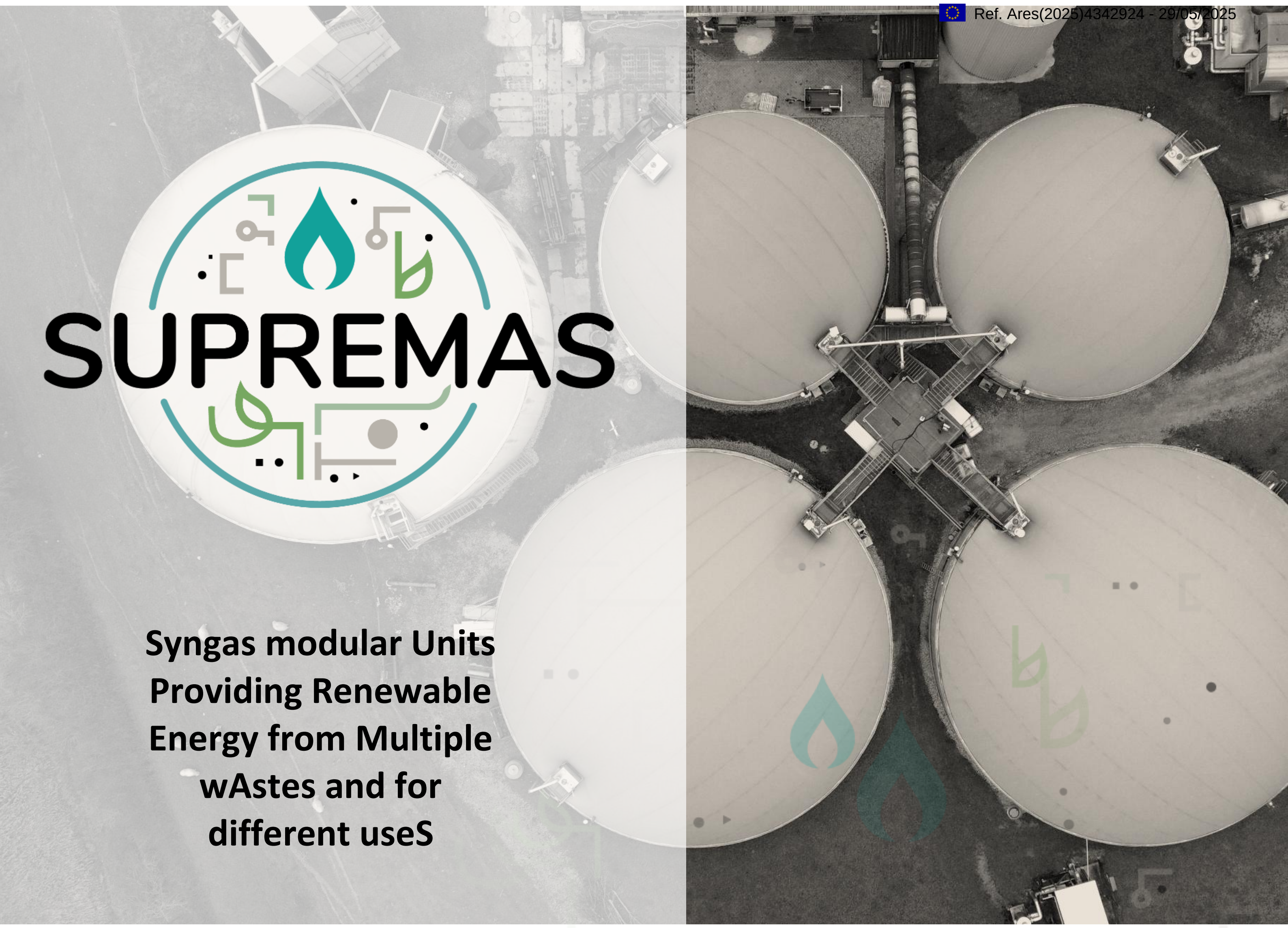

Syngas modular Units Providing Renewable Energy from Multiple wAstes and for different useS

D1.3 SUPREMAS solutions for Renewable Energy Communities

April 2025

ENGREEN SRL

Co-funded by the European Union

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14th May 2025	02	Silvia Caneva (WIP)	First review
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27th May 2025	1.0	Laura Bertolacci (RINA)	Final revision

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List of acronyms

ADENE - Agência para a Energia (Energy Agency)

ARERA - Autorità di Regolazione per Energia Reti e Ambiente

BBVA - Banco Bilbao Vizcaya Argentaria

BMs – Business Models

CAPEX - Capital Expenditure

CAGR - Compound Annual Growth Rate

CDP - Cassa Depositi e Prestiti

CEP - Clean Energy Package

CHP - Combined heat and power

CSR - Corporate Social Responsibility

CSCG - Collective Self-Consumption Groups

DGEG - Directorate-General for Energy and Geology

DH&CNs - District Heating & Cooling Networks

DHN - District Heating Network

DL - Decree-Law

DME - DiMethyl Ether

DSOs – Distribution System Operators

DSS – Decision Support System

EDSEP - Experiments Decentralised, Sustainable Electricity Production

EEG - Erneuerbare-Energien-Gesetz (Renewable Energy Sources Act)

EBA - European Biogas Association

EED - Energy Efficiency Directive

ENEA - Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile

ESCOs - Energy Service Companies

ESG - Environmental, Social, and Governance

EV – Electric Vehicle

EU – European Union

EU ETS - EU Emissions Trading System

FER – Fonti Energetiche Rinnovabili (RES – Renewable Energy Sources)

GLP - Green Loan Principles

GSE - Gestore dei Servizi Energetici

H2P - Heat-to-Power

HVAC - Heating, Ventilation, and Air Conditioning

ICT - Information and communication technology

ICF - Catalan Institute of Finance

ICO - Instituto de Crédito Oficial

IFEM – Financing Instruments for Innovative Enterprises

IP - Intellectual Property

IoT - Internet of Things

JTF - Just Transition Fund

KPIs – Key Performance Indicators

LCA – Life Cycle Assessment

LCC – Life Cycle Cost

MASE - Ministry of the Environment and of Energy Security

M&E - Monitoring and Evaluation

MIMIT - Ministry of Enterprises and Made in Italy

MSW – Municipal Solid Waste

NRW - North Rhine-Westphalia

ODK – Open Data Kit

OFMSW - Organic Fraction of Municipal Solid Waste

OPEX - Operating Expenditure

OSS - One-Stop-Shops

P2H - Power-to-Heat (P2H)

PPA - Power Purchase Agreement

PNIEC - Piano Nazionale Integrato per l’Energia e il Clima

PNRR - National Recovery and Resilience Plan

POT - Planning Optimizing Tool

PPPs - Public-Private Partnerships

REC – Renewable Energy Communities

RED - Renewable Energy Directive

RRF - Recovery and Resilience Facility

ROI - Return on Investment

SAF - Sustainable Aviation Fuel

SNAI - Strategia Nazionale Aree Interne (Italy’s National Strategy for Inner Areas)

SMEs - Small and Medium Enterprises

SOFC – Solid Oxide Fuel Cell

SPVs - Special Purpose Vehicles

SUPREMAS - Syngas modular Units Providing Renewable Energy from Multiple wAstes and for different useS

TECs - Thermal Energy Communities

TIAD - Testo Integrato Autoconsumo Diffuso

TSO - Transmission System Operator

UPAC - Unidade de Produção para Auto-Consumo (Production Units for Self-Consumption)

USPs - Unique Selling Points

WP – Work Package

WWTP – Wastewater Treatment Plant

EXECUTIVE SUMMARY

The SUPREMAS project is funded by the European Union, under the Horizon Europe programme, and it is coordinated by RINA Consulting SpA. The consortium is composed of twelve participants, including large enterprises, universities, small and medium enterprises, research center and Non-for-Profit Organization.

The project is set against the backdrop of the European Union's ambitious climate goals, such as the European Green Deal (in 2020) and the Fit for 55 plan (in 2021), which aim for a 55% cut in CO2 emissions by 2030 (from 1990 levels) and for net-zero emissions by 2050 are supporting Europe leadership in energy transition. However, many EU countries are net importers of oil and gas (in 2022 the EU's natural gas import dependency rate was 97 %), and thus particularly exposed to energy reliability and market volatility risks. As such the EU Agenda ambitious objectives, together with the external dependence on natural gas implies that green gases as syngas is essential in the energy transition.

Synthesis gas (syngas) is one of the potent energy alternatives to generate transport fuels, chemicals, and energy products. Nowadays, syngas is mainly produced by gasification of natural gas, coal, and occasionally from heavy oil residues. Maximizing the syngas yield from biomass will largely promote the biomass utilization and waste management with high efficiency. Despite of this, biosyngas is not fully exploited because of different reasons. Lower prices of fossil fuels for instance concerns end-consumers as it creates a risk for them to pay more than 'usual' and this could lead to a lack of participation from syngas plant developers. Moreover, syngas high capital costs represent the main barriers to industry growth.

SUPREMAS in this framework is determined to advance the European technology leadership in bio-energy development by fostering decentralized gas systems development, promoting innovation as well as sustainable development. SUPREMAS will contribute to the energy transition for different end users (e.g., WWTP, MSW plant REC, etc..) developing technologies enabling the development of circular value chains where multiple residues, discarded from different processes, will be valorized to obtain electricity, heat, and cooling at the benefit of local districts energy needs.

The main objective of the SUPREMAS project is demonstrating the potential and viability of innovative compact, modular and movable (i.e., transportable on truck) syngas production units capable to recover the bioenergy content from multiple waste feedstocks (e.g. wood, chips, sludges from wastewater treatment, digestate).

Within the project logical framework, this Deliverable [D1.3 – *"SUPREMAS solutions for Renewable Energy Communities"*] is part of the WP1 and implements the Task 1.3, having the ambition of providing the necessary instruments for performing an analysis of the SUPREMAS solution when adopted in the Renewable Energy Communities (RECs) and then identifying the most robust and replicable Business Models (BMs).

The overall approach of the study is founded on strong understanding of the State of the Art of the sector of intervention. The study is performed by (i) reviewing official reports, documents, literature and (ii) involving stakeholders to gather updated information. Defining benchmarks is approached not only by studying the market in its general terms (macroeconomics, regulatory, sizing, financing, etc.), but focusing on adopted business models, which are chosen as the key tool for identifying barriers and opportunities in the reference market.

The proposed methodology builds upon a comprehensive Market Analysis [D1.1 – *"Syngas decentralized production framework"*] to investigate the role of SUPREMAS systems as enablers within the Renewable Energy Communities (REC) sector in Europe. It begins with a focused exploration of market dynamics and stakeholder consultation to assess the readiness and relevance of SUPREMAS in accelerating the decarbonisation of local energy systems. This phase is complemented by targeted desk research to map the broader enabling environment, including regulatory, financial, technical, environmental, and social dimensions.

The comparison of market dynamics between biosyngas technologies and Renewable Energy Communities (RECs) highlights both strong synergies and divergencies, as well as challenges within Europe's energy transition framework and countries where demonstration sites are placed.

The biosyngas sector is experiencing rapid growth, driven by increasing demand for renewable energy and sustainable waste management solutions. Supported by major European policies such as the Green Deal, Fit for 55, and REPowerEU, biosyngas projects are typically large-scale, requiring significant technological infrastructure and industrial investment. In contrast, RECs are emerging from a grassroots, citizen-led movement, emphasizing local empowerment, collective ownership, and decentralized renewable energy production, underpinned by legislation such as the Clean Energy Package and Renewable Energy Directives (RED II/III).

Although their development pathways differ, both biosyngas and RECs are fundamental for achieving Europe's climate neutrality goals. Both of them are boosted by technological innovation and industrial demand, as well as by environmental, economic, and social factors, even if each has its own peculiarities. In terms of barriers, biosyngas faces challenges related to high capital expenditure, feedstock variability, and regulatory complexity, while RECs struggle with legal uncertainty, financial limitations, and the need for technical capacity-building.

With regard to competitive advantages, biosyngas companies leverage advanced technologies and strategic pricing models, often supported by public funding programs like REPowerEU, whereas RECs succeed through social innovation, combining diverse financing mechanisms and fostering citizen participation to ensure local ownership and equitable energy access.

With regard to market applications, biosyngas targets energy-intensive industries and municipal waste-to-energy projects, whereas RECs is affected by regulatory restrictions for large enterprises in some countries (i.e. Italy), and it is more focused on addressing community needs like residential energy self-consumption, electric mobility, and district heating initiatives.

At a preliminary analysis, the SUPREMAS biosyngas technology seems to have good synergies with main REC models identified so far. Three types of business models have been investigated: Business Model A-"Collective Self-Consumption Groups", Business Model B-"Community-Led RECs" and Business Model C-" Industrial RECs". In the Business Model A-"Collective Self-Consumption Groups", SUPREMAS could complement rooftop solar by providing flexible, dispatchable energy solutions; in the Business Model B-"Community-Led RECs", SUPREMAS could support decentralized waste valorization as well as electricity grid ancillary services and/or flexibility services; in the Business Model C-" Industrial RECs", SUPREMAS could enable large-scale waste-to-energy conversion and generates additional value through products like biochar and synthetic fuels, thus Business Model C-"Industrial RECs" exhibits the highest potential due to economies of scale and reliable waste supply chains.

1 INTRODUCTION

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Policy initiatives, such as the European Green Deal (in 2020) and the Fit for 55 plan (in 2021), which aim for a 55% cut in CO_2 emissions by 2030 (from 1990 levels) and for net-zero emissions by 2050 are supporting Europe leadership in energy transition.

However, many EU countries are net importers of oil and gas (in 2022 the EU's natural gas import dependency rate was 97 %), and thus particularly exposed to energy reliability and market volatility risks.

As such the EU Agenda ambitious objectives, together with the external dependence on natural gas implies that green gases as syngas is essential in the energy transition.

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Despite this, biosyngas is not fully exploited for different reasons. Lower prices of fossil fuels, for instance, concern end-consumers as it creates a risk for them to pay more than 'usual', and this could lead to a lack of participation from syngas plant developers. Moreover, biosyngas high capital costs represent the main barriers to industry growth.

SUPREMAS in this framework is determined to advance the European technology leadership in bio-energy development by fostering decentralized gas systems development, promoting innovation, as well as sustainable development. SUPREMAS will contribute to the energy transition for different end users (e.g., WWTP, MSW plant REC, etc..) developing technologies enabling the development of circular value chains where multiple residues, discarded from different processes, will be valorized to obtain electricity, heat, and cooling at the benefit of local districts energy needs.

The main objective of the SUPREMAS project is to demonstrate the potential and viability of innovative compact, modular and movable (i.e., transportable on truck) syngas production units capable to recover the bioenergy content from multiple waste feedstocks (e.g. wood, chips, sludges from wastewater treatment, digestate).

The chosen feedstocks are byproducts that result from very different processes and can be easily found in several European regions, both urban and non-urban.

In particular, the SUPREMAS solution is foreseen to be easily adaptable to small communities or plants having to treat residual biomass (e.g. woodchips from forest and urban maintenance, nut and almond shells….) and other organic wastes (e.g. digestate, OFMSW) valorizing the syngas through CHP direct integration.

The obtained syngas will be exploited by increasing the production yield and contributing to the achievement of CO2 free waste valorization plants.

This particular modular arrangement has been conceived to maximize the flexibility for the management of the system in different configurations according to the variability of the inputs in terms of feedstock and of the demand of energy from the local energy ecosystem, and to enable, in the future, the adaptability of the design to other end uses.

The demonstrations proposed in SUPREMAS are expected to contribute to ensuring gas supply security, exploiting bioenergy sources from a sustainable and cost-efficient perspective.

This Deliverable [D1.3] is part of WP1 and implements Task 1.3, having the ambition of providing the necessary instruments for performing an analysis of the SUPREMAS solution when adopted in the Renewable Energy Communities (RECs) and then identifying the most robust and replicable Business Models (BMs). T1.3 and D1.3 will serve as input for the following tasks T6.3 (SUPREMAS Scalability and replicability pre-feasibility studies) and T7.5 (SUPREMAS Business modelling and Roadmapping), which will include a major contribution from ENGREEN for what concerns the aspects related to RECs.

2 METHODOLOGY

2.1 Overall approach of the study

The overall approach of the study carried out for the preparation of this deliverable, and for future insights in the Task T6.3 and T7.5, is founded on a strong understanding of the State of the Art of the sector of intervention. The study is performed by (i) reviewing official reports, documents, literature and (ii) involving stakeholders to gather updated information. Defining benchmarks is approached not only by studying the market in its general terms (macroeconomics, regulatory, sizing, financing, etc.), but focusing on adopted business models, which are chosen as the key tool for identifying barriers and opportunities in the reference market.

Based on a broader Market Analysis [D1.1] developed by RINA in collaboration with other Consortium partners, which is necessary for the full understanding of the context, the methodology starts from a **first phase dedicated to the Market Analysis, focused on the Renewable Energy Communities (REC) sector**. It is devoted to the exploration of how SUPREMAS systems can become a catalyst for sustaining the REC sector in Europe. Thus, in other words, it aims to investigate the market readiness of the SUPREMAS systems in RECs, leading to a comprehensive understanding of how SUPREMAS can empower the REC environment, and providing REC practitioners with reference figures, derived from Business Model Simulations.

RECs are looking at the promotion of decarbonizing energy systems to ensure more sustainable and locally produced energy resources, limiting fossil fuels usage. For this reason, **identification of key technologies able to boost this transition** may help communities accelerate in this green revolution.

Thus, the first phases of the methodology deals with a REC market analysis, which leverages a specific **stakeholder consultation (first phase)**, which is not only to perform simulations to explore the techno-economic feasibility of innovative business models adopting SUPREMAS systems in REC initiatives (developed later on) but also to integrate the **desk research (second phase)** for a full analysis of the **REC enabling environment**, including regulatory, financing, political and technical aspects for a strong project viability as well as environmental and social implications for a long-term project sustainability.

Leveraging on a full understanding of the REC sector, addressed in this Deliverable [D1.3], the **third phase of the methodology is a Preliminary Business Model (BM) Assessment,** starting from a categorization of all the SUPREMAS potential applications in different REC types. This long list of BMs is to be short-listed by selecting the most promising ones, representing typical applications in different contexts of interventions.

The **fourth phase of the methodology** aims to perform a detailed analysis of selected applications, and thus provide simulations of Full Business Model (BM) Assessment of SUPREMAS in REC. The Full BM Assessment will also be reviewed at a final project stage, when additional inputs from finalized project tasks could support an improved BM analysis, in alignment with the project's development.

The **fifth phase of the methodology** regards the replicability and scalability of the SUPREMAS project across different locations, both within the original demonstrator countries (Spain and Portugal) and in new regions.

According to this methodology, phase I and phase II are addressed in this Deliverable [D1.3], setting the context for further developments which will be analysed in the Deliverables D6.5, D6.6 and D7.10 (Phase III, Phase IV and Phase V).

The methodology is summed up in the following flowchart, representing the key phases it is composed of.

INPUT	PHASE	OUTPUT	DELIVERABLE
D1.1 Syngas decentralized production framework D1.2 Stakeholder mapping	Phase I – Stakeholder consultation	Analysis of needs, requirements, barriers and opportunities	Stakeholder Consultation Report (internal, it is not a deliverable)
D1.1 Syngas decentralized production framework Stakeholder Consultation Report (internal, it is not a deliverable)	Phase II - Desk Reseach on general terms of Market Analysis	Review of current legal, socioeconomical, financing and governance of REC with a focus on biomass energy production and wastes	D1.3 SUPREMAS solutions for Renewable Energy Communities
D1.1 Syngas decentralized production framework Stakeholder Consultation Report (internal, it is not a deliverable) D1.3 SUPREMAS solutions for Renewable Energy Communities	Phase III - Preliminary Business Model Assessment of SUPREMAS in REC	Identification of the 3 most promising REC configurations for the Full BM Assessment	D7.10 Business modelling and roadmapping (part on BM)

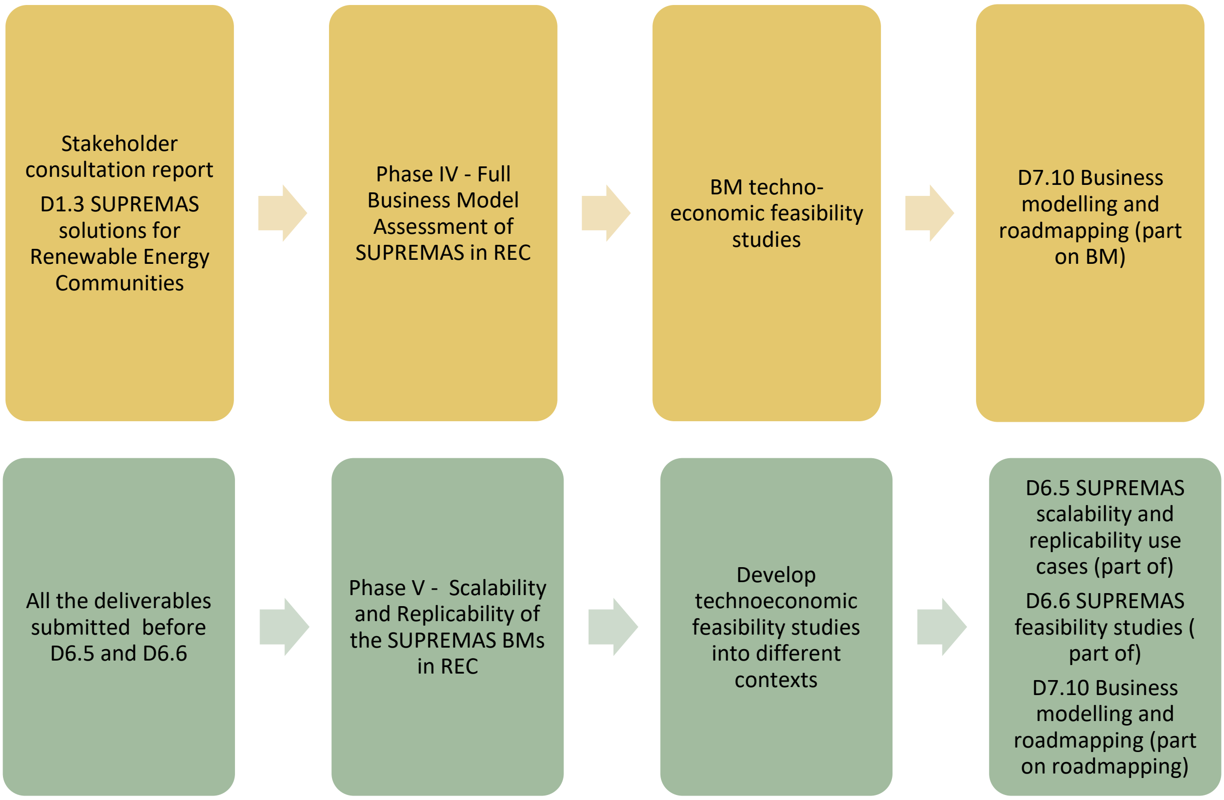

Figure 2.1 Methodology workflow

2.2 Phase I: Stakeholder consultation

The first phase of the SUPREMAS project is focused on engaging key stakeholders to identify the technological, regulatory, and socio-economic barriers and opportunities related to the integration of syngas technology within Renewable Energy Communities (RECs).

This phase sets the foundation for the successful deployment and replication of SUPREMAS solutions across Europe by ensuring that technology meets the real-world market needs.

Task 1.3 has been divided into several sub-tasks in order to provide a structured approach during the development of D1.3.

Phase I is composed of the following sub-tasks:

- [T1.3.1] Stakeholder mapping fully focused on REC, starting from the general stakeholder mapping [D1.2]
- [T1.3.2] Outlining the Table of Contents for deliverable [D1.3]
- [T1.3.3] Identification of data to be collected by means of the stakeholder consultation
- [T1.3.4] Development of the stakeholder survey, in partnership with RESET for the input data on the SUPREMAS technology
- [T1.3.5] Data collection
- [T1.3.6] Data analysis
- [T1.3.7] Preparation of the Stakeholder Consultation Report

The outcomes of Phase I ensure that the SUPREMAS project is grounded in stakeholder needs and market realities. By identifying the key barriers and enablers for syngas deployment, this phase paves the way for the subsequent development of tailored business models, policy recommendations, and technical solutions, which will be elaborated in later phases of the project.

This phase will also provide strategic input into the subsequent phases of the project, particularly the REC Market Analysis (Phase II) and the Preliminary Business Model Assessment (Phase III).

[T1.3.1] Stakeholder Mapping

The Stakeholder Consultation starts by defining a general stakeholder mapping, resulting in an input deliverable for EnGreen's task [D1.2] that provides the initial framework for this consultation. On this basis, EnGreen integrates the deliverable [D1.2] with further data for guiding the identification and categorization of stakeholders specific to the syngas-REC context.

The main objective of the Stakeholder Mapping is to identify relevant actors who can influence or be impacted by the deployment of syngas in RECs, understand their perspectives, and collect data that actually support the development of viable business models for syngas deployment in RECs.

The stakeholder mapping may include REC practitioners, technology providers, policymakers, financial institutions, and local communities.

- REC operators and developers
- Technology providers in the syngas sector
- Policymakers and regulatory bodies
- Financial institutions and investors
- Local communities and end-users

[T1.3.2] Outlining the Table of Contents for deliverable [D1.3]

A preliminary structure for the Stakeholder Consultation Report will be outlined, ensuring that it covers all necessary sections such as the stakeholder mapping results, analysis of needs and barriers, and recommendations for REC-syngas synergies.

This phase will define the type of data to be gathered from stakeholders, which includes:

- Technological requirements for integrating syngas into REC systems
- Perceived regulatory and financial obstacles
- Socio-economic impacts and potential community benefits
- Environmental considerations, such as sustainability and waste valorization

[T1.3.3] Identification of data to be collected and [T1.3.4] Development of the stakeholder survey

Among various data collection methods, in this project EnGreen has selected a hybrid survey method composed of:

- a preliminary online questionnaire (through ODK) followed by
- a face-to-face semi-structured interview (in-person or online).

In collaboration with RESET, a semi-structured questionnaire is developed to gather detailed feedback on syngas technology and its potential application in RECs from key stakeholders identified in [T1.3.1]. The survey will collect input on:

- Technical to socio-economic aspects
- Stakeholder priorities and expectations
- Regulatory compliance and market conditions
- Opportunities for technology adoption and collaboration
- Specific concerns about syngas capital and operational costs
- Trends, challenges, and opportunities

[T1.3.5] Data collection

The methodology for Data Collection is subdivided in the following steps:

- **First introductory email about the project**: the purpose of this email is to introduce the project, explain its objectives, and request the stakeholder's availability to participate to the survey. If no response is received within 5-7 days, a follow-up email will be sent to prompt a reply.
- **Second instruction email** (for who is interested): if stakeholders had express interest in participating, a second email is sent to share instructions on the survey method.

- **Data Collection** (by using the defined survey tool): Among various data collection methods, in this project, EnGreen has selected an hybrid method composed of a preliminary online questionnaire (through ODK) followed by a face-to-face semi-structured interview (in-person or online). In addition to ODK raw data, minutes of interviews are archived to document key data collected.
- **Data clearing and integration**: once the data collection round is completed, raw data are reviewed, cleared and missing or uncertain information are identified. Missing and/or uncertain data are double checked by contacting stakeholders interviewed. This step is to increase that reliability of the data collection methodology.
- **Validation of data publishable with stakeholder's direct citation:** while aggregate results is a sole responsibility of EnGreen, data publishable with stakeholder's direct citation should be approved by the cited stakeholders in a written form.

[T1.3.6] Data analysis

The data gathered are systematically analyzed to identify trends, challenges, and opportunities. The analysis is aimed also to provide insights into how SUPREMAS project can address the identified needs and barriers, enabling tailored solutions for different REC contexts.

Aggregated and disaggregated analysis across the stakeholders groups are carried out.

Weighted analysis is used to compare data from different stakeholders groups.

Cross-cutting controls to identify misleading results are performed.

[T1.3.7] Stakeholder Consultation Report

A Stakeholder Consultation Report is developed. It is a detailed internal report (not an official project deliverable) summarizing the consultation process and the key findings from the data analysis.

The Stakeholder Consultation Report represents a key input document for deploying the deliverable [D1.3] "SUPREMAS solutions for Renewable Energy Communities" and it is to provide (i) a comprehensive view of the stakeholder landscape as well as (ii) an overview of identified barriers, needs and enablers for syngas in RECs.

2.3 Phase II: REC market analysis

Phase II analyses the current State of the Art of the REC sector, having a specific focus on the European context with particular attention to Italy, Spain and Portugal).

- Phase II is composed of the following sub-tasks:

- [T1.3.8] Validation of Table of Contents for deliverable [D1.3]
- [T1.3.9] Inserting relevant contents from Input Deliverables
- [T1.3.10] Desk research on market analysis
- [T1.3.11] Review of existing business models for biomass/waste-to-energy-based REC
- [T1.3.12] Draft Version of deliverable [D1.3], mainly focused on REC market analysis
- [T1.3.13] Gathering comments from WP partners on Draft [D1.3]

[T1.3.8] Validation of Table of Contents for deliverable [D1.3] [T1.3.9] Inserting relevant contents from Input Deliverables

In particular, the following different elements are analysed:

- Macroeconomics
- Renewable energy sources in Europe
- REC panorama, including success stories and best practices
- Key actors in the REC sector
- Policy and regulatory framework
- Financial supporting mechanisms

[T1.3.10] Desk research on market analysis

This Phase II is to comprehensively understand the REC sector in order to assess potential business models and propose sustainable mechanisms for promoting SUPREMAS technology in the reference context. However, it has to be intended as a "light" analysis mostly because it will be carried out only via remote research, with limited interactions with local stakeholders. Thus, the methods adopted are the following:

- Desk research of official reports, scientific literature and websites;
- Analysis of the key actors' background;
- Direct online consultation with key actors.

Data analysis of the Stakeholder consultation followed a structured approach combining digital tools and manual synthesis. Survey responses, collected via the Open Data Kit (ODK)[1] platform, were pre-processed using Python[2] scripts to extract, clean, and structure the data for each question. Closed-ended questions were subjected to quantitative analysis to identify trends and frequency distributions, while open-ended responses underwent qualitative content analysis. This dual approach enabled both statistical aggregation and thematic interpretation. Pre-processed datasets informed the development of a narrative synthesis, which was integrated into the deliverable [D1.3] to contextualize key findings across technical, regulatory, financial, and socio-environmental dimensions.

The selection of responses presented in this study adheres to a predefined criterion: only responses for which the percentage of valid answers exceeded 30% of the total number of respondents (corresponding to 6.6% of the overall stakeholder group contacted) were included in the analysis. This approach is to ensure that findings are representative of the most prevalent perspectives within the sampled stakeholders.

[T1.3.11] Review of existing business models for biomass/waste-to-energy-based REC

Phase II aims also to analyses the current State of the Art of the biomass utilization and waste management sectors for the energy production, having a specific focus on European applications.

The intention is to establish which are the requirements of an area or of a community to create the best synergies between SUPREMAS technology and Renewable Energy Communities. Actually, each of the proposed models includes unique features to be observed for significantly improving energy productivity and thus for justifying any investment costs.

This analysis will be led by taking into account the following ToR requirements:

- Renewable Energy Communities in Europe and
- Energy production through biomass or wastes

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Deliverable [D1.3] builds on Deliverable [D1.1] "Syngas Decentralized Production Framework", developed by the partner RINA, which is actually a market analysis at the EU level on biosyngas. Deliverable [D1.3] aims to provide a market analysys both on biosyngas and Renewable Energy Communities (RECs) instead, including a comparative analysis to explore their potential synergies.

Thus, each section of the market analysis is structured in two sub-sections to properly describe the two target sectors of (1) biosyngas and (2) RECs. Leveraging on [D.1.1], the contents of biosyngas come directly from deliverable [D1.1], ensuring consistency and continuity between the two deliverables. This methodological approach allows deliverable [D1.3] to offer a parallel assessment of the biosyngas and REC markets, facilitating a nuanced understanding of their respective developments, challenges, and opportunities.

[D1.3] is structured as follows:

[1] ICTD (2010): Hartung, C., Lerer, A., Anokwa, Y., Tseng, C., Brunette, W., & Borriello, G. *Open data kit: tools to build information services for developing regions*.

[2] https://www.python.org/

- market dynamics on biosyngas/waste-to-energy applied in the REC sector: european market overview, including drivers, barriers, competitive strategies and advantages (chapter 3);
- end use application markets: industrial applications and non-industrial applications (chapter 4);
- future potential applications (chapter 5);
- market strategies (chapter 6);
- preliminary synergies between SUPREMAS technology and REC models (chapter 7);
- conclusions and recommendations (chapter 9).

3 MARKET DYNAMICS

3.1 European market overview

This section explores the current state of **biosyngas** and **Renewable Energy Communities (RECs)** across Europe, examining market trends, key regulatory drivers, challenges, and best practices shaping these fast-evolving sectors.

Biosyngas[3]

The European biosyngas market is rapidly evolving, reflecting a broader shift towards renewable energy and sustainable waste management practices. This section provides a comprehensive overview of the current market landscape, including its size, growth trends, and the regulatory environment that shapes its development. As Europe strives to meet ambitious climate goals and transition to a circular economy, the biosyngas sector is positioned as a key player in the renewable energy landscape. By examining the market dynamics, we can better understand the opportunities and challenges that lie ahead for stakeholders in this burgeoning industry.

REC

In recent years, **RECs** have emerged as a transformative force in the European energy landscape, reshaping how energy is produced, shared, and consumed. Rooted in the principles of **decentralization, sustainability, and citizen empowerment**, RECs enable groups of individuals, businesses, local authorities, or other stakeholders to jointly invest in and manage renewable energy projects.

Local ownership of renewable energy production through RECs is essential for securing an affordable, clean energy supply. RECs operate across the energy sector and are part of the cooperative and social economy. From offshore wind to large-scale district heating and cooling projects, energy communities—often composed of citizens, small and medium enterprises (SMEs), and local authorities—are already showing that local communities can play an active role in driving the EU's decarbonization and green industrialization goals. Local communities that can secure ownership of renewable energy production can protect themselves from the effects of high and volatile wholesale electricity and gas prices. RECs represent a fundamental shift towards a more decentralized and citizen-centric energy system.

The European Union (EU) has strongly supported this model through policies and legislative actions, particularly within the **Clean Energy for All Europeans package**, which formally recognizes the energy communities and provide a common legal framework for their establishment and operation across Member States.

Driven by these policies, RECs are gaining traction as model to[4]:

- Provision of local and clean energy
- Mobilization of local capital
- Strengthening of local development
- Contribution to environmental protection
- Promotion of energy savings
- Addressing the environmental crisis
- Increased social acceptance of renewable energy
- Strengthening of social cohesion

The European Union's Renewable Energy Directive (EU) 2018/2001, as amended by Directive (EU) 2023/2413[5], mandates Member States to promote the establishment and expansion of RECs. This initiative aims to achieve

[3] Sub-section on biosyngas is extracted from SUPREMAS [D1.1] Syngas Decentralized Production Framework.
[4] Heinrich Böll Stiftung. (2023, June 7). *The social impact of energy communities: Ten benefits they bring*.
[5] EUR-Lex (2023), *Directive (EU) 2023/2413 of the European Parliament and of the Council of 18 October 2023 amending Directive (EU) 2018/2001, Regulation (EU) 2018/1999 and Directive 98/70/EC as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652*

the EU's climate targets for 2030 and 2050 by democratizing the energy transition, empowering citizens and communities to actively participate in renewable energy generation and consumption.

3.1.1. Market Size and Growth Trends

- Biosyngas[6]

The European biosyngas market has been experiencing significant growth, driven by the increasing demand for renewable energy sources and the need for sustainable waste management solutions. Europe is dominating the biogas plant market with the maximum production of biogas. As of 2020, the region was the largest biogas producer, with around 18,943 biogas plants[7].

Biosyngas Market Growth

The average CAGR (Compound Annual Growth Rate) estimated at 4-7% for the European syngas market, including biosyngas, derives from an aggregation of projections provided by key sources. Here's how the data is interpreted to arrive at this estimate:

- Grand View Research[8]: This source suggests moderate growth in the European syngas market, particularly emphasizing the adoption of alternative feedstocks such as biomass and waste. While specific growth figures are not provided, "moderate growth" typically corresponds to a 4-5% range based on sector characteristics and comparable markets.
- Market Research Future[9]: This source highlights "significant growth" supported by governmental investments and technological innovations, aligning with a higher CAGR of around 6-7%. This estimate is based on the increasing adoption of advanced gasification technologies and incentives to reduce carbon emissions.
- Weighted Average: Given that the projections are generally expressed in qualitative terms rather than precise figures, the 4-7% range represents an average that spans scenarios of moderate growth (4-5%) and more optimistic scenarios (6-7%), providing a representative view of the market's potential. Europe's biogases production (combined biogas and biomethane) in 2022 amounted to 21 billion cubic meters (bcm), representing 6% of the EU's natural gas consumption[10]. Biomethane production alone grew from 3.5 bcm in 2021 to 4.2 bcm in 2022[11]. The REPowerEU Plan targets the production of 35 bcm of biomethane annually by 2030, a ten-fold increase from current levels. This ambitious target is expected to drive further growth in the biosyngas market.

The updated estimate shows that **44 bcm target for 2030** and **165 bcm target for 2050[12]** are achievable (of which 40 bcm in 2030 and 150 bcm in 2050 are foreseen for the **EU 27**).

The increasing focus on circular economy principles and the recycling of municipal waste further bolster the market, as biosyngas production aligns with these objectives[13]. The European Green Deal and the Fit for 55 packages aim to reduce greenhouse gas emissions by at least 55% by 2030, promoting the use of renewable energy sources, including biosyngas[14]. These initiatives are expected to significantly impact market growth, providing a favorable environment for the development and deployment of biosyngas technologies.

Small-scale digesters are expected to witness significant growth during the forecast period, mainly owing to the reasonable capital requirement and demand for flexible, affordable, and reliable technologies in growing economies.

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[6] Sub-section on biosyngas is extracted from SUPREMAS [D1.1] Syngas Decentralized Production Framework.
[7]https://www.mordorintelligence.com/industry-reports/biogas-plant-market
[8] https://www.grandviewresearch.com/industry-analysis/syngas-market-report
[9] https://www.marketresearchfuture.com/reports/syngas-market-7487
[10] https://www.europeanbiogas.eu/gas-for-climate-market-state-and-trends-report-2021
[11]https://www.europeanbiogas.eu/eba-statistical-report-2020-shows-significant-growth-and-potential-of-biomethane-to-decarbonise-the-gas-sector/
[12] European Biogas Association's (EBA) report "Biogases towards 2040 and beyond."
[13] https://www.europeanbiogas.eu/eba-statistical-report-2023/
[14] https://www.europeanbiogas.eu/wp-content/uploads/2023/12/EBA-Statistical-Report-2023-Excerpt.pdf

- REC

Important European regulations such as the **Clean Energy For All Europeans** package (CEP, 2019), with the recast of the Renewable Energy Directive and the Internal Electricity Market Directive, have introduced new instruments to empower citizens and put RECs at the forefront of the action against the climate crisis and the transition towards renewable energy. By 2050, half of all European Union citizens could be producing their own electricity, meeting 45% of the EU's energy demand, and 83% of European households could be engaged in the energy system through demand response and/or energy storage[15]. Achieving this potential would help lessen the EU's reliance on foreign energy sources, contributing to autonomy in the secure supply of renewables.

Concerning the current renewable energy exploitation (with or without REC) among potential REC stakeholders, **the most common source is solar power (45%)**, followed by **wind (36%)** and **hydropower (27%)**. Biomass and biogas were mentioned less frequently (9% each)[16].

Additionally, **91% of participants** indicated that their organization planned to invest in renewable energy projects, with **photovoltaic (PV) installations being the dominant technology (64%)**. These ranged from community-owned PV parks to large-scale facilities. Hydroelectric projects and future energy initiatives were mentioned less frequently (9% each), while 18% of respondents gave no further detail. This data highlights both the strong interest in solar-based community energy and the clear willingness of local stakeholders to engage in energy transition efforts, despite existing regulatory hurdles.

Further underscoring the commitment to community energy initiatives, 91% of REC stakeholders interviewed positively rate the attractiveness of community energy systems in innovative energy actions. Of these, 45% rated interest as high, 18% as very high, and 27% as low. In addition, regarding their entity's readiness to participate in community energy projects, 55% rated their entity's readiness as very high, 36% as high, and 9% as low. These responses underscore the strong propensity of stakeholders to engage in and support community energy solutions, such as RECs.

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<u>With a focus on the target countries of Italy, Spain and Portugal, focus paragraphs are reported herafter.</u>

In Italy, RECs suffered a setback due to delays in the publication of the Authority's regulation (Testo Integrato Autoconsumo Diffuso -TIAD) and the decree on incentive mechanisms[17]. This has led operators on hold before undertaking concrete initiatives and investments regarding the diffusion of these models. Despite this delay, ferment regarding RECs development in Italy has to be reported. Support tools, such as national and regional calls, private and open-access REC-modeling platforms, and seminars and conferences have been made available to develop and disseminate information and best practices about RECs. Moreover, it is worth mentioning that, in Italy, the energy sector legislation is shared among the national authority and regional authorities. In such circumstances, regional authorities, as public entities in contact with the territory and its citizens, have played an important role in promoting REC experiences. Most of the Italian regions have issued *ad hoc* actions with the aim of promoting and supporting REC configuration.

Complementary findings from the *Electricity Market Report 2024*[18] show that, by May 2024, there were 168 active configurations between RECs and collective self-consumption initiatives, marking an 89% increase compared to 2023. **As of 31 December 2024, there were 379 qualified REC configurations in Italy, with a total installed capacity of 53.2 MW and 3.733 associated customers,** according to data from the PNIEC (Piano Nazionale Integrato per l'Energia e il Clima) monitoring platform[19]. The PNIEC platform monitors Italy's progress

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[15] RESscoopEU (2025). *Ensuring access to affordable, secure renewable energy: local ownership through energy communities*

[16] REC stakeholder consultation.

[17] Sustainability (2023, 15, 6792). Tatti, A.; Ferroni, S.; Ferrando, M.; Motta, M.; Causone, F. *The Emerging Trends of Renewable Energy Communities' Development in Italy.*

[18] Energy & Strategy Group, Politecnico di Milano. (2024) *Electricity Market Report 2024: Le traiettorie abilitanti la decarbonizzazione del sistema elettrico italiano*. ISBN 9788864931135.

[19] PNIEC Monitoring Platform. *Incentivi e altre misure per le Comunità Energetiche Rinnovabili (CER)*.

toward national and EU climate and energy targets, providing updated data and strategic indicators for policy evaluation.

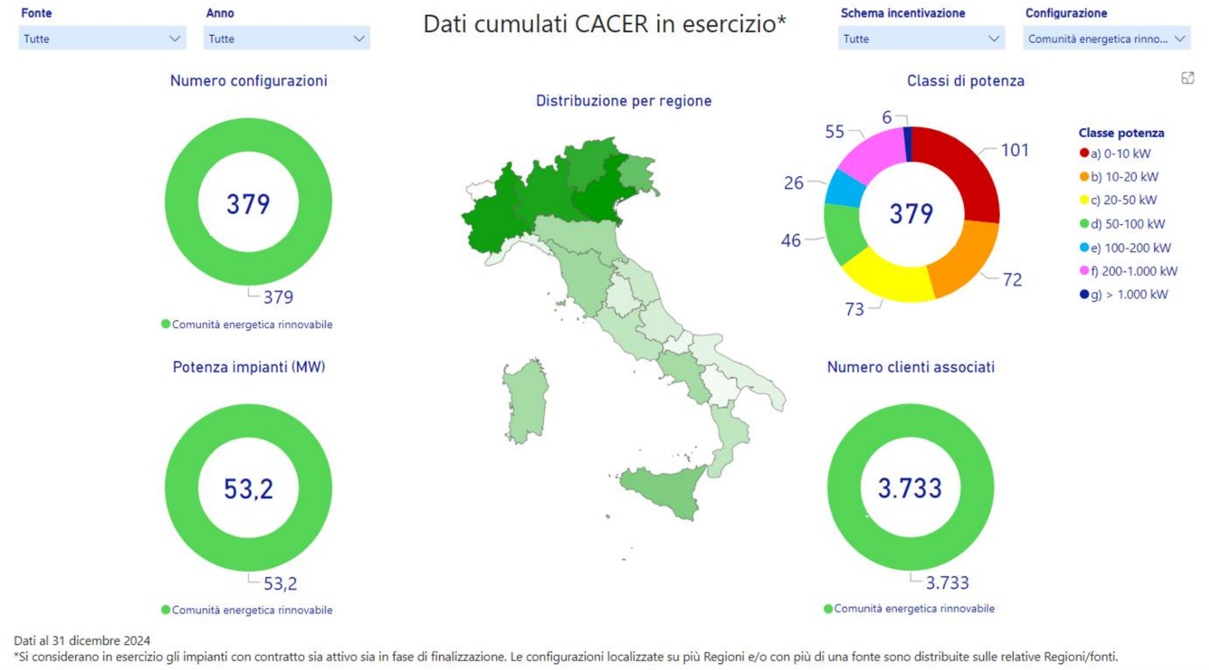

Figure 3.1 Italian Renewable Energy Communities Operational as of 31 December 2024

This growth underscores the rising interest in sustainable energy models that offer economic, environmental, and social benefits, though the absolute numbers remain modest when weighed against Italy's decarbonisation and energy independence goals. Regional dynamics reveal a concentration of initiatives in Piedmont, Lazio, Sicily, and Lombardy, which together account for nearly 48% of the national total, highlighting the importance of local policies and incentives.

Nevertheless, the growth rate remains insufficient to meet the ambitious target of 5 GW of incentivized new plants in self-consumption configurations by the end of 2027. Access to credit and external funding is expected to play a crucial role in supporting the expansion of RECs. In this context, the extension of the PNRR (National Recovery and Resilience Plan) funding window to 30 November 2025[20] (€2.2 billion are allocated) is a critical measure aimed at facilitating project development and accelerating investments necessary to achieve national energy transition objectives.

In Spain, the growth of RECs has been significantly boosted by the "CE Implementa" and "CE Oficinas" programs, which have provided financial support for the development of pilot projects and advisory offices to facilitate community-led energy initiatives. The CE Implementa program has played a crucial role in funding pilot REC projects, with €71.79 million allocated to 128 projects across four calls. The program continues to grow, with an additional €120 million allocated for upcoming fifth and sixth calls, broadening the scope of RECs beyond self-consumption to include renewable heating, sustainable mobility, and energy storage solutions. These trends show increasing community participation, a growing presence of cooperative models, and a strong push for social inclusion and gender equality.

Portugal has made significant strides in renewable energy, achieving 71% of its electricity consumption from renewable sources in 2024, with solar energy contributing 10% and experiencing a 37% year-on-year growth[21]. Despite this progress, the development of RECs in Portugal faces several challenges. As of late 2023, only three

[20] Ministero dell'Ambiente e della Sicurezza Energetica (MASE). *Investimento 1.2 - Promozione rinnovabili per le comunità energetiche e l'auto-consumo*

[21] PV Magazine (2025). *Renewables covered 71% of Portugal's power demand in 2024*.

RECs were legally operational, with over 200 projects awaiting authorization due to lengthy permitting processes, often exceeding a year[22]. To address this, the Portuguese government enacted Law 99/2024, aiming to streamline the establishment of RECs and promote decentralized energy production[23]. Looking ahead, RECs are projected to contribute up to 21% of Portugal's solar energy production by 2030[24]. Achieving this will require continued investment in infrastructure, regulatory reform, and public engagement. In summary, while Portugal leads in renewable energy adoption, the expansion of RECs necessitates overcoming regulatory hurdles to fully realize their potential in the nation's energy transition.

3.1.2. Policy And Regulatory Landscape

- #### Biosyngas[25]

The regulatory framework governing the biosyngas market in Europe is characterized by stringent environmental policies and ambitious climate targets set by the European Union. The European Green Deal and the Fit for 55 packages aim to reduce greenhouse gas emissions by at least 55% by 2030, promoting the use of renewable energy sources, including biosyngas[26]. Additionally, the REPowerEU Plan targets the production of 35 billion cubic meters of biomethane annually by 2030[27].

Various national regulations and incentives support the development and deployment of biosyngas technologies, creating a favorable environment for market growth. These regulations often include feed-in tariffs, renewable energy certificates, and grants for research and development, which encourage investment in biosyngas projects. For instance, Germany has implemented the Renewable Energy Sources Act (EEG), which provides financial incentives for the production of renewable energy, including biosyngas[28]. Similarly, France has introduced the Energy Transition for Green Growth Act, which aims to increase the share of renewable energy in the country's energy mix[29].

T6.6 – "Policy recommendations" will map and examine additional EU policies and regulations, especially in the geographical areas hosting the Projects' demonstrators.

The European Biogas Association (EBA) plays a crucial role in shaping the regulatory landscape by engaging with policymakers and advocating favorable policies for the biogas and biomethane sector[12]. The EBA's efforts have been instrumental in promoting the adoption of biosyngas technologies and ensuring that the regulatory framework supports the growth of the market.

Strong policy and regulatory support from the European Union and member states is a major driver for the biosyngas market. Key elements include:

- **Incentives**: Feed-in tariffs, renewable energy certificates, and grants for research and development encourage investments in biosyngas projects[12]. T6.5 – "Syngas/Syngas blended Gas Market Design" will analyze the key incentives to be exploited by the consortia
- **Alignment with Circular Economy Goals**: The EU's commitment to a circular economy fosters a conducive environment for biosyngas production, as it aligns with waste reduction and resource recovery objectives[4].

- #### REC

Within the EU regulatory framework for RECs, which reflects the EU's commitment to decarbonization and the energy transition, the aim is to promote cooperative energy models and improve energy efficiency.

The following are the most recent regulations developments at the EU level:

[22] PV Magazine (2023). *Only 3 Portuguese energy communities operating despite massive demand*.
[23] Strategic Energy (2025). *PPA Renewable Energy Portugal – policy updates and community energy*.
[24] Nova Green Lab. *Renewable Energy Communities in Portugal: The Local Path to the European Energy Transition*.
[25] Sub-section on biosyngas is extracted from SUPREMAS [D1.1] Syngas Decentralized Production Framework.
[26] https://www.europeanbiogas.eu/biomethane-map-2022-2023/
[27] https://www.bioenergy-news.com/news/bioenergy-europe-releases-biogas-statistical-report-2023/
[28] https://www.europeanbiogas.eu/overview-on-key-eu-policies-for-the-biogas-sector/
[29] https://www.europeanbiogas.eu/biogases-towards-2040-and-beyond/

Energy Efficiency Directive (EED) (2012, amended in 2018 & 2023). The Energy Efficiency Directive aims to improve energy efficiency by 32.5% by 2030, targeting energy savings across buildings, industries, public sectors, and energy systems. It promotes policies to reduce consumption and improve efficiency. The directive applies to EU member states, businesses, energy consumers, industries, and local authorities. Funding sources include EU funds (2021–2027 framework), the Recovery and Resilience Facility, InvestEU, the European Investment Facility, and financing programs such as energy performance contracts and green financing schemes. However, challenges remain in implementation across Member States, particularly for SMEs and RECs, due to financial constraints and frequent regulatory changes.

Renewable Energy Directive (REDII, 2018, amended to REDIII, 2023). The Renewable Energy Directive (RED II) promotes the use of renewable energy, setting binding targets for renewable energy (32% by 2030 under RED II, which became 42,5% under RED III). It includes provisions to encourage RECs, decentralized energy production, and the integration of renewables into the energy system. Stakeholders include EU member states, energy producers, RECs, industries, and local authorities. Financial mechanisms involve feed-in tariffs, subsidies, grants, and other support schemes. However, national disparities in renewable energy targets, inconsistent support for RECs, and administrative barriers hinder the full deployment of decentralized renewable energy solutions.

Electricity Market Directive (2019/944/EU). This directive aims to create common rules for the internal electricity market, ensuring fair competition, better integration of renewable energy, and consumer-driven markets. It also facilitates the empowerment of RECs. It applies to TSOs, small producers, energy consumers, energy cooperatives, and distributed energy systems. Financing sources include the European Investment Bank and European financial institutions, with additional support from private financing schemes. Implementation challenges include misalignment between national policies, residential and small-scale producers facing grid obstacles, and varying adaptation strategies among Member States.

Clean Energy for All Europeans Package (2019). This legislative package focuses on modernizing the EU energy system by integrating renewables, increasing energy storage capacity, and enhancing energy interconnection among Member States. The main stakeholders are EU energy producers, grid operators, consumers, and local authorities. Financial backing includes EU budget allocations (2021–27) for climate measures, the European Energy Programme for Recovery, and the EU's Just Transition Fund. Administrative complexities, particularly for SMEs, can discourage participation in clean energy projects.

European Green Deal (2019). The European Green Deal aims to make the EU the first climate-neutral continent by 2050, with policies centered on emissions reductions, renewable energy expansion, and circular economy models. Sectors affected include industry, energy, transport, agriculture, and biodiversity. Funding programs focus on investments in renewables, climate adaptation projects, and support from the Recovery and Resilience Facility. However, implementation requires coordinated action across sectors and Member States, as well as streamlined permitting processes.

Fit for 55 Package (2021). The Fit for 55 Package is a comprehensive legislative effort to cut emissions by 55% by 2030, including policies and regulations to align with the Green Deal's objectives. It affects EU member states, businesses, energy producers, and industries. While direct funding is limited, financing mechanisms include InvestEU, EU ETS revenues, bonds, and the Recovery and Resilience Facility. The success of Fit for 55 depends on adequate financial and regulatory efforts, requiring clear policies and substantial investments to meet emissions reduction goals.

According to the 2024 European Commission's report[30], it is important to acknowledge that RECs are still very new in EU energy policy. **Very few EU Member States had frameworks in place with the explicit aim of supporting and enabling RECs prior to the adoption of the Renewable Energy Directive (RED II).** In many Member States, there were no RECs until the impulse of RED II started to motivate actors in parallel with the development of frameworks at the national level. Establishing new policy and legal frameworks for RECs from the ground up involves inherent complexities. The EU definitions of RECs require further elaboration and details at the national level, including acknowledgment across different sectors and topics (electricity, heating and cooling, gas, energy efficiency, renovations, etc.).

Creating a legal framework at the national level requires not only acknowledging specific rights and responsibilities for RECs but also integrating them into existing renewable support schemes. Additionally, it involves developing detailed enabling frameworks that address the removal of unjustified barriers, promoting

[30] EC Directorate-General for Energy (2024). *Energy communities repository. A roadmap to developing a policy and legal framework that enables the development of energy communities.*

awareness, access to information and finance, capacity building for local authorities, and ensuring inclusiveness. This necessitates the development of national legislation and regulations, integrating RECs into climate and energy plans, and assigning different roles and responsibilities to National Regulatory Authorities, Executive Agencies and other authorities, from the national to the regional to the local level.

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A brief overview of the national regulatory framework on RECs in Italy, Spain and Portugal is provided hereafter.

Italy's regulatory framework for RECs includes the following groups of measures:

Promotion of RECs. Decree No. 199/2021 transposes the EU's *Renewable Energy Directive (RED II)* into Italian law, promoting decentralized renewable energy production and encouraging self-consumption and energy sharing within RECs. The decree offers grants and incentive tariffs through GSE (Gestore dei Servizi Energetici), but eligibility is restricted to municipalities with fewer than 5,000 residents, limiting its impact on industrial parks.

Regulation of Energy Self-Consumption and Energy Sharing. The ARERA Resolution 727/2022 defines the regulatory framework for diffuse self-consumption, aligning self-consumption and RECs with Legislative Decree 199/2021. It introduces provisions on shared energy and incentives for renewable energy production, primarily targeting low-voltage systems with geographical proximity requirements and installation limits of 1 MW.

Testo Integrato Autoconsumo Diffuso - TIAD CER 2024 Decree. TIAD provides a regulatory framework for RECs, collective self-consumption, and prosumers. It promotes shared renewable energy use, particularly in collective self-consumption projects. Grants and support schemes are available for energy-sharing initiatives, though they are mainly limited to municipalities with populations below 5,000.

Milleproroghe Decree (Decree No. 162/2019). It is a Legislative Extensions and Administrative Simplification. It provides urgent provisions for extending legislative deadlines and supporting public administration reforms and technological innovation. It promotes local renewable energy generation and self-consumption models by offering grants based on self-consumed energy within RECs. However, it is initially limited to systems below 200 kW, later expanded to 1 MW, and is primarily applicable in low-voltage contexts.

Simplification Decree (Decree No. 120/2020). It is a Legislative Extensions and Administrative Simplification. It introduces urgent measures for administrative simplification and digital innovation in renewable energy project development. By streamlining processes, it enables access to public funds at the European, national, regional, and chamber levels. However, disparities in local and regional implementation may cause delays.

Regional Law of Piemonte (Law 12/2018). It promotes the establishment of RECs within the region by providing financial support for project development and preparatory documentation. The law requires RECs to allocate at least 70% of their energy production for self-consumption to maintain producer status. If communities fail to meet strategic objectives, they risk losing regional, national, or EU funding for up to two years until compliance is restored.

Italy's regulatory framework for Innovative Renewable Technologies includes the following measures:

FER 2 Decree (DM 19-06-2024, amended on 10-12-2024) incentivizes high-cost renewable energy plants that use innovative technologies with low environmental and territorial impact. It prioritizes new renewable energy installations such as floating offshore wind, advanced geothermal, and marine energy sources. Incentives are awarded through competitive auctions and feed-in tariffs, but the measure excludes traditional onshore photovoltaic systems and focuses on new rather than existing installations.

Focus on The Italian Regulations on technological requirements in the REC sector[31]

The Operational Rules of the GSE, the Italian body that regulates the activation and management of renewable energy communities, establish precise eligibility criteria for biogas and biomass plants wishing to participate in Renewable Energy Communities (RECs), collective self-consumption groups or as individual self-consumers at a distance. These criteria ensure regulatory alignment with national and EU sustainability goals and promote the integration of exclusively environmentally friendly energy systems into community configurations.

For biomass installations, heat energy recovery is mandatory and must be primarily self-consumed on site to support industrial or agricultural processes. Alternatively, the recovered heat can be fed into an efficient district heating network. At least 80 per cent of the raw material must be by-products listed in Appendix D2, Part A, such as straw, maize stalks, pruning residues, grape marc and stalks, fruit and rice husks, sawdust or biomass from forestry and grounds maintenance activities. The remaining 20 per cent may include non-pelletised energy crops listed in Appendix D2, Part B, such as Miscanthus spp., Arundo donax (giant reed), Paulownia, Populus spp., Salix spp. and other annual or perennial herbaceous or woody species grown for energy purposes. In all cases, the procurement of raw materials must be formalised through contracts that clearly identify the geographical origin and places of provenance, ensuring full traceability and compliance with sustainability requirements.

Biogas plants, on the other hand, must comply with a specific set of conditions detailed in Appendix D1, particularly regarding the type and proportion of substrates used. The eligible feedstock includes, for example, livestock effluents, sludge from dairy processing, olive pomace, fruit and vegetable processing residues, and food industry by-products such as pasta scraps, bakery waste, or brewery residues. Importantly, at least 51% of the biomass input must originate from the production cycle of the agricultural enterprises operating the plant. The regulations also require gas-tight storage for digestate, equipped with biogas recovery systems, and the thermal energy produced must be recovered for on-site use or distributed through efficient networks.

Notably, the inclusion of hybrid plants within RECs or self-consumption configurations is explicitly prohibited. According to the definitions provided in Appendix A of the Operational Rules and Article 8, paragraph 4, letters c) and d) of Ministerial Decree 23 June 2016, hybrid plants fall into two categories:

- Plants fuelled by partially biodegradable waste, i.e., waste streams containing a biodegradable fraction of less than 100%;
- Other hybrid plants, which are powered by both a renewable source (such as biomass) and a non-renewable fuel (e.g., natural gas or coal) in excess of 5%. This category also includes installations using non-renewable fuels in combination with partially biodegradable waste.

It is important to note that, as of now, the GSE's regulatory framework does not provide specific eligibility criteria for gasification plants such as those developed under the SUPREMAS project. Instead, the current rules focus primarily on the type and origin of the feedstock used. To address this regulatory gap, a formal request for clarification (interlocutory communication) will be submitted to the GSE to assess the potential inclusion of gasification-based systems like SUPREMAS within Italian REC configurations. This step aims to ensure regulatory compliance and to clarify how such innovative waste-to-energy technologies can be integrated into the evolving national framework for renewable energy communities.

The Spanish regulatory framework for RECs. In alignment with the broader EU objectives for energy transition and decarbonization, Spain has developed a series of legislative instruments to foster RECs. These laws aim to simplify access to self-consumption systems, encourage community-based participation in the energy transition, and enable fair access to renewable energy resources. Here is a synthesis of the main Spanish regulations relevant to RECs:

[31] GSE - DECRETO CACER e TIAD – Regole operative per l'accesso al servizio per l'autoconsumo diffuso e al contributo PNRR.

Real Decreto 244/2019. This decree regulates the administrative, technical, and economic conditions for self-consumption of electricity in Spain. It sets out the framework for both individual and collective self-consumption systems, including surplus energy compensation mechanisms. Key stakeholders include self-consumers, individuals, and groups engaged in shared generation and use of electricity. Incentives include tax benefits and surplus compensation schemes. However, technical limitations exist for installations over 100 kW, along with burdensome documentation requirements for grid connection.

Real Decreto 1183/2020. This law defines the procedures and criteria for gaining access to and connecting with electricity transmission and distribution networks. It supports the development of renewable energy and self-consumption projects by establishing clearer rules for grid connection. It targets community energy operators, energy companies, and transmission entities, with support from state funding and infrastructure incentives. The main challenges are technical barriers, capacity limits, and transparency issues in infrastructure management.

Real Decreto 24/2021 (Catalonia). This regional decree transposes several EU directives and places a focus on the acceleration of distributed renewable energy deployment through community involvement. It promotes participatory projects by supporting citizens and businesses engaged in RECs. However, implementation is restricted to rooftop and urban settings, and projects with significant environmental impact are excluded.

Orden TED/1247/2021. This regulation introduces flexible sharing mechanisms for collective self-consumption, allowing more efficient distribution of locally generated energy. It mainly applies to citizens, SMEs, and local cooperatives engaged in collective projects. Financial support comes from state and local incentives, though administrative complexity can make the setup and management of sharing coefficients challenging.

Law 23/2020 (as amended by Law 8/2023). This legislative update formally introduces RECs into Spanish law, with the aim of enhancing economic recovery through local participation in the energy transition. It simplifies administrative procedures and strengthens economic resilience. Beneficiaries include renewable energy producers, SMEs, local communities, and public entities. It offers support through grants, resilience programs like InvestEU, and competitive remuneration schemes. A key limitation is the geographic proximity requirement for REC participation and the legal restriction against profit distribution, as RECs must operate on a non-profit basis.

Real Decreto 5/2023. This decree was adopted in response to various crises, including the war in Ukraine and the La Palma volcanic eruption, and also to transpose EU directives. It promotes RECs to lower energy costs and enhance energy efficiency, particularly in vulnerable regions. Stakeholders include citizens, SMEs, cooperatives, and both public and private entities. Funding is supported by NextGenerationEU and national incentives. However, accessing these supports may be hindered by complex regulatory frameworks and demanding technical or geographic criteria.

Portugal's regulatory framework for RECs is established under Decree-Law (DL) 162/2019, which defines the legal regime for self-consumption and energy community models. This legislation enables multiple renewable energy production units (UPACs) to connect to one or more points of consumption, fostering a decentralized energy model. For RECs the Portuguese law permits consumers to organize collectively, provided they share a close physical proximity. RECs in Portugal can take two forms:

1. Collective self-consumption – a group of consumers who share energy internally through a common set of rules, defined by an internal regulation.
2. Energy communities – legally established entities, often as cooperatives or partnerships, that include both self-consumers and other stakeholders involved in the energy project.

Eligible participants include individual consumers, organized groups, and larger entities such as residential condominiums, urban neighborhoods, business parks, agricultural units, industrial facilities, parishes, and municipalities—provided they maintain a proximity relationship to the energy infrastructure.

3.1.3. Key Market Players

▪ Biosyngas[32]

The biosyngas industry value chain involves several key stakeholders, including:

- **Bioenergy and biogas Producers:** key market players driving the growth of the European biosyngas market through their investments in new technologies, strategic partnerships, and active engagement with policymakers. Their efforts are crucial in advancing the market and ensuring that the regulatory framework supports the development and deployment of biosyngas technologies.
- **Feedstock Suppliers:** Provide organic waste and biomass for biosyngas production, ensuring a steady supply of raw materials.
- **Technology Providers**: Develop and supply gasification technologies and systems, driving innovation in the production process.
- **Energy Producers:** Utilize biosyngas for electricity generation and heating, integrating it into their energy portfolios.
- **End-Users:** applications across various sectors, especially in energy production, industrial processes, and emerging technologies, such as (i) Manufacturing and Chemical Industry, (ii) Transportation Sector, (iii) Waste Management and (iv) Agriculture.
- **Regulatory Bodies:** Establish and enforce policies and regulations governing the industry, ensuring compliance and sustainability.

In Europe, major players in the biosyngas sector include **companies engaged in bioenergy and biogas production**. Here are some of the key organizations:

- **Engie SA** - Focus: Renewable energy, including biogas and biosyngas production.
- **Air Liquide SA** - Focus: Hydrogen and syngas technologies, including renewable gas projects.
- **EnviTec Biogas AG** - Focus: Biogas plants and renewable gas solutions.
- **Scandinavian Biogas** - Focus: Large-scale biogas and biosyngas production from organic waste.
- **Gasum Oy** - Focus: Renewable gases, particularly biogas and biosyngas, for energy and transportation.
- **TotalEnergies** - Focus: Diversified energy solutions, including advanced biofuels and syngas technologies.
- **Neste Oyj** - Focus: Renewable diesel and bio-based fuels.
- **Verbio Vereinigte BioEnergie AG** - Focus: Industrial-scale production of bioethanol, biodiesel, and biogas.
- **BTS Biogas** - Focus: Biogas and biosyngas plant construction and operation.
- **AB Holding SpA (Gruppo AB)** - Focus: Cogeneration and renewable energy solutions.

The stakeholder mapping within the SUPREMAS project implementation [D1.2] will list and sort the main stakeholders identified by the consortia.

Key market players usually collaborate in the following ways:

- **Joint Ventures and Alliances**
- **Special Purpose Vehicles (SPVs)**
- **Public-Private Partnerships (PPPs)**
- **Commercial Partnerships**

▪ REC

The key stakeholders taking part to RECs can be clustered within the following groups:

- Financing Entities (Banks, Funds, Financial consulting, Crowdfunding, etc.)
- Public Institutions and Administrations
- Technical Agencies/ Entities (Universities, Public services, Energy operators, etc.)
- Producers & Manufacturer
- Civil/ Sectorial Associations (Sectorial organizations, Research institutions, Cooperatives)
- Residential Users
- Business Entities (SMEs, Commercial enterprises, Industrial enterprises)

[32] Sub-section on biosyngas is extracted from SUPREMAS [D1.1] Syngas Decentralized Production Framework.

Financing Entities, including banks, investment funds, financial consultants, and crowdfunding platforms, ensure the financial viability of RECs. They provide loans, grants, and tailored financial models to support RECs projects. By mitigating financial risks and lowering investment barriers, they facilitate the growth and expansion of community-led energy initiatives.

Public Institutions and Administrations play a crucial role in the creation and governance of RECs by providing regulatory support and ensuring policy alignment. They can also offer public buildings, such as schools and city halls, as infrastructure for community energy projects. Additionally, they facilitate access to public funding, grants, and incentives, while also promoting community engagement and awareness about renewable energy adoption.

Technical Agencies and Entities, including public operators, Energy Service Companies (ESCOs), universities, and research institutions, contribute their expertise to the design, implementation, and optimization of REC projects. They support feasibility studies, technical assessments, and energy audits, ensuring that communities adopt the most efficient and sustainable energy solutions. ESCOs play a particularly significant role in financing and executing renewable energy projects, while research institutions drive innovation in smart grids, energy storage, and digitalization.

Producers & Manufacturer, especially those involved in equipment, components, and technology for renewable energy systems (such as solar panels, inverters, wind turbines, biomass units, heat pumps, and storage systems), play a critical enabling role in the development and scaling of RECs. By supplying the necessary hardware, they are integral to building the infrastructure that allows communities to generate, store, and manage renewable energy locally.

Civil and Sectorial Associations, including research institutions, cooperatives, and sectorial organizations, act as key advocates for RECs. They work to influence policy changes that support decentralized energy production and help communities access knowledge, best practices, and capacity-building programs. By serving as intermediaries between citizens, institutions, and businesses, they strengthen participation in RECs and enhance cooperation among stakeholders.

Residential Users are at the heart of RECs, actively participating as energy producers, consumers, or prosumers. By generating and sharing renewable energy, they benefit from lower energy costs, greater energy security, and reduced dependence on traditional utility providers. Their involvement in decision-making and governance ensures democratic participation in the energy transition, strengthening the resilience and sustainability of RECs.

Business Entities, such as small and medium-sized enterprises, commercial enterprises, industrial players, and agricultural businesses, contribute to RECs as prosumers, by both producing and consuming renewable energy. By integrating renewables into their operations, they can optimize energy use and create shared economic benefits within the community. Additionally, they provide demand-side flexibility by adjusting energy consumption based on availability and pricing mechanisms established within RECs. Relevant note is that the current Italian regulations explicitly exclude large enterprises and electricity producers from becoming members of RECs, in order to preserve their local, collaborative, and non-profit nature.

According to the REC stakeholder consultation, surveyed organizations primarily serve residential customers (27%), with additional mentions of households, businesses, and public administrations (9% each). Ownership structures vary as follows: 18% indicated private ownership, 9% reported a public-private mix, 9% described cooperative ownership, and 9% indicated other models, the remaining ones do not respond.

Core business activities included renewable energy production (27%) and project management (9%). Other activities mentioned were clean energy research, self-consumption promotion, and solar PV development. Resource bases varied across respondents, with assets (9%), EU project funds and self-financing (9%), social contributions (9%), and volunteer labor (9%) cited. Communication channels favored online platforms (36%), followed by phone and direct contact (9% each).

Staffing structures reflected a small-scale, flexible sector: 27% reported no permanent staff, 9% relied on external collaborators, and another 9% employed a small core team (five staff members). Main cost streams included renewable plant development, legal and accounting services, and administrative expenses, each cited by approximately 9% of respondents. Revenue streams were equally diverse: electricity sales, shared incentives, EU project funding, social donations, and GSE contributions each received similar attention.

In terms of operational scale, among those who responded, 27% described their activities as local, 18% as regional, and 9% as national. However, a significant 45% did not provide quantitative information.

A strong willingness to support new technologies emerged: 64% of respondents expressed a high or very high willingness to engage in advocacy activities promoting innovations such as SUPREMAS. Only 18% showed low interest, while another 18% did not respond. This demonstrates a favorable environment for advocacy initiatives aimed at scaling decentralized renewable energy solutions.

A remarkable 73% of participants expressed a high or very high willingness to participate in community energy projects to reduce energy bills, highlighting a fertile ground for REC growth and biosyngas integration.

Regarding key institutions active in the field, 63.6% of respondents identified major players, with mentions including GSE, ENEA, ARERA, regional agencies, municipalities, and cooperatives, each cited by 9% of respondents.
As for the not-for-profit sector, 45.5% of participants listed relevant organizations. Among them, Legambiente, Legacoop, APPA, AVEBiom, Electra Energy Cooperative, The Green Tank, and Caritas were each cited by 9% of respondents, reflecting a highly diversified ecosystem. Nonetheless, 55% did not provide responses, indicating a partial knowledge gap in the sector mapping.

Coordination among sectoral stakeholders appears to be limited: 45% of respondents reported insufficient coordination, and an additional 18% indicated only limited awareness of coordination activities. Only 9% perceived existing efforts as sufficient.

When exploring the barriers to better collaboration, participants cited diverse and conflicting objectives (10%), market-driven approaches (10%), sectoral rivalries (10%), underfunded coordination bodies (10%), and the lack of technical coordination platforms (10%) as primary obstacles.

3.2 Drivers

▪ Biosyngas[33]

The biosyngas market is propelled by several key drivers that facilitate its growth and adoption across Europe, such as:

- **Advanced Catalytic Processes**: These processes enhance the conversion efficiency of biomass into syngas, allowing for higher yields and better quality of the produced gas[12].
- **Integrated Biorefineries**: These facilities enable the simultaneous production of multiple bio-based products, including biosyngas, biofuels, and biochemicals, thus maximizing resource utilization and economic viability[34].
- **Modular and Movable Syngas Production Units**: Initiatives like SUPREMAS promote the development of compact, transportable units that can be easily deployed in various locations, making biosyngas production more accessible and adaptable to local needs[35].
- **Environmental Awareness**: Increasing public concern about climate change and environmental degradation is pushing consumers and businesses to seek cleaner energy sources.
- **Energy Independence**: The desire for energy security and independence from fossil fuel imports is motivating investments in renewable energy, including biosyngas.
- **Corporate Social Responsibility (CSR)**: Businesses are increasingly focusing on sustainability reporting and CSR initiatives, which drives the demand for renewable energy sources like biosyngas.

[33] Sub-section on biosyngas is extracted from SUPREMAS [D1.1] Syngas Decentralized Production Framework.
[34] https://www.europeanbiogas.eu/wp-content/uploads/2023/12/PR_EBA-Statistical-Report-2023.pdf
[35] https://www.europeanbiogas.eu/wp-content/uploads/2020/11/Biogas-Report-2020-EBA-Bioenergy-Europe.pdf

▪ REC

As stated in the 2024 report by the European Commission[36], development and operation of RECs is facilitated by key cross-cutting action drivers across Europe, irrespective of their specific activities. These drivers address systemic challenges and contribute to enabling frameworks across Member States.

Cross-Cutting Drivers

- **Dedicated finance arrangements to support investment.** National and local public funding schemes are crucial in supporting RECs during early-stage investments, particularly in feasibility and planning. Programs like Scotland's CARES offer grants for feasibility studies, transitioning to loans if projects proceed. Similar models exist in the Netherlands, Denmark, Germany, and Ireland. These public funds can be combined with alternative financing sources, such as equity financing, bank loans, crowd investment, and bonds, to create a diversified financial strategy for EC projects.
- **Tools to promote awareness, access to expertise, and trust building.** Governments and civil society organizations have established models to raise awareness and provide technical guidance for RECs. One-Stop-Shops (OSS) offer centralized support services, including consultations, legal and financial advice, and assistance with permits. Examples include Austria's Coordination Office, Belgium's Brugel, and Portugal's agencies ADENE and DGEG. Local bodies like North Rhine-Westphalia's NRW.Energy4Climate and city-level support in Gent, Valencia, and Barcelona also play significant roles. However, many local authorities face capacity limitations and may delegate responsibilities to civil society actors, such as Scotland's CARES managed by Local Energy Scotland. Digital tools and comparison platforms, like Flanders' VREG, enhance transparency and build trust.
- **Facilitating access for vulnerable households.** Expanding inclusivity in RECs involves enabling access for vulnerable and low-income households. Initiatives include reduced share prices, municipal pre-financing of community shares, and allocating a portion of self-generated energy to low-income households. Models like Leuven's ECoOB and Mechelen's Klimaan integrate co-ownership structures. Partnerships with social services, such as Scotland's ALIenergy and France's Enercoop-led Énergie Solidaire fund, support fuel-poor households. Policy measures in Lithuania and Sicily mandate inclusion of vulnerable consumers in RECs to qualify for funding.

Drivers to Renewable Energy Production by RECs

- **Policy objectives, goals or targets for RECs.** Setting policy objectives and targets for RECs promotes community ownership in renewable energy production. Scotland aims for 2 GW of community or locally owned capacity by 2030. Italy's Recovery and Resilience Plan targets 2 GW from RECs by 2026. France plans for 1,000 locally governed community projects by 2028. The EU's Solar Strategy calls for at least one REC in every municipality over 10,000 inhabitants by 2025. Regional targets, like Valencia's goal of 100 RECs by 2030, further support this initiative. Some governments embed community participation obligations into large-scale projects, such as the Netherlands' encouragement of 50% citizen ownership in new onshore wind and solar projects.
- **Providing space through public tenders.** Public procurement procedures are adapted to support citizen participation in renewable energy projects. Belgian municipalities like Eeklo include social criteria in tenders, requiring citizen ownership shares and community engagement plans. Flanders mandates 50% citizen investment in renewable projects on municipal land. France's Strasbourg Metropolis prioritizes citizen-financed PV installations in public tenders. Spain's cooperative COMPTEM-Enercoop secured municipal contracts emphasizing social co-benefits. Despite these examples, many municipalities remain cautious due to complex legal frameworks. The EU's updated Renewable Energy Directive aims to support the integration of social objectives into procurement.
- **Integrating RECs into the Design of Renewables Support Schemes.** EU Member States have adapted renewable energy support schemes to foster EC participation. Germany exempts citizen energy companies owning solar PV systems up to 6 MW or wind turbines up to 18 MW from tenders, provided they meet citizen control requirements. Ireland's RESS scheme includes ring-fenced tenders for RECs between 1 MW and 5 MW, requiring full ownership by RECs and reinvestment into the community. Austria offers market premiums for energy sharing initiatives, encouraging self-consumption and storage integration. However,

[36] EC Directorate-General for Energy (2024). *Energy communities repository. Barriers and action drivers for the development of different activities by renewable and citizen energy communities*

stakeholders express concerns that such schemes may disincentivize complementary technologies like wind or biogas.

- **Measures to facilitate a grid connection. RECs** often face barriers in accessing the electricity grid due to high connection costs and complex procedures. Denmark socializes grid connection costs, passing limited costs to developers. Flexible connection agreements and zero-interest loans improve planning security. Ireland reserves specific grid access slots for RECs under its RESS scheme. Lithuania reserved 2 GW of grid capacity for communities and prosumers. Spain proposed a 5% grid capacity reservation for RECs. Challenges include potential misuse by for-profit entities and fragmentation if grid capacity is divided into small allocations. Transparency and proactive planning with DSOs are essential for integrated solutions.

Drivers for energy sharing by RECs

- **Creating a clear legal distinction between RECs and energy sharing.** Establishing a clear legal distinction between RECs and energy sharing activities is vital. In France, Belgium, and Greece, energy sharing through mechanisms like virtual net metering was possible before the Clean Energy Package. Belgium's Brussels-Capital Region distinguishes governance rules for RECs from energy sharing regulations. The Netherlands' draft energy legislation clarifies that RECs can engage in all energy market activities. Germany defines proximity for citizen energy companies to qualify for tender exemptions. Greece restructured its framework, separating proximity requirements for virtual net metering and RECs. Tailoring geographical limits based on technical constraints and social criteria supports effective energy sharing deployment.
- **Clarifying roles and duties for system operators in facilitating energy sharing.** DSOs are pivotal in facilitating energy sharing by managing grid access, administrative processes, data handling, and infrastructure support. Initiatives like Austria's and Portugal's guidance manuals, and Spain's Elecsum platform, aid citizens in participating in local energy initiatives. Transparency is enhanced by publishing grid information and simplifying registration procedures. In some countries, DSOs face financial penalties for delays. Robust IT infrastructure, including smart meters and real-time data communication, is essential. Austria mandates smart meter installation within two months upon request, while the Czech Republic has established a joint entity for data management and interoperability.
- **Providing flexibility to RECs in the design and scope of energy sharing arrangements.** Flexibility allows RECs to tailor operations to local needs. Communities can define energy allocation methods, such as fixed ratios or dynamic sharing keys. Portugal permits communities to choose their calculation methods, while Austria and Italy are exploring options for members to join multiple communities and adjust sharing parameters regularly. Geographical eligibility criteria are being expanded in countries like France and Italy to include more participants. Regular monitoring, as seen in Austria's quarterly DSO reports, supports adaptive policymaking.
- **Ensure fair cooperation between the supplier of residual energy and RECs.**
  - Fair collaboration between RECs and residual energy suppliers is crucial. Regulations, like the Netherlands' draft 2022 Energy Law, aim to prevent punitive charges against EC participants. Suppliers are encouraged to enhance forecasting tools to better predict consumption and production patterns. Operational tasks, such as calculating shared energy, are better handled by neutral entities like DSOs to avoid conflicts of interest. Balancing responsibilities for smaller projects can be minimized or delegated, with practices varying across countries.
- **Allowing for the use of third party service providers.** Some Member States allow RECs to collaborate with third-party service providers for tasks like metering, data exchange, and surplus energy sales. Portugal designates a "management entity" for overseeing technical and commercial aspects, while in Luxembourg, DSOs step in if a community opts out of managing this role. While outsourcing can streamline processes, it's essential to maintain appropriate auditing and oversight to ensure member control and prevent misuse.
- **Cost-reflective volumetric network charges.** Equitable contribution to grid infrastructure costs is vital. While local energy sharing can reduce strain on higher-voltage grids, tariff structures must ensure fairness. Austria's Grid Usage Ordinance offers reduced network charges for local RECs, with reductions up to 57% at local grid levels. However, exemptions from broader grid costs could shift the financial burden to non-participating users, raising equity concerns.
- **Investment support and remuneration for excess production.** To promote energy sharing, several EU Member States provide financial instruments supporting renewable energy installations and storage. For instance, Slovenia offers grants for self-consumption and storage, while Italy's National Recovery and Resilience Plan (PNRR) provides interest-free grants covering up to 100% of eligible costs. Mechanisms for

remunerating excess electricity include feed-in tariffs in France, market price purchases by Italy's GSE, net billing schemes in Spain, and guaranteed purchase schemes in Slovenia.

Action drivers for RECs supply

- **Exemption/simplification of regulation of electricity supply for RECs.** Complex regulatory requirements can hinder RECs from engaging in electricity supply. Some countries have introduced tailored frameworks to ease these burdens. The Netherlands' EDSEP experimental framework allowed cooperatives to operate without a supply license, influencing draft legislation for permanent exemptions. Ireland and Belgium offer limited supply licenses for small-scale suppliers. Regulatory flexibility also includes alternative compliance methods and support for capacity building.
- **Provision of supply-related services by other market actors. RECs** increasingly partner with established market actors for supply-related services, such as wholesale trading and balancing responsibilities. Mechanisms like "sleeving" allow commercial suppliers to deliver electricity from local renewable projects directly to community members. Platforms like the Netherlands' ENTRANCE facilitate direct electricity exchange between producers and consumers, enhancing autonomy for RECs. Legislative frameworks in regions like California and the UK are evolving to mandate support for community-based energy supply.

Action drivers of flexibility by RECs

- **Dynamic and Time-of-Use Tariffs.** Dynamic and time-of-use tariffs can help RECs shift consumption to off-peak hours, optimizing energy use and reducing costs. In Spain, all electricity contracts below 15 kW must apply a three-tiered grid tariff depending on the time of day, providing a direct price signal that encourages load shifting and improves grid efficiency.
- **Access to Relevant ICT Tools.** RECs are developing ICT tools to support energy sharing and flexibility services. These include open-source platforms such as The Mobility Factory and Carbon Co-op's integration with Home Assistant in the UK. In Spain, Som Energia is co-developing a multi-service platform for RECs with local authority support. Open-source software allows communities to share resources and reduce costs while maintaining operational autonomy.
- **Allowing Aggregation of Smaller Consumer Loads.** Aggregating smaller loads enables RECs to access flexibility markets. Spain allows aggregation for generation, demand, or storage with a 1 MW threshold, creating new opportunities for community engagement. In the UK, the National Grid's Demand Flexibility Service pays consumers to reduce demand during peak times—offering financial incentives that energy cooperatives can harness by acting as aggregators.
- **Use of Regulatory Sandboxes.** Regulatory sandboxes allow experimentation with innovative business models and technologies under real-world conditions but with relaxed regulatory constraints. For example, the Endona cooperative in the Netherlands used a sandbox to test local supply and flexibility services in collaboration with DSOs and TSOs. These environments help regulators and innovators co-design effective regulatory frameworks.
- **Development of Local Flexibility Markets.** Local flexibility markets are emerging across Europe to better manage grid congestion and enhance system efficiency.
  - Examples include:
    - Piclo Flex (UK) – A DSO-oriented flexibility trading platform.
    - Enera (Germany) – A collaboration between power exchanges and grid operators.
    - GOPACS (Netherlands) – A congestion management platform run by national and regional grid operators.
    - NODES (Nordic countries) – A platform originally co-owned by Nord Pool and Agder Energi.

    These platforms vary in structure, integration with EU market sequences, third-party roles, product standardization, and the extent of TSO-DSO cooperation. Such diversity highlights the need for tailored solutions depending on regional contexts and market needs.

According to the REC stakeholder consultation, profitability and access to clean energy emerged as the primary drivers, mentioned by 64% of participants. The importance of financial considerations was further confirmed when participants were asked about the role of energy expenditure savings in deciding to join a REC. While 27% rated such savings as highly important, the majority (55%) considered them moderately important, and a smaller portion (9%) judged them slightly important. Only 18% deemed them unimportant.

In addition to economic motivations, social dimensions also play a critical role: 45% of stakeholders highlighted job creation and public acceptance as significant factors that could encourage adoption, while 27% stressed the importance of fostering strong relationships with citizens. Although less frequently mentioned, availability of resources and innovation were also recognized (by 9% each) as contributing elements to the success of renewable energy solutions.

Stakeholders also highlighted the expected social benefits linked to REC or waste-to-energy models. Environmental impact was the most frequently cited benefit, mentioned by 73% of respondents. Community resilience — the ability of local areas to respond to energy, economic, and social challenges — was emphasized by 55%, while 45% indicated that job creation and security are key expectations.

Finally, community engagement was identified as a central success factor for the adoption of new technologies. A strong majority of stakeholders rated community involvement in decision-making as highly important (55%), and another 18% considered it very highly important. This underscores that participatory approaches are not merely desirable, but are considered essential for the effective deployment and lasting acceptance of renewable energy technologies such as SUPREMAS.

3.3 Barriers

Biosyngas[37]

Despite the promising outlook for the biosyngas market, several barriers hinder its growth and widespread adoption, such as:

- **Competition from Alternative Technologies**: SUPREMAS should educate users on its benefits and functions to gain market traction. Clear communication, demos, pilot projects, and stakeholder engagement are key to building trust. Aligning with EU initiatives like the Green Deal and the circular economy can boost credibility and appeal.
- **Market Acceptance and Awareness:** SUPREMAS should educate users and build trust through demos and engagement to drive adoption. Aligning with EU green initiatives like the Green Deal enhances its credibility. By tackling challenges and showcasing strengths, SUPREMAS can lead in the waste-to-energy sector and support EU sustainability goals.
- **Financial and Investment Challenges:** high initial capital costs, infrastructure investment and funding complexity. Addressing these financial barriers is crucial for unlocking the market potential of biosyngas. Initiatives such as the REPowerEU Plan, which aims to mobilize €25 billion in private investments for the biomethane sector by 2030, are essential for overcoming these challenges[21].
- **Technological Limitations:** Feedstock variability, process efficiency, management of diverse feedstocks. Overcoming these technological limitations is essential for enhancing the competitiveness of biosyngas. Continued investment in research and development, as well as collaboration between industry and academia, is necessary to address these challenges.
- **Regulatory hurdles:** compliance with environmental regulations, permitting processes, lack of clear guidelines. streamlining regulatory processes and providing clear guidelines can facilitate market entry and growth. The European Biogas Association (EBA) advocates for coherent planning and faster permissions processes to encourage market and project developers to operate at a significantly faster pace.

REC

As stated in the 2024 report by the European Commission[38], the development of RECs in Europe faces multiple barriers that can be grouped into five main categories. Cross-cutting barriers impact all aspects of RECs, from legal definitions to financial and technical challenges. Barriers to renewable energy production relate to difficulties in securing sites, accessing support schemes, and connecting to the grid. Energy sharing faces regulatory uncertainty, technical limitations, and market interdependencies. Retail supply barriers stem from

[37] Sub-section on biosyngas is extracted from SUPREMAS [D1.1] Syngas Decentralized Production Framework.

[38] EC Directorate-General for Energy (2024). *Energy communities repository. Barriers and action drivers for the development of different activities by renewable and citizen energy communities*

complex licensing, market access difficulties, and restrictions on direct sales. Finally, barriers to flexibility provision highlight challenges in market participation, data access, and regulatory constraints.

Relevant barrier is that the current Italian regulations explicitly exclude large enterprises and electricity producers from becoming members of RECs, in order to preserve their local, collaborative, and non-profit nature.

Cross-Cutting Barriers

- **Difficulties designing and monitoring a clear and uniform legal definition for RECs.** The lack of a consistent national legal definition for RECs creates legal uncertainty, making it difficult for potential participants to invest and engage. Governance principles such as proximity, autonomy, and social and environmental benefits are open to multiple interpretations, complicating their implementation at the national level. The distinction between RECs and Citizen Energy Communities (CECs) remains unclear in many countries, leading to inconsistent regulations. This ambiguity also allows commercial actors to take advantage of broad definitions, potentially distorting the intended purpose of energy communities.
- **Lack of certainty, predictability, and accessibility of public and private financing.** RECs face significant financial uncertainty due to frequent regulatory changes and unstable public support schemes. Accessing financing, particularly in the early stages of project development, is a major challenge, as banks are often reluctant to lend to RECs due to their cooperative or non-profit structure. Many RECs struggle to secure loans, as financial institutions view them as high-risk investments. Additionally, public funding mechanisms at the national and EU level are often inaccessible or insufficient to bridge the financing gap, making it difficult for RECs to scale their operations.
- **Lack of awareness, trust, and access to technical expertise.** There is still limited public awareness about the role and benefits of RECs, particularly in regions where the concept is new. Many citizens, businesses, and local authorities lack the necessary knowledge to engage with or support RECs. The complexity of administrative procedures and licensing further complicates the participation of RECs in the energy market. In some countries, cultural scepticism towards cooperatives also reduces trust in these initiatives. Without sufficient technical support and expertise, RECs struggle to navigate regulatory requirements and implement successful projects.
- **Lack of accessibility for energy-poor and vulnerable households.** Despite the potential of RECs to address energy poverty, participation remains out of reach for many vulnerable households. High financial entry costs and investment requirements prevent low-income individuals from becoming members. In some cases, receiving financial benefits from a REC can impact a household's eligibility for social welfare programs, further discouraging participation. There is also a lack of targeted policies that integrate energy-poor households into RECs, and many energy initiatives lack the knowledge and expertise needed to engage with these groups effectively.

Barriers to Renewable Energy Production by RECs

- **Lack of sites for production.** Finding suitable locations for renewable energy projects is a significant challenge for RECs. Private landowners and public authorities often prioritize large-scale commercial developments over community-led initiatives. There is also a lack of integration of RECs into local and national spatial planning policies, making it difficult for RECs to secure the necessary land or rooftops for renewable energy installations.
- **Auction-based procedures for accessing national renewables support schemes.** Many national renewable energy support schemes have shifted from fixed feed-in tariffs to auction-based mechanisms, which favor larger, commercially driven projects. RECs, which often lack the financial resources and administrative capacity to compete in auctions, struggle to secure funding for their projects. Some countries have introduced exemptions or dedicated tenders for RECs, but these remain limited, leaving most energy communities at a disadvantage.
- **Difficulties obtaining a grid connection.** RECs often face complex and costly procedures when trying to connect their projects to the grid. Limited grid capacity and non-transparent connection rules make it difficult for RECs to secure access. In many cases, RECs are unable to compete with larger commercial actors for grid space, which is often allocated on a first-come, first-served basis.

Barriers to Energy Sharing by RECs

- **Lack of distinction between RECs, active customers, and energy sharing.** The legal and regulatory framework for energy sharing remains unclear in many Member States, making it difficult for RECs to differentiate their role from individual self-consumers or commercial third-party energy-sharing initiatives. This uncertainty hinders the development of community-led energy-sharing models.
- **Lack of clear duties and roles of network operators.** RECs often struggle with unclear regulations regarding the responsibilities of Distribution System Operators (DSOs) in facilitating energy sharing. Many DSOs lack transparent procedures for registering energy-sharing projects, and the necessary IT infrastructure for data collection and validation is often underdeveloped.
- **Limitations for how energy sharing can be arranged.** Many Member States impose geographical and technical restrictions on energy sharing, limiting the feasibility of such initiatives. In some cases, regulatory frameworks require all participants to have the same energy supplier, reducing flexibility for RECs.
- **Interdependencies with energy suppliers.** Traditional energy suppliers sometimes impose high administrative fees or create delays in processing shared energy transactions, making energy sharing more costly and inefficient. Some suppliers also resist taking on balancing responsibilities for RECs, adding another layer of complexity to energy-sharing arrangements.
- **Limited sustainable remuneration pathways for excess production and knock-on effects for access to financing.** In several Member States, RECs cannot receive financial compensation for excess energy production, making it harder to establish viable business models. Restrictions on selling surplus energy further limit financing options and discourage investment in energy-sharing projects.

Barriers to Retail Supply by RECs

- **Obtaining a supplier licence.** The process of acquiring a supplier licence is often designed for large energy companies and imposes high administrative and financial burdens on RECs. Many RECs find it difficult to comply with these complex licensing requirements.
- **Operating as a supplier.** Once licensed, community energy suppliers face additional challenges in the form of high collateral requirements and difficulties accessing wholesale energy markets. Many small suppliers lack the ability to hedge against price fluctuations, making their operations financially risky, especially during energy crises.
- **Selling production directly through PPAs.** Some national regulations prevent RECs from selling their generated electricity directly to their members or third parties through Power Purchase Agreements (PPAs). These restrictions limit their ability to establish direct, community-based energy supply models.

Barriers to Flexibility Provision by RECs

- **Barriers from the perspectives of RECs.** RECs often lack the necessary scale, financial resources, and technical expertise to provide flexibility services. Many RECs do not have the infrastructure required to optimize energy consumption and generation in response to price signals.
- **Summary of regulatory and market barriers.** The regulatory framework for flexibility markets is still evolving, with many rules favoring large aggregators over smaller participants. RECs face difficulties accessing real-time data and smart meter technologies, which are essential for participating in demand-side response markets. Furthermore, existing market rules often set high minimum bid thresholds, making it difficult for small-scale community initiatives to compete.

The stakeholder consultation under the SUPREMAS project revealed several key barriers that could hinder the development and scaling of RECs. Overall, legal, financial, and technical challenges emerged as the dominant obstacles across the different sectors analyzed.

According to the REC stakeholder consultation, financial barriers were cited by 45% of participants, underlining the ongoing challenge of securing sufficient investment for community energy initiatives. However, legal obstacles were even more prominent, mentioned by 64% of respondents, positioning regulatory complexity as the single greatest impediment to REC development. Technical difficulties, although less prominent, were still recognized by 27% of stakeholders. Additionally, 18% identified a combination of legal, technical, and financial issues acting together to constrain progress, emphasizing the interlinked nature of the barriers faced.

When asked to rank the relevance of different obstacle categories, legal aspects received an average score of 3.4 out of 4, with 75% of respondents assigning them a score of either 3 or 4, confirming their critical importance.

Financial aspects also ranked high, with 50% assigning a rating of 3 and 27% a rating of 4, highlighting that financial hurdles are perceived as highly influential in determining project viability. Technical aspects, by contrast, scored lower, with an average of 2.3, and a high non-response rate (64%), suggesting either limited experience or lower immediate concern compared to financial and legal factors.
On the regulatory front, permitting emerged overwhelmingly as the major hurdle across different sectors. Specifically, 55% of respondents pointed to permitting issues as the main regulatory barrier for RECs, followed by grid connection problems (27%) and taxation challenges (18%).

Specific to biomass projects, the main barriers included resource availability and management (cited by 27%), followed by environmental concerns and challenges related to supply chain development (18%). Initial community distrust, waste management issues, infrastructure limitations, and permitting obstacles were each noted by 9% of respondents, indicating a wide variety of interconnected challenges.

Regarding movable or temporary energy systems, regulatory and permitting barriers were highlighted again, cited by 27% of participants. Resource availability and product end-use concerns were equally cited at 27%, while reliability, legislative frameworks, economic functionality, and biomass supply chain weaknesses each accounted for a smaller share (9% respectively).

Thermal energy projects also face unique barriers: cost and legislation were cited by 18% of respondents each, while impacts related to distribution network management, lack of local demand, and limited public or institutional familiarity with thermal energy (compared to electricity) were each mentioned by 9%.

When focusing specifically on waste-to-energy based RECs, 73% of stakeholders identified permitting as the top obstacle. In addition, 45% noted challenges related to waste management regulations, and 36% cited the absence of supportive policies. Safety concerns were raised by 18%, indicating that public and institutional perceptions of risk still play a role in slowing down adoption.

Overall, the consultation highlighted that the main obstacles to REC operation are multifaceted: start-up costs, limited technical expertise, insufficient training in energy management, community acceptance hurdles, and particularly complex or unclear regulatory environments.

Finally, in terms of external support needs, respondents indicated that financial, legal, regulatory, and marketing assistance are equally critical (9% each), underscoring the necessity of integrated, multidisciplinary support structures that can help RECs, waste-to-energy systems, and innovative projects like SUPREMAS overcome barriers and reach their full transformative potential.

3.4 Competitive strategies and advantages

Biosyngas[39]

Pricing strategies in the biosyngas market vary significantly among competitors. Key approaches include:

- **Competitive Pricing**: Some companies adopt competitive pricing to attract new customers and gain market share. This strategy is often used by emerging startups looking to establish themselves in the market. According to the EBA, competitive pricing is crucial for new entrants to penetrate the market and build a customer base.
- **Premium Pricing**: Established players with advanced, high-efficiency technologies may opt for premium pricing. This approach targets customers willing to pay more for superior performance and reliability. The EBA notes that premium pricing is often justified by the higher quality and efficiency of the technologies offered.
- **Government Subsidies and Incentives**: Pricing is also influenced by government subsidies and incentives for renewable energy projects. These financial supports can make biosyngas more affordable and competitive than traditional fossil fuels. The European Commission's REPowerEU plan provides substantial subsidies to promote the adoption of renewable gases, including biosyngas. Local policies and incentives will be a key trigger for opening future markets for the SUPREMAS technology, SUPREMAS partners like

[39] Sub-section on biosyngas is extracted from SUPREMAS [D1.1] Syngas Decentralized Production Framework.

RESET are already involved in national funding schemes connected with REPowerEU and Post COVID recovery.

- REC

The creation of RECs leverages on a blend of environmental, technical, economic, and social competitive advantages[40], as described hereafter.

- **Environmental drivers.** From an environmental perspective, RECs facilitate the reduction of CO2 emissions by promoting the use of renewable energy sources. By installing small and medium-sized renewable energy plants close to consumers, these communities help decrease the energy lost during transportation and minimize overall energy dispersion.
- **Technological drivers.** the self-consumption model within RECs enhances grid efficiency by reducing transmission and distribution losses and mitigating the imbalances between energy supply and demand. Incentive schemes, which reward the sharing of locally produced energy among community members, further bolster these technical benefits.
- **Economical drivers.** RECs offer the potential for significant cost savings on energy bills by redistributing incentives among members according to internally established rules. Moreover, they stimulate economic development by generating added value and creating job opportunities, particularly in the installation and maintenance sectors of renewable energy technologies. Although the current manufacturing landscape in Italy faces challenges, the growing demand spurred by RECs could drive further industrial development and economic growth.
- **Social drivers.** RECs represent a form of social innovation that transforms energy consumers into active participants in the energy market. By engaging citizens in energy production and management, these communities help build local capacity and raise awareness about energy and environmental issues. This process not only fosters a sense of ownership and empowerment but also makes energy a common good, accessible to all—especially benefiting vulnerable and marginalized groups. Furthermore, the active participation of local governments in RECs strengthens the relationship between citizens and public administrations, creating a foundation for collaborative local development and a just energy transition.

[40] CARIPLO (2024) G*uida CER impatto sociale. pp.16-19.*

4 END USE APPLICATION MARKETS

- Biosyngas[41]

The advancement of biosyngas technology marks a major step forward in achieving the European Union's climate and energy targets. As a renewable and flexible energy source, biosyngas plays a crucial role in the shift toward a sustainable and circular economy. It is produced by gasifying biomass and various waste materials, resulting in a gas mixture primarily composed of hydrogen, carbon monoxide, and small amounts of carbon dioxide.

Biosyngas has wide-ranging applications across sectors such as energy production, industrial processes, and emerging clean technologies. Its versatility allows it to address both energy demands and waste management challenges by converting feedstocks like agricultural residues, municipal solid waste, and industrial by-products into valuable energy and chemical products.

This dual benefit – meeting energy needs while enhancing resource efficiency – positions biosyngas as a key contributor to environmental sustainability.

- REC

RECs play a crucial role in decentralizing energy production, reducing energy costs and promoting sustainability. By optimizing energy use and fostering local resilience, RECs serve as a key driver of a cleaner, more sustainable energy future. This chapter delves into the primary applications across industrial, non-industrial, and future applications.

In industrial sectors, RECs enable self-consumption through renewable generation, green hydrogen production, smart grids, waste heat recovery, and electrification of manufacturing processes. They also open opportunities for carbon credit sales and peer-to-peer energy trading.

Non-industrial applications extend to residential, commercial, and municipal sectors, where RECs enhance energy savings, storage, electric mobility, and public infrastructure sustainability while addressing energy poverty.

Looking ahead, future applications such as Thermal RECs will integrate renewable heating and cooling, further advancing the transition to a low-carbon economy.

4.1 Industrial applications

- Biosyngas[42]

Biosyngas technology offers a multitude of industrial applications, significantly contributing to the decarbonization and sustainability goals of the European Union. By leveraging biosyngas, industries can reduce their reliance on fossil fuels, lower greenhouse gas emissions, and enhance energy efficiency. This section explores the diverse industrial uses of biosyngas, emphasizing its role in the energy sector, chemical production, and other high-temperature industrial processes. The integration of biosyngas into industrial operations not only supports environmental sustainability but also promotes economic resilience by utilizing local waste resources and reducing dependency on imported fuels[12].

- **Manufacturing and Chemical Industry:** The manufacturing and chemical industries are increasingly adopting biosyngas as a feedstock for various processes. Its application in these sectors not only supports sustainability goals but also enhances the economic viability of operations. Notable applications include (i) Production of Chemicals, (ii) Synthetic Fuels, (iii) Biochar Production. **Market Focus:** Feedstock for producing methanol, ammonia, and other chemicals traditionally derived from fossil fuels. **Opportunities:** Green hydrogen and ammonia production using syngas as a precursor.
- **Transportation Sector: Market Focus:** Use of syngas to produce synthetic fuels (e.g., methanol, DME, hydrogen) as low-carbon alternatives for aviation, maritime, and heavy-duty transport. **Opportunities:** Sustainable aviation fuel (SAF) and renewable diesel markets are experiencing significant growth.

[41] Sub-section on biosyngas is extracted from SUPREMAS [D1.1] Syngas Decentralized Production Framework.
[42] Sub-section on biosyngas is extracted from SUPREMAS [D1.1] Syngas Decentralized Production Framework.

- **Waste Management: Market Focus:** Municipalities and industries looking to manage organic waste sustainably. **Opportunities:** Syngas technology can be used to process waste-to-energy, particularly in regions with high waste generation and strict landfill regulations.
- **Agriculture: Market Focus:** Conversion of agricultural residues (e.g., straw, husks, manure) into biosyngas for on-farm energy use. **Opportunities:** Decarbonizing the agricultural sector by reusing waste streams.

REC

Industries, particularly small and medium-sized enterprises (SMEs), are among the primary beneficiaries of RECs due to their high energy demands and capacity to integrate innovative energy solutions. Their involvement helps to diversify the community's energy profile, improve local energy resilience, and reduce operational costs through shared renewable resources. While EU regulations restrict participation to SMEs (excluding large enterprises) to ensure community focus and fair governance, these businesses can contribute technical expertise, investment capacity, and infrastructure, making them valuable partners in achieving local sustainability goals. However, enterprises whose primary commercial activity is energy production or supply are generally restricted from participating as controlling members, in order to preserve the community-driven, non-profit nature of RECs and ensure democratic governance. Below are some key industrial applications of RECs:

Self-Consumption and Cost Savings. Firms and Industrial districts within a REC can produce their own electricity using renewable energy systems. By doing so, they reduce dependence on grid electricity and lower operational costs. Additionally, shared energy storage solutions, such as batteries or hydrogen storage, enable more efficient energy use by mitigating fluctuations in supply and demand. This ensures a stable energy supply and helps industries avoid peak energy charges, further contributing to economic sustainability.

Green Hydrogen Production. Participation in a REC can facilitate the adoption of green hydrogen production technologies through electrolysis powered by renewable energy systems. This application is particularly beneficial for industries with high carbon footprints, such as steel production, chemicals, and heavy transport. By integrating hydrogen production within the REC, industrial members can secure a steady supply of clean energy for decarbonizing critical processes. The availability of green hydrogen helps industries transition towards sustainable energy models, reducing their environmental impact while improving energy security.

Smart Grid and Demand Response. The integration of IoT-enabled smart grids and advanced metering systems within RECs allows industries to optimize their energy usage dynamically. These smart systems enable demand-side management strategies, allowing industries to shift non-critical operations to periods of high renewable energy generation. This not only reduces energy costs but also minimizes stress on the grid, improving overall system efficiency. Through smart grid solutions, industries can better align energy consumption with production, reducing wastage and enhancing grid stability.

Waste Heat Recovery and Circular Energy Use. Many industrial processes generate significant amounts of waste heat, which can be recycled within the REC for district heating or other industrial applications. By capturing and reusing waste heat, industries can enhance their overall energy efficiency and contribute to circular economy models. This approach minimizes energy losses and reduces the need for additional energy input, making better use of available resources while lowering operational costs. Circular energy use also supports sustainability goals by maximizing energy recovery and reducing emissions.

Electrification of Industrial Processes. Industries reliant on high-temperature processes, such as cement, glass, and aluminium manufacturing, can transition from fossil fuels to renewable electricity or hydrogen-based solutions within a REC. The adoption of electrification strategies helps industries reduce their carbon footprint while maintaining productivity. Additionally, RECs support e-mobility by providing charging infrastructure for electric industrial vehicles and logistics fleets. This shift reduces emissions from transportation, contributing to cleaner and more sustainable industrial operations.

Sale of Carbon Credits from RECs. RECs offer industries an opportunity to monetize their carbon emission reductions by selling carbon credits. These credits can be traded under regulatory frameworks such as the EU Emissions Trading System (EU ETS) or in voluntary carbon markets. By participating in carbon credit trading, industries within RECs can generate additional revenue while incentivizing cleaner energy practices. This model supports industries in meeting their sustainability targets while aligning with global efforts to reduce greenhouse gas emissions.

In conclusion, industrial applications of RECs present a transformative opportunity for businesses to enhance their energy efficiency, reduce costs, and contribute to sustainability goals. By leveraging renewable energy solutions, smart grid technologies, circular energy practices, and carbon credit trading, industries can position themselves at the forefront of the energy transition while securing long-term economic and environmental benefits.

4.2 Non-industrial applications

Biosyngas[43]

The potential of biosyngas extends beyond traditional applications, paving the way for innovative uses in emerging sectors. Cutting-edge applications of biosyngas are focused on its role in renewable energy integration, sustainable mobility solutions, waste management, energy security, and greenhouse gas emissions.

Main **Renewable Energy Integration** are the following:

- **Biomass-to-Energy Systems**:
- **Grid Stability**

Main **Sustainable Mobility Solutions** are the following:

- **Biofuels for Transportation**
- **Hydrogen Production**

REC

Beyond industrial applications, RECs play a crucial role in residential, commercial, and municipal sectors, helping local communities transition to cleaner and more sustainable energy systems.

- **Residential Self-Consumption.** Households and small businesses within a REC benefit from locally produced renewable energy, reducing dependency on traditional electricity suppliers and lowering energy bills. By leveraging rooftop solar panels and small-scale wind or biomass systems, these members gain greater energy autonomy while contributing to overall grid resilience.
- **Grid Stability Improvements.** RECs can enhance grid stability as they allow energy surpluses to be efficiently distributed within the community, preventing energy losses and optimizing the use of available resources. RECs also provide greater flexibility in energy distribution, allowing energy to be directed where it is most needed at any given time. Moreover, power peak shaving strategies within RECs help households and firms avoid excessive electricity costs by balancing loads and reducing pressure on the grid during peak demand periods. Additionally, shared battery storage can improve energy reliability, ensuring continuous power availability even when renewable generation fluctuates. This reduces the impact of intermittency and makes energy consumption more predictable.
- **Public Sector integration into energy transition.** Municipalities can join RECs to power public infrastructure, including street lighting, schools, hospitals, and public transportation, with locally produced renewable energy. This approach helps reduce municipal energy costs and emissions, supporting national climate goals. By integrating RECs into public energy policies, local governments can lead by example, demonstrating the feasibility and benefits of community-led energy transition.
- **Energy Poverty Mitigation.** By lowering energy costs and redistributing benefits, RECs can help vulnerable communities gain access to affordable, clean energy. Socially inclusive RECs ensure that low-income households benefit from energy savings and reduced dependence on volatile fossil fuel markets. This not only reduces energy poverty but also strengthens community resilience, fostering equitable access to sustainable energy solutions.
- **Electric Mobility and Public Charging Stations.** RECs can incentivize the adoption of EV charging stations powered by renewable energy, supporting the widespread diffusion of electric mobility for both personal and public transport. With transportation accounting for a significant portion of carbon emissions, charging infrastructure included in RECs plays a vital role in enabling cleaner urban mobility.

[43] Sub-section on biosyngas is extracted from SUPREMAS [D1.1] Syngas Decentralized Production Framework.

5 FUTURE POTENTIAL APPLICATIONS

Biosyngas[44]

The SUPREMAS project is strategically positioned to leverage the increasing demand for sustainable energy solutions, particularly through the innovative production of syngas from waste. Below are the identified market opportunities, the value proposition of SUPREMAS, and anticipated future trends that may influence the market landscape.

Main **Identification of Potential Applications** are the following:

- **Decentralized Energy Production**
- **Waste-to-Energy Solutions**

REC

As RECs continue to evolve, their applications can extend beyond electricity production to include thermal energy solutions. **Thermal Energy Communities (TECs)** represent the next stage in sustainable energy systems, leveraging renewable energy sources (RES) to optimize heating and cooling services. These communities facilitate efficient thermal energy management by integrating various innovative solutions that enhance energy efficiency, sustainability, and cost-effectiveness. Below are some of the key future applications of TECs:

- **Operation of a District Heating Network (DHN) with Renewable Energy Sources.** TECs can play a critical role in the operation of district heating networks (DHNs) powered by renewable energy sources such as biomass, solar thermal, and geothermal energy. By replacing fossil-fuel-based heating systems with RES-powered DHNs, TECs contribute to reducing carbon emissions and enhancing energy security. The decentralized nature of TECs allows for optimized thermal energy distribution, reducing heat losses and improving overall system efficiency.
- **Sale of Waste Heat to a District Heating Network.** Industrial facilities, data centers, and other energy-intensive operations generate significant amounts of waste heat that typically goes unused. TECs create a framework for capturing and redistributing this excess heat through a DHN. By monetizing waste heat, industries can generate additional revenue while contributing to energy conservation. This circular energy model enhances sustainability by maximizing the use of available resources and reducing the overall energy demand for heating purposes.
- **Balancing Thermal Demand through District Heating & Cooling Networks (DH&CNs).** Just as electricity grids require balancing mechanisms to manage demand fluctuations, thermal demand response is essential for stabilizing heating and cooling networks. TECs help balance the supply and demand of thermal energy by integrating real-time data and predictive analytics. By adjusting thermal loads in response to energy availability and demand patterns, TECs prevent inefficiencies, reduce peak loads, and improve system reliability. This flexibility is particularly valuable in urban areas where thermal energy needs vary significantly throughout the day and across seasons.
- **Heating and Cooling as a Service.** TECs introduce innovative heating and cooling as a service model, shifting from traditional ownership-based heating solutions to a subscription-based or pay-per-use model. Under this approach, users receive optimized heating and cooling without the need for individual system ownership or maintenance. TECs manage the infrastructure, ensuring efficiency and cost-effectiveness while reducing the financial burden on end-users. This model promotes the widespread adoption of sustainable heating and cooling technologies, particularly in residential and commercial buildings.
- **Power-to-Heat (P2H) and Heat-to-Power (H2P) Technologies.** Power-to-Heat (P2H) and Heat-to-Power (H2P) technologies enable the conversion between electrical and thermal energy, enhancing energy storage and flexibility:
  - **P2H technologies** convert excess renewable electricity into thermal energy, which can be stored in thermal reservoirs for later use. This helps stabilize the electricity grid by absorbing surplus renewable energy during peak production periods.
  - **H2P technologies** convert stored thermal energy back into electricity when demand is high, improving energy system resilience.

[44] Sub-section on biosyngas is extracted from SUPREMAS [D1.1] Syngas Decentralized Production Framework.

  - TECs leveraging these technologies can optimize the use of intermittent renewable energy sources, such as wind and solar power, while maintaining efficient heating and cooling services.
- **Building Energy Management and Optimization.** TECs enable advanced building energy management systems that integrate thermal comfort, system optimization, and electricity consumption control. Smart control systems use real-time data, IoT sensors, and AI algorithms to optimize heating, cooling, and energy use based on occupancy patterns and environmental conditions. This approach ensures maximum comfort while minimizing energy waste. Furthermore, demand-side flexibility allows buildings to interact dynamically with the TEC, adjusting energy consumption in response to supply fluctuations and grid conditions.

In conclusion, the inclusion of Thermal Energy Communities within the RECs Panorama marks a significant step toward a more integrated and sustainable energy future. By leveraging district heating networks, waste heat utilization, demand response strategies, and advanced energy management technologies, TECs provide a holistic approach to heating and cooling. These future applications will enhance energy efficiency, reduce greenhouse gas emissions, and create new economic opportunities, positioning TECs as a key driver of the global energy transition.

6 MARKET STRATEGIES FOR RECS

RECs are a cornerstone of Europe's strategy to democratize the energy system, foster local empowerment, and accelerate the green transition. As decentralized entities governed by citizens, cooperatives, or municipalities, RECs are uniquely positioned to engage in sustainable energy production, storage, consumption, and sharing. However, tailored market strategies are required to ensure the widespread adoption of innovative technologies like SUPREMAS within these contexts. These must reflect the socio-economic structure of RECs, their cooperative governance, policy frameworks, and access to finance.

Specifically, this chapter highlights the unique technology advantages, explores strategic approaches to market engagement, and considers the financial mechanisms essential for enabling adoption. Additionally, it highlights the importance of effective communication and stakeholder involvement to foster acceptance and participation. The analysis also identifies priority market segments and outlines the strategies to monitor performance and ensure ongoing operational success. Finally, it underscores the need for capacity building, after-sales support, and practical tools to replicate and scale the business model across diverse contexts. Together, these insights offer a roadmap to support the acceleration of sustainable, community-driven energy solutions.

Strategic Positioning of SUPREMAS within RECs

SUPREMAS technology should be positioned as a complementary, circular economy-aligned solution for RECs—particularly effective in rural areas or municipalities with access to organic waste and residual biomass. The system's decentralized, containerized design enables on-site production of renewable electricity, heat, and cooling from locally sourced feedstocks, supporting both self-consumption and shared energy use among community members.

Key Unique Selling Points (USPs):

- **Plug & Play modularity** for scalable deployment in diverse REC contexts
- **Syngas generation** from a wide range of feedstocks including digestate, sludges, and agricultural waste
- **Combined heat and power (CHP)** output enabling efficient energy use and cost savings
- **High compatibility** with smart grid infrastructure, battery storage, district heating networks, and demand-response systems[45,46]

Tailored Marketing Approaches

To effectively reach and serve RECs, SUPREMAS' market strategy should be built around four core engagement dimensions:

- **Community-Oriented Co-Creation**
  - Promote participatory workshops and co-design sessions with early adopters to ensure local ownership and alignment with REC values
  - Utilize storytelling campaigns (e.g., "energy from our waste") to foster emotional resonance and community pride
  - Build governance trust through collaboration with cooperatives, civil society actors, and inclusive decision-making processes[47]
- **Collaboration with Public Authorities**

[45] European Commission. (2020). *Circular economy action plan: For a cleaner and more competitive Europe*. https://environment.ec.europa.eu/strategy/circular-economy-action-plan_en

[46] REScoop.eu. (2021). *Community energy: A practical guide to building your own*. https://www.rescoop.eu/toolbox

[47] European Commission. (2023). *European Climate Pact – Communication Toolkit*. https://climate-pact.europa.eu

- Target municipalities with fewer than 5.000 inhabitants, which are eligible for dedicated REC incentives under Italy's PNRR[48]
- Position public buildings—such as schools, community centers, and hospitals—as anchor sites for pilot installations
- Present SUPREMAS as a resilience solution for rising energy prices and geopolitical supply shocks

- **Partnership with Technical and Financial Enablers**
  - Partner with ESCOs and regional innovation agencies to provide turnkey installation, monitoring, and maintenance services
  - Combine SUPREMAS systems with energy storage, digital REC platforms, and metering technologies
  - Engage with ethical finance actors (e.g., Banca Etica, Crédit Agricole, Intesa Sanpaolo's S-Loans) and explore crowdfunding or cooperative investment models[49]

Funding and Financing Strategy

Given the capital-intensive nature of energy infrastructure, a blended financing strategy is essential to support REC uptake of SUPREMAS. This includes:

- **EU Funding**: Recovery and Resilience Facility (RRF), Just Transition Fund, and ERDF to support infrastructure and circular economy projects[50]
- **National Programs**: CE Implementa and CE Oficinas (Spain), Mission 2 of the PNRR (Italy), and Law 99/2024 (Portugal) which streamline authorization and support energy democratization[51,52]
- **Private Mechanisms**: Green and ESG-linked loans, cooperative crowdfunding, and public-private partnerships (PPPs)

According to the REC stakeholder consultation, the analysis of the European energy sector priorities reveals that optimization of renewable energy sources (RES) is the most prominent theme (36%). Optimization of waste and RES is mentioned by 27%, while other optimization strategies (including electric vehicles (EV)) represent 27% of responses.

Communication and Dissemination

Targeted communication and dissemination actions are critical to building awareness and social acceptance of syngas technologies in REC contexts:

- Organize educational webinars and local "technology open days" to demystify syngas and promote circular economy benefits
- Co-host information sessions with energy agencies and cooperative networks to reach practitioners and policymakers
- Produce easy-to-understand infographics, videos, and brochures explaining how SUPREMAS integrates with RECs
- Publish demonstration case studies and impact stories through European REC platforms such as REScoop.eu

Target Market Segments

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[48] GSE (Gestore dei Servizi Energetici). (2024). *Linee guida per l'accesso agli incentivi per le Comunità Energetiche Rinnovabili*. https://www.gse.it

[49] Energy Cities. (2022). *Financing the energy transition in European cities*. https://energy-cities.eu/publication/financing-the-energy-transition/

[50] European Commission. (2021). *Recovery and resilience facility: Factsheet*. https://commission.europa.eu/business-economy-euro/economic-recovery/recovery-and-resilience-facility_en

[51] IDAE (Instituto para la Diversificación y Ahorro de la Energía). (2024). *CE Implementa & Oficinas*. https://www.idae.es

[52] MITECO (Ministerio para la Transición Ecológica y el Reto Demográfico). (2024). *Regulatory bases of CE Implementa 5 & 6*. https://www.miteco.gob.es

Table 6-1 Targe Market Segments

Segment	Key Characteristics	Strategic fit for SUPREMAS
Rural communities	Abundant local biomass, limited grid access, high potential for autonomy	Strong
Industrial parks	Thermal energy demand, co-location of businesses, interest in circularity	Moderate to strong
Mountain/ island areas	Geographic isolation, higher energy prices, need for energy independence	Strong
Municipalities	Political commitment, visibility needs, availability of pilot infrastructure	Moderate

Performance Monitoring and Validation

To strengthen REC trust and support long-term operational success, the deployment of SUPREMAS units should be coupled with a transparent monitoring and evaluation (M&E) framework. Key Performance Indicators (KPIs) should include:

- Energy generated (kWh/year)
- Avoided CO_2 emissions (tCO_2/year)
- Share of locally valorized waste (%)
- System availability and maintenance records
- Community-level economic savings (€)

An open-access dashboard with real-time or periodic data can improve visibility and build public trust. Additionally, this evidence base will be essential for securing future financing, evaluating policy impact, and informing replication strategies across other REC environments[53].

After-Sales Support and Capacity Building

Recognizing the limited technical expertise available in many REC contexts, SUPREMAS must include robust after-sales support and tailored capacity building. This should involve:

- Training programs for local operators and energy managers
- Simple user manuals in local languages
- Online and in-person workshops for REC coordinators
- Remote diagnostics and technical hotline services

Partnerships with regional universities, ESCOs, and technical agencies can support know-how transfer and ensure long-term autonomy in system operation[54].

Business Model Replication Toolkit

To promote scalability across regions and support policy alignment at local levels, SUPREMAS should be accompanied by a "Business Model Replication Toolkit." This resource may include:

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[53] European Commission. (2023). *European Climate Pact – Communication Toolkit*. https://climate-pact.europa.eu

[54] REScoop.eu. (2021). *Community energy: A practical guide to building your own*. https://www.rescoop.eu/toolbox

- Templates for cooperative or municipal ownership models
- Guidelines on stakeholder governance, equity structures, and legal formation
- Financial simulation tools to assess CAPEX, OPEX, and ROI under various subsidy scenarios
- Checklists for permitting and policy compliance per Member State

Such a toolkit can reduce administrative burden and facilitate quicker uptake of the technology in new communities, while ensuring consistency with EU RECs legislation and sustainability goals[55].

The following country examples—Italy, Spain, and Portugal—highlight how national frameworks and regional dynamics can support the effective deployment of SUPREMAS within Renewable Energy Communities.

Regional Leverage in Italy for SUPREMAS Deployment

In Italy, the strong role of regional administrations offers a promising channel for SUPREMAS deployment. Several regions, such as Piemonte, Emilia-Romagna, Tuscany, and Apulia, have launched regional calls for proposals aimed at supporting the establishment of RECs through co-financing, feasibility studies, and legal advisory services[56]. SUPREMAS, with its plug-and-play modularity and compatibility with small-scale, dispersed biomass sources (e.g., forest residues, agro-waste), is particularly well suited for inner and rural areas prioritized under Italy's National Strategy for Inner Areas (SNAI)[57].

Furthermore, alignment with the **Regional Energy and Climate Plans** and **Just Transition territorial plans** can open additional financing windows, especially in cohesion-targeted regions such as Sicily, Calabria, and Basilicata. These areas face both energy poverty and waste management inefficiencies, creating ideal conditions for showcasing SUPREMAS as a dual-benefit solution.

Spain – Amplifying through CE Oficinas and Energy Diversification

Spain's national strategy for RECs benefits from an institutional ecosystem that includes **CE Oficinas**—publicly funded Community Transformation Offices operating across most autonomous regions. These offices are tasked with REC promotion, technical support, and capacity building, and represent an ideal partner network for scaling awareness around SUPREMAS[58].

Co-organizing technical workshops and site visits in collaboration with CE Oficinas could help highlight SUPREMAS' potential as a complementary solution to solar-dominated REC portfolios. Additionally, the technology's focus on circularity aligns with the **Spanish Bioeconomy Strategy**, supporting diversification into community-based waste-to-energy models (e.g., biomass-based district heating, biosyngas for shared CHP)[59].

National Insights: Unlocking Market Potential in Portugal

While Portugal's Decree-Law 162/2019 provides a strong regulatory foundation for RECs, lengthy permitting procedures—often exceeding 12 months—and limited interconnection clarity continue to delay implementation. SUPREMAS' movable and containerized design reduces civil engineering requirements, which may help circumvent these procedural bottlenecks and facilitate faster deployment[60].

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[55] Energy Cities. (2022). *Financing the energy transition in European cities*. https://energy-cities.eu/publication/financing-the-energy-transition/

[56] Regione Piemonte. (2023). *Programma regionale CER 2023–2026*. https://www.regione.piemonte.it

[57] Agenzia per la Coesione Territoriale. (2024). *Strategia Nazionale per le Aree Interne (SNAI)*. https://www.agenziacoesione.gov.it

[58] IDAE (Instituto para la Diversificación y Ahorro de la Energía). (2024). *CE Implementa & Oficinas*. https://www.idae.es

[59] Ministerio para la Transición Ecológica (MITECO). (2023). *Estrategia Española de Bioeconomía Horizonte 2030*. https://www.miteco.gob.es

[60] Direção-Geral de Energia e Geologia (DGEG). (2024). *Comunidades de Energia Renovável: Diagnóstico e Propostas*. https://www.dgeg.gov.pt

Moreover, most Portuguese RECs to date have focused on rural solar PV. However, municipalities such as Lisbon, Évora, and Braga are actively exploring urban-scale RECs. SUPREMAS could serve as a flagship for **urban circular energy systems**—leveraging public buildings and municipal waste streams to supply local heat, power, or cooling, particularly through integration with district energy networks or e-mobility charging hubs[61].

7 SOURCES OF FINANCING FOR RECS

7.1 EU

The transition to a sustainable and decarbonized energy system requires substantial investments, supported by a **combination of public and private funding mechanisms**. These financial instruments are essential to bridge the gap between ambitious climate goals, such as those set by the European Green Deal and Fit for 55 targets, and the practical implementation of renewable energy projects and energy efficiency improvements.

This section provides a comprehensive overview of the key funding programs available across Europe, focusing on their role in enabling the development of RECs. The analysis spans European Union initiatives, such as the European Regional Development Fund (ERDF) and the Recovery and Resilience Facility (RRF), as well as national programs tailored to the specific needs of the studied countries.

European Regional Development Fund (ERDF) (2021–2027). The ERDF, managed by the European Commission, aims to reduce regional disparities and improve living standards through investments in growth, jobs, and European Territorial Cooperation. It provides total funding of €226 billion, including specific allocations for European Territorial Cooperation (€9 billion) and outermost and sparsely populated regions (€1.9 billion). The co-financing rates reach 85% for less developed regions and up to 60% for more developed regions. The ERDF focuses on innovation (P01), green transition (P02), and sustainable urban development (8% of total resources). Its funding is crucial for supporting local energy projects, particularly within RECs, enhancing regional sustainability and economic development.

Cohesion Fund (2021–2027). The Cohesion Fund, administered by the European Commission, provides €42.6 billion in funding, with €10 billion allocated to the Connecting Europe Facility. The fund supports EU Member States with a Gross National Income (GNI) per capita below 90% of the EU average, targeting environmental sustainability, renewable energy, circular economy, and transport infrastructure. The fund's co-financing rates reach up to 85%, and 37% of its resources contribute to EU climate objectives. This mechanism plays a crucial role in fostering equitable energy transitions across economically disadvantaged regions, ensuring access to sustainable energy investments.

Just Transition Fund (JTF) (2021–2027). The Just Transition Fund (JTF), under the European Commission, aims to support territories most affected by the shift toward climate neutrality. With a total funding of €17.5 billion (€7.5 billion from the Multiannual Financial Framework and €10 billion from NextGenerationEU), it prioritizes economic diversification, professional reskilling, clean energy technologies, emission reduction, and industrial site rehabilitation. The co-financing rates reach 85% for less developed regions and up to 70% for more developed regions. The JTF provides crucial financial backing to regions transitioning away from fossil fuels, helping communities develop sustainable and inclusive energy projects, including RECs.

Recovery and Resilience Facility (RRF) (2021–2026). The Recovery and Resilience Facility (RRF) is the largest financial instrument of NextGenerationEU, designed to support Member States in recovering from the COVID-19 crisis while addressing major sustainability challenges. With a total funding of €650 billion (€359 billion in grants and €291 billion in loans), the RRF supports sustainability, resilience, and green and digital transitions. Member States receive funding based on agreed milestones and targets under the European Semester framework. The RRF is essential in accelerating investments in renewable energy infrastructure, energy efficiency measures, and innovative clean energy technologies, directly benefiting RECs.

[61] Câmara Municipal de Lisboa. (2023). *Plano Municipal de Ação Climática – PAC Lisboa 2030*. https://www.lisboa.pt

7.2 Italy

Financing Instruments for RECs in Italy. The development of RECs in Italy is supported by the following range of financial instruments, dived into public and private funding mechanisms:

Public Sector Funding for RECs

- **Mission 2, Component 2, Investment PNRR** – Managed by the Ministry of the Environment and of Energy Security (MASE) and GSE, this €2.2 billion fund supports municipalities with fewer than 5.000 inhabitants in installing at least 2 MW of new renewable capacity and generating 2.500 GWh/year of energy. The programme provides grants covering up to 40% of eligible project costs. **Feed-in Tariff** – This initiative offers a fixed tariff (€60-€120/MWh) for self-consumed renewable energy, particularly from photovoltaic sources, incentivizing local energy renewable production and community-based energy sharing.
- **ARERA – Valuation Fee for Self-Consumed Energy** – A financial compensation scheme supporting shared renewable energy within RECs, offering 11 €/MWh incentives to encourage energy exchange and collective energy management.
- **Transition Plan 5.0** – A €12.2 billion initiative by the Ministry of Enterprises and Made in Italy (MIMIT) that funds energy and digital transformation. It offers tax credits for companies investing in renewable energy, energy storage, and energy efficiency improvements.
- **Net Zero Development Contracts** – An industrial development fund providing €2.18 billion to support projects that reduce carbon emissions. The funding includes grants, capital contributions, and tax benefits, which can support RECs focused on local renewable energy production.
- **Sustainability of Production Processes** – A €650 million fund aimed at enhancing energy efficiency, biomass adoption, and industrial decarbonization. It prioritizes energy efficiency projects in Southern Italy, offering 60% support for energy efficiency and 40% for renewable energy adoption.
- **Strategic Plan 2025-2027 (Cassa Depositi e Prestiti, CDP)** – A €170 billion initiative aimed at boosting Italy's competitiveness and sustainability. This plan includes funding for energy transition projects, social impact initiatives, and local infrastructure improvements, which can be leveraged by RECs.
- **Conto Termico 3.0** – A decree currently under discussion in Italy, aimed at updating and expanding the existing incentive scheme (Conto Termico 2.0) for promoting renewable heating and cooling systems and energy efficiency measures. For the first time specific incentives for renewable heating and cooling projects developed within RECs are introduced. This aligns with the broader Italian and EU strategies of fostering decentralized energy systems and citizen participation. By supporting shared renewable thermal systems—such as biomass boilers, heat pumps, and solar thermal plants—within RECs, the decree aims to integrate thermal energy into community-based models, complementing the already incentivized electricity-based systems. If approved, it would represent a significant step in making RECs more comprehensive and capable of managing both electricity and heat collectively.

Private Sector Funding for RECs

- **Finanziamento Futuro Sostenibile (Unicredit)** – Offers loans starting from €10,000 to support businesses committed to Environmental, Social, and Governance (ESG) targets, including renewable energy projects and RECs.
- **Finanziamento Business Sostenibile (Banca Sella)** – Provides capital support for companies and social enterprises investing in sustainability initiatives. The loan structure includes reduced interest rates for projects meeting ESG goals.
- **S-Loan CER (Intesa Sanpaolo)** – A customized financing solution for RECs, focusing on energy efficiency, self-consumption, and renewable systems. Interest rate reductions are available for projects that meet ESG criteria.
- **Energia Impresa (Intesa Sanpaolo)** – A financing solution covering up to 100% of eligible investments in renewable energy, energy efficiency, and carbon reduction projects.
- **Energicamente Sostenibles (Crédit Agricole)** – Supports up to 100% of renewable energy project costs, including wind, solar, hydro, biomass, and energy efficiency initiatives, offering flexible repayment structures.
- **Finanziamento Green e Sostenibilità (BNL BNP Paribas Group)** – Provides financial incentives for green projects, offering favorable interest rates and eligibility for regional and state incentives.
- **Investment Green (BPER Bank)** – Offers variable-rate green investment financing for projects focusing on renewable energy production and energy efficiency improvements.

7.3 Spain

Spain's Financing Programs for RECs. The realization of RECs in Spain depends heavily on the availability and accessibility of targeted financial support. A combination of public and private instruments, ranging from state-backed loans to ESG-aligned corporate financing, form a diverse ecosystem designed to foster local renewable energy initiatives and sustainable infrastructure. The following overview highlights the key financial mechanisms currently in place:

- **Línea ICO Verde -** Managed by the Instituto de Crédito Oficial (ICO), this program provides up to €22 billion in financing for public and private entities, including households. It supports projects that contribute to the green transition—particularly those in sustainable transport, energy efficiency, renewable energy, water management, and circular economy initiatives. Financing options include direct loans, bank-mediated lines, acquisition of debt securities, and venture capital. The program offers up to 100% financing for mediation lines and 70% for direct loans, demonstrating a strong commitment to fostering clean investment.
- **ICO Companies and Entrepreneurs Program -** Also administered by ICO, this line targets private companies and self-employed individuals under Spain's Recovery, Transformation, and Resilience Plan and the NextGenerationEU initiative. The total funding amount is €8.15 billion, with dedicated budgets for tourism and university digitalization projects. The program offers loans and leasing with fixed or variable interest rates and generous repayment terms (up to 20 years, with 3 years of grace). It aims to promote sustainability, competitiveness, and digital transformation, indirectly benefiting RECs through enhanced infrastructure and innovation.
- **ICF Eco Green (Catalonia) -** This ongoing program by the Catalan Institute of Finance (ICF) supports sustainable investments in green and circular economies, energy efficiency, and climate change mitigation. Eligible beneficiaries include self-employed individuals, companies, public and private entities, energy communities, and homeowner associations in Catalonia. When eligible, the European Investment Fund backs up to 70% of the credit risk, reducing lender exposure and promoting access to capital for small-scale and community-driven energy initiatives.
- **BBVA Green Loans -** Offered by BBVA, these private-sector financing instruments target companies committed to Environmental, Social, and Governance (ESG) standards. Projects may include renewable energy, pollution control, sustainable land and water management, biodiversity preservation, and circular economy models. Loans follow the Green Loan Principles (GLP), requiring environmental impact assessments and usage transparency. Structures vary from term loans to revolving credit and working capital lines, offering flexibility to businesses and energy communities.
- **Santander Green Loans and Bonds -** Banco Santander has mobilized over €114.6 billion in green financing since 2019. The bank supports renewable energy and energy efficiency projects through tailored loans and ESG-compliant green bonds. It collaborates with institutions like the European Investment Bank (EIB) to extend credit lines, and aligns its portfolio with the Paris Agreement goals. Santander's initiatives are particularly suited to funding shared community energy systems and sustainable infrastructure across Spain.
- **IFEM – Financing Instruments for Innovative Enterprises -** Promoted by the ICF, IFEM provides convertible participatory loans to early-stage businesses in Catalonia. Designed to support high-potential, technology-based companies, this mechanism is structured for co-investment with private backers. Although not REC-specific, it offers valuable opportunities for startups developing renewable energy technologies or community-oriented solutions in the green energy space.
- **CaixaBank Green Loans -** CaixaBank's green lending program supports renewable energy generation, energy efficiency, and broader sustainability initiatives. The loans are well-suited for RECs and IRECs, as they can be used to fund shared renewable installations, such as solar and wind, within industrial parks or local communities. The loans comply with GLP and ESG standards, ensuring environmental integrity and financial transparency.

7.4 Portugal

Portugal has progressively built a robust legal and financial framework to support RECs, recognizing their strategic role in the energy transition and local development.

Central to this effort is the **National Recovery and Resilience Plan (NRRP)**, which includes 83 investments and 32 reforms, supported by €13.9 billion in grants and €2.7 billion in loans. Notably, 38% of the plan is dedicated to climate objectives, with a portion channelled specifically toward RECs under **Component C-13**, focused on energy efficiency in buildings. The **funding program TC-C13 – 'Support for the Implementation of Energy**

Communities and Collective Self-Consumption' allocated €30 million in its first call and €75 million in the second, launched for applications between 1 August and 1 October 2024. The funds support installations on residential, commercial, and public administration buildings, aiming for demand reduction and increased energy efficiency. Despite the ambitious targets—such as **93 MW of REC/CSC capacity by 2025**—the results of the first call are still pending, and the proportionality of funding dedicated specifically to RECs remains unclear, as RECs and collective self-consumption projects share budget lines. Grants are the main financial instrument, typically covering 20–30% of costs upfront, with the remainder reimbursed post-investment by the promoter.

Funds for RECs are also present in 4 out of 7 regional Operational Programmes (Centro, Alentejo, Norte, Algarve), though in most cases they are bundled within broader RES or energy efficiency budgets. While the **legal definition of RECs is based on Decree-Law 162/2019**, it is not yet fully aligned with EU Directives. Nonetheless, RECs are increasingly recognized under multiple national and regional objectives, especially for their link to **building renovation, energy efficiency**, and **community-led sustainability initiatives**. The tender processes are **decentralized**, but information regarding transparency, inclusiveness, selection criteria, and tailored financing tools remains limited. Still, due to the strong integration with Portugal's **National Reform Programme 2022**, which sets a target of 35 MW additional capacity via RECs and private prosumers by 2025, a degree of stability and predictability for funding schemes is expected to continue.

In addition, national energy agencies such as ADENE have published practical manuals and internal regulation templates to guide the creation and governance of RECs. Alongside public funding, a growing ecosystem of private companies and energy providers now offers technical and operational support, facilitating the implementation and management of RECs across the country. This multi-level approach reflects Portugal's commitment to a more decentralized, sustainable, and citizen-driven energy model.

RECs rely on multi-source financing models combining EU funds (e.g., ERDF, RRF), national support schemes, local grants, and citizen investments. Financial accessibility is crucial for RECs to ensure participation from a broad range of stakeholders, including vulnerable groups and smaller municipalities.

According to the REC stakeholder consultation, financing challenges are crucial in the REC sector. When asked about subsidized financing experiences, **91%** of participants reported **no prior access** to subsidized financing for renewable energy projects, highlighting a significant financing gap.

Only 9% had previously benefited from such support. In terms of preferred financing mechanisms, a wide variety was cited: bank loans, PNRR funds, crowdfunding, direct grants, self-financing, state support, EU/local funds, incentive programs (like those from GSE), and private financing — each mentioned by 9% of respondents. This fragmentation suggests that stakeholders are actively seeking diversified financing avenues but lack widespread access to them.

Regarding existing financial incentives for RECs, 73% of respondents identified grants as the most common instrument (mentioned by 55%), followed by tax breaks (18%) and feed-in tariffs (18%). However, when asked about improvements needed in current incentive schemes, suggestions included zero-interest loans, incentives linked to energy profiles, expanded tax benefits, regional funds to assist REC creation and feasibility studies, and enhanced crowdfunding opportunities. Moreover, for the REC sector, 45% considered existing mechanisms inadequate, while 27% were uncertain. Only 18% agreed that funding was sufficient.

Going through economic challenges specifically hindering REC deployment, **Capital costs** were identified as the primary barrier by **55%** of respondents, often linked to concerns about financing models and maintenance expenses. **Return on investment (ROI)** was also seen as a significant challenge by **27%**, suggesting that projects must be structured to deliver attractive, predictable financial returns to attract broader participation.

Regarding existing financial incentives about waste-to-energy technologies such as biosyngas systems, responses were more cautious: 55% of participants did not answer, while among those who did, grants, tax credits, and feed-in tariffs were mentioned. A significant portion (36%) suggested introducing **zero-interest financing** to improve the attractiveness of investments, with others proposing incentives supporting **full circular economy models**.

Importantly, the survey revealed a strong interest in collaborative financing solutions: **64%** of respondents expressed willingness to explore **joint REC financing** models, where multiple entities share costs and risks, thus enabling larger-scale investments and better risk management. Similarly, regarding the adoption of blended financing models (a mix of grants, loans, and private investments) to support technologies like SUPREMAS, **36%** of stakeholders were already familiar with blended financing, **27%** expressed support, while another **27%** opposed or were unsure about its applicability.

In terms of strategic financing models to promote innovative energy technologies, **Public-Private Partnerships (PPPs)** and **cooperative structures** emerged as the preferred solutions. PPPs, sometimes combined with crowdfunding or bond financing, were mentioned by **64%** of respondents as highly effective, while cooperative models, either independently or blended with other instruments, accounted for **36%**.

On PPP participation specifically, 27% of respondents stated they were not involved in any PPPs, while 18% confirmed active involvement and another 18% expressed indirect support. Encouragingly, 64% of stakeholders declared being in favor of PPPs in the energy sector, viewing them as valuable mechanisms for unlocking additional private funding, increasing project visibility, ensuring citizen-centered services, and allowing public entities to access renewable energy solutions without heavy initial investments.

However, weaknesses of PPPs were also acknowledged. Bureaucratic complexity and regulatory hurdles were cited by 36% of participants as key risks, with additional concerns about difficulties in project implementation and excessive reliance on government structures.

8 PRELIMINARY SINERGIES BETWEEN SUPREMAS TECHNOLOGY AND REC MODELS

8.1 Business model classification: REC and Biomass/Waste-To-Energy models

In alignment with the European RED II directive, European Union have developed a regulatory framework that promotes the creation of RECs (RECs) and Collective Self-Consumption Groups (CSCG), and EU identifies the, as key initiatives for the energy transition, enabling the local sharing of renewable energy among citizens, businesses, and public entities.

The design and implementation of RECs or CSCG schemes vary significantly depending on legal frameworks, participant profiles. To preliminarily classify the REC business models in order to assess their synergies with the SUPREMAS solution, the selected classification criteria are **the Type of REC Members (residential, commercial, civil society, industrial, public).**

Understanding the nature and role of the members within a REC is critical in shaping business strategies, technological infrastructure, and value-sharing mechanisms. Each stakeholder group has different risk resilience, investment horizon, and operational needs, which influence the options for governance, financing, and revenue-sharing structures inside the business model.

Based on this preliminary classification, three typical **REC business models** are described in this chapter:

REC BM - A: Collective Self-Consumption Group (e.g., residential condominium or an integrated complex combining a supermarket with housing)

BM - A describes a Collective Self-Consumption Group (CSCG) established within a mixed-use urban complex, such as a residential condominium integrated with commercial activities (e.g., supermarkets, offices). In this model, a single or multiple private/public entities invest in a shared renewable energy plant. The energy produced is allocated among participating units, both residential and commercial, based on sharing mechanism. The BM - A is well-suited to urban communities and prosumer groups in multi-owner buildings or mixed developments.

REC BM - B: Community-led Renewable Energy Community

BM – B describes a Renewable Energy Community formed within residential neighbourhoods in urban, peri-urban areas or rural. These communities bring together a diverse group of participants—including residents, small and medium-sized enterprises (SMEs), public administrations, and energy prosumers—who collectively produce and consume renewable energy. The model operates within the boundaries of the same primary substation (medium/low voltage level), as required by regulatory frameworks, and must be established as a non-profit legal entity. BM – B promotes local energy democracy, enhances civic engagement, and supports inclusive urban decarbonization strategies by ensuring access to clean energy for all, including vulnerable and low-income groups.

REC BM - C: Industrial efficiency with REC

BM – D describes an Industrial Renewable Energy Community (Industrial REC) established within business clusters, industrial parks, or commercial zones. In this model, multiple companies—often located within the same primary substation area—collaborate to produce, share, and manage renewable energy through jointly owned infrastructure. This model is particularly attractive for businesses pursuing decarbonization, energy cost reduction, and compliance with ESG (Environmental, Social, Governance) standards. In industrial Renewable Energy Communities, energy efficiency improvements across production processes and facilities are just as crucial as energy sharing itself, making energy efficiency a core pillar alongside collective renewable energy generation.

8.2 Typical REC models

Table 8-1 REC Business Models Canvas matrix

BM Blocks	REC BM - A: Collective Self-Consumption Group (e.g., residential condominium or an integrated complex combining a supermarket with housing)	REC BM - B: Community-led Renewable Energy Community	REC BM - C: Industrial efficiency with REC
VALUE PROPOSITION What value do you deliver to the customer?	• Production and self-consumption of energy (electric and/or thermal) from renewable sources for the reduction of carbon emissions • Reduction of energy costs through integrated optimization of production, consumption, and energy price • Promotion of environmental and social sustainability initiatives in the local area • Electric mobility service (optional) • Energy efficiency upgrading and improvement of buildings • Creation of a collective for the promotion of commercial partnerships	• Production and self-consumption of energy (electric and/or thermal) from renewable sources for the reduction of carbon emissions • Reduction of energy costs through integrated optimization of production, consumption, and energy price • Promotion of environmental and social sustainability initiatives in the local area • Electric mobility service (optional) • Renovation and efficiency of buildings • Opportunity to act as an active player in the energy market with effects on energy consumption and expenditure ('Electricity grid ancillary services') (optional)	• Production and self-consumption of energy (electric and/or thermal) from renewable sources for the reduction of carbon emissions • Reduction of energy costs through integrated optimization of production, consumption, and energy price • Promotion of environmental and social sustainability initiatives in the local area • Electric mobility service (optional) • Renovation and efficiency of buildings • Creation of a collective for the promotion of commercial partnerships • Promotion of research and employment development • Catalyst of entrepreneurial realities • Development of entrepreneurial skills • Control of energy assets
KEY ACTIVITIES What are the main activities of your business?	• Production of energy (electric and/or thermal) from renewable sources • Consumption (consumer) and self-consumption (prosumer) of energy • Ordinary and extraordinary maintenance of the energy production plant (electric and/or thermal) • Activation and operation of private smart meters	• Production of energy (electric and/or thermal) from renewable sources • Consumption (consumer) and self-consumption (prosumer) of energy • Ordinary and extraordinary maintenance of the energy production plant (electric and/or thermal)	• Production of energy (electric and/or thermal) from renewable sources • Consumption (consumer) and self-consumption (prosumer) of energy • Ordinary and extraordinary maintenance of the energy production plant (electric and/or thermal)

	• Activation and operation of a “software platform” for efficient management of energy and incentives • Monitoring of energy flows to evaluate performance and redistribute the incentive • Administrative management • Fiscal management • Member meetings for administration and organization of common activities • Communication and community engagement activities (e.g. events, etc.) • Management of electric mobility service (optional) • Injection of energy into the grid (only if capitalized)	• Activation and operation of private smart meters • Activation and operation of a “software platform” for efficient management of energy and incentives • Monitoring of energy flows to evaluate performance and redistribute the incentive • Administrative management • Fiscal management • Member meetings for administration and organization of common activities • Communication and community engagement activities (e.g. events, etc.) • Management of electric mobility service (optional) • Injection of energy into the grid (only if capitalized) • Electricity storage (also for ‘ancillary services to the electricity grid’) (optional) • Activation and operation of smart meters for ‘ancillary services to the electricity grid’ (optional)	• Activation and operation of private smart meters • Activation and operation of a “software platform” for efficient management of energy and incentives • Monitoring of energy flows to evaluate performance and redistribute the incentive • Administrative management • Fiscal management • Member meetings for administration and organization of common activities • Communication and community engagement activities (e.g. events, etc.) • Injection of energy into the grid (only if capitalized) • Communication activities in the territory • Rental of upgraded spaces (if available) • Management and maintenance of rented spaces (if available)
KEY RESOURCES What are the resources used to operate the business?	• Surface area for installation (it is an asset only if capitalized • Energy production plant (electric and/or thermal) from renewable sources (it is an asset only if capitalized) • Asset: “Software platform” to support efficient energy management • Asset: Energy flow monitoring system • Asset: Charging stations (optional) • Private smart meters • Personnel: for ordinary and extraordinary maintenance of the plants	• Surface area for installation (it is an asset only if capitalized) • Energy production plant (electric and/or thermal) from renewable sources (it is an asset only if capitalized) • Asset: “Software platform” to support efficient energy management • Asset: Energy flow monitoring system • Asset: Charging stations (optional) • Private smart meters • Personnel: for ordinary and extraordinary maintenance of the plants	• Asset: Surface area for installation • Asset: Industrial area (offices, warehouses) • Surface area for installation (it is an asset only if capitalized) • Energy production plant (electric and/or thermal) from renewable sources (it is an asset only if capitalized) • Asset: “Software platform” to support efficient energy management • Asset: Energy flow monitoring system • Asset: smart meters

	• Administrator • Fiscal manager • CSC member personnel for communication and community engagement (e.g. events, etc.) • Responsible for the distribution of incentives • Energy performance evaluator	• Administrator • Fiscal manager • REC member personnel for communication and community engagement (e.g. events, etc.) • Responsible for the distribution of incentives • Energy performance evaluator • Asset: energy storage system • Installation area of the storage system • Staff for managing the electric mobility service (optional) • Asset: smart meters for 'ancillary services to the electricity grid (optional) • Two-way charging stations (optional)	• Internal staff: administrative officers, marketing manager, logistics manager, maintenance workers, electricians • Personnel: for ordinary and extraordinary maintenance of the plants • Administrator • Fiscal manager • Responsible for the distribution of incentives • REC member personnel for communication and community engagement (e.g. events, etc.) • Energy performance evaluator • Electricity sales manager
KEY PARTNERS Who are the important actors for this business?	• GSE • DSO • Supplier of the "software platform" • Supplier of the monitoring system • Supplier of energy plants (electric and/or thermal) from renewable sources • Public authorizing bodies at municipal, provincial, and regional levels • Public funding bodies at regional and national levels • Private funding bodies (crowdfunding, funds, banks, etc.)	• GSE • DSO • Supplier of the "software platform" • Supplier of the monitoring system • Supplier of energy plants (electric and/or thermal) from renewable sources • Public authorizing bodies at municipal, provincial, and regional levels • Public funding bodies at regional and national levels • Private funding bodies (crowdfunding, funds, banks, etc.) • Ancillary Electric Service Aggregator – BSP (optional)	• GSE • DSO • Supplier of the "software platform" • Supplier of the monitoring system • Supplier of energy plants (electric and/or thermal) from renewable sources • Public authorizing bodies at municipal, provincial, and regional levels • Public funding bodies at regional and national levels • Private funding bodies (crowdfunding, funds, banks, etc.)
CUSTOMER SEGMENTS What are the different types of	• Commercial/Residential consumers • Commercial/Residential prosumers • Electric mobility users (optional)	• Commercial/Residential consumers • Commercial/Residential prosumers • Electric mobility users (optional)	• Commercial/Residential consumers • Commercial/Residential prosumers • Electric mobility users (optional) • Tenants of refurbished spaces (start-ups, companies, professionals)

customers you have?			
CUSTOMER RELATIONSHIPS What do you do to retain and satisfy your customers?	• Redistribution of the incentive • Initiatives to improve common movable/immovable assets • Initiatives to promote environmental and social sustainability in the local area • Discounted tariff for electric charging (optional) • Promotion of local activities and partnerships	• Redistribution of the incentive • Initiatives to improve common movable/immovable assets • Initiatives to promote environmental and social sustainability in the local area • Promotion of local activities and partnerships	• Innovative, state-of-the-art infrastructure serving tenants • Redistribution of the incentive • Initiatives to improve common movable/immovable assets • Initiatives to promote environmental and social sustainability in the local area • Promotion of local activities and partnerships
CHANNELS What supply and sales channels do your services or products have?	• App of the “software platform” • CSC member assemblies • Extraordinary collective events • Administrative assistance • Website and social media	• App of the “software platform” • REC member assemblies • Extraordinary collective events • Administrative assistance • Website and social media	• App of the “software platform” • REC member assemblies • Extraordinary collective events • Administrative assistance • Website and social media • Meetings with space tenants • Operator portal for energy sales
COST STRUCTURE What are the main costs associated with your business?	**CAPEX:** • Development costs: feasibility study, establishment and registration of the CSC, community engagement • Energy production plant from renewable sources • Energy efficiency improvement of buildings • Electric charging infrastructure (optional) • Costs for activation procedures of the “software platform” • Activation of the monitoring system • Installation of private meters • Electric mobility infrastructure (optional) • Electrical energy storage system (optional) **OPEX:**	**CAPEX:** • Development costs: feasibility study, establishment and registration of the REC, community engagement • Energy production plant from renewable sources • Energy efficiency improvement of buildings • Electric charging infrastructure (optional) • Costs for activation procedures of the “software platform” • Activation of the monitoring system • Installation of private meters • Electric mobility infrastructure (optional)	**CAPEX:** • Development costs: feasibility study, establishment and registration of the REC, community engagement • Energy production plant from renewable sources • Costs for activation procedures of the “software platform” • Activation of the monitoring system • Installation of private meters • Renovation and redevelopment of new buildings • Energy efficiency buildings **OPEX:**

	- Ordinary and extraordinary maintenance of the energy production plant - CSC administration - CSC fiscal management - Responsible for the distribution of incentives - Evaluation of the energy performance of the energy production plant (electric and/or thermal) - Planning and organization of communication and community engagement activities - Implementation of communication and community engagement activities - Maintenance of electric mobility service infrastructure (optional) - Leasing/rent of surface area for installation of the storage system (only if capitalized)	- Electrical energy storage system (optional) **OPEX:** - Ordinary and extraordinary maintenance of the energy production plant - REC administration - REC fiscal management - Responsible for the distribution of incentives - Evaluation of the energy performance of the energy production plant (electric and/or thermal) - Planning and organization of communication and community engagement activities - Implementation of communication and community engagement activities - Maintenance of electric mobility service infrastructure (optional) - Leasing/rent of surface area for installation of the storage system (only if capitalized)	- Ordinary and extraordinary maintenance of the energy production plant - REC administration - REC fiscal management - Responsible for the distribution of incentives - Evaluation of the energy performance of the energy production plant (electric and/or thermal) - Planning and organization of communication and community engagement activities - Implementation of communication and community engagement activities - Maintenance of electricity storage systems (optional) - Administration of existing buildings (e.g. property taxes) - Rental space management (heating, lighting, marketing) -optional - Maintenance of rented space (cleaning, gardening, other) -optional
REVENUES STREAMS What are the main products or services that make the most money in this business?	- Shared energy incentive and enhancement contribution - Remunerated injection of surplus energy into the grid (not consumed) - Sale of electric mobility service (optional)	- Shared energy incentive and enhancement contribution - Remunerated injection of surplus energy into the grid (not consumed) - Sale of electric mobility service (optional) - Flexibility services incentive	- Shared energy incentive and enhancement contribution - Remunerated injection of surplus energy into the grid (not consumed) - Rent from coworking spaces and warehouses - Exploitation of carbon credits

8.3 Preliminary synergies between SUPREMAS technology and REC models

The following tables analyze the synergies between Renewable Energy Community (REC) business models and biosyngas systems across nine key building blocks of the Business Model Canvas: **Value Proposition**, **Key Activities**, **Key Partnerships**, **Key Resources**, **Customer Segments, Customer Relationships, Channels, Revenue Streams and Cost Structure**. Each table highlights how biosyngas can enhance the effectiveness and sustainability of different REC models (residential, community-led, and industrial), while also identifying critical areas requiring deeper investigation to support future integration.

1. Value Proposition

Table 8-2 Synergies between REC BMs and biosyngas - Value Proposition

Value Proposition[62]**:** The Value Propositions Building Block describes the bundle of products and services that create value for a specific Customer Segment. A Value Proposition creates value for a Customer Segment through a distinct mix of elements catering to that segment's needs. Values may be quantitative (e.g. price, speed of service) or qualitative (e.g. design, customer experience). *What value do we deliver to the customer? Which one of our customers' problems are we helping to solve? Which customer needs are we satisfying? What bundles of products and services are we offering to each Customer Segment?*		
REC model	**Synergy with biosyngas**	**Critical aspects for next deep-dive analysis**
REC model A: **Collective Self-Consumption Group (e.g., residential condominium or an integrated complex combining a supermarket with housing)**	• Production and self-consumption of renewable energy (electric and thermal) to significantly reduce carbon emissions. • Reduction of energy costs through the integrated optimization of local energy production and consumption • Promotion of environmental and social sustainability initiatives within local communities, fostering stronger societal engagement. • Energy resilience enhancement by ensuring continuous energy supply during periods of low solar and wind generation, supporting fully autonomous building clusters.	• Space and siting constraints: technical study on space availability for biosyngas system deployment. • Waste feedstock availability: evaluation of whether the volume and type of organic waste from residents is sufficient and consistent for continuous biosyngas production. • Building integration: technical compatibility with existing HVAC (Heating, Ventilation, and Air Conditioning) systems for CHP integration.

[62] Osterwalder, A., & Pigneur, Y. (2010). *Business model generation: A handbook for visionaries, game changers, and challengers*. Hoboken, NJ: John Wiley & Sons.

	• Strengthening self-consumption models by maximizing the use of locally produced energy. • Activation of a local circular economy, valorizing organic waste streams into energy and economic opportunity. • Cost-effective, modular deployment through plug-and-play biosyngas units, scalable to fit diverse REC sizes and needs. • Provision of combined heat and power (CHP) solutions for both residential buildings and industrial facilities, improving overall energy utilization efficiency. • By-products valorization from residential, agricultural, and industrial sources, transforming local waste challenges into sustainable energy solutions. •	• Ownership models: legal and governance frameworks for shared ownership of biosyngas system among residents. • Noise, emissions, and safety: risk and regulatory analysis for deploying biosyngas units in densely populated residential environments. • User acceptance: strategies for resident engagement, education, and trust-building in accepting waste-to-energy technology within living spaces.
REC model B: **Community-led Renewable Energy Community**	• Production and self-consumption of renewable energy (electric and thermal) supporting carbon emissions reduction at the community level. • Reduction of energy costs through optimized local production • Promotion of environmental and social sustainability initiatives that reinforce community identity and resilience. • Transformation of community waste into community energy, creating shared assets from organic residuals and promoting local resource utilization. • Participation in energy markets, leveraging biosyngas as a flexible, dispatchable resource for grid services such as demand-response and balancing. • Development of thermal energy loops to enable efficient district-level heating powered by biosyngas.	• Waste aggregation: logistics planning for collecting and processing waste from multiple sources (homes, farms, small businesses). • Flexibility and seasonal variations: assessment of how seasonal changes in feedstock availability affect biosyngas production and storage needs. • Grid interaction: modeling of energy injection into local grids and participation in flexibility markets (e.g., frequency regulation, demand response). • Governance and decision-making: tailoring the biosyngas business model to fit democratic governance structures of citizen-owned RECs.

	• Activation of a local circular economy, turning waste streams into energy and economic value within the community. • Cost-effective, modular deployment of biosyngas units, adaptable to a wide range of REC sizes and project scopes. • Combined heat and power (CHP) generation for residential, public, and industrial facilities, increasing total energy system efficiency. • By-product valorization from households, agricultural operations, and industries, reducing disposal needs while producing renewable energy. • Smart-grid compatibility ensuring seamless integration with local storage, monitoring, and demand-side management infrastructures. • Alignment with participatory governance models, empowering citizens and local stakeholders to co-manage energy resources. • Fostering innovation and job creation, supporting local technical skills, entrepreneurial development, and new green business models.	• Economic viability: business case validation based on small-medium scale deployment: CAPEX, OPEX, ROI projections tailored to community sizes. • Policy and subsidy access: mapping of relevant national and EU funding schemes for community-led renewable and circular economy projects.
REC model C: **Industrial efficiency with REC**	• Production and self-consumption of renewable energy (electric and thermal) contributing to significant reductions in carbon emissions across industrial and agricultural sectors. • Reduction of energy costs by optimizing local energy production, aligning consumption patterns, and leveraging dynamic pricing. • Promotion of environmental and social sustainability through community-driven and industry-supported green initiatives. • Valorization of industrial and agricultural by-products, transforming key waste streams like	• Large-Scale feedstock management: supply chain design for reliable, high-volume organic waste inputs from multiple industrial actors. • Energy demand matching: synchronization of biosyngas production with high and variable industrial energy demands (24/7 operations). • Customization of units: engineering adaptations needed for larger energy loads and multi-output systems (electricity, heat, cooling).

	sludge, digestate, and agricultural residues into valuable biosyngas. • Scalability for large installations, with biosyngas systems capable of serving multi-firm industrial parks and agricultural cooperatives. • Stimulation of innovation and employment, creating local jobs in technical operations, maintenance, biomass logistics, and energy management. • Support for renewable energy industrial clusters, anchoring business ecosystems around circular economy and sustainable energy production. • Enhancement of self-consumption strategies, ensuring that more locally generated energy is used on-site. • Activation of a local circular economy, closing the loop between waste production and energy generation. • Cost-effective, modular deployment, adaptable to the size and needs of industrial parks or agricultural hubs. • Provision of combined heat and power (CHP) solutions for efficient energy utilization in manufacturing, processing, and agro-industrial settings. • By-products valorization from residents, agriculture, and industries, contributing to zero-waste and carbon neutrality goals. • Smart-grid compatibility, enabling intelligent energy flow, storage integration, and demand-response participation. • Driving innovation and job creation, strengthening regional economies and promoting skills development in the green technology sector.	• Asset ownership and operation models: definition of operational models: single owner, joint venture, or third-party operator managing biosyngas system for multiple firms. • Compliance and industrial regulations: detailed legal compliance mapping for industrial waste-to-energy installations (emission limits, permits, industrial safety). • Cluster innovation synergies: strategy to leverage biosyngas system to foster regional innovation hubs and entrepreneurial ecosystems around waste valorization.

2. Key Activities

Table 8-3 Synergies between REC BMs and biosyngas - Key Activities

Key Activities[61]: The Key Activities Building Block describes the most important things a company must do to make its business model work. Every business model calls for a number of Key Activities. These are the most important actions a company must take to operate successfully. *What Key Activities do our Value Propositions require? Our Distribution Channels? Customer Relationships? Revenue streams?*		
REC model	**Synergy with biosyngas**	**Critical aspects for next deep-dive analysis**
REC model A: **Collective Self-Consumption Group (e.g., residential condominium or an integrated complex combining a supermarket with housing)**	• Both biosyngas and REC models focus on renewable energy production, but biosyngas introduces an additional phase of thermal feedstock conversion before energy generation. This offers a synergy, as RECs can consume biosyngas energy locally, enhancing their energy self-sufficiency. • Biosyngas provides backup power for residential and industrial energy systems, complementing rooftop solar and minimizing reliance on external grid energy during renewable intermittencies. • Both systems require ongoing technical maintenance, though biosyngas units demand more specialized handling, such as feedstock management and syngas cleaning. • A key difference lies in governance: CSC groups are participatory and community-led, whereas biosyngas projects have traditionally been industrially managed. • Moreover, biosyngas integration into CSC groups requires the introduction of feedstock logistics into the operational model, which is not yet standard in CSC/REC activities.	• Assess technical solutions for installing containerized units within limited residential or shared spaces (e.g., underground garages, small courtyards). • Align biosyngas management processes with residential CSC group administrative and fiscal tasks (e.g., incentive redistribution among apartment owners). • Evaluate how biosyngas-produced electricity and thermal energy can be integrated into residential building systems (small scale, low-load variability).

REC model B: **Community-led Renewable Energy Community**	Similar to REC Model A, but with some additions: • in BM B (community-led RECs), biosyngas integration is more natural due to the easier aggregation of by-products and the flexibility of community governance structures. • Biosyngas technology helps municipalities and industries turn organic waste into energy, offering a sustainable solution in regions with high organic waste production and strict landfill regulations. • However, effective feedstock management processes would need to be formally established to ensure consistent operation.	• Formalize decentralized feedstock collection (household organic waste, agricultural residues) into a community-managed logistics chain. • Integrate biosyngas production with smart grid systems and optional storage to complement intermittent renewable generation (solar, wind).
REC model C: **Industrial efficiency with REC**	Building on the considerations for REC Model A, with further additions: • in industrial RECs, there is clear potential for complementary efforts, as space management could accommodate biosyngas unit siting and maintenance. • Moreover, the integration is even stronger in BM C thanks to the availability of larger by-products volumes, greater operational flexibility, and suitable industrial spaces. • Biosyngas can expand REC activities by supplying manufacturing and chemical industries with renewable chemicals like methanol, ethanol, and hydrogen, producing synthetic fuels for transportation, and generating biochar to support sustainable agriculture and carbon sequestration.	• Design an industrial-grade by-products aggregation system from multiple SMEs or farms within the park (efficient collection, preprocessing, storage).

3. Key Partnerships

Table 8-4 Synergies between REC BMs and biosyngas - Key Partnerships

Key Partnerships[61]: The Key Partnerships Building Block describes the network of suppliers and partners that make the business model work. Companies create alliances to optimize their business models, reduce risk, or acquire resources. *Who are our Key Partners? Who are our key suppliers? Which Key Resources are we acquiring from partners? Which Key Activities do partners perform?*		
REC model	**Synergy with biosyngas**	**Critical aspects for next deep-dive analysis**
REC model A: **Collective Self-Consumption Group (e.g., residential condominium or an integrated complex combining a supermarket with housing)**	In biosyngas, partnerships focus on technological innovation, feedstock supply, and energy production, while in RECs, partnerships emphasize community governance, public sector support, technical expertise, and financial facilitation. The clear overlap lies in actors like public institutions, who can facilitate space, funding, and regulatory support; technical agencies, who ensure optimal integration of biosyngas into REC infrastructures; and financial entities, who can tailor financing schemes for both technologies and community ownership models. These synergies create a solid foundation where biosyngas technology can be embedded into REC projects, combining technical reliability with social, local empowerment. For each involved key partner, an explanation of the possible synergies is provided: • Public institutions and administrations: public bodies can host biosyngas plants on public land or buildings (e.g., schools, city halls) and facilitate permits, incentives, and funding. • Technical agencies and ESCOs: These actors can design, optimize, and operate the integration of biosyngas systems in REC energy networks, ensuring maximum efficiency.	• Engage with local authorities early to secure permits for biosyngas units in residential or mixed-use areas, focusing on building codes, emissions limits, and urban planning constraints. • Structure accessible financing models tailored to collective residential settings (e.g., shared loans, cooperative ownership structures) to lower the barrier for initial investment into biosyngas technologies.

	• Financing entities: banks, funds, and crowdfunding platforms can finance biosyngas systems as part of broader CSC/REC projects making biosyngas deployment financially viable and scalable within communities. • Bioenergy and biogas producers: experienced bioenergy players can bring expertise in scaling, operating, and maintaining biosyngas systems. • Feedstock suppliers: local waste collection networks, farmers, and industries guarantee a steady supply of biomass needed for continuous biosyngas production. • Technology providers: developers of advanced gasification solutions (like SUPREMAS) bring modular, efficient systems ready for community-scale deployment. • Regulatory bodies: clear, supportive regulations can accelerate the approval of biosyngas plants in RECs and align them with renewable energy targets reducing bureaucratic barriers and supports market growth.	
REC model B: **Community-led Renewable Energy Community**	Same as REC model A	• Alignment of governance structures: how to integrate a technically sophisticated biosyngas system into a participatory REC decision-making frameworks. • Joint stakeholder engagement models: how to align the industrial partnerships typical of biosyngas with the community-driven, participatory frameworks of RECs. • Community engagement strategies: building social acceptance and trust around biosyngas technology, particularly in residential environments.

		• Feedstock aggregation logistics within RECs: designing sustainable waste collection networks compatible with small, distributed communities. • Economic modeling: tailoring financial schemes that fit small, decentralized community budgets
REC model C: **Industrial efficiency with REC**	Same as REC model A	• Regulatory compliance and incentives: navigating different regulatory expectations for industrial bioenergy plants • Economic modeling: tailoring financial schemes that fit large industrial players.

4. Key Resources

Table 8-5 Synergies between REC BMs and biosyngas - Key Resources

Key Resources[61]: The Key Resources Building Block describes the most important assets required to make a business model work . These resources allow an enterprise to create and offer a Value Proposition, reach markets, maintain relationships with Customer Segments, and earn revenues. Key Resources can be categorized as follows: physical, intellectual, human and financial. *What Key Resources do our Value Propositions require? Our Distribution Channels? Customer Relationships? Revenue Streams?*		
REC model	**Synergy with biosyngas**	**Critical aspects for next deep-dive analysis**
REC model A: **Collective Self-Consumption Group (e.g., residential condominium or an integrated complex combining a supermarket with housing)**	• Both require dedicated installation areas but limited available space in residential environments could constrain the installation of biosyngas units. • Biosyngas can complement solar/wind by providing dispatchable energy and heat; space and maintenance logistics must be managed together.	• Feedstock logistics: explore practical models for residential organic waste collection (volume, quality, hygiene management) to sustain biosyngas production. • Personnel training: identify gaps and define minimal upskilling for building administrators and maintenance personnel for biosyngas operation.

	• The biosyngas system must be fully compatible with the residential REC's smart metering and incentive distribution platform; some digital upgrades may be necessary. • Existing personnel structures (administrator, maintenance, fiscal manager) are in place but additional specialized support will be needed for feedstock management and safety checks.	
REC model B: **Community-led Renewable Energy Community**	• Rural areas or small-town land availability allows for easier siting of biosyngas units compared to dense residential settings. • A medium-sized biosyngas plant could effectively complement decentralized solar/wind assets and strengthen overall community energy resilience. • Community personnel will need training for feedstock logistics (household and farm waste collection) and basic gasification plant oversight.	• Scalability plan: develop modular deployment strategies allowing future biosyngas capacity increases as community participation grows.
REC model C: **Industrial efficiency with REC**	• Industrial RECs have abundant space for biosyngas units, feedstock pre-processing areas, and possibly future plant expansions. Integration is straightforward. • Large-scale biosyngas units align well with high, continuous industrial energy demands and CHP applications (electricity and heat recovery). • Internal logistics managers, electricians, and maintenance staff are already available and can be quickly upskilled for biosyngas operation and maintenance. • While industrial parks often install large battery banks, biosyngas reduces the need for peak-shaving, providing economic optimization between dispatchable generation and storage costs.	• Feedstock supply chain: map industrial, agricultural, and municipal waste sources and design an efficient logistics system for continuous feedstock supply.

5. Customer Segments

Table 8-6 Synergies between REC BMs and biosyngas - Customer Segments

Customer Segments[61]**:** The Customer Segments Building Block defines the different groups of people or organizations an enterprise aims to reach and serve. For whom are we creating value? Who are our most important customers?		
REC model	**Synergy with biosyngas**	**Critical aspects for next deep-dive analysis**
REC model A: **Collective Self-Consumption Group (e.g., residential condominium or an integrated complex combining a supermarket with housing)**	• Members of CSC Groups and property developers: biosyngas system can be promoted as a renewable energy solution for new green housing projects, supporting biosyngas integration to enhance sustainability certifications and strengthen the market appeal of eco-friendly developments. • Residential can also integrate biosyngas systems to boost local energy resilience and promote circular economy models. • Supermarkets generate organic waste that becomes feedstock for biosyngas production and consume the electricity, heat, and cooling produced. • Residential associations and building managers: biosyngas system offers an efficient retrofit option for existing buildings, using biosyngas technology to deliver cost savings, improve energy performance, and access government incentives aimed at boosting renewable energy adoption.	Industrial Customers and Public Customers can potentially be shared in both REC and biosyngas models. Residential customers are peculiar to REC only. Business customers' engagement strongly depends on the nature of business. Service Sector has instead a good potential in both REC and biosyngas as the Industrial one.
REC model B: **Community-led Renewable Energy Community**	• Residents, farmers, SMEs, and municipalities are direct users and contributors in the community energy ecosystem with biosyngas.	Critical aspects reported in REC model A section.

	• Energy cooperatives and local authorities play a key role in governance, system management, and securing public support. • Public operators, researchers, and financial institutions enable the technical, financial, and innovative backbone needed to scale biosyngas within RECs. • Civil and sectorial associations: associations can promote the adoption of biosyngas technology through education, advocacy, and community mobilization.	
REC model C: **Industrial efficiency with REC**	• Industrial and business entities (SMEs and farms): small businesses and farms supply organic waste and use biosyngas energy for their operations, creating a circular energy economy within RECs. • Industrial customers have greater technical, logistical, and financial capacities to fully exploit biosyngas potential. • They can diversify the use of biosyngas across multiple applications: generating electricity and heat for internal operations (CHP systems), producing renewable chemicals such as methanol, ethanol, and hydrogen for manufacturing processes, creating synthetic fuels through Fischer-Tropsch synthesis for transportation needs, and valorizing by-products like biochar to support sustainable agriculture and carbon sequestration initiatives. • Furthermore, the flexibility and scalability of biosyngas systems fit well into industrial parks and agro-industrial clusters, where multiple enterprises can share infrastructure, optimize	Critical aspects reported in REC model A section.

	feedstock supply chains, and co-develop circular economy initiatives.	

6. Customer Relationships

Table 8-7 Synergies between REC BMs and biosyngas - Customer Relationships

Customer Relationships[61]: The Customer Relationships Building Block describes the types of relationships a company establishes with specific Customer Segments. What type of relationship does each of our Customer Segments expect us to establish and maintain with them? Which ones have we established? How costly are they? How are they integrated with the rest of our business model?		
REC model	**Synergy with biosyngas**	**Critical aspects for next deep-dive analysis**
REC model A: **Collective Self-Consumption Group (e.g., residential condominium or an integrated complex combining a supermarket with housing)**	• Biosyngas-generated savings shared among residents, reinforcing participation. • Reinvestment of incentives in building upgrades (e.g., energy efficiency, shared spaces). • Promotion of environmental and social sustainability linking local waste generators (residents/supermarkets) to energy projects. • Collaborations with universities for pilot projects on residential biosyngas use.	Approaches used in the REC sector result in a challenging application in the biosyngas sector. Despite a typical REC, which is focused on shared channels both via online tools and in person activities, biosyngas sector is more based on sector-specific network and platforms. A customized shared channels should be explored.
REC model B: **Community-led Renewable Energy Community**	• Larger incentive pool distributed across community members and small businesses. • Community-level reinvestments (e.g., energy storage, waste facilities). • Strong collective environmental mission driving REC cohesion and public image. • Partnering with farmers, local businesses, municipalities for feedstock and education. • Research partnerships for optimizing small-scale community biosyngas systems.	Critical aspects reported in REC model A section.

	• Joint Ventures and Public-Private Partnerships (PPPs) with SMEs and public entity • Participation through energy cooperatives and local associations.	
REC model C: **Industrial efficiency with REC**	• Incentives or energy savings redistributed among industrial tenants. • Upgrading park-wide infrastructure with advanced biosyngas energy systems. • Corporate ESG strategies strengthened through circular waste and energy models. • Industrial symbiosis partnerships for waste sharing and energy co-production. • Industrial R&D initiatives on synthetic fuels, biochar, advanced energy integration. • Joint ventures among firms for waste aggregation and biosyngas plant management. • Strong participation through industry consortia like EBA to influence policies.	Critical aspects reported in REC model A section.

7. Channels

Table 8-8 Synergies between REC BMs and biosyngas - Channels

Channels[61]: The Channels Building Block describes how a company communicates with and reaches its Customer Segments to deliver a Value Proposition. Through which Channels do our Customer Segments want to be reached? How are we reaching them now? How are our Channels integrated? Which ones work best? Which ones are most cost-eΩicient? How are we integrating them with customer routines?		
REC model	**Synergy with biosyngas**	**Critical aspects for next deep-dive analysis**
REC model A:	Biosyngas channels are mainly B2B, targeting industries and enterprises, while REC channels focus on citizen engagement and community participation. Successful integration of biosyngas into CSC groups requires	As previously noted, the biosyngas sector relies more heavily on sector-specific networks and platforms. Therefore, the development of customized, shared communication channels should be further explored. This

Collective Self-Consumption Group (e.g., residential condominium or an integrated complex combining a supermarket with housing)	blending professional industrial communication with inclusive, community-driven strategies.	need appears to be more aligned with the industrial sector than with the REC environment.
REC model B: **Community-led Renewable Energy Community**	Biosyngas communication channels, such as local media campaigns, community events, and partnerships with energy cooperatives, align naturally with REC channels like the software app, assemblies, and administrative support. Together, they create a seamless pathway from broad public awareness to active community engagement, accelerating biosyngas adoption in RECs.	Critical aspects reported in REC model A section.
REC model C: **Industrial efficiency with REC**	In Business Model C, biosyngas communication channels like industry trade shows, direct sales outreach, and technical webinars align strongly with REC channels such as tenant meetings, the operator portal, and the REC digital platforms. Together, they create a seamless pathway from technical promotion to direct engagement with industrial tenants, supported by administrative assistance and collective decision-making in member assemblies.	Critical aspects reported in REC model A section.

8. Revenue Streams

Table 8-9 Synergies between REC BMs and biosyngas - Revenue Streams

Revenue Streams[61]: The Revenue Streams Building Block represents the cash a company generates from each Customer Segment (costs must be subtracted from revenues to create earnings). *For what value are our customers really willing to pay? For what do they currently pay? How are they currently paying? How would they prefer to pay? How much does each Revenue Stream contribute to overall revenues?*		
REC model	**Synergy with biosyngas**	**Critical aspects for next deep-dive analysis**

REC model A: **Collective Self-Consumption Group (e.g., residential condominium or an integrated complex combining a supermarket with housing)**	• Biosyngas energy can increase the overall volume and stability of energy sales, improving REC revenue streams. • Biosyngas can unlock additional incentives (especially for waste-to-energy solutions) that benefit the REC collectively. • New revenue streams (e.g., biochar sales) diversify the REC's financial base, adding value beyond pure energy production. • Municipalities or local businesses may pay gate fees for waste disposal, providing extra income for biosyngas operations integrated into the REC.	Revenue diversification strategy: integrate income streams from electricity sales, heat supply, synthetic fuels production and biochar sales.
REC model B: **Community-led Renewable Energy Community**	Same as REC model A.	Critical aspects reported in REC model A section.
REC model C: **Industrial efficiency with REC**	Same as REC model A.	Critical aspects reported in REC model A section.

9. Cost Structure

Table 8-10 Synergies between REC BMs and biosyngas - Cost Structure

Cost structure[61]: The Cost Structure describes all costs incurred to operate a business model. Creating and delivering value, maintaining Customer Relationships, and generating revenue all incur costs. Such costs can be calculated relatively easily after defi ning Key Resources, Key Activities, and Key Partnerships. *What are the most important costs inherent in our business model? Which Key Resources are most expensive? Which Key Activities are most expensive?*		
REC model	**Synergy with biosyngas**	**Critical aspects for next deep-dive analysis**

REC model A: **Collective Self-Consumption Group (e.g., residential condominium or an integrated complex combining a supermarket with housing)**	CAPEX: • Biosyngas plants can be integrated as part of the renewable energy infrastructure investment in RECs, diversifying the production mix. • Energy efficiency upgrades can be coupled with biosyngas CHP outputs, improving building thermal performance. • Existing REC digital platforms can be expanded to monitor biosyngas energy flows, avoiding duplication of systems and saving costs. • Shared use of industrial/residential areas reduces additional land costs for biosyngas unit siting within RECs. OPEX: • Maintenance contracts can be bundled, optimizing technician schedules and lowering costs per unit. • Biosyngas management tasks (e.g., biomass logistics) can be integrated into the REC/CSC's administrative system, streamlining processes. • Joint energy performance assessments improve overall system transparency and optimization. • Synergistic public engagement strengthens REC cohesion and acceptance of new biosyngas technologies.	• Matching financing models to the social structure of each REC (residents vs. SMEs vs. industries). • Optimizing access to national/EU financial incentives across different project phases (CAPEX phase vs. OPEX optimization). • Ensuring alignment between community governance and financial ownership models (especially for joint biosyngas investments). • Building robust sensitivity analyses (e.g., variations in feedstock availability, energy prices, maintenance costs). • Evaluating third-party operational models vs. fully community-owned structures.
REC model B: **Community-led Renewable Energy Community**	Same as REC model A.	Critical aspects reported in REC model A section.
REC model C: **Industrial efficiency with REC**	Same as REC model A.	Critical aspects reported in REC model A section.

8.4 Synergies arising from the REC stakeholder consultation

The REC stakeholder consultation performed within the SUPREMAS project revealed important insights regarding the factors influencing the successful adoption of new waste-to-energy technologies in RECs, as well as the motivations and support needs driving innovation.

Community engagement emerged as the most critical success factor for implementing new waste-to-energy technologies within RECs. According to 27% of participants, ensuring active participation and acceptance by local citizens is essential for the effective deployment of such systems. Equally important, albeit to a slightly lower extent, are regulatory and financial feasibility, cited by 18% of respondents. This highlights the need for clear, supportive policy frameworks and accessible financing models to enable widespread technology adoption. Technical support was also mentioned, though by a smaller portion of stakeholders (9%), emphasizing that practical assistance remains relevant, especially for smaller or less technically experienced RECs. It is noteworthy that 36% of participants did not provide an answer to this question, suggesting either uncertainty or limited direct experience with waste-to-energy technologies.

Financial incentives were identified as the most powerful motivator for encouraging RECs to adopt innovative technologies such as SUPREMAS. A significant 73% of respondents pointed to financial support as the primary driver for technology uptake. Regulatory support was also seen as influential, cited by 36% of participants, reflecting the importance of streamlined procedures, permitting, and legal clarity. Environmental benefits, such as the positive impact on local sustainability, were mentioned by 27% of respondents, demonstrating that environmental considerations, while important, are typically viewed alongside financial factors. Community pressure, meaning citizen demand for greener initiatives, was less frequently mentioned (18%), indicating that external demand from members, while relevant, is not yet the leading trigger for innovation. A portion of respondents (27%) did not answer this question, suggesting a need for better communication about the benefits and opportunities associated with adopting new technologies.

When asked about additional support needed to adopt biosyngas technologies, stakeholders indicated a wide range of needs. These included the establishment of centralized or local thermal energy demand, technical and design assistance, authorization and permitting support, access to specialized expertise, and administrative, legal, or tax guidance to support the business development process. Each of these aspects was cited equally by 9% of respondents. However, 45% did not provide a response, which may reflect a current lack of readiness or understanding regarding the adoption of biosyngas solutions in their communities.

The consultation also highlighted the importance of social dynamics in technology adoption. A strong sense of belonging to the energy community significantly influences participation in new initiatives. About 73% of participants reported that their feeling of belonging either significantly or moderately impacted their willingness to engage with REC-promoted activities.

Perceptions of synergy between SUPREMAS technology and existing REC initiatives were generally positive. Among respondents, 64% recognized potential synergies, suggesting that the SUPREMAS system fits well within the broader objectives of many energy communities. Another 18% acknowledged the potential but emphasized the need for improvements to ensure full integration. However, 36% did not answer, indicating that further engagement and demonstration activities may be necessary to fully communicate the advantages of integrating biosyngas solutions.

9 CONCLUSIONS AND RECOMMENDATIONS

The SUPREMAS project represents a significant advancement in fostering a sustainable, decentralized energy transition across the European market. By integrating modular biosyngas technologies within Renewable Energy Communities (RECs), the study has shown the potential of byproducts-to-energy solutions to enhance local energy resilience, improve energy efficiency, and support carbon emission reductions within industrial ecosystems.

This deliverable discloses a market analysis focused on the REC sector and enables a comparison with the biosyngas market analysis performed in D1.1.[63] This comparison covered market size and trends, policy and regulatory frameworks, key drivers and barriers, pricing structures, sources of financing, and market strategies. Following this comparison, a preliminary synergy assessment was carried out to explore the potential integration of SUPREMAS technology with different REC models. Starting from such preliminary results, a more detailed analysis will be conducted in Task 7.5 through a full assessment of SUPREMAS business models within the REC sector. Additional data and insights generated throughout the project will be crucial for refining and validating the preliminary synergies identified in this phase.

The present study suggests that the SUPREMAS biosyngas technology holds substantial synergies for integration into RECs, addressing key objectives related to energy resilience, sustainability, and local value creation. Through the analysis, it is evident that SUPREMAS is aligned with REC value propositions, particularly in promoting energy self-consumption, ensuring grid stability, and enabling waste-to-energy transitions.

Although their development pathways differ, both biosyngas and RECs are fundamental for achieving Europe's climate neutrality goals. Both of them are boosted by technological innovation and industrial demand, as well as by environmental, economic, and social factors, even if each has its own peculiarities. In terms of barriers, biosyngas faces challenges related to high capital expenditure, feedstock variability, and regulatory complexity, while RECs struggle with legal uncertainty, financial limitations, and the need for technical capacity-building.

With regard to competitive advantages, biosyngas companies leverage advanced technologies and strategic pricing models, often supported by public funding programs like REPowerEU, whereas RECs succeed through social innovation, combining diverse financing mechanisms and fostering citizen participation to ensure local ownership and equitable energy access.

With regard to market applications, biosyngas targets energy-intensive industries and municipal waste-to-energy projects, whereas RECs is affected by regulatory restrictions for large enterprises in some countries (i.e. Italy), and it is more focused on addressing community needs like residential energy self-consumption, electric mobility, and district heating initiatives.

The integration potential of SUPREMAS varies across different REC models.

Business Model C "Industrial RECs" exhibits the highest potential due to economies of scale and reliable waste supply chains.

At a preliminary analysis, the SUPREMAS biosyngas technology seems to have good synergies with the main REC models identified so far. Specifically, in the Business Model A - "Collective Self-Consumption Groups", SUPREMAS could complement rooftop solar by providing flexible, dispatchable energy solutions; in the Business Model B - "Community-Led RECs", SUPREMAS could support decentralized waste valorization as well as electricity grid ancillary services and/or flexibility services; in the Business Model C - " Industrial RECs", SUPREMAS could enable large-scale waste-to-energy conversion and generates additional value through products like biochar and synthetic fuels.

Economic viability remains a central consideration for the widespread adoption of biosyngas systems. To ensure financial feasibility, particularly within Models A and B, projects must diversify revenue streams — including energy sales and by-product valorization — and access blended financing sources, combining public grants, soft loans, and private capital. The establishment of enabling regulatory frameworks, aligned with the revisions introduced by Directive (EU) 2018/2001 (RED II) as amended by 2023/2413, is critical to streamline permitting procedures and facilitate REC-led biosyngas investments.

In conclusion, the findings of this study suggest that SUPREMAS technology could become a cornerstone in Europe's energy transition by empowering communities, enhancing the utilization of local resources, and

[63] SUPREMAS [D1.1] Syngas Decentralized Production Framework.

fostering a resilient and sustainable decentralized energy system. However, realizing this potential will require a comprehensive, model-specific strategy that addresses the technical, financial, regulatory, and social dimensions identified. By strategically overcoming the critical barriers mapped in this study and leveraging the strong synergies between biosyngas solutions and REC models, SUPREMAS can substantially contribute to driving Europe's decentralized, circular, and citizen-led energy future.