schemes and clean energy models reflect community priorities.

Collaborative governance platforms, such as community-led committees or advisory bodies, give residents a sustained voice in strategic decisions, reflecting principles of procedural justice and energy democracy.

EnerCmed employs a clear monitoring and feedback framework focusing on KPIs such as participation, satisfaction, energy burden reduction, and behavioural shifts to ensure and adapt its social engagement strategy continually.

This robust engagement strategy is expected to broaden the energy transition by ensuring that community-led RECs evolve from initial involvement into lasting and ensuring continuity and self-formation of new RECs by empowering vulnerable communities.

3.3 The ToR for RECs/SCSs Creation

The first WP1 consisted of preparing the ToR, a document that provides a comprehensive framework detailing the fundamental stages in the development of RECs or SCSs coupled with the NBSs [7]. It ensures coherence with the overarching project objectives and deliverables, thereby facilitating effective planning, execution, and long-term success.

The ToR aims to conceptualize a transnational Hinterland Renewables Communities Guideline for marginalized neighbourhoods. That is meant to be an innovative multicriteria decision-making protocol that gathers all the key aspects, such as the social engagement, the energy dimension (technical aspects) and the economic/financial/governance dimension enhanced with the principles related to microclimate actions and deliver an efficient energy-positive & climate resilient planning paradigm around the concept of REC through the implementation of 6 NBS.

The project Guideline [25] will provide a common diagnosis and feasibility framework for developing the pilots (WP2) under a unified transnational approach.

It is subdivided into the following sections (see Figure 4), and checklists are provided for each of them to check whether all the necessary information is included in the document.

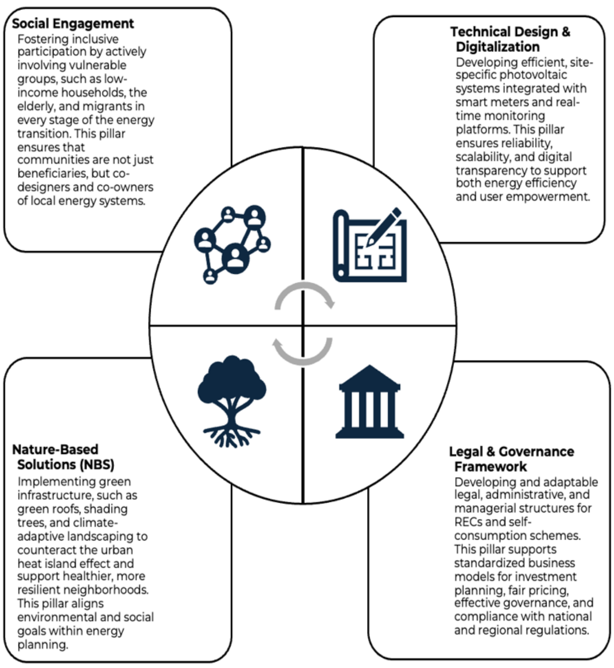

Figure 4. The four pillars of ToR

• ToR for social engagement of vulnerable Populations.

• ToR for energy community technical design & digitalization of the RECs or SCSs.
• ToR to build a legal, administrative and management structure of the RECs or SCSs.
• ToR for the application of NBS to mitigate UHI effects.

These pilot interventions are being developed following the ToR guideline, which is created to standardize the deployment of RECs to the heterogeneous regulatory environment of the Mediterranean. Through this ToR guideline, rather than traditional planning paradigms that treat energy sizing and urban refitting as unrelated entities, a multi-dimensional protocol is employed to align the technical dimensioning with the requirements of climate adaptation.

4 Social Impact and Active Citizen Engagement in Energy Transition Processes

The EnerCmed project adopts a systemic and participatory approach to address the social and economic challenges associated with marginalized urban-port areas, emphasizing social inclusion and the active involvement of local communities [26]. Vulnerable populations have been engaged through collaborative governance tools, including co-design workshops, local open days, public consultations, and multi-stakeholder institutional roundtables. These participatory processes have contributed to the shared definition of pilot sites, the configuration of RECs/SCSs (Figure 5), and the development of NBSs for mitigating climate impact, with a specific focus on energy poverty, demographic vulnerability, and exposure to UHI effects. Recent studies focused on give adequate conceptual knowledge to adaptation strategies and mitigation measures related to climate change even in the school population [27, 28].

The implemented model is based on an inclusive governance structure and, where permitted by national legislation, the collective ownership of energy infrastructures. Its objectives are to democratize access to renewable energy, promote urban climate improvement, and activate mechanisms for the local redistribution of the value generated.

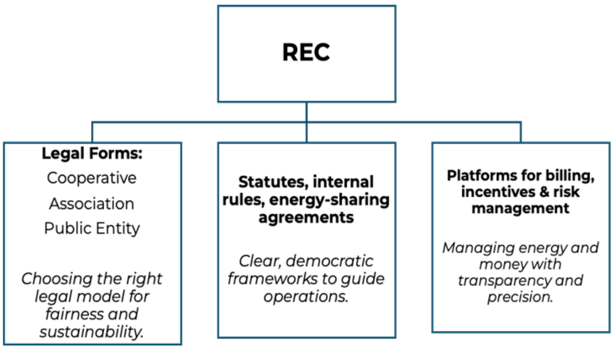

Figure 5. Making RECs work for everyone

This configuration fosters civic empowerment and the development of social capital, enhancing community resilience to energy and economic shocks. The expected social impacts include reducing energy vulnerability, strengthening community autonomy in decision-making, and promoting solidarity-based and sustainable practices in urban areas under experimentation.

The set of NBS is carefully selected and adapted to align with the specific microclimatic conditions of the pilot sites, which often differ significantly from one another [9]. These interventions are designed to mitigate thermal impacts and enhance both environmental and public health conditions. The implemented NBS include small-scale measures such as the strategic placement of trees, vertical green infrastructures, shadowing surfaces, or porous floors [29]. The expected benefits are quantifiable in terms of reduced surface temperatures, improved air quality, and enhanced physical and psychological well-being of residents in the targeted intervention areas [29].

Additionally, a new tool called the Knowledge Facility Instrument (KFI) [30] supports stakeholders and potential new cities in creating these hybrid interventions to support the pilots during implementation stages and disseminate project results, thereby facilitating the green transition in the Mediterranean area.

Finally, each pilot city developed its own communication plan, which was aligned with the project's overall communication strategy. These plans aim to raise public awareness of the project's messages and activities by integrating digital tools, school-based education, and information campaigns. The objective is to enhance public understanding of the opportunities associated with the energy transition, the creation of green jobs, and the broader social contributions of climate action.

5 Conclusions

In this paper, it was illustrated how the EnerCmed project develops RECs and SCSs and NBSs to address environmental issues and social challenges in Mediterranean port hinterlands. By focusing on fragile urban areas in port cities, the project supports these regions, which face challenging climate conditions, energy poverty, and inadequate infrastructure. The lessons learned from the pilot sites across five European cities will help to establish a transnational Action Plan that could be replicated in other EU cities with similar conditions. The Action Plan considers the various technical, legal, and community aspects that affect the implementation of those actions.

Although we require more time to assess the effectiveness of these efforts, early observations during the local pilot implementation reveal some interesting trends, particularly regarding the interaction between local energy management, climate strategies and community involvement. The next phase of the project aims to expand the EnerCmed approach to more urban areas, with plans to involve additional follower cities. The follower cities will adapt and adopt the framework that was tested in the first pilot actions. This replication phase will be supported from the KFI and will include technical guidance, local planning sessions, and opportunities for cities to share experiences.

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Author Contributions

Conceptualization, C.S., J.A.B., and D.B.; methodology, D.B.; investigation, J.R., J.P., and E.P.; resources, C.S. and J.A.B.; data curation, J.P. E.F., and E.P.; writing—original draft preparation, J.R.; writing—review and editing, J.P., D.B., E.P., and E.F.; visualization, J.R.; supervision, C.S., D.B., and J.A.B.; project administration, E.P. and C.S.; funding acquisition, C.S. All authors have read and agreed to the published version of the manuscript.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] B. Nogué-Alguerό, "Growth in the docks: Ports, metabolic flows and socio-environmental impacts," *Sustain. Sci.*, vol. 15, no. 1, pp. 11–30, 2019. https://doi.org/10.1007/s11625-019-00764-y

[2] P. Nastos and H. Saaroni, "Living in Mediterranean cities in the context of climate change: A review," *Int. J. Climatol.*, vol. 44, no. 10, pp. 3169–3190, 2024. https://doi.org/10.1002/joc.8546

[3] D. Streimikiene, V. Lekavičius, T. Baležentis, G. L. Kyriakopoulos, and J. Abrhám, "Climate change mitigation policies targeting households and addressing energy poverty in European Union," *Energies*, vol. 13, no. 13, p. 3389, 2020. https://doi.org/10.3390/en13133389

[4] G. Yiasoumas, L. Berbakov, V. Janev, A. Asmundo, E. Olabarrieta, A. Vinci, G. Baglietto, and G. E. Georghiou, "Key aspects and challenges in the implementation of energy communities," *Energies*, vol. 16, no. 12, p. 4703, 2023. https://doi.org/10.3390/en16124703

[5] Normattiva, "DECRETO LEGISLATIVO 2 febbraio 2021, n. 19," 2021. https://www.normattiva.it/uri-res/N2Ls?urn:nir:stato:decreto.legislativo:2021-11-08;19

[6] A. Panori, N. Komninos, D. Latinopoulos, I. Papadaki, E. Gkitsa, and P. Tarani, "Blending nature with technology: Integrating NBSs with RESs to foster carbon-neutral cities," *Designs*, vol. 9, no. 3, p. 60, 2025. https://doi.org/10.3390/designs9030060

[7] S. Razzaghi Asl, "Re-powering the nature-intensive systems: Insights from linking nature-based solutions and energy transition," *Front. Sustain. Cities*, vol. 4, p. 860914, 2022. https://doi.org/10.3389/frsc.2022.860914

[8] E. Park, "Social acceptance of renewable energy technologies in the post-fukushima era," *Front. Psychol.*, vol. 11, p. 612090, 2021. https://doi.org/10.3389/fpsyg.2020.612090

[9] R. Mendonça, P. Roebeling, T. Fidélis, and M. Saraiva, "Socio-economic models to assess and policy instruments to steer the impact of nature-based solutions: A review," *WIT Trans. Ecol. Environ.*, vol. 1, pp. 551–564, 2021. https://doi.org/10.2495/sc210451

[10] S. Rafael, L. P. Correia, A. Ascenso, B. Augusto, D. Lopes, and A. I. Miranda, "Are green roofs the path to clean air and low carbon cities?" *Sci. Total Environ.*, vol. 798, p. 149313, 2021. https://doi.org/10.1016/j.scitotenv.2021.149313

[11] S. Ahmed, A. Ali, and A. D'Angola, "A review of renewable energy communities: Concepts, scope, progress, challenges, and recommendations," *Sustainability*, vol. 16, no. 5, p. 1749, 2024. https://doi.org/10.3390/su16051749

[12] B. Antonioli Mantegazzini, C. Clastres, and L. Wangen, "Energy communities in Europe: An overview of issues and regulatory and economic solutions," *Econ. Policy Energy Environ.*, vol. 2, pp. 5–23, 2023. https://doi.org/10.3280/efe2022-002001

[13] European Commission, "Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions the European Green Deal," 2019. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52019DC0640

[14] J. A. Bocanegra, E. Pallavidino, and C. Schenone, "Energy balance of a renewable energy community using stochastic methods, a case study in Genoa city," *J. Phys. Conf. Ser.*, vol. 2893, no. 1, p. 012123, 2024. https://doi.org/10.1088/1742-6596/2893/1/012123

[15] J. A. Bocanegra, F. Scarpa, V. Bianco, and L. A. Tagliafico, "Feasibility of green roofs in the mediterranean region: A stochastic study using a Monte-Carlo financial model," *Energy*, vol. 309, p. 132995, 2024. https://doi.org/10.1016/j.energy.2024.132995

[16] P. Mouzourides, A. Kyprianou, M. K.-A. Neophytou, J. Ching, and R. Choudhary, "Linking the urban-scale building energy demands with city breathability and urban form characteristics," *Sustain. Cities Soc.*, vol. 49, p. 101460, 2019. https://doi.org/10.1016/j.scs.2019.101460

[17] J. A. Bocanegra, J. Peshku, C. Schenone, P. Mouzourides, G. Alexandrou, and M. Neophytou, "Performance of green roofs in the mediterranean region: A numerical study based on energy balance," *E3S Web Conf.*, vol. 654, p. 01003, 2025. https://doi.org/10.1051/e3sconf/202565401003

[18] G. Alexandrou, P. Mouzourides, J. A. Bocanegra, J. Peshku, C. Schenone, V. Bianco, and M. Neophytou, "Urban shortwave radiation trapping: An index for pedestrian-level radiative exposure in dense urban areas," *E3S Web Conf.*, vol. 654, p. 04008, 2025. https://doi.org/10.1051/e3sconf/202565404008

[19] A. Tatti, S. Ferroni, M. Ferrando, M. Motta, and F. Causone, "The emerging trends of renewable energy communities' development in Italy," *Sustainability*, vol. 15, no. 8, p. 6792, 2023. https://doi.org/10.3390/su15086792

[20] M. Zatti, M. Moncecchi, M. Gabba, A. Chiesa, F. Bovera, and M. Merlo, "Energy communities design optimization in the Italian framework," *Appl. Sci.*, vol. 11, no. 11, p. 5218, 2021. https://doi.org/10.3390/app11115218

[21] L. Pellegrino and G. Coletta, "The impact of energy communities on the Italian distribution systems," in *2021 IEEE International Conference on Environment and Electrical Engineering and 2021 IEEE Industrial and Commercial Power Systems Europe*, Bari, Italy, 2021, pp. 1–4. https://doi.org/10.1109/eeeic/icpseurope51590.2021.9584514

[22] G. F. Sargentis, R. Ioannidis, N. Mamassis, V. Zoukos, and D. Koutsoyiannis, "A review of the energy policy in Greece in the last 50 years and its implications for prosperity," *Clean Energy Sustain.*, vol. 3, no. 1, p. 10021, 2025. https://doi.org/10.70322/ces.2024.10021

[23] M. G. Antić, T. Capuder, and T. Medved, "Bridging the gap between theory and practice in local energy sharing-energy communities in Croatia," in *2024 IEEE PES Innovative Smart Grid Technologies Europe (ISGT EUROPE)*, Dubrovnik, Croatia, 2024, pp. 1–5. https://doi.org/10.1109/isgteurope62998.2024.10863780

[24] Generalitat Valenciana, "Plan de Fomento de las Comunidades Energéticas Locales en la Comunitat Valenciana," 2020. https://www.coopelectricas.com/wp-content/uploads/2021/05/Plan_CEL_2030-Comunitat_Valenciana.pdf

[25] EnerCmed Project, "What We Achieve," 2025. https://enercmed.interreg-euro-med.eu/what-we-achieve/

[26] K. A. Levin, "Study design III: Cross-sectional studies," *Evid. Based Dent.*, vol. 7, no. 1, pp. 24–25, 2006. https://doi.org/10.1038/sj.ebd.6400375

[27] M. O. R. Maulidian, S. Utaya, D. Taryana, S. Bachri, R. P. Shrestha, H. Hifjir, and C. V. R. Jummi, "Assessing high school students' conceptual knowledge, adaptation, and mitigation of climate change in Aceh, Indonesia," *Int. J. Environ. Impacts*, vol. 8, no. 5, pp. 1064–1078, 2025. https://doi.org/10.56578/ijei080518

[28] Mahsun, Sumarmi, S. Utaya, B. Handoyo, and N. A. Wibowo, "Enhancing environmental awareness: Evaluating the impact of project-based hybrid learning on critical thinking for high school students," *Int. J. Environ. Impacts.*, vol. 8, no. 1, pp. 123–135, 2025. https://doi.org/10.18280/ijei.080113

[29] G. Alexandrou, P. Mouzourides, H. Li, Y. Zhao, J. Carmeliet, and M. K. A. Neophytou, "Impact of trees with varying size on street canyon flow under isothermal and non-isothermal conditions using water channel PIV measurements," *Urban Clim.*, vol. 58, p. 102188, 2024. https://doi.org/10.1016/j.uclim.2024.102188

[30] E. Pallavidino, J. A. Bocanegra, D. Borelli, E. Fracchia, J. Peshku, J. Roberts, and C. Schenone, "The knowledge facility instrument: An innovative expert-driven tool to support energy transition projects," *E3S Web Conf.*, vol. 654, p. 05001, 2025. https://doi.org/10.1051/e3sconf/202565405001