

THE KNOWLEDGE FACILITY INSTRUMENT: AN INNOVATIVE EXPERT-DRIVEN TOOL TO SUPPORT ENERGY TRANSITION PROJECTS

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Abstract. Can structured knowledge management improve the impact of projects on the development of the Renewable Energy Communities (RECs)? The EnerCmed project proposes a new methodological framework through the development of the *Knowledge Facility Instrument (KFI)*, a thematic structure designed to provide scientific support throughout the entire project cycle integrating five key areas: energy planning, governance, social engagement, climate adaptation, and digitalization. This study analyses the first phase of the project in which KFI produced two fundamental tools: a *Terms of Reference (ToR)* for the implementation of RECs and Nature Based Solutions (NBS) at the local level and a *Policy Brief*, providing strategic guidance to overcome key barriers to establishing Renewable Energy Communities (RECs). The study demonstrates how, through the application of knowledge governance from the initial stages of project development up to the end and systemic coordination, territorial replicability can be achieved. This approach promotes coordination among local actors, thematic experts, decision-makers, as well as social engagement contributing to a more effective and inclusive urban energy transition.

1 Introduction

In recent decades, the growing awareness of climate change and the need for energy sustainability has led the European Union (EU) to promote innovative policies aimed at encouraging the use of renewable energy sources [1]. In this context, Renewable Energy Communities (REC) represent a true paradigm shift from the traditional approach [2], emerging as an innovative and vital tool for the production and management of energy at the local level. These communities enable the active involvement of a variety of actors, including

citizens, businesses, local authorities, and associations, promoting not only improvements in energy efficiency and reductions in greenhouse gas emissions but also social cohesion and resilience.

In the context of the European Green Deal and the 'Fit for 55' package [3], the European Union has adopted several directives and regulations to promote the use of renewable energies and the implementation of renewable energy communities (RECs). These directives provide a comprehensive regulatory framework that guides Member States in promoting renewable energies and energy communities. The Clean Energy for All Europeans Legislative Package (CEP) [4], and in particular the Directive EU 2018/2001 (Renewable Energy Directive, or RED II) [5] and Directive (EU) 2019/944 (Electricity Directive, or IMED) [6], introduced several new legal concepts acknowledging specific market actors and activities that reflect the evolving role of consumers in the energy system including Renewable Energy Communities (RECs) and Citizen Energy Communities (CECs).

The national implementation of European directives remains uneven, generating regulatory asymmetries, uncertainties for local actors, and operational difficulties in establishing communities, highlighting the need for shared and replicable tools to develop the growth of renewable energy communities in different local contexts.

The establishment of a Renewable Energy Community (REC) is a multi-phase process that requires a strategic, inclusive, and technically sound approach aligned with European Union directives and national energy transition goals. Besides the legal aspect, the implementation of these communities must consider socio-cultural, economic, technological and political factors.

Recent studies [7] have highlighted how the development of Renewable Energy Communities (RECs) is partly limited by barriers such as regulatory complexity, uncertain economic sustainability, infrastructure gaps, low levels of community participation, and limited access to knowledge and technical support. An integrated, multidisciplinary approaches that bring together legal, technical, social, and environmental expertise from the very beginning is the possible solution to overcoming these challenges.

In the European context, projects on Renewable Energy Communities (RECs) are increasingly numerous and diverse[8]: some focus on technological innovation, others on social participation, governance, the development of technical skills, or sustainable urban planning. Rarely is a fundamental aspect systematically and clearly addressed: how to manage knowledge within the project from the earliest stages. The absence of an organized and shared structure to collect, organize, and transfer knowledge and skills can undermine the quality and replicability of the results.

To mitigate the effects of climate change, actions can be taken, such as the implementation of Self Consumption Schemes coupled with Nature-Based Solutions (NBS) Self-Consumption Schemes [9] play a crucial role in energy transition because enable consumers to produce and use their energy, as for instance in case of photovoltaic panels or mini wind generation use. Other intervention areas can include the Nature-Based Solutions (NBS) [10]. NBS solutions can be of different types as a function of the intervention areas [11], while in urban context innovative roofing systems called green roofs are proposed, aiming to mitigate heat island effects, improve air quality and reduce energy consumption [12]. In response to such complexities, this study explores the concept and operational application of a Knowledge Facility Instrument (KFI), developed within the Interreg EnerCmed project [13], which proposes a thematic and functional framework to facilitate knowledge management and support the integrated development of renewable energy communities (RECs).

This manuscript focuses on the analysis of the first period of the project, delving into the composition and the functioning of the Knowledge Facility Instrument (KFI) understood as

an integrated management of regulatory, technical and social knowledge that has produced guidelines, shared deliverables, and adaptable coordination tools for partner cities.

2 The EnerCmed project: architecture overview

The EnerCmed project introduces an innovative approach to building more sustainable and climate-resilient urban areas, starting with marginalized neighbourhoods in port cities that are often affected by energy poverty [14]. The project integrates traditional REC trilemma (engaging people, ideal business model and governance structure, system engineering/interoperability/digitalization) with energy planning principle at micro-site climate & social dimension (marginalized neighbourhoods) level with the aims to demonstrate that a fair and inclusive energy transition is not only possible, but also scalable and adaptable to different urban contexts across Europe [15].

The project comprises five pilot actions (see *Figure 1*) located in Genoa (Italy), Valencia (Spain), Patras (Greece), Pula (Croatia), and Novigrad (Croatia), where the development of Renewable Energy Communities and Self-Consumption Schemes are combined with Nature-Based Solutions (NBS) intervention, which is strategically implemented as a natural heat sink to alleviate the urban heat island (UHI) effect and reduce residential cooling energy demands.



Figure 1. Pilots in the EnerCmed project.

The project is organized in 3 Word Packages:

- WP1 – Transnational paradigm of energy-positive & climate resilient MED hinterlands centred on REC & NBS: it constitutes the methodological basis of the project in which the Knowledge Facility Instrument (KFI) is defined, that is, the thematic structure that collects the scientific and technical competencies of the partnership, the Terms of Reference (ToR) to guide the creation of Energy Communities in vulnerable urban contexts, and a Policy Brief, designed to provide actionable recommendations and strategic guidance to policymakers, local authorities, and stakeholders to facilitate the establishment and effective governance of Renewable Energy Communities. It seeks to address key regulatory, technical, social, and financial barriers hindering REC formation and facilitate the replicability of the model.
- WP2 – Testing applicative models for energy & climate positive neighbourhoods: it constitutes the operational part of the project in which the pilot cities implement the model through four steps:
 - Engaging families and users within the REC framework.
 - Defining optimal business and legal model for each pilot REC.
 - Engineering and installing photovoltaic (PV) systems on public infrastructure and smart home meters.

- Deploying NBS as natural heat sinks.
- WP3 – Uptake strategy for large-scale replication: it focuses on the transition from project to territorial strategy, is dedicated to sustainability and replication, supported by four Action Plans (Genova, Patras, Valencia, Pula & Novigrad) and service portfolios that aid urban authorities in promoting RECs for socio-economically challenged residents.

3 The Knowledge Facility Instrument (KFI): structure and function

The EnerCmed Project is an Interreg Euro-MED project co-founded by the European Union and has received funding of approximately 3M€. The EnerCmed Project starts from the assumption that the establishment of a REC is not only a technical installation of the Photovoltaic plant, but a legal-socio-technical construction that involves the analysis of at least six dimensions, as shown in **Table 1**.

Table 1. Socio-technical parameters in REC establishment

Involved dimension	Objective of the analysis
Regulatory framework	EU, national, regional and municipal regulation
Renewable Energy Systems Planning	System configuration, consumption and production estimation,
Governance, Business Model & Contracting	Business model, contracts, ownership, redistribution
Social Engagement	Engagement, awareness, inclusion, trust
Urban Heat Island Phenomena	Co-benefits (UHI, green, air quality), sustainability
Digitalization for Energy Tracking & DR	Monitoring systems, dashboard, automatization, DR

As already mentioned, the Knowledge Facility Instrument is not a tool introduced in the implementation phase, but it was born as a foundational element of the EnerCmed project: from the stage of writing the proposal, the entire partnership was built through the identification of scientific partners capable of assuming a specific, structured, and recognizable thematic role within the KFI, in line with the five identified dimensions. This choice allowed for the formalization, from the writing of the proposal, of a multi-level cognitive model capable of integrating technical-energy, legal-economic, social, environmental and digital aspects (**Figure 2**).

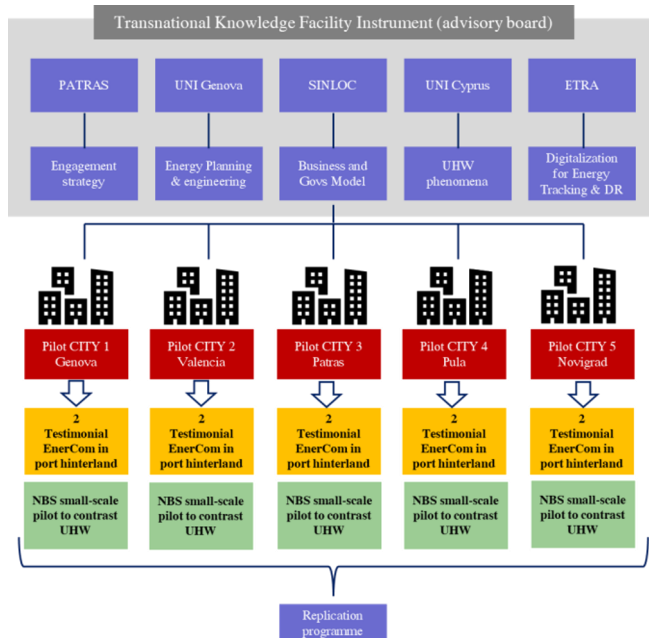


Figure 2. KFI definition in the EnerCmed Project. Violet squares represent the technical partners and their associated experiences; red squares indicate the pilot cities; yellow squares define the REC activations while, green squares define the NBS actions.

Since the project's inception, this structure has enabled the integration of scientific, technical, and operational skills in a concrete manner. The initial phase was not just a moment of setting up, but a truly active laboratory for building shared project capacity.

The Knowledge Facility Instrument (KFI) acts as a unified advisory mechanism offering comprehensive technical guidance and mentorship to pilot cities. It leverages EnerCmed technical partners know-how and employs a co-design process to integrate local expertise with specialized knowledge, ensuring that tailored solutions are developed to address the specific needs of each city. The KFI aims to enhance the overall impact and replicability of the project by providing structured and strategic support throughout the implementation phases.

KFI operates as a technical advisory board with expertise from pilot cities across four vertical trajectories and one horizontal technical domain:

- Renewable Energy Systems Planning & Engineering: the technical partner leads the technical design and engineering aspects, ensuring that renewable energy systems are technically sound and optimized for local conditions.
- Business Model, Governance & Contracting: the technical partner provides financial modelling, business models, and contractual arrangements, ensuring economic feasibility and sustainability.
- Social Engagement: the technical partner develops social engagement strategies to involve local communities in the REC projects, ensuring initiatives are inclusive and socially beneficial.
- Urban Heat Island Phenomena: the technical partner integrates Nature Based Solutions to mitigate the impact of urbanization on local climates, addressing urban heat island effects.

- Digitalization for Energy Tracking & Demand-Response: the technical partner supports the integration of digital technologies to enhance energy management and system efficiency.

Every KFI actor contributes to the project through their unique knowledge domain, leveraging specialized expertise to support the successful implementation of Renewable RECs and NBS in pilot cities. Each actor offers tailored services, resources, and technical know-how to address specific challenges within their domain.

The KFI committee, composed by the technical partners, has identified two models of know-how transfer to address the diverse needs of Pilot Leaders. The first model targets common needs among the partners, which are explicitly addressed through recurring technical assistance activities (*Figure 3*).

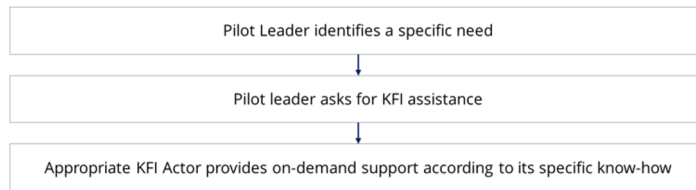


Figure 3. On demand technical assistance process

The second model involves transferring specific knowledge tailored to the unique needs of each pilot, responding to their requests as they arise.

To ensure the effectiveness and continuous improvement of support provided to Pilot Leaders, the KFI will provide systematic monitoring and reporting of all interventions. This activity will help track progress, document outcomes, and inform future actions. The REC Global Advisory Reports serve as comprehensive documentation of the technical, business, and strategic support provided to the five pilot cities. These reports offer a detailed analysis of desk research, technical design assistance, and business modelling, reflecting the impact of KFI's advisory services on each pilot.

Besides the support to the pilots, the Knowledge Facility Instrument (KFI) foresees the establishment of a Knowledge Sharing Helpdesk Platform aimed at disseminating project materials to other Mediterranean cities. This platform serves as a central repository for communication and training materials produced by the KFI, making knowledge and best practices accessible to local entities interested in replicating the EnerCmed approach.

4 From organization to production: the ToR as an operational expression of the KFI

The Terms of Reference (ToR) for the development of the REC represents the first concrete product of the KFI and is designed as a practical guideline to assist partners in planning energy communities coupled with the NBS solutions in their local contexts. The document, in which technical, social, regulatory, environmental, and digital skills have intertwined, is structured as the result of a shared process.

The ToR is a multicriteria decision-making protocol that gathers all the key aspects such as the social engagement, the energy dimensioning, monitoring (technical aspects) and the economic/financial/governance dimension enhanced with the principles related to the microclimate actions and deliver an efficient energy-positive & climate resilient planning paradigm around the concept of Renewable Energy Communities.

The ToR is subdivided into four sections:

- I. ToR for social engagement of vulnerable Populations
- II. ToR for energy community technical design & digitalization
- III. ToR to build a legal, administrative and management structure
- IV. ToR for UHI principle as driver factors to offset REC externalities

Each Terms of Reference (ToR) is meticulously structured and systematically organized into chapters and subchapters, serving as a detailed step-by-step guideline toward achieving the overarching objective. Within each section, clearly defined tasks are articulated, accompanied by comprehensive explanations to ensure clarity of purpose and methodological coherence. More than a technical document, the ToR represents a flexible and adaptable tool, designed to be applied in pilot neighbourhoods as well as in other contexts, to support those who wish to build energy communities rooted in their territories and aware of their specificities.

5 Conclusions

The manuscript has presented the Knowledge Facility Instrument (KFI) as a core component of the EnerCmed project, designed to coordinate multidisciplinary expertise for the establishment of Renewable Energy Communities (RECs) in energy-poor port hinterlands. Structured around five thematic areas, such as energy planning, governance, social engagement, climate adaptation through Nature-Based Solutions, and digitalization, the KFI supports both strategic guidance and technical implementation.

By producing shared tools such as the Terms of Reference (ToR), Policy Brief and delivering targeted advisory services, the KFI enhances project coordination and ensures tailored, replicable solutions for pilot cities. It represents a scalable model for integrating technical, regulatory, and social dimensions in energy transition projects, offering valuable insights for similar initiatives across the Mediterranean and beyond.

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