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Energy Communities in Mediterranean Small Islands

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To Flavia and Martina, may they never stop being curious

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List of Abbreviations

ANCIM	Italian National Association of Municipalities of Minor Island
ARERA	Italian Regulatory Authority for Energy, Grid and Environment
ASSI	Astypalea Smart & Sustainable Island Project
COP	Conference of the Parties
CE4EUI Initiative	Clean Energy for EU Islands Initiative
CEC(s)	Citizen Energy Community (-ies)
CEP	Clean Energy Package
CET	Clean Energy Transition
CETA	Clean Energy Transition Action Plan
CoM	Covenant of Mayors
DSO	Distribution System Operator
DM	Ministerial Decree
EC(s)	Energy Community (-ies)
EEA	European Environment Agency
EECF	European Energy Community Facility
EIB	European Investment Bank
ELSTAT	Hellenic statistical service
ENEA	National Agency for New Technologies, Energy and Environment
ESIN	European Small Islands Federation
ETS	Emissions Trading System
ETS	(Procida REC) Ente del Terzo Settore – Third Sector Organisation
EU	European Union
EV(s)	Electric Vehicle(s)
EVCP	Electric Vehicle Charging Plan
GHG	Greenhouse gas
HEDNO	Hellenic Electricity Distribution Network Operator
HERA	Croatian Energy Regulatory Agency
IEMD	Internal Electricity Market Directive

IPCC	Intergovernmental Panel on Climate Change
JRC	Joint Research Centre
LGUs	Local Government Unit(s)
LIFE ISLET	The Innovative Support for citizen-led Local Energy Transition Project, funded by EU LIFE Programme
MS	Member States
NESOI	New Energy Solutions Optimized for Islands project
NII	Non-Interconnected Islands
NIMBY	Not-In-My-Back-Yard
NM	Nautical mile
NPEC	National Plan for Energy and Climate
PEAR	Campania Regional Energy-Environmental Plan
PNIEC	Italian National Integrated Plan for Energy and Climate
PNRR	Italian National Recovery and Resilience Plan
POD	Point Of Delivery
PV	Photovoltaic
PVGIS	Photovoltaic Geographical Information System
RAE	The Greek Regulatory Authority for Energy
RECs	Renewable Energy Community (-ies)
RED (RED II)	Renewable Energy Directive
RES	renewable energy sources
RoI	Return of Investment
SCI	Sites of Community Importance
SECAP	Sustainable Energy and Climate Action Plan
SME(s)	Small-Medium Entrerprise(s)
SPA	Special Protection Areas
SUMP	Sustainable Urban Mobility Plan
TYNDP	Ten-Year Network Development Plan
UNFCCC	United Nations Framework Convention on Climate Change

EXTENDED ABSTRACT

For years, European communities and local authorities have claimed that citizens must play a key role in meeting Europe's ambitious climate targets and achieving the goal of becoming the world's first climate-neutral continent. Already in 2016, the European Commission acknowledged the social innovation potential of community-led energy initiatives within the energy sector, even considering only the energy (self-) production.

Although various forms of community-based organisations providing energy services have existed since the end of 1800, the formal recognition of the 'energy community' as a distinct regulatory entity within the European Union emerged only with the 2018 revision of the Renewable Energy Directive (RED II). Energy Communities are now successfully expanding across the EU Member States, contributing to the energy transition through citizen-led initiatives. At least 8,000 energy communities have been counted across the EU, with many differences between them.

Indeed, Energy Communities embrace a broad range of activities, including the production, storage, sale, sharing, and consumption of energy. As socio-technical systems, ECs display a high degree of complexity, with their configuration shaped by several interdependent dimensions: temporal and spatial scales, local contextual factors, stakeholder involvement, technological infrastructures, and the underlying business and organisational models.

Small islands—whether connected to a mainland grid or operating as isolated systems—display distinctive characteristics across all these dimensions. These specificities, in turn, influence the feasibility, design, and operational performance of ECs in insular environments. Many researches indicate that the 'classic' Renewable Energy Community (REC) model may be unsustainable or unsuitable when applied to small islands, given their unique socio-technical and infrastructural constraints. Typical Mediterranean small island scenario includes:

- highly seasonal demand and variable electricity load due to tourism;
- isolation;
- concentrated consumption;
- energy and socio-economic vulnerability;
- lack of technical skills;
- energy demand covered by diesel generators;
- low Return of Investment;
- poor grid management in a monopolistic energy system;
- a high potential added value of the water-energy nexus;
- specific legislation.

This study aims at investigating whether a specific model for Renewable Energy Community (REC) development can be identified for small islands, taking into account the distinctive characteristics of these territories.

In recent years, small islands have received a great deal of attention from institutions at both European and national level. Several initiatives have been promoted to ensure that the energy

transition of small islands is as inclusive as possible and appropriate to the fragility of these territories. Island decarbonisation can progress rapidly and effectively when all relevant stakeholders act in a coordinated manner, generating both local and global benefits and potentially inspiring similar initiatives in other regions.

The energy landscape of islands, however, presents unique challenges for energy planners and policy makers, particularly in the pursuit of decarbonisation. Islands vary in terms of size, population, climate conditions, economic structures, availability of energy resources, grid capacities, and the degree to which they are connected—or isolated—from mainland electricity systems. They also display heterogeneous patterns of energy demand, electricity pricing schemes, and regulatory conditions, often shaped by environmental, aesthetic, or other site-specific constraints. These factors collectively create a complex and highly context-dependent setting for the design and implementation of sustainable energy transitions on islands.

This study examines the barriers and enabling conditions for the deployment of Energy Communities on small Mediterranean islands, drawing on insights from the LIFE ISLET (Innovative Support for Citizen-Led Local Energy Transition) project. The project aims to establish energy communities on both interconnected and non-interconnected small islands across Greece, Croatia, and Italy, thereby providing a comparative basis for understanding the specific challenges and opportunities that characterise insular contexts. This work examines the LIFE ISLET pilot cases (Astypalea, Cres and Procida) to derive lessons that may be transferable to other small islands experiencing comparable conditions. Its findings contribute to a more comprehensive understanding of the distinctive characteristics of energy communities in insular contexts, evaluating their potential, strengths, and limitations, and highlighting the remaining challenges and open research questions that deserve further investigation.

Island communities face significant socio-economic challenges, including social depopulation, limited local expertise, strong dependence on political goodwill, restricted energy market options, and a degree of institutional isolation from the mainland. In non-interconnected islands, electricity generation costs can be up to an order of magnitude higher than on the mainland, while local households often lack both personal financial resources and knowledge about accessing third-party funding. Although island residents typically possess a solid understanding of public finance mechanisms, they tend to exhibit lower levels of trust in private capital, fiscal incentives, and other financial instruments. Consequently, the development of island energy communities requires strengthened capacities in the financial and investment dimensions of project planning.

At the same time, renewable energy technologies frequently encounter public opposition, driven by concerns about landscape aesthetics, potential environmental impacts, and insufficient community engagement during project development, and perceived inequalities in the distribution of costs and benefits. Evidence indicates that renewable energy communities can help mitigate these issues by promoting greater local participation, enhancing transparency, and fostering more equitable benefit-sharing in renewable energy and energy-efficiency initiatives. In that framework, Energy Communities represent a very good opportunity for social development of small islands and for their decarbonisation.

To exploit this opportunity, the study shows that three key priorities emerge for speeding up EC development in Mediterranean islands:

- simplifying and harmonizing national REC legislation with the legislation specifically address small islands and their decarbonisation, to reduce legal and administrative obstacles;
- establishing funding mechanisms for local facilitators and coordinators who can maintain trust and engagement, recognising the EC as a mean for local development and jobs;
- promoting small, visible pilot projects on public or community-owned buildings to build legitimacy and increase public awareness.

These steps would lower entry barriers and strengthen local ownership, particularly in island settings.

Moreover, the case studies experience analysed in this work generated some key lessons relevant for the development of energy communities on small islands.

First, islanders tend to draw inspiration primarily from the experiences of other small islands rather than from mainland examples, underscoring the importance of context-specific knowledge transfer. Second, small islands represent favourable environments for piloting Renewable Energy Communities particularly in relation to social innovation processes, given their scale, community cohesion, and clearly defined socio-technical boundaries. Additionally, on islands, integrating the water–energy nexus into REC design can significantly enhance system efficiency and overall impact. Finally, in Mediterranean contexts, the involvement of local municipalities may further strengthen REC initiatives—for example, by providing access to municipal assets such as school rooftops during summer months, when electricity demand typically peaks. This is true only if the membership include specific demand loads that can take profit from a high energy production in summer.

1 – Introduction

Consistent with the commitments made at the 21st Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) in Paris in 2015, the European Union (EU) has established ambitious goals to reduce greenhouse gas emissions by 2030. In addition, in December 2019, the European Commission introduced the European Green Deal, a set of proposals to reshape EU climate, energy, transport and taxation policies with the aim of reaching climate neutrality by 2050 [1].

With the adoption of the European Climate Act (May 2021), member states and the EU as a whole commit to cut net emissions, creating challenges and opportunities for developing innovative energy supply systems that envision European consumers as the main protagonists of the energy transition, as the set of policies approved at the European level indeed aims to reduce net greenhouse gas (GHG) emissions by at least 55% from 1990 levels by 2030. To secure these objectives, the European Commission proposed the European Climate Law, enforced on the 29th of July 2021, with the goal of reducing greenhouse gas emissions to zero by 2050 and making the target of EU Green Deal legally applicable for all Member States (MS) [2].

Under the European Green Deal, and in line with the European Climate Law, the Renewable Energy Directive [3] is a pillar of the clean energy transition. Since the introduction of the first RED, the share of renewable energy sources in EU energy consumption has increased from 12.5% in 2010 to 24.6% in 2023.

For years, EU communities and local authorities have argued that citizens must play a crucial part in achieving Europe's ambitious climate goals and becoming the first climate-neutral continent [4]. Now, practical tools to accomplish this have been incorporated into European policy initiatives. One of these accomplishments is the "Fit for 55" legislative package. The prominence of Energy Communities is another example of Europe putting this new systemic vision into practice.

Still in 2016, the European Commission recognised the social innovation brought from community-led energy projects in the energy market, even considering only the energy (self-) production. Estimation suggests that by 2030, Energy Communities (ECs) could represent the owner of about 17% of wind capacity and 21% of solar [5].

Even if different forms of communities organised with the objective to provide energy services have existed since the end of 1800, is with the revision of Renewable Energy Directive in 2018 (RED II) that the concept of Energy community has been introduced in EU legislative framework [6].

According to the 10th State of the Energy Union report [7], Energy Communities are successfully expanding across the Member States, contributing to the energy transition through citizen-led initiatives. More than 8,000 energy communities now exist across the EU, with some other sources mentioning around 9200 energy communities legally formed, half of them based in Germany [8]. Nevertheless, Existing statistics and surveys do not break down energy communities by type of territory. Consequently, energy communities are counted only as a single overall category, and information on small islands is especially limited. European Union recognises that different areas have different needs and opportunities for energy communities' implementation, with the institution. For example, of the Rural Energy Community Advisory Hub, an initiative of the European Commission, which aims to accelerate the development of sustainable community-led energy projects in European rural areas, from which useful lessons learnt can also be drawn for the geographical islands.

The Energy Community activities encompass the production, storage, sale, sharing, and consumption of energy. An EC constitutes a complex energy system whose characteristics depend on several key dimensions: temporal and spatial scales, the local context, stakeholder involvement, technological solutions, and the business and organizational models in place. Small islands—whether connected to mainland's grid or operating as non-interconnected systems—exhibit distinctive features across all these dimensions, which in turn determine specific pathways and challenges for implementing a successful and effective EC.

Several studies on small islands shows that the "classic" REC model may not be sustainable [9], [10], [11], [12], because the typical Mediterranean small island scenario includes:

- highly seasonal demand and variable electricity load due to tourism;
- isolation;
- concentrated consumption;
- energy and socio-economic vulnerability;
- lack of technical skills;
- energy demand covered by diesel generators;
- low Return of Investment (RoI);
- poor grid management in a monopolistic energy system;
- a high potential added value of the water-energy nexus
- existing *ad hoc* legislation and legal constraint.

Islands worldwide represent geographically and socially vulnerable territories, facing challenges related to accessibility, healthcare and social services, economic stability, environmental pressures, biodiversity preservation, and energy provision. In terms of energy supply in particular, most islands rely on imported fossil fuels, which are typically combusted in small-scale power plants [13].

This work explores the barriers and the enabling factors for the implementation of Energy Communities in small Mediterranean Islands, thanks to the experience of the LIFE ISLET (Innovative Support for citizen-led Local Energy Transition) project, aiming at establishing energy communities in interconnected and non-interconnected small islands in Greece, Croatia and Italy [14].

Thus, this work aims to investigate whether a specific model for Renewable Energy Community (REC) development can be identified for small islands, considering the distinctive characteristics of these areas. Following a general overview of the EU regulatory framework on renewable energy and a brief review of the current literature and practical experiences related to Energy Communities in small islands, the study analyses the LIFE ISLET case study to draw lessons that may be applicable to other small islands facing similar conditions.

Both energy communities and small islands energy systems have been studied theoretically, and with simulations and assumptions. The LIFE ISLET project gives the opportunity to explore real experiences in implementing an Energy community in small islands and to analyse and better understand the path.

After a brief overview of the progress of energy communities in the European Union, while acknowledging that the framework is continuously evolving, the work introduces the topic by addressing the specific challenges that community-led energy initiatives face in particular energy systems such as those of small islands, and the role they can play in their energy transition. The chapter "Methods" shows the starting point of the research and the assumptions made and explains how the data were collected on the different islands, in an attempt to adhere as closely as possible to real-life situations in the three pilot cases. The LIFE ISLET project is then described in detail, with a particular focus on the energy profile of the three islands under study. For each island, the energy community established during the project is described; focusing solely on current members, ways of maximising shared energy are explored, with a view to identifying possible generalisations or at least common ground amongst experiences that remain very different.

The conclusions contribute to a deeper understanding of the specific features of energy communities in small island contexts, assessing their potential, strengths, and weaknesses, as well as identifying the remaining challenges and open research questions in this field.

2 – Energy Communities in EU

Various types of communities organized to provide energy services have existed since the late 1800s, and several studies have attempted to offer an overview of the experiences gained. Historically, energy communities have been established as grassroots initiatives intended to facilitate the energy transition while generating economic, environmental, and social benefits for their members. In the European context, the evolving framework gives rise to substantial challenges for the design and governance of energy communities [15].

The concept of Energy Communities (ECs) is finally explicitly defined in the These provisions were introduced by the Renewable Energy Directive (RED II) and the Internal Electricity Market Directive (IEMD) [16], which are contained within the European Union's Clean Energy Package (CEP). With these directives, bottom-up initiatives all over Europe find a framework that starts to officially recognise the citizens-led energy experience, despite differences between countries due to varying methods of national transposition.

The Directive (EU)2018/2001 (RED II) and the Directive (UE) 2019/944 (IEMD) distinguish between Renewable Energy Communities (RECs) and Citizens Energy Communities (CECs) with some differences in terms of sources of energy productions, geographical constraints, scope of their activities.

While Citizen Energy Communities (CECs) and Renewable Energy Communities (RECs) share a common foundation, they are distinguished by specific legal and operational nuances. Both require a formal legal personality, with national legislation determining the specific organizational structure—often favouring non-profit models like cooperatives or associations to align with the primary goal of community benefit over profit.

To avoid the exploitation of energy communities for purely financial purposes by corporate actors, RED II prohibits energy companies, large enterprises, and non-local authorities from joining renewable energy communities. In contrast, the IEMD does not apply comparable membership restrictions to citizen energy communities.

RECs are characterized by stricter 'proximity' and 'autonomy' requirements, focusing on localized, multi-carrier renewable energy (electricity, gas, and heat). In contrast, CECs offer greater geographical and technological flexibility; they may operate at a national scale and include fossil-fuel-based electricity, while also managing a broader service portfolio that includes distribution and EV charging infrastructure. [6].

The table 1 summarises the differences between a CEC and a REC according to the EU laws.

Table 1 – Differences between a CEC and a REC according to the EU laws

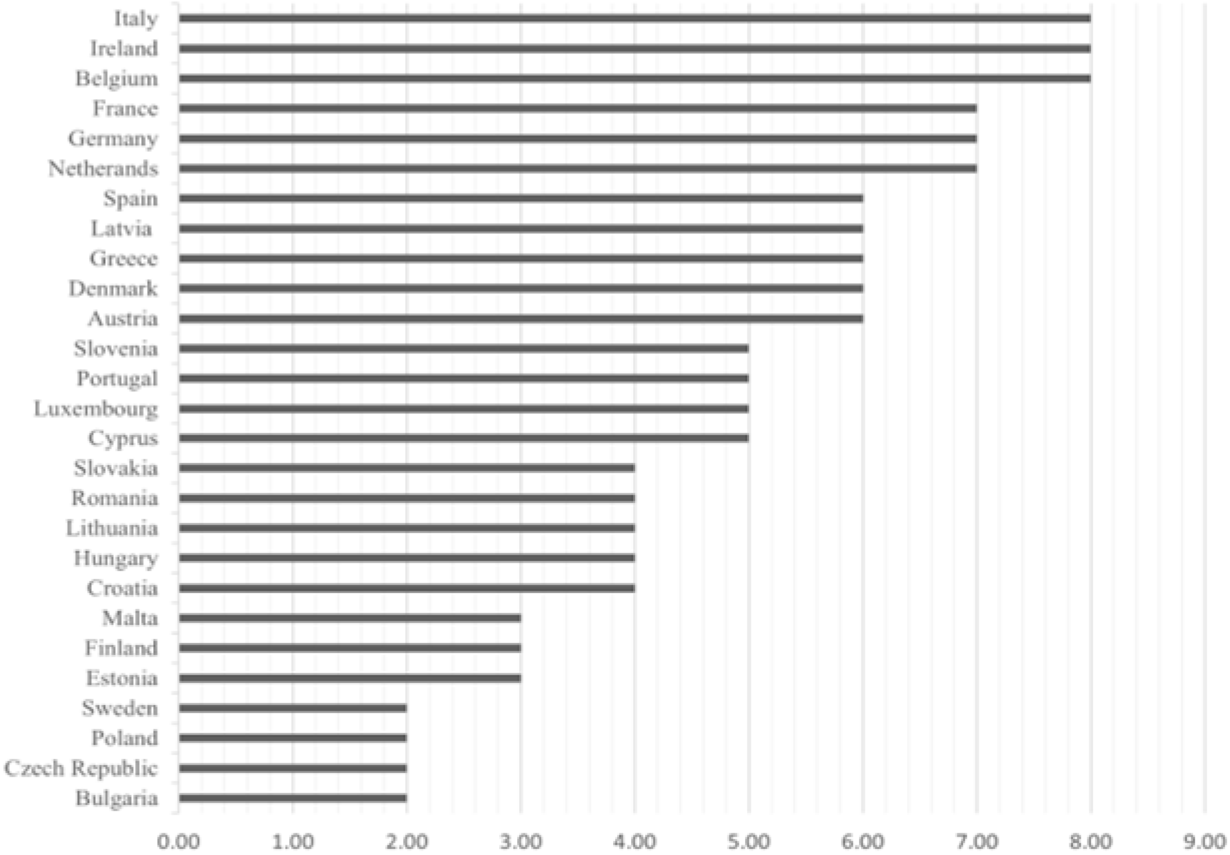
	REC	CEC
Purpose	increase the penetration of RES	collective investment to cut initial investment costs
Activities	Renewable energy self-consumption at community-level	Local production, distribution and transmission of energy
Geographical constraints	Members should be "in proximity" of energy projects	No geographical limits defined
Membership	Citizens, local authorities, SMEs, controlled by members at local level	Citizens, public authorities, companies
Primary legal reference	(EU) 2018/2001	(EU) 2019/944 (EU) 2018/2001

Energy communities are a multidisciplinary challenge, as social, technical, legal and economic dimensions are relevant in their creation and development. The establishment of Energy Communities is guided by three macro-objectives [17]:

- Community Empowerment: to enhance public awareness and empower citizens in the domain of energy self-production;
- Energy System Transition: to facilitate the energy system's transition towards decarbonization, decentralization, and digitization;
- Local Economic Growth: To stimulate the local economy by redistributing revenues from energy production back into the community.

According to the EU legislator, national policymakers have to take the challenge of striking a balance between standardization and flexibility, ensuring sufficient scope for local communities to tailor projects to their specific needs and preferences. Consequently, Member States (MS) must enable facilitating schemes—such as technical and financial support, assistance with entry into the energy market, and streamlined procedures—by customizing regulatory frameworks to reflect local territorial characteristics. By incorporating targeted provisions and measures into their national plans, MS should provide Energy Communities with the necessary legal framework and support to thrive, thereby fostering the development of a decentralized and participatory energy system.
Transposition of the Directives in the EU Countries really affect the implementation of working citizen-led energy projects. Several initiatives have reviewed the transposition advancements at national level, both in terms of definition and enabling and supporting schemes, e.g. RESCoop Transposition Tracker - updated to April 2024, and the analyses of the national legislation for energy communities in the 27 EU countries provided by the European Energy Community Facility (EECF).
Not all the European criteria are still now achieved, while enabling frameworks are missing completely from a large number of MS. Fig. 1 gives an overview of the MS positioning at early 2024, highlighting how varied is the European panorama on RECs.

Figure 1. – Overview of the MS Degree of legislative framework maturity, where 0 is worst performing and 10 is best performing [Magni et al, 2023)



EU Directives interpret energy communities as, in principle, open to all, while allowing communities to establish entry conditions that are non-arbitrary and non-discriminatory. RED II specifically excludes certain powerful actors from membership in order to prevent energy communities from being captured by corporate interests or non-local public authorities. With regard to financing, the directives do not require members to make financial contributions. Although RED II obliges Member States to facilitate the participation of vulnerable households, it does not set a cap on the financial contributions that energy communities may request from vulnerable or low-income members.

Effective control of energy communities is intended to remain independent from dominant corporate actors and non-local public authorities, with RED II explicitly excluding non-local interests from exercising such control. Beyond these exclusions, the directives do not prescribe a specific distribution of voting rights or decision-making powers within the community. Notably, community managers may be appointed from outside the community. The same flexibility applies to renewable energy installations, which may—but are not required to—be owned or operated directly by the community. Finally, while the directives require that energy communities generate benefits for their members and the surrounding area—such as environmental protection, local economic development, or reduced energy costs—they do not generally prohibit the distribution of surplus revenues to members.

In this general framework, many differences are in place in the real-life implementation following the national transposition of the EU legislation on ECs, In terms of size and scale, rights and obligations, membership and services, legal definitions. Stricter regimes apply in Latvia and in Croatia, with Hungary, Romania and Italy seem to allow more options in the legal and governance aspects [18].

3 – Energy Transition in EU Mediterranean Small Islands

Still in the 2014 IPCC Evaluation Report "Climate Change 2014: Impacts, Adaptation, and Vulnerability" [19] and the report of the European Environment Agency (EEA) "Climate change, impacts and vulnerability in Europe 2016”[20], Europe and in particular the Mediterranean basin was indicate as a region where negative climate change impacts, in the frequency of extreme weather events and changes in rainfall, have being increasing, with possible worsening of already existing conditions of strong pressure on water resources. This, in addition to the anthropic pressures on natural resources, makes the Mediterranean region one of the most vulnerable areas of Europe. Current and future climate-related drivers of risk for small islands during the 21st century include sea level rise, tropical and extratropical cyclones, increasing air and sea surface temperatures, and changing rainfall patterns. The future risks associated with these drivers include:

- Loss of ecosystems, settlements, and infrastructure, as well as negative impacts on human health and islands’ economies.
- Serious harm and loss of subsistence lifestyles with a consequent potential increase in internal migration. Loss of coastal protection and beaches, loss of tourist revenue.
- Loss and harm due to sea level rise in small island communities [19].

EU Islands background and decarbonisation

According to the European Small Island Federation (ESIN), in the EU there are almost 360.000 islanders distributed on 1,640 small islands. Islands have been in the forefront of raising international awareness of climate change and advocating for robust climate action. Although islands are among the least responsible for global climate change, they are likely to bear the brunt of its negative consequences. In light of these unique circumstances, the 2015 Paris Agreement recognizes that small islands are particularly vulnerable to climate change. At the same time, islands are recognized as enhancers of resilience and mitigation strategies against global climate change through decarbonisation of energy and other sectors such as agriculture and transportation (owing to their potential as pioneers for new technologies). In reality, island communities are more likely to engage in the research and testing of innovative solutions to the challenges of maintaining a sustainable lifestyle on their island due to their fragility.

makes special reference to the potential of islands to contribute to Europe's energy transition [21]. Acknowledging this potential resulted in the launch of a special initiative for Islands, the Clean Energy for EU Islands Initiative (CE4EUI Initiative). The CE4EUI Initiative intends to support EU islands in their clean energy transition. Core objective of the Initiative is to assist islands with exploiting their own renewable energy sources and adopting innovative technological solutions and so reduce their dependence on fossil fuels, benefit from lower energy costs, better air quality and lower greenhouse gas emissions [22].

The European Commission published its Communication 'The European Green Deal' (2019), outlining a new growth strategy aimed at transforming the EU into a fair and prosperous society with a modern, resource-efficient, and competitive economy by 2050, with no net greenhouse gas emissions and economic growth decoupled from resource use. The 75% of EU emissions come from energy use and production, and as a result, energy policy is at the heart of the Green Deal. European islands are in a unique position to be early adopters of the European Green Deal and catalysts for a renewable energy transformation. The renewable energy transition of islands will help to achieve the European Green Deal's goals while saving money, benefiting both local communities and island businesses, as well as mainland residents [1].

The European Commission and the MS of Croatia, Cyprus, Denmark, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Malta, Portugal, Spain's dominion, and Sweden signed the 2020 Memorandum of Split in recognition of this possibility. The Memorandum's main goal is to establish a long-term framework for cooperation in order to advance the energy transition for islands, while considering the unique characteristics of each island and the national distribution of legal competences in the field of energy and territorial development. The study "Islands of The European Union: State of play and future challenges" of the European Parliament, (2021) points out that "Islands rely on water and energy imports, fossil-fuels and unsustainable transport means, even for basic activities. Islands are facing a double race: towards recovery and towards sustainability". In addition, the report underlines that “in the future, islands will have to be more resilient, […]. Inter alia, islands should develop sustainable, less seasonal and more diversified economies.” [23].

The recast Renewable Energy Directive opens the door to the creation of renewable energy communities that can contribute to self-sufficiency in energy generation. The Directive also permits MS to "modify financial support programs" for RES initiatives in outermost regions and small islands. (art. 4). At the same time, the recast Electricity Directive recognizes distributed energy technology and consumer empowerment as viable tools for improving domestic energy efficiency. In accordance with the Directive, the MS should ensure that renewable energy communities are treated equally to large participants in available support schemes, as they are thought to contribute significantly to the energy transition in terms of local acceptance of renewable energy technologies and access to additional private capital, resulting in local investment, more consumer choice, and greater citizen participation in the energy transition. The Energy Efficiency Amending Directive emphasises the critical need of enhancing energy efficiency across the whole energy supply chain. The CoM for Climate & Energy (which completely embeds the old Pact of Islands Initiative) will devote more resources in its new management phase to provide specific support to island municipalities within the Initiative.

The European Commission places a strong emphasis on the creation of a European Climate Pact. This Pact strives to educate, inspire, and promote collaboration among people and organisations ranging from national, regional, and municipal governments to businesses, unions, civil society organisations, educational institutions, research and development organisations, consumer groups, and individuals. European islands that embrace this collaborative attitude in their energy planning strategies could be role models for the implementation of local Climate Pacts. The decarbonisation of islands can continue swiftly and seamlessly with the coordinated efforts of all concerned parties, creating local and global benefits and encouraging comparable measures in other geographical contexts.

The energy context of islands poses distinct challenges for energy planners, particularly in the context of decarbonisation. Islands differ widely in size, population, climate, economic structure, availability of energy resources, grid capacity, and the degree of connection—or isolation—from mainland electricity systems. They also exhibit diverse energy demand patterns, electricity pricing mechanisms, and regulatory frameworks, including environmental and aesthetic constraints, as well as other location-specific limitations [24]. According to the DG for Energy of European Commission, European small islands face a unique energy paradox. Despite being endowed with abundant renewable energy sources (RES) such as wind, solar, and wave energy, they remain heavily dependent on expensive and polluting fossil fuel imports. For these areas, the energy transition is not only an environmental necessity but a pathway toward economic resilience and "energy sovereignty. Since electricity production costs on islands can be 3 to 10 times higher than on the mainland, the adoption of local production models and the shift to renewable energy sources are highly efficient. In many Mediterranean small islands, a significant share of renewable energy can be achieved with minimal effort, with tailored incentives and initiatives addressing the unique geographical characteristics of them. However, the decarbonization process is progressing slowly, with nearly all islands falling short of meeting both the 2020 and, even more so, the 2030 capacity targets [25].

In 2021 and 2022 the Clean energy for EU islands Secretariat conducted a study on the regulatory barriers affecting the clean energy transition of islands. This showed that grid constraints and the lack of security of supply were identified as two of the key barriers to the decarbonisation of EU islands' energy systems.

Other identified challenges can be grouped into five main categories:

- Frequent power interruptions and outages, resulting from grid instability and the high vulnerability of energy systems to extreme weather events.
- Significant curtailment of variable renewable energy generation, implemented to maintain system stability and reliability.
- Insufficient controllability of existing system assets, coupled with the slow adoption of smart technologies due to financing constraints.

- Limited institutional and technical capacity to design and implement targeted regulatory frameworks that support the transition from thermal-based to renewable-based energy systems.
- Complex and fragmented permitting and grid-connection procedures for renewable energy power plants.

To address these challenges, a set of policy, regulatory, and operational measures is recommended at the system operator, national, and EU levels.

These measures focus on:

- improving the planning and operation of island electricity systems,
- ensuring that national grid and renewable energy regulations are adapted to the specific characteristics of island systems, and
- preparing island grids for safe, reliable operation throughout the energy transition.

In addition, they aim to support the efficient and beneficial integration of variable renewable energy generation.

Primary responsibility for implementation rests with system operators, national regulatory authorities, and national and regional governments. Nevertheless, the EU has an important enabling role to play by facilitating the exchange of best practices, issuing guidance, and designing funding programmes that incentivise and require systemic change [26].

Despite these obvious benefits, many islands continue to rely on costly and harmful fossil fuels, especially diesel and heavy oil generators. Many island communities suffer issues like social desertification and a scarcity of islander expertise, a heavy reliance on good political will, a lack of energy market options, and some institutional isolation from the mainland. Furthermore, the cost of power generation on non-interconnected islands can be up to ten times higher than on the mainland, and islanders lack sufficient personal funds as well as knowledge of how to obtain funding from third parties. In reality, while the island populations appear to have a good understanding of public finances, they have little faith in private funds, fiscal incentives, and other mechanisms. To achieve progress, island energy communities require additional knowledge in the financial aspects of project development.

At the same time, renewable energy technologies are encountering opposition due to worries about their aesthetic (for landscape) or environmental implications, as well as a reaction to a lack of local community involvement in project development and an overall unequal cost-benefit distribution. Renewable energy communities have been shown to assist resolve these concerns and improve people's participation in renewable energy and energy efficiency project development. While difficult, coordination among all stakeholders in the development of such projects and campaigns is critical for a seamless and rapid decarbonisation of EU islands that leaves no one behind.

4 – Renewable Energy Communities in small islands

Access to energy usage statistics on the islands is not always easy to come by, making it difficult for the island population to grasp the scope of the overall effort required, as well as to track any progress made. In truth, not all islands have a carbon reduction strategy in place. Many islands lack the resources and skills necessary to establish and implement renewable energy transition plans. From defining specific roles and responsibilities for the development of renewable energy projects to navigating complex legal and regulatory frameworks to identifying and pursuing appropriate financial opportunities, island energy communities require assistance in building their own capacities and connecting to experts in order to mobilise specific expertise to fill capacity gaps, such as around tendering issues. As possible sites for solar and wind farms, island communities frequently lack the skills to negotiate national tendering processes, putting them at greater risk of embarking on a technical, legal, and economic arduous trip before seeing a return on their investment. Tendering processes are regulated and handled on a national level, necessitating improved access to national data and assistance in order for smaller island energy communities to produce their own green electricity.

The peculiar territorial characteristics make small islands ideal laboratories to face the urgent and impacting environmental challenge. In these isolated and vulnerable (eco)systems, it is possible to apply innovative models in the field of energy, water cycle and waste management aimed at the protection of the natural resources. A key point is providing new solutions to water and raw materials management in the perspective of a circular economy as well as replacing energy production from fossil sources with renewable ones [9], [10], [11].

Regarding the latter aspect, the Renewable Energy Communities and Collective Self-Consumption, introduced at European level with the EU Directive 2001/2018 represent a great opportunity for the small islands to switch to an innovative model focused on renewable sources. This rule eliminated the barriers to the possibility of producing and self-consuming, sharing and storing energy from renewable sources by citizens, small and medium-sized enterprises, and local authorities.

The renewable energy communities are a huge opportunity for the small islands because they represent a way to overcome their historical dependence on the mainland and on a production of energy almost entirely focused on polluting and climate-changing fossil fuels. With the active involvement of citizens, RECs give the opportunity to overcome typical existing barriers in small islands: lack of information, social acceptance, and scarcity of external investments [27].

As very few scientific works deal with Energy Community in geographic islands, in cooperation with the Institute of social policies and population of National Research Council (CNR-IRPPS), ISLET project explores the factors influencing participation in Renewable Energy Communities on Italy's small islands, focusing on socio-demographic, knowledge, behaviours and perceptions dimensions. Using a web-based survey, the study (still currently being submitted in May 2026) seeks to examine the factors shaping the willingness of residents of Italy's small islands to participate in, or contribute to, the establishment of a Renewable Energy Community (REC), and to compare these determinants with those identified in an analogous survey conducted across the entirety of Italy, including both islands and the mainland. Respondents who are more familiar with energy transition and sustainable development show a significantly higher inclination to engage with community energy initiatives, indicating that energy literacy is a key driver for REC deployment. The findings of this study suggest that REC development on small Italian islands is primarily envisioned as a collaborative effort between local governments and community groups, while businesses, research institutions, and industry associations serve a supporting function. The results highlight that promoting RECs adoption on Italian small islands requires a multifaceted strategy that simultaneously addresses cognitive, economic, and institutional barriers. Effective policy packages should integrate several complementary pillars: islands' context-specific awareness campaigns, capacity-building programs for local administrators, and targeted financial instruments to lower entry barriers also for low-income households.

Other EU experiences underline that to maximise the socio-economic impact of decarbonising geographical islands' energy systems, it is recommended that the RES facility be owned by the community and integrated into the local area, as this approach brings broader social and economic benefits and helps raise public awareness of sustainable development [28].

The underlying premise of this research is, however, that purely energy-related issues are of minimal importance in the early stages of establishing island energy communities, compared to cultural, social and regulatory considerations.

Thus, the research question to what this work try to answer is the following: is it suitable to define a specific model for the creation of energy communities in the small Mediterranean islands that is sustainable, has a positive social and environmental impact, and is able to overcome barriers and exploit the enabling factor offered by small islands?

5 – Methods

This work is based on the experience of the real-word Energy Communities built in three pilot small islands in the framework of the LIFE ISLET project [14]. Case studies are the real Energy Communities created during the project. This work analyses what is really happening on the islands, using actual data and make estimation on concrete possibilities. Indeed, Energy Communities are in huge number on paper, but very few works analyse case-studies in the real word.

The ISLET project aims to establish energy communities on both interconnected and non-interconnected small islands across Greece, Croatia, and Italy, thereby providing a comparative basis for understanding the specific challenges and opportunities that characterise insular contexts. The case studies differ in terms of their social and technical characteristics and operate within different regulatory frameworks.

After analysing the general features of each island, some simulations of different configurations for each RECs are made, to explore which factor could be relevant in the RECs optimisation. Nevertheless, the social and regulatory framework never have to be forgotten, as it seems the pillar of RECs development in small islands.

The initial reference point is the existing energy configuration, and the corresponding energy demands of its members, with the awareness that the formation of an energy community involves not only technical considerations but also active citizen participation and commitment.

The process followed by the project is a bottom-up approach, aiming at involving people in taking part in a community-based energy initiative without any consideration about energy sharing optimisation. Only in a second phase, the RECs development will include the possibility to make choices concerning new members' involvement, considering the EC's energy sharing performance.

For the three islands, starting with the existing situation, this study wants to make some hypotheses about energy production, verifying which scenario will maximise energy sharing. In order to provide the general landscape, for each Energy Communities, the national framework and local context is described as well as the Energy community description and the membership composition.

Data of members' energy demand has been provided by LIFE ISLET partners, often the local municipality or the project partner, which is locally supporting the EC creation and development.

This is why obtaining high-quality data was the greatest challenge in this study.

Difference in data format occurred in different pilots, so studies for energy sharing in ECs slightly differ among them. Nevertheless, everywhere "Shared Energy" is defined as the minimum hourly amount between:

- Energy fed into the same primary substation by all the plants in the EC perimeter
- Energy withdrawn from the Points of Delivery (PODs) which are part of the EC:

When prosumers are present, both in actual configurations and in the simulated energy configurations, for the EC point of view and load calculation, the energy demand of this member correspond to the deficit compared to the self-production (so the energy demand from the grid), while the Production corresponds to the surplus in the self-production:

$$\textbf{DEM in EC} = \textbf{dem} - \textbf{Selfcons} \qquad (4.1)$$

$$\textbf{PROD in EC} = \textbf{surplus} = \textbf{Prod} - \textbf{Selfcons} \qquad (4.2)$$

Where

selfcons = min (dem; prod)

dem= energy demand of the individual user POD (kW)

prod= production of PV panel installed and connected to the individual user POD (kW)

Thus, the energy sharing corresponds to:

$$\mathbf{E_{shared}} = \textbf{min } (4.1; 4.2) \qquad (4.3)$$

Data collection & availability

Where a local energy agency was involved in supporting the construction of the REC, like in Croatia, the quality of the data is far superior to that in other cases. Indeed, in Cres, only three organisations are part of the Energy Community, and for everyone data about energy demand were available, for every quarter of an hour. The same detail was available for the energy production of the kindergarten's PV plant. To use the hourly data, the average of the four quarterly data each hour has been considered, and then the energy demand and production considered correspond to the hourly one.

The result is a more accurate estimation of the shared energy on hourly bases, compared to the other islands.

For the energy community in island of Astypalea, we got actual hourly demand data for at least one member in each category (hotels, households, restaurants) of Energy Community. Thus, we assume that similar members have similar energy profiles, considering that the hotels/guest houses and restaurants are similar in size, location and how they operate The Energy community includes:

- 2 Hotels, with about 30 rooms each
- 2 Restaurants (SMEs)
- 2 Guest houses, with 7 and 8 rooms
- 6 two-people households
- 8 four-people households

Using data collected from installed smart meters in typical households and small businesses, detailed time series of energy profiles were developed. These profiles served as a first approximation of local electricity demand, allowing for an initial estimate of the community's overall energy needs. Thanks to metering installation, demand data for these categories were available, but for Guest Houses. In that case, we assumed that they have about ¼ of hotel load.

In Procida, official actual data were not available. Only one member gave us the permission to get data from e-distribuzione, that manages electricity meters in Procida. Data for most members of the energy community was collected from their utility bills of 2024, with a monthly or bi-monthly frequency. Estimates of the division of energy consumption between night and day and between different months for the Procida REC were made using ARERA statistics for 2024 on average household consumption, considering the Province of Naples [30].

Table 2 – Average consumption profile for domestic customers in the province of Naples

	kWh	%
Night	5,2223	48,07%
Day	5,6416	51,93%

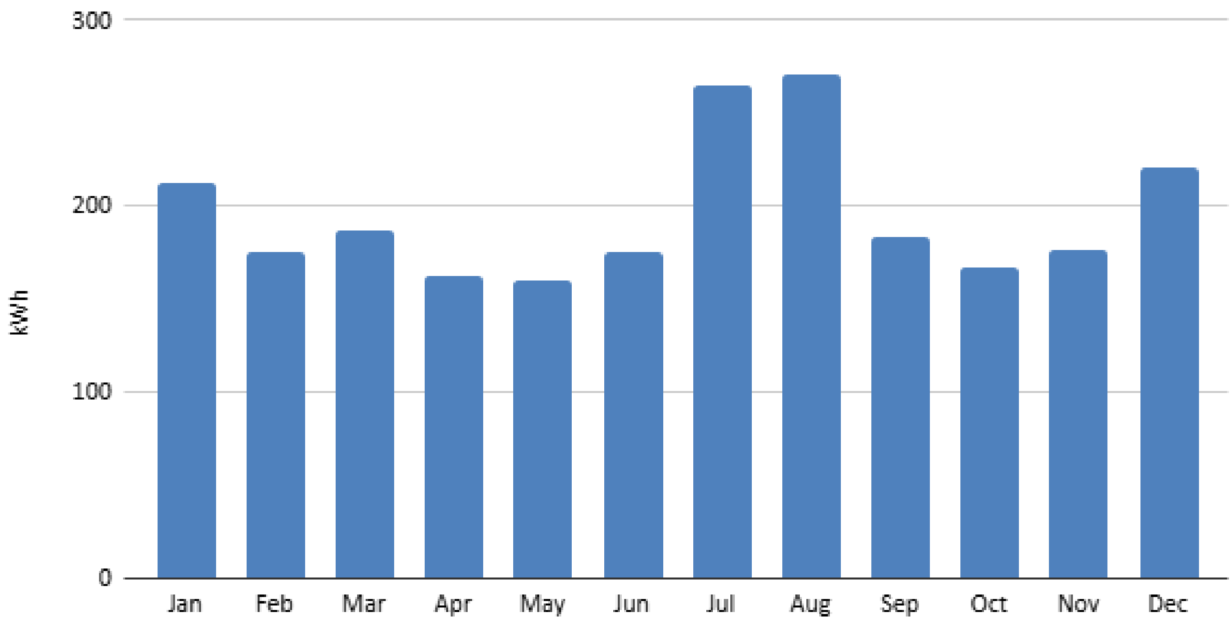


Figure 2 – Average monthly consumption for domestic customers permanently residing in the province of Naples [30]

By cross-referencing these average values with consumption data from the bills of EC Procida members, monthly consumption data for day and night were estimated, considering 'day' to be the hours from 7 a.m. to 7 p.m. and 'night' to be the remaining hours. Data about production of existing renewable energy power plants (PV panels), when not available, have been estimated through the Photovoltaic Geographical Information System (PVGIS) online tool on photovoltaics performance [29], offered by the European Joint

Research Centre, for each site (Astypalea, Cres and Procida) for the last year available, notably the 2023. The same tool has been used to estimate the energy production of new renewable energy sources plant (PV panels) potentially installed in the framework of the ECs.

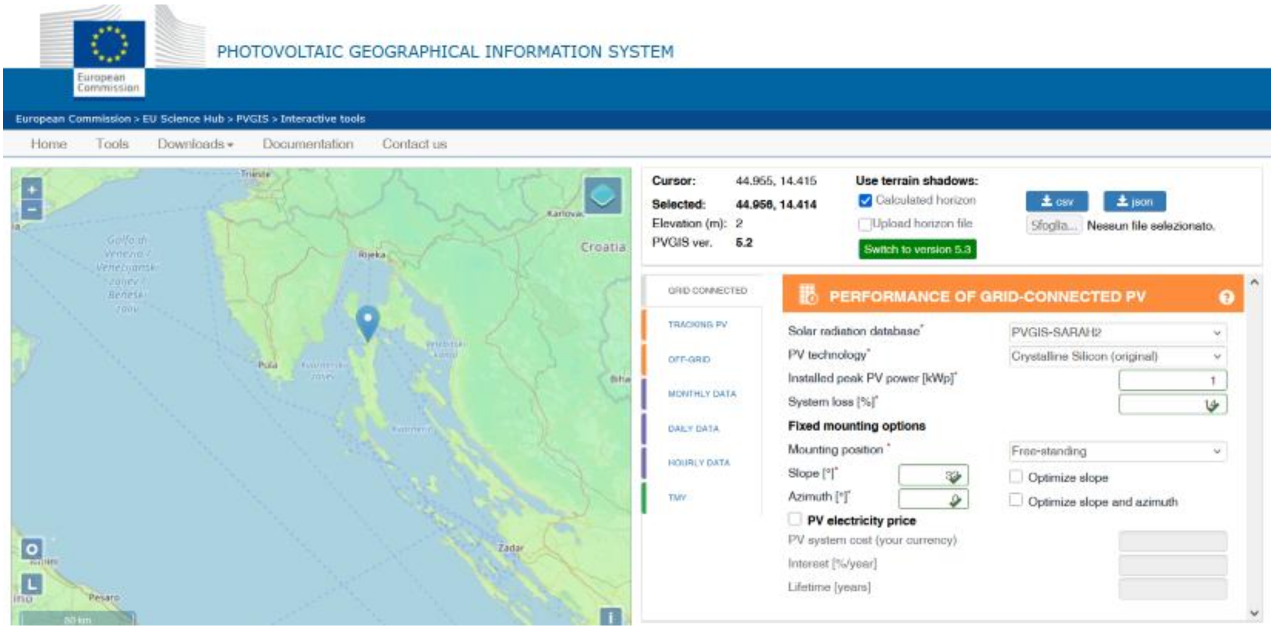


Figure 3 – PVGIS tool for Photovoltaic performance

In that tool, Slope has been estimated fixed for all the pilots and equal to 32°, that is considered the optimal tilt angle for PV panel for the central Italy latitude, average latitude for the considered islands.

Once data of consumption and production are collected and the new instalment for each Energy Communities is fixed, sharing of energy have been estimated, trying to get some important results for relevant feature in small islands.

Simulation studies are aiming at finding the optimal configuration of the energy communities in terms of members and in terms of prosumers, considering real constraints and conditions of the Energy Community at local level (roofs availability, capacity of investment, local regulatory framework). The timeframe under consideration is that of the very early stages of the energy community's development and is therefore very short-term. This is because, in our analysis of real-world case studies, we found that the greatest difficulty lies in starting up the mechanism for energy production and sharing up. As there was little data to analyse – either because the energy communities under consideration had few members or because data available were limited – the calculations for energy generated, surplus energy and shared energy were simply carried out in Excel.

The simulations facilitate the formulation of general conclusions by enabling a comparative analysis of the three island experiences and an examination of the differences between small islands and the mainland, thereby addressing the aforementioned research question. As already introduced, each analysis is analysis is based on the belief that island energy communities isn't just a technical challenge; especially in the early phases, cultural, social, and regulatory hurdles take precedence over purely energy-related issues.

6 – The LIFE ISLET project

Citizens and local administration can play a crucial part in achieving Europe's ambitious climate goals and becoming the first climate-neutral continent. With the formal introduction of Energy Communities by the EU Directive 2018/2021, their role has been incorporated into European policy initiatives and legal framework [6]. Local authorities can enable this process, increasing the control of their energy system, not just in terms of energy generation, but also in terms of energy storage, selling, aggregating, sharing, and providing energy services. Local and regional authorities in small Mediterranean Islands can learn from the EU best practices, take advantage of their unique characteristics, and play an increasingly important role in their local sustainable energy transition assisting with energy community formation, by becoming main shareholders and promoters. Mediterranean islands RECs can invest in various sustainable energy projects. Yet the barriers islands face when trying to make their energy systems more sustainable are multi-dimensional.

Technical barriers

Because all grid balancing and flexibility must be provided within islands, non-interconnected ones have considerable technical challenges. Increased RES penetration necessitates bigger spinning reserves to ensure available power during generation fluctuations.

On non-interconnected islands, traditional thermal generators (typically powered by light diesel or heavy fuel oil) are subject to operating constraints: they are not permitted to operate below a specific power output threshold to avoid unnecessary wear and tear, and maintenance. This 'technical minimum' limitation is rather high, frequently kept at 40-50 percent of the theoretical capacity of the conventional unit, implying that there is little "space" available to be supplied by RES.

Economic barriers

Many islands suffer economically because of their reliance on imported fuel. In comparison to the mainland, islands must pay greater transport expenses per energy unit contained in the fuel due to the necessity for frequent supply of relatively small amounts of fuel. Because of their reliance on fossil fuels, islands are more subject to global oil price volatility, while global oil prices have fallen in recent years, making fossil fuel electricity production more competitive; oil prices are likely to rise again.

Furthermore, because of higher transportation expenses, RES installation costs on islands may be less appealing than on the mainland, making traditional thermal units more appealing. Simultaneously, the shift to full decarbonisation necessitates significant expenditures in storage infrastructure to provide grid flexibility, lowering the return on investment. While islands' interconnections to larger islands or the mainland may enhance the use of renewable energy, the prices of such projects can be prohibitive, and the planning and implementation timeframes can be lengthy.

Moreover, considering the small dimension and low population rate of islands, for private investors the development of RES in islands is not economically appealing without huge fiscal incentives or public aid.

Environmental barriers

Increasingly rigorous fuel quality regulations, as well as European legislation imposing strict limit values for NOx and SOx particles included in flue gas, will force islands to take action to enhance air quality by reducing exhaust gas emissions. However, the efficiency of technologies such as selective catalytic reduction and flue gas desulphurization (which are installed to minimize NOx and SOx emissions) is dependent in significant part on the diesel engine's stable (base load) performance. This is in direct opposition to the needs of a power system that must accommodate a large amount of renewable energy while also managing to satisfy a varied daily load curve, which requires flexible systems of plants that can swiftly ramp up and down. Furthermore, some forms of renewable energy generation, such as wind turbines or pumped hydro, require landscape changes and new infrastructure, which may have a negative impact on natural resources and raise environmental issues.

Political barriers

RES deployments and energy transition projects in general frequently demand broad political support, particularly when they are long-term plans with substantial financial costs and political impact.

There is often a lack of communication across the levels of government in terms of regional and local administration. In the absence of a better methodology, projects frequently come to a halt. As a result of these delays, investors are diverting their funds to other projects where the implementation may go more quickly and easily. Competition between multiple land uses, particularly on tourism islands (as Mediterranean ones), can significantly complicate spatial planning on islands, affecting RES project licensing.
Finally, local populations often oppose energy transition projects because they do not want new infrastructure to disturb their environment or because they feel excluded from an investment that uses resources from "their" land without their agreement, requiring more support and engagement. This is the so-called NIMBY phenomenon, which politicians often play along with because opposing such behaviour has a huge political cost.

Social barriers

As there is a considerable shortage of specialised labour and local experience, the smaller the population on an island, the greater the requirement for capacity building to respond to the deployment and operation of energy transition plans and projects.
Local citizens are frequently excluded from the decision-making process when it comes to energy transition plans, or they are given very little incentives to support them. Top-down government has a long history, and changing it takes time. Citizens must first embrace the energy transition for it to be successful. NIMBY phenomenon can affect the social acceptance of RES, because citizens have many concerns about their losses - in terms of landscape, environment, higher costs of the starting investment, - compared to the gains of the private investors or the public purchasing agent.

Renewable Energy Communities can help citizens and local authorities in small Mediterranean islands to overcome those challenges and barriers, and eventually to invest in renewables and energy efficiency. The participation of citizens in renewable energy projects can also overcome social acceptance at the local level, which is a crucial issue within the Med area. Community-owned projects will allow local Mediterranean island authorities to finance sustainable energy investments that deliver local economic benefits, social cohesion, and other priorities such as improving the energy efficiency of housing.

In addition, existing market barriers are often hindering community energy projects, with the most significant ones for Mediterranean island Energy Communities to be summarised as follows:

- Financial institutions are willing to fund wind and solar energy projects. Other forms of renewable energy initiatives are thought to be more commercially risky, particularly in terms of energy source supply and/or pricing (water, biomass, bio-waste, etc)
- Typically, funding is provided on a project finance basis, which means that all project documents are pledged in favour of the financing institution, giving it complete control over the project's cash flow and assets, as well as step-in rights.
- There is no major experience in financing cooperative firms, with the exception of cooperative banks, which are considered as providing considerable administrative and organisational risks that must be properly handled if funding is to be made available.
- Other barriers include inefficient government bureaucracy, policy instability, and the complexity of tax regulations.

The scope of ISLET is to foster the collaboration between island Mediterranean local authorities and energy communities to develop integrated services to support community energy and overcome market barriers related to community energy projects.

The ISLET Project Objectives are:

- To enhance the municipalities' capacity to create a favourable environment for Renewable Energy Communities (RECs) in small Mediterranean islands
- To Increase the cooperation between local and regional authorities and citizens that want to create energy communities, by improving public participation and engagement in citizen-led initiatives
- To empower local actors to collectively address energy transition targets through use of public resources
- To help local authorities to provide support to citizen energy initiatives

- To foster the dialogue among different actors involved in islands' energy projects to create a supportive local policy framework for the development of renewable energy communities
- To provide Mediterranean small islands with a model of a successfully process of REC creation
- To train relevant actors and enhance their capacity in community energy development and citizen engagement in small islands.
- To improve the information of RECs and related national and EU laws among local authorities and representatives in small island, as well as among citizens
- To Evaluate the contribution of citizens-led initiatives in Mediterranean islands decarbonisation
- To Create a network of peer-to-peer support for Islands municipalities in providing support to their citizens for building RECs.

7 – Three Mediterranean Case studies.

The ISLET project works on three pilot small islands: Astypalea (Greece), Cres (Croatia), and Procida (Italy), very different among them for geographical contexts, socio-cultural characteristics, energy profiles, political commitment towards the decarbonisation and citizen awareness about sustainability. Each context is described in different paragraph; the table below summarise the islands main energy information.

Table 3 – Summary of pilot island ECs description

	Astypalea	Cres	Procida
Country	Greece	Croatia	Italy
Basin	Mediterranean	Mediterranean	Mediterranean
Inhabitants	1,376 (2021)	2,716 (2023)	10,118 (2023)
National grid	Non-interconnected	Interconnected	Interconnected
DSOs	1 (Hedno)	1 (HEP ODS)	1 (e-Distribuzione)
PV installed	3.71 MW	207.8 kW	832.71 kW
RES penetration	≈ 9%	≈ 0.3%	≈ 0.04%
Peak load	2,36 MW in August	25.99 MW in August	n.a.
Energy Community members	21	3	12

7.1 – GREECE, Astypalea

Greece includes 6,000 islands and islets scattered in the Aegean and Ionian seas, of which only 227 are inhabited, for approximately 1,650,000 people, equal to 15% of the Greek population. Isolation from the mainland, weak electricity networks, and a strong cultural identity, which usually led to problems of social acceptance of new interventions in the direction of energy transition [13] are the main challenges for Greek islands decarbonisation. Many Greek islands are located far from the mainland and therefore must rely on autonomous electricity systems and isolated grids. These islands are classified as Non-Interconnected Islands (NII) under Greek legislation and by the Regulatory Authority for Energy (RAE). According to the Hellenic Electricity Distribution Network Operator (HEDNO), NIIs exhibit four main characteristics:

- They vary widely in size and population, and many of them are difficult to access, particularly by sea.

- They possess significant renewable energy potential, especially in terms of wind and solar resources.
- They are unable to exchange electricity with other power systems, which affects both the reliability and the security of their energy supply.
- Their lack of interconnection with high-inertia electrical systems creates challenges for voltage and frequency stability, especially increasing intermittent renewable energy sources (RES) [31].

Nevertheless, the only official plan regarding energy system in the Greek NII is the gradual interconnection of them with the mainland grid, thanks to a roadmap in four steps that is leading to an integrated system in 2030, being part of Ten-Year Network Development Plan (TYNDP) [32].

In the Non-Interconnected Islands (NII), the total installed capacity of wind power plants is 106.42 MW, while that of PVs is 58.28 MW. There are no small hydro and biogas plants in Greek NIIs. The total installed capacity of hybrid plants is 2.95 MW, of which 2.55 MW in Ikaria and 0.4 MW in the Kos-Kalymnos system. In the Greek interconnected islands, PVs have a total installed capacity of 154.53 MW, while wind and biogas plants connected to the medium voltage have an installed capacity of 497.73 MW and 1.72 MW respectively. Small hydro installed capacity is only 0.3 MW located in Crete Finally, there are wind power plants connected to the high voltage with an installed capacity of 656 MW. The rest are located in Cephalonia and on the uninhabited island of St. George near Athens. Overall, the Greek islands had approximately 1.478 GW of installed RES capacity in 2022 [33].

The Greek National Plan for Energy and Climate (NPEC), approved in 2019, sets national targets for 2030 in energy and climate. These include achieving 35% from renewable energy sources, with specific sector goals of 60% in electricity, 40% in heating and cooling, and 14% in transportation. There's also a target to increase energy efficiency by one third by 2030 and reduce energy poverty, ensuring equal access to basic goods and services for all. Greenhouse gas emissions outside the Emissions Trading System are to be reduced by 16% compared to 2005 levels [34]. Greece, as several EU MS, has made decarbonisation of their islands a top goal in the National Energy and Climate Plans (NECPs). Connecting Greek islands to the mainland is expected to contribute to these goals while saving €400-450 million annually in electricity costs. For non-connected islands, the plan involves installing hybrid power stations (renewables with storage) and upgrading heating and cooling systems in buildings. Transportation aims include lowering electric vehicle costs, developing smart charging infrastructure, promoting second-generation biofuels, and reducing the cost of alternative fuels.

The country's strategy is to connect them to the mainland grid, which will eliminate utility costs, as well as to install innovative hybrid RES power production systems on those islands that will not be connected or will be connected later, for the benefit of all consumers.

Relevant regulations for RES installations in Greece are:

- Law 4951/2022 on reform and acceleration of the RES licensing process, grid capacity, storage systems and introduction of floating PVs installations
- Laws 3468/2006, 3734/2009, 3851/2010 and 4546/2018 on climate change and RES installations
- Law 4414/2016 and Ministerial Decree 2373ΒΔ/25-10-2011 on supporting and licensing of RES and co-generation stations

Energy consumers in Greece can participate in the transition through self-generation schemes:

- Net-Metering (enabled by Law 3468/2006 and Law 4414/2016) allows households, businesses, and Energy Communities to offset their electricity consumption by installing PV systems. Virtual net-metering extends these benefits to municipalities and farmers.
- Virtual Net-Billing allows multiple consumers to participate collectively in a renewable energy system located at a different site from their consumption points. Each participant is financially compensated for their share of the energy injected into the grid, based on market prices, while their consumption is billed separately. This scheme enables energy offsetting and financial benefits without physical connection, making it ideal for Energy Communities and collective self-consumption projects.

- The new Net-Billing scheme, introduced by Law 5037/2023, is gradually replacing net-metering. Net-Billing is a self-consumption scheme whereby the consumer (prosumer) uses the electricity produced by their photovoltaic system to cover their own consumption, while any surplus energy that is not used on-site is injected into the grid and financially compensated based on the day-ahead wholesale market price at the time of injection.

Law 3468/2006 and Law 4414/2016 promoted and fixed the definition of prosumers through the net-metering scheme. Net-metering, through the installation of PV stations, is popular in residencies and in businesses and has been supported through various state-subsidizing programs for the procurement and installation of PV and storage system. Virtual net-metering scheme is also possible for Energy Communities, municipalities and farmers. Law 5037/2023 introduced the net-billing scheme which will gradually replace the net-metering schemes.

Greece actively promotes electromobility through a legal framework developed in recent years. Law 4233/2014 allows for the installation of charging stations at fuel stations, highways, and other locations. EU Directive 2014/94 was incorporated into Law 4439/2016, setting standards for charging infrastructure.

Law 4710/2020 provides economic incentives such as free parking spots and tax exemptions for zero-emission electric vehicles. Rules for managing and operating charging systems are defined by Law 4643/2019, while Ministerial Decision 42863/438/27.5.19 specifies technical specifications for charging installations [35].

National laws regarding renewable energy (RES) installations on islands may vary slightly from those on mainland, taking into account specific challenges and opportunities related to geography and the resources available on the islands. Specifically, the operation of the autonomous non-interconnected systems to the mainland electricity grid is fully described in the "Management Code for Non-Interconnected Islands" [36].

Concerning the Energy Communities, The Greek legislative framework preceded the adoption of EU directives offering its own approach, which is particularly innovative in terms of energy poverty and insularity. The objectives that the law highlighted, alongside the production, distribution, and supply of energy, are the promotion of self-sufficiency and energy security in island municipalities (Art. 1.1 Law No. 4513/2018) [22].

Law 4513/2018 introduced the concept of Energy Communities, defining all the details about who can participate, the minimum numbers, their fields of activities and the incentives provided to them.

In May 2019, the Recast Electricity Directive and Electricity Regulation established citizen energy communities as a governing principle of Europe's internal energy market and transition to cleaner and more citizen-led energy systems, marking the official end of the legislative process for the Clean Energy for All Europeans Package. Greece was a pioneer as the first member state in the EU to pass a law about Energy Communities (ECs) in the Parliament in early 2018, according to which ECs can invest in specific project categories: Renewable Energy Sources (RES), Combined Heat and Power, energy efficiency, sustainable transport, demand management, production, distribution and supply of energy. Currently, the Energy Communities in Greece are mainly regulated by the Law 5037/2023 which transposed the European directives related to energy communities in Greek regulation framework [38] in order to harmonize national legislation to EU directives 2018/2001 and 2019/944 introduced the concept of Renewable Energy Communities (RECs) and Citizen Energy Communities (CECs). Both entities are defined as mainly non-profit driven, but rather focusing on improving the social, financial and environmental quality of life of the members and the region. In the law, some specific provisions for Greek islands are introduced, in term of number of members and capacity allowed. This regulation foresees that for islands with a population smaller than 3100 people, the minimum number of members for the creation of a REC is 20 instead of 30 and their main fields of activities are production, consumption, storage and sale of energy from RES and biomass/bio fluids/biogas.

ASTYPALEA ISLAND

Geography

Astypalea island is located at the south part of the Aegean Sea and belongs to the Dodecanese complex. It is the fourth biggest island of the Dodecanese complex and the westernmost one. It is located west of the Nisyros Island and east of the Anafi Island (which belongs to the Cyclades complex). Around the island of Astypalea there are 22 islands (most of them non-inhabited: Agia Kyriaki, Aderfoi, Avgo, Glyno, Zaforas, Kaiki, Karavi, Katsagreli, Kounoupoi, Koutsomyti, Mesonisi, Mikro Sofrano, Ophidoussa, Plakida, Pontikoussa, Sohas, Stefania, Syrna, Tigani, Fokionisia, Chondronisi and Chondro.

Astypalea has a total extent of 97 km2 and a coastline of 110 km2. The main feature of the island's morphology is its shape, as it has the shape of a butterfly. Thus, Astypalea is called the butterfly of the Aegean. There are also some significantly larger islands near Astypalea. Kos with a distance of 23 NM (42.5 km) and Rhodes with a distance of 96 NM (177.8 km). To reach the island, the island nearest port in the mainland is Piraeus, with a distance of 117 NM (216.7 km).

Figure 4 – Astypalea's position in Aegean Sea

The island includes four settlements. The main town is Chora, where there is the town hall and the majority of permanent inhabitants: the other settlements are Analipsi, Livadi and Vathi.

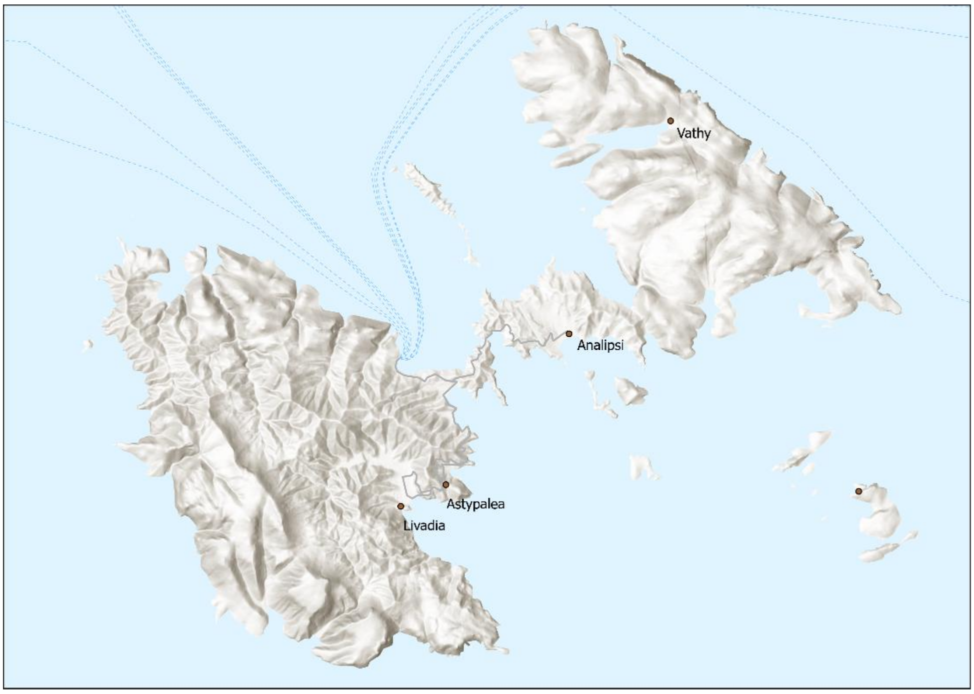


Figure 5 – Settlements of Astypalea, and its distinctive butterfly shape

Climate, natural resources and special zones

Astypalea has a typical Mediterranean climate with hot and dry summers and mild and wet winters. According to the Hellenic National Meteorological Service and the National Observatory of Athens in the period 1977 – 2013, the average annual air temperature is 19.27 °C, while the average minimum value per month is 7.73 °C (in February) and the average maximum value is 32.09 °C (in July. The average humidity level is calculated approximately at 70.13% and the precipitation level per month for the period 1985 – 2012 was varying between 196.4 – 620.9 mm, with an average value of 400mm. A more detailed analysis of temperature data can be found in Table 4 (data are referred to 2023). Table 5 contains the precipitation and the wind speed data per month as measured at 2023 [35].

Table 4 - Monthly temperature of Astypalea (°C)

Month	Max Average	Average	Min Average	Max	Min
January	**14.60**	**12.0**	**9.3**	**22.10**	**-1.80**

February	14.80	12.1	9.3	22.15	-1.30
March	16.30	13.3	10.2	26.40	1.10
April	19.40	16.1	12.5	30.55	5.15
May	23.10	19.4	15.4	34.20	7.85
June	27.05	23.2	19.2	36.20	12.30
July	28.55	24.7	21.7	38.20	15.80
August	28.40	25.4	21.7	37.60	15.30
September	26.45	22.6	19.8	34.20	10.90
October	22.90	19.3	16.6	32.00	7.20
November	19.35	16.2	13.4	28.60	3.45
December	16.20	13.7	10.9	23.40	1.60

Table 5 – Monthly precipitation [mm] and wind speed data [km/h] of Astypalea

Month	Total Precipitation (mm)	Average Wind Speed (km/h)	Max Wind Speed (km/h)
January	109.5	3.0	23.42
February	88.5	3.2	28.34
March	62.5	3.0	28.07
April	21.0	2.6	26.20
May	12.0	2.4	21.28
June	3.0	2.5	20.48
July	0.5	3.2	22.53
August	1.5	3.3	18.05
September	6.5	3.1	23.69
October	51.5	2.8	22.70
November	67.5	2.5	28.78
December	107.0	2.9	22.17

The Municipality of Astypalea is part of the European Network Natura 2000. In Table 6 and in fig. 6 there is information about all the protected areas that belong to the Municipality of Astypalea.

Table 6 - Protected areas belonging to the Municipality of Astypalea.

Natura Code	Description of the protected zone	Type of zone	Area (ha)
GR4210009	East part of Astypalea and the surrounding islets, Ophidoussa and the maritime zone	Protected under the Habitats Directive	7,023.04
GR4210011	Rocky islets of South Aegean: Velopoula, Falkonera, Ananes, Christiana, Paheia, Fteno, Makra, Astakidonisia, Syrna - Surrounding islands and maritime zone	Protected under the Habitats Directive	4,582.26
GR4210021	East part of Astypalea and the islets Kounoupoi, Fteno, Chondropoulo, Koutsomytis, Moni, Agia Kyriaki, Tigani, Chondri, Ligno, Fokionisia, Katsagreli, Pontikoussa, Ophidoussa, Ktenia	Protected under the Birds Directive	28,315.78
GR4210022	Syrna island and the islets Megalos Aderfos, Mikros Aderfos, Katsikas, Mesonisi, Plakida, Stefania, Navagio	Protected under the Birds Directive	976.85
GR4210023	Islets of the Karpathian Sea: Megalo Sofrano, Sohas, Mikro Sofrano, Avgo, Divounia, Chamili, Astakidonisia	Protected under the Birds Directive	337.01

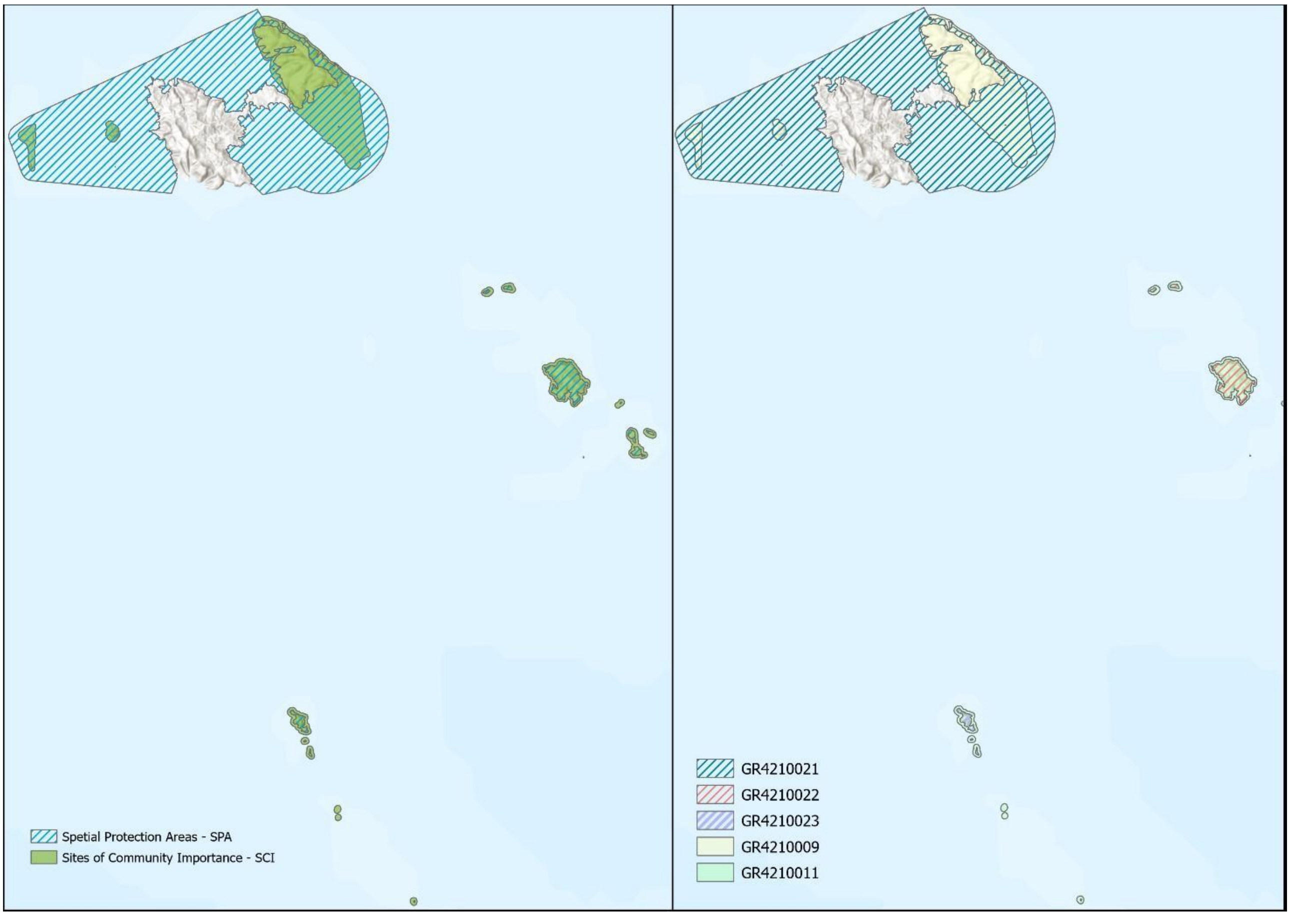


Figure 6 – Areas of environmental interest and protection (Astypalea)

Moreover, Astypalea has 18 areas that have been declared as archaeological areas: Chora, Livadi, Vathi, Drakospilia, Vatses, Analipsi (Maltezana), Agios Ioannis, Messaria, (Panagia Kokkinohomati), Armenochori - Souloudrani, Moura – Mavri Pounta, Syggeros - Marmari, Agios Andreas, Agrelidi, Kaminakia, Panormoy, Vounio, Vaios. The town of Chora and Livadi have been declared as protected traditional settlements.

Demography

According to the population census of 2021, Astypalea has a population of 1376 people and 501 households. The population density of the island is 14.1 people per km2. Distribution of population in the settlements is shown in Table 7. Also, Table 8 show the distribution of population per age. Astypalea gender ratio is 51 to 49 (male to female).

The population evolution in Astypalea, according to the population census of the past 5 decades, is presented in Table 9. Moreover, the seasonal population is estimated according to the available data about the rise in island's arrivals and departures in high season compared to the regular season at around 36,000 people every year.

Table 7 - Distribution of population in settlements of Astypalea

Settlement	Chora	Analipsi	Vathi	Livadia
Population	1084	111	17	159

Table 8 - Age distribution of population of Astypalea

Age range	**0-14**	**15-64**	**65+**	**Total**
Percentage	14.9%	64.6%	20.5%	
Population	204	886	281	1,371

Table 9 - The evolution of population in Astypalea in the last 5 decades

	2021	**2011**	**2001**	**1991**	**1981**
Population	1,371	1,334	1,385	1,073	1,034
Population change (%)	3%	-4%	29%	4%	

The education level of the population in Astypalea is indicated in Table 10. This measurement does not take into consideration children younger than 6 years old. Regardless the educational level, the percentage of island's population that is unemployed is 5.8%. The percentage of households that are under the poverty threshold is 17.5%. Though, those that are beneath the energy poverty threshold are a bit more, at 22%, with a threshold of 6000€ for one-person household and 12000€ for family household. Regarding families, the number of nuclear families that couples live together is 333, the ones that are single fathers is 10 and the ones with single mothers is 36 [40].

Table 10 – Education level of the population in Astypalea

Level of education	**Population**	**Percentage**
Less than primary	209	16.5%
Primary	354	28.0%
Secondary	525	41.5%
Tertiary	176	13.9%
Total	**1,264**	

Economic activities

Regarding the economy of the island, the sector that shows dynamic growth is the tertiary sector. The primary and secondary sectors remain stable without any significant growth, due to limited cultivable land. As Table 11 indicates, the main pillar of Astypalea economy is the tertiary sector and more specifically tourism, which accounts for more than half of the island's businesses.

As it concerns touristic accommodations, according to the Hellenic Chamber of Hotels there are 127 of them on the Astypalea island, 19 of which are hotels and 108 guesthouses. These facilities provide 1870 beds, 511 at the hotels and 1359 at guesthouse or room renting services [41].

Table 11 - The number of businesses and employees per sector in Astypalea Region of South Aegean

Sector		**Number of Businesses**	**Percentage (%)**	**Employees**	**Percentage (%)**
Primary	Agriculture, Forestry, Fishing	27	12.9%	62	14.2%
Secondary	Construction	22	10.26%	90	20.5%
Tertiary	Wholesale and retail trade Repair of motor vehicles and motorcycles	45	74.17%	58	51.6%
	Transportation and storage	7		19	
	Accommodation and food service activities	51		41	

	General public administration and social security	14		11	
	Defense, justice, police and fire departments	15		44	
	Education	0		43	
	Human health and social work activities	23		10	
Other		6	2.69%	60	13.7%
Total		210	-	438	-

Transport to and from the island

Astypalea has two ports, Agios Andreas port and Skala. The first port is the new port and the main one, Skala port is only for sailing boats. The interconnection with mainland is through Piraeus (Athens), while there are also interconnections with many other islands, especially in summer. There are ferries to and from Paros, Naxos, Donoussa, Amorgos, Kalymnos, Kos, Nisyros, Tilos and Rhodes. The frequency of ferry routes to the mainland is 4 times per week in low demand period and 6 times per week in high season (summer).

Astypalea also has an airport, which is not international. It has direct flights with the mainland to the airport of Athens and with three other islands, Leros, Rhodes and Kalymnos. The frequency of airline routes is 11 flights per week in low demand period and 35 in peak demand period.

Transport on the island

Astypalea has a total road network of 190 km length, which diverse in 30 km of main road, 40 km of secondary and 120 km of rural road.

Figure 7 – Roads' network of Astypalea

On 2019, the Astypalea smart & sustainable island (ASSI) project has been launched. One of the four pillars of the project focuses on electromobility. On the scope of the project, there have been installed 20 publicly accessible charge points, 10 chargers comprised of 2x11 kW sockets, as well as one 50 kW DC fast charger, dedicated to the islands medical centre and the first electrical ambulance in Greece.

Furthermore, through ASSI project so far there have been deployed six municipal EVs, 12 public transport electric buses, as well as a shared EVs fleet in collaborations with rent-a-car companies. Through the program named "e-Astypalea", which subsidizes the purchase of new private EVs, an important section of the private vehicles has also been electrified.

Table 12 – Vehicle on Astypalea Island

Type of vehicle	Company	Individual	Total
Public Use		**33**	**33**
Tractors		5	**5**
Cars		2	**2**
Semi - trailers		14	**14**
Buses		5	**5**

Trailers		1	**1**
Tricycle lorry		1	**1**
Lorry		5	**5**
Private Use	**65**	**1145**	**1210**
Motorcycles	24	581	**605**
Cars	24	400	**424**
Buses	3	6	**9**
Multipurpose	1		**1**
Tricycle car		15	**15**
Lorry	13	143	**156**
Total	**65**	**1178**	**1243**

Astypalea is an autonomous electricity system, thus is not interconnected either to the mainland or to any other island, while there are no plans for future interconnections as it is very far from any other land. Thus, it has a number of conventional units, details of which are shown in Table 13. In addition, it has a total power of 3.71 MW of photovoltaic stations installed, providing an annual penetration in electricity production that reaches 9%. The operator of Astypalea's electrical system is HEDNO (Hellenic Electricity Distribution Network Operator).

The annual electrical consumption of the island per sector is presented in Fig. 8. Tertiary and primary sectors are the major consumers while there is a significant electrical consumption from residential sector. One source of this consumption is heating, as Astypalea uses electricity for consumption in a percentage of approximately 42% (Table 14) with the annual heating consumption being 1,028.33 MWth.

The peak of electrical load is 2.36 MW and occurs in August, while the average load in low demand period is 0.78 MW. Furthermore, in the tables below can be found a 10-year projection of the peak of the electricity load, as well as of the total energy demand in Astypalea (Table 15).

Table 13 - Conventional units using diesel in Astypalea

No of Unit	Model	Rated Power (MW)
G5	MITSUBISHI S16R-PTA	1.275
G6	MITSUBISHI S16R-PTA	1.275
G7	MITSUBISHI S16R-PTA	1.275
G8	MITSUBISHI S16R-PTA	1.275
Total	-	5.1

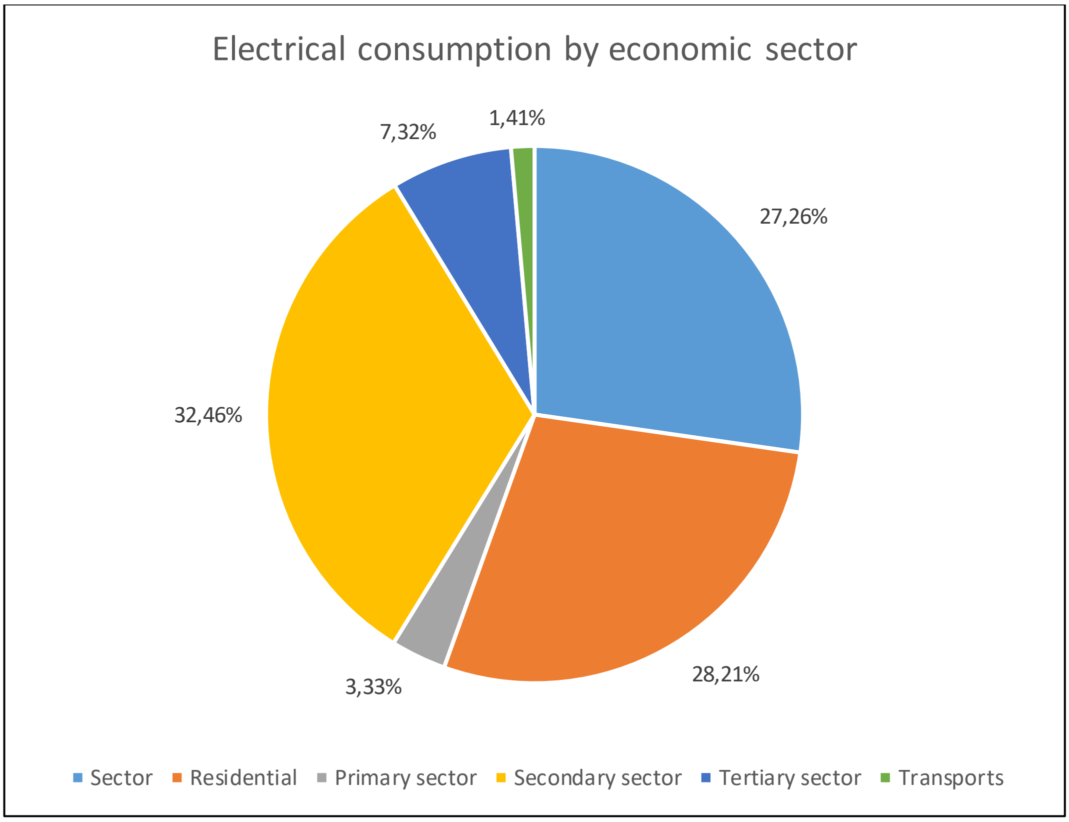


Figure 8 – Annual electrical consumption per sector in Astypalea

Table 14 - Sources of heating and percentage of use

Source of heating	Percentage of total use
electricity	41.97%
diesel	41.64%
LPG	0.29%
biomass	0.29%

Table 15 - Ten-year projection of the energy demand and the peak of electricity load

Year of projection	Total energy demand [MWh]	Peak [MW]
0	12,784	2.36
1	12,796.6	2.43
2	12,829.1	2.73
3	12,882.1	2.76
4	12,946.4	2.82
5	12,952.2	2.88
6	12,803.9	2.94
7	12,667.8	3.00
8	12,543.4	3.07
9	12,430.4	3.13
10	12,328.4	3.20

Other infrastructure

Waste management:

According to the Astypalea Operational Plan 2015-2019, the sewerage network has a length of 12.5 km and covers the south-western part of the island, while there also exist wastewater treatment plant. The production of urban waste amounts is estimated to approximately 860 tonnes per year, of which 390 tonnes come from residents, 68 from holidaymakers and 400 from tourist accommodation. Astypalea has two landfills, while there is one uncontrolled waste disposal site and one biological waste treatment plant [35].

Water management:

In Astypalea there is a dam that was constructed in 1997 with a net volume of 875,000 m3. The dam supports the irrigation of the area as well as supplying water to part of the island. Additionally, two desalination plants are located in Maltezana settlement. The one plant uses seawater and the other brackish water. Both desalination plants have a capacity of 300 m3/day of freshwater production and are operating through the reverse osmosis technology. The 18.5 km long water supply network is mainly fed by the dam, as well as five drilling boreholes through eight water storage tanks with a total capacity of capacity of 900 m^3 [35].

Regional and local regulation on decarbonisation

In July 2021, the initial draft of the new Operational Programme of the South Aegean Region 2021-2027 was published, awaiting approval from the European Commission. Aligned with the EU strategy for a greener Europe, the vision of the programme focuses on promoting fair clean energy transitions, green and blue investments, circular economy, climate change mitigation and adaptation, as well as risk prevention and management. Key priorities include developing renewable energy and energy-saving systems, particularly in high-consumption public buildings (administrative, schools, hospitals), promoting climate adaptation, disaster risk prevention, sustainable water resource management through infrastructure development, water desalination, and leakage control systems, sustainable waste management, protection and exploitation of natural heritage, and enhancing green urban areas through green mobility adoption, urban renewal, pedestrian infrastructure development, and public lighting upgrades.

At local level, The Municipality of Astypalea has developed a Clean Energy Transition Plan (CETA), with the support of NESOI island facility [43]. The CETA vision is related to the targets and the interventions of the aforementioned ASSI project. It focuses on the exploitation of RES potential through small-scale projects with the aim to cover the island's energy needs, the transition to sustainable transport, the decrease of energy cost, and the participation of local community. Based on the hybrid RES-station project these objectives will be attained, as the energy cost will significantly decrease supporting at the same time the sustainable electrification of the transport sector. More small-scale projects such as rooftop solar panels and load management applications such as generation of desalinated water with the use of excess RES power or more storage capacity would be beneficial for the stability of the energy grid.

The Energy Community of Astypalea.

In the framework of ISLET project, an Energy Community is born in the small settlement of Maltezana. Maltezana (also known as Analipsi) is a remote village located at the eastern region of Astypalea Island. Being the third settlement in terms of population and located far away from the two central towns of Astypalea (Chora and Livadia), makes Maltezana a distinct case from the majority of the island. The touristic development that the island in the last ten years has been mainly concentrated on Chora and Livadia, leaving the local community of Maltezana mainly focused on fishing and agriculture. The role of the local authorities, specifically the Municipality of Astypalea, was crucial at the preparatory phase of establishing the EC and setting its objective: to enhance the local community and provide opportunities for development, and to reduce the high cost of electricity. In doing so, the Energy Community not only supports the island's broader energy transition but also ensures that benefits are equitably distributed across different settlements, strengthening social cohesion and local engagement.

The Law 5037/2023, aligned with the EU provisions on Energy Communities, introduced a clear distinction between Renewable Energy Communities (RECs) and Citizens' Energy Communities (CECs). One of the most important differences between the two entities concerns membership eligibility: while RECs are limited to the participation of SMEs, CECs allow all private legal entities to join. This provision represented a key factor in determining the most appropriate legal form for the EC in Maltezana. Equally important were the minimum membership requirements, which vary depending on geographical scope and member composition.

People involved in the EC creation concluded that the most suitable legal form for the Maltezana Energy Community would be a CEC, with a minimum of 20 members for small islands' project. Membership includes natural persons, small and medium-sized enterprises, potentially larger enterprises, and the Municipality of Astypalea.

The energy community in Astypalea includes 21 members:

- 2 Hotels, with about 30 rooms each
- 2 Restaurants (SMEs)
- 2 Guest houses, with 7 and 8 rooms
- 6 two-people households
- 8 four-people households

- the municipality of Astypalea

The Maltezana CEC is designed to advance the island's energy policy through the following strategic objectives:

- Energy Independence: By enabling residents to co-own and operate renewable energy installations, the CEC reduces Astypalea's reliance on imported fuels, increasing local control over energy production, pricing, and resilience. This shift lays the foundation for a more self-sufficient and secure energy future.
- Grid Stability: The deployment of distributed photovoltaic systems under a net-billing framework can help alleviate pressure on the island's centralized diesel-based generation. This decentralized approach promotes more balanced grid operation, particularly during peak demand in the tourist season, reducing both fuel use and system stress.
- Local Resilience: In the absence of mainland backup, Astypalea must rely entirely on local energy resources. The CEC can enhance energy security by prioritizing critical infrastructure—such as water pumping stations, desalination units, and municipal buildings—through targeted renewable energy projects. This ensures vital services remain operational even during grid disturbances or fuel supply disruptions.
- Support for Public Policy and Innovation: Astypalea already serves as a national testbed for smart island initiatives, including e-mobility and digital infrastructure. The CEC complements these efforts by demonstrating how community-led energy solutions can effectively compensate for the lack of interconnection. Moreover, as a pilot case, it may attract regulatory support, tailored incentives, and flexibility mechanisms that promote innovation and replicability across other islands.

Energy poverty remains a persistent challenge on Astypalea-particularly in remote or less developed settlements, where seasonal incomes, aging infrastructure, and high energy costs create significant burdens for residents.

The Maltezana CEC provides a practical and inclusive pathway to alleviate energy poverty, through the following targeted measures:

- Lowering household energy expenses by enabling access to shared renewable energy production via net-billing mechanisms,
- Prioritizing participation of low-income and vulnerable households, ensuring they benefit first from energy savings and support programs,
- Strengthening essential public services—such as water supply systems, public lighting, and municipal facilities—which are especially important for underserved areas,
- Promoting financial transparency and democratic governance, so that the benefits of the Energy Community are distributed fairly and equitably across all members.

By combining social inclusion with clean energy, the Energy Community becomes a powerful tool not only for sustainability, but also for social justice and community resilience.

ΕΝΕΡΓΕΙΑ ΜΑΛΤΕΖΑΝΑΣ

ΕΝΕΡΓΕΙΑΚΗ ΚΟΙΝΟΤΗΤΑ ΠΟΛΙΤΩΝ

Figure 9 – The logo of the "Maltezana Energy" CEC

Even being a member, the municipality does not own Point of delivery (POD) there, so it is not included in energy calculation. Nevertheless, it can participate in the investment or provide spaces for PV panel installation.

The main features and the content of the signed statute of the Citizen Energy Community are the following:

- The statute formally establishes the "Maltezana Energy Citizens' Energy Community" as a limited liability cooperative, aiming to generate environmental, economic, and social benefits for both its members and the wider local community. Its core activities include the production, consumption, and sharing of renewable energy through the virtual net-billing mechanism, along with services related to energy efficiency, electric vehicle charging, and sustainability awareness. The community also seeks to support vulnerable consumers by offering energy assistance, enhancing household energy efficiency, and engaging in nationally and EU-funded projects.

- The cooperative's headquarter is in the Municipality of Astypalea in the South Aegean region and is established for an indefinite period starting from its official registration. It operates under cooperative principles, requiring members to hold at least one share and ensuring democratic governance through a one-member, one-vote system. The statute outlines the governance framework, designating the General Assembly as the supreme decision-making body and a Board of Directors responsible for day-to-day management. Membership is open to individuals, local authorities, and legal entities aligned with the cooperative's objectives.
- Financial viability is ensured through cooperative share capital, with clear provisions governing capital contributions, profit allocation, and members' financial responsibilities. The statute also specifies the procedures for admission, withdrawal, and exclusion of members, promoting transparency and accountability. Furthermore, it enables participation in renewable energy projects and funding schemes, strengthening the cooperative's commitment to energy sustainability and local development.

Members have different load profiles, from hotels and other touristic SMEs to private households, that give the opportunity to exploit this feature in REC's optimisation.

The total hourly energy demand of CEC is shown in the Fig. 10:

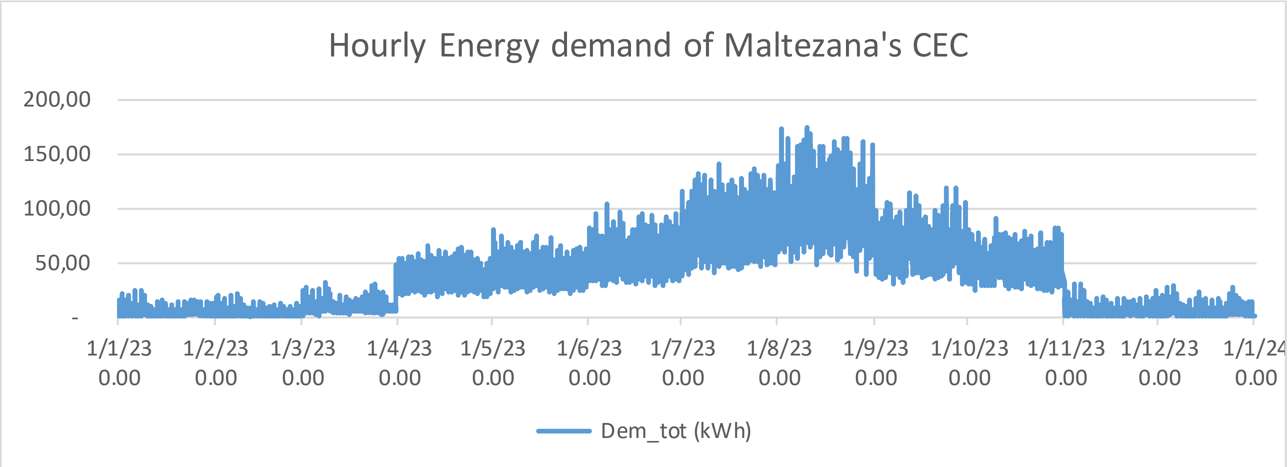


Figure 10 - hourly energy demand of CEC as per data of 2024

In Astypalea, as in all Greek non-interconnected islands, new renewable energy installations are subject to capacity limits set by the national energy regulator (RAE) and validated by the Hellenic Electricity Distribution Network Operator (HEDNO), which operates the island's autonomous power system. At present, there is no remaining capacity available for additional RES installations on the island, meaning that new renewable projects cannot be connected under standard conditions. Consequently, any new RES project is required to formally apply to HEDNO for a special capacity allocation in order to move forward that are still ongoing.

Considering the feasibility, compatibility with existing plans, and overall potential for implementation, for the Maltezana's Energy Community, the installation of photovoltaic (PV) panels on municipal and residential buildings or land, under a net-billing scheme is the most suitable option.

The Maltezana CEC do not have at the moment of foundation any prosumer.

Considering this starting point, simulation on energy production aims at assessing the potential of first investment, dimensioning it in a proper way and establishing the best option about producers or prosumers of renewable energy.

The first and quick option to start to produce energy is a common investment in a public surface or land, with 20 kW PV panels completely for CEC use. In this case, there is not a new prosumer, but the energy produced is completely for sharing:

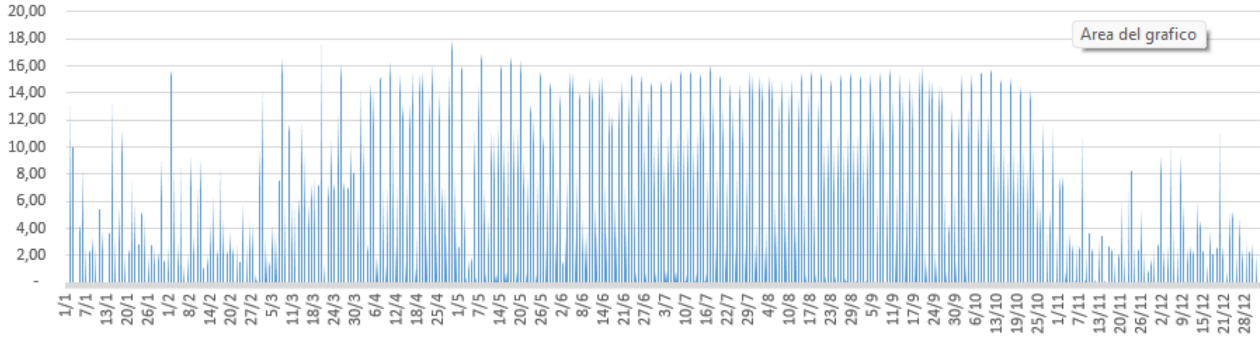


Figure 11 – Hourly energy sharing (kW) in a year in Maltezana CEC with the installation of a new PV 20 kW plant

In that option, performance of the CEC in term of energy shared varies according to the season:

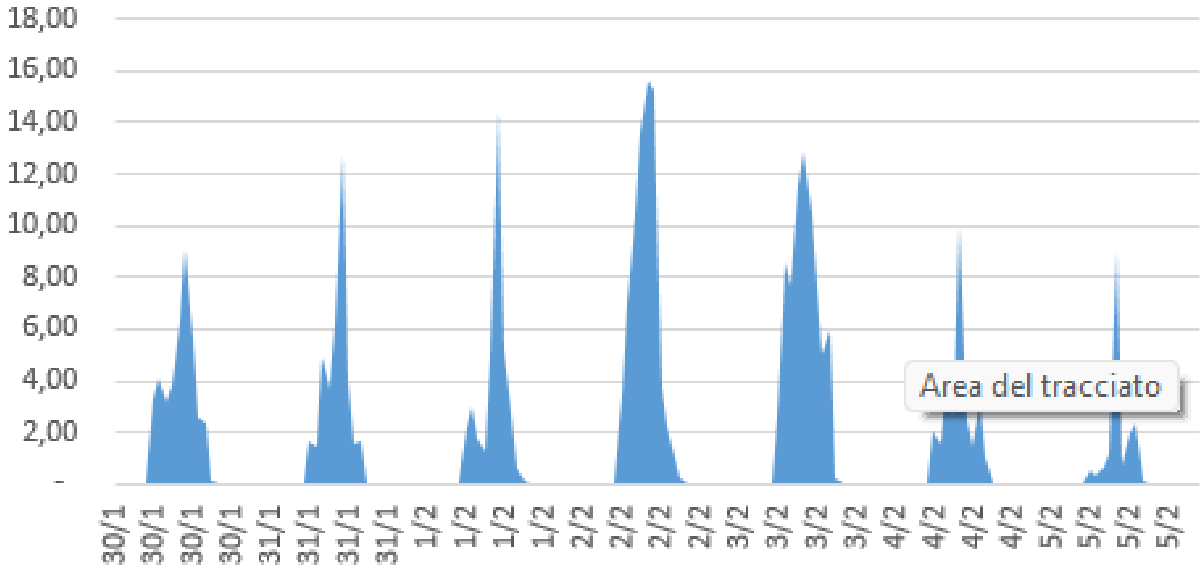


Figure 12 – Estimation of hourly energy sharing (kW) in Maltezana CEC during the week 30/01 – 05/02, with a new 20 kW PV panel installed by the CEC

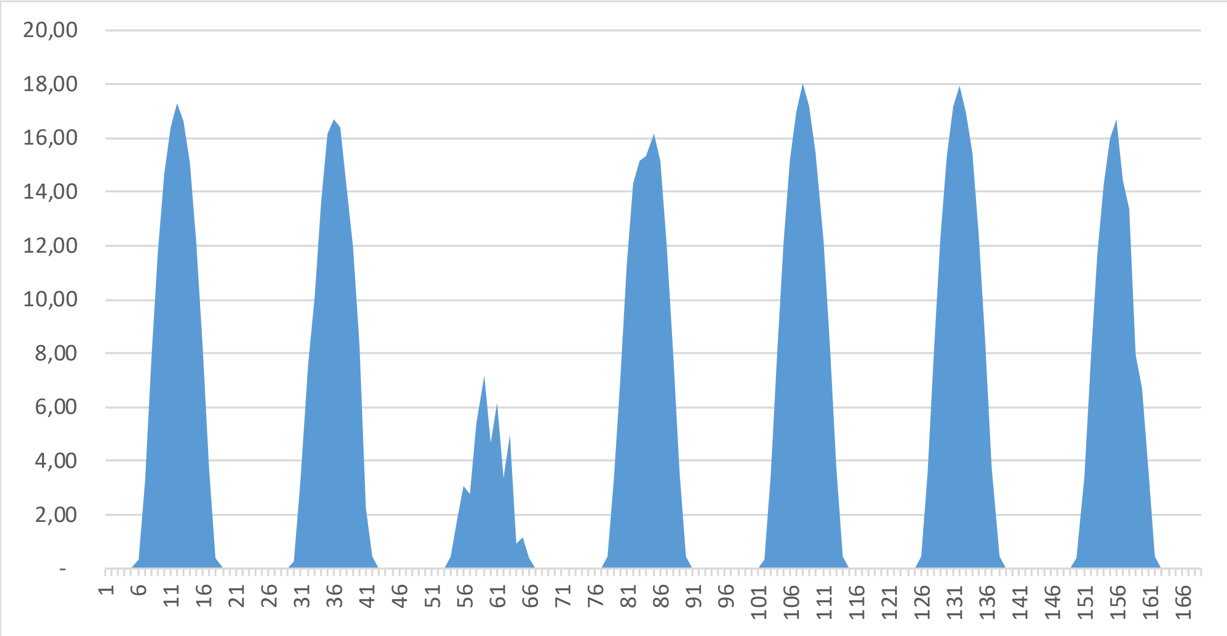


Figure 13 – Estimation of hourly energy sharing (kW) in Maltezana CEC during the week 24/04 – 30/04, with a new 20 kW PV panel installed by the CEC

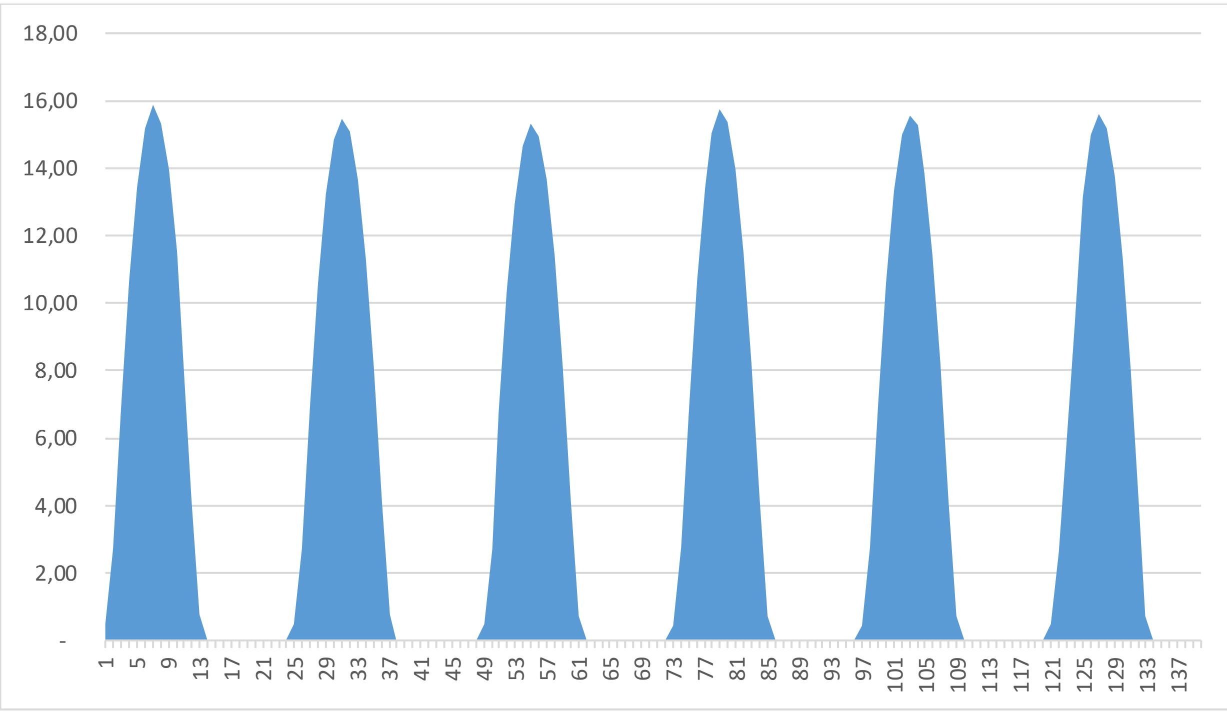


Figure 14 – Estimation of hourly energy sharing (kW) in Maltezana CEC during the week 31/7 – 6/08, with a new 20 kW PV panel installed by the CEC

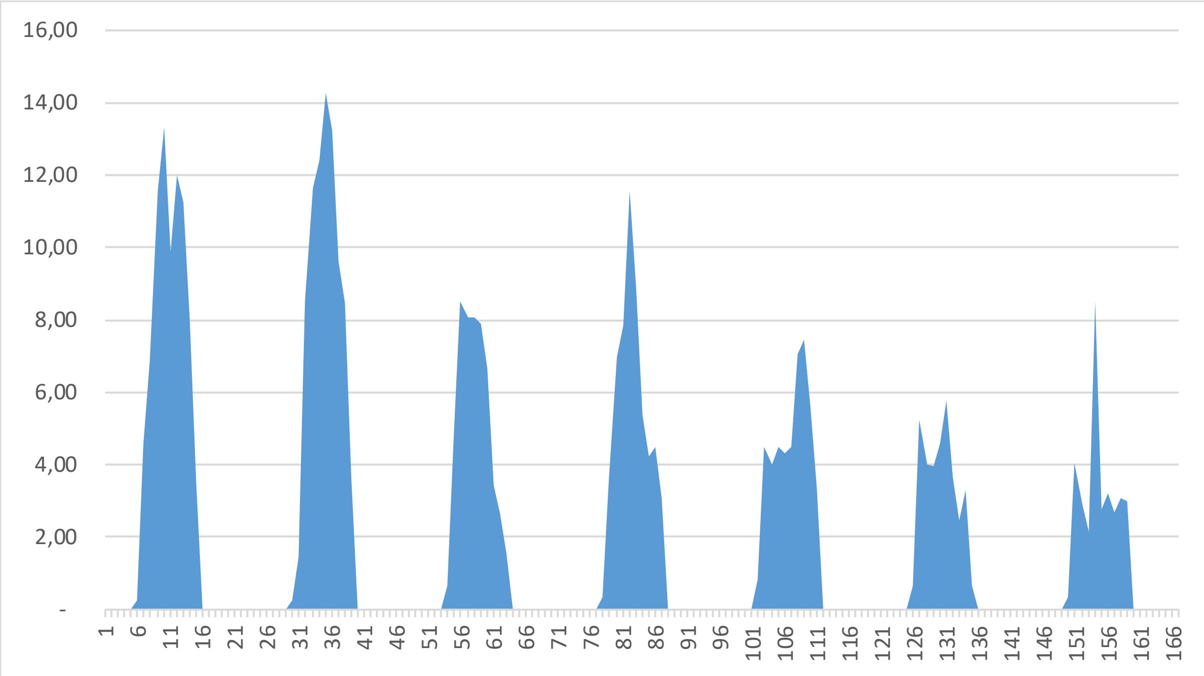


Figure 15 – Estimation of hourly energy sharing (kW) in Maltezana CEC during the week 30/10 – 5/11, with a new 20 kW PV panel installed by the CEC

Nevertheless, having an external PV plant of 20kWp it seems guarantee a better performance in term of energy sharing than having the hotels and restaurants installing each one 20 kWp for self-consumption and sharing the surplus to the rest in term of hours of sharing, but of course, as the energy produced is higher, also the energy shared is, but only of around 5500 kWh more, in view of four time more of power installed:

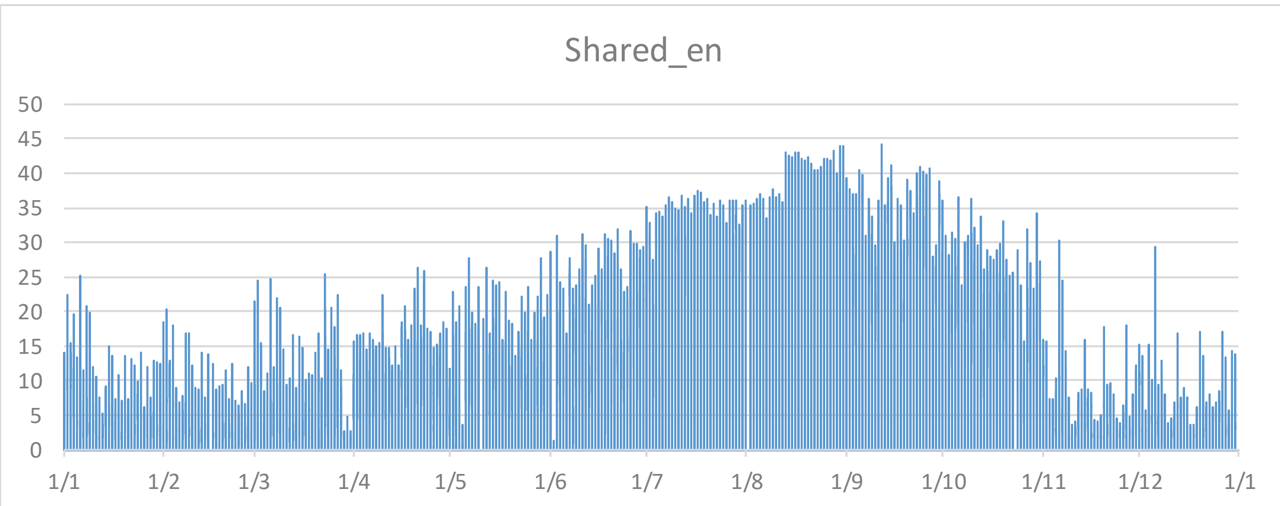


Figure 16 – Estimation of hourly energy sharing (kW) in Maltezana CEC with four prosumers with 20 kW installed each and three private households installing 6 kW each

Is interesting to see the limit option: an installation of PV plant of 100 kWp serving all the Astypalea community. 100 kWp is in fact the maximum power that is possible to install according to the Greek law. The total energy shared with hourly counting is equal 108261.29 kWh, but the hours during which the energy is shared are the same amount with 20kWp. To improve the performance in that regards we should change the member profile, choosing a different kind of CEC member.

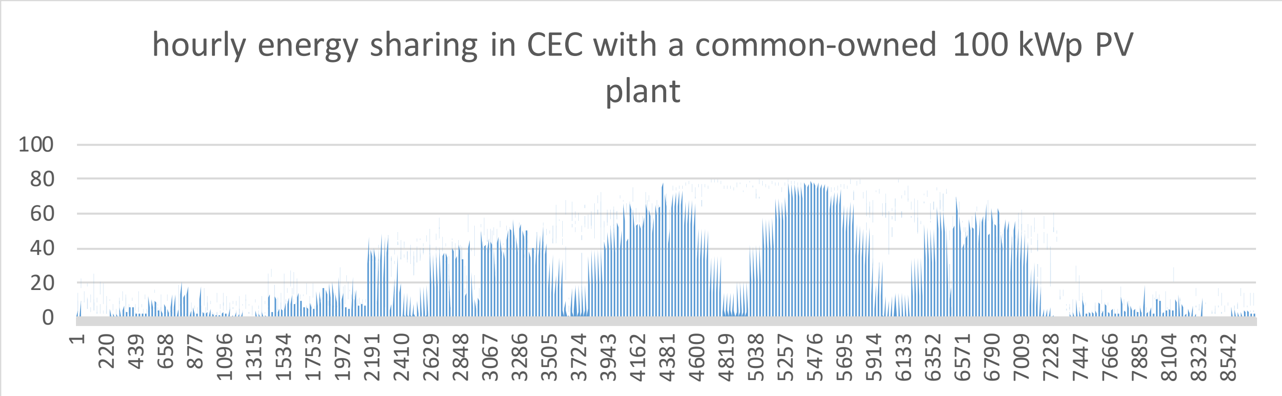


Figure 17 – Estimation of hourly energy sharing (kW) in Maltezana CEC with a common-owned 100-kWp PV plant

Even installing the maximum allowed, the CEC will register a deficit of energy for 6694 hours, that is for 76,4% of the year.

Summarizing the three different configurations' performances, we have:

Table 16 – Maltezana Energy Community configurations studied:

	Power installed (kW)					
	SMEs	Private	Municipality (only producer)	Energy shared (kWh) per year	hours of sharing per year	surplus energy into the grid
CEC1 - 20kW tot	0	0	20	**29.382,18**	4.207	4.495,57
CEC2 - 98 kW tot	80	18	0	**46.408,38**	3.836	59.520,10
CEC3 - 100 kW tot	0	0	100	**108.261,29**	4.207	61.127,47

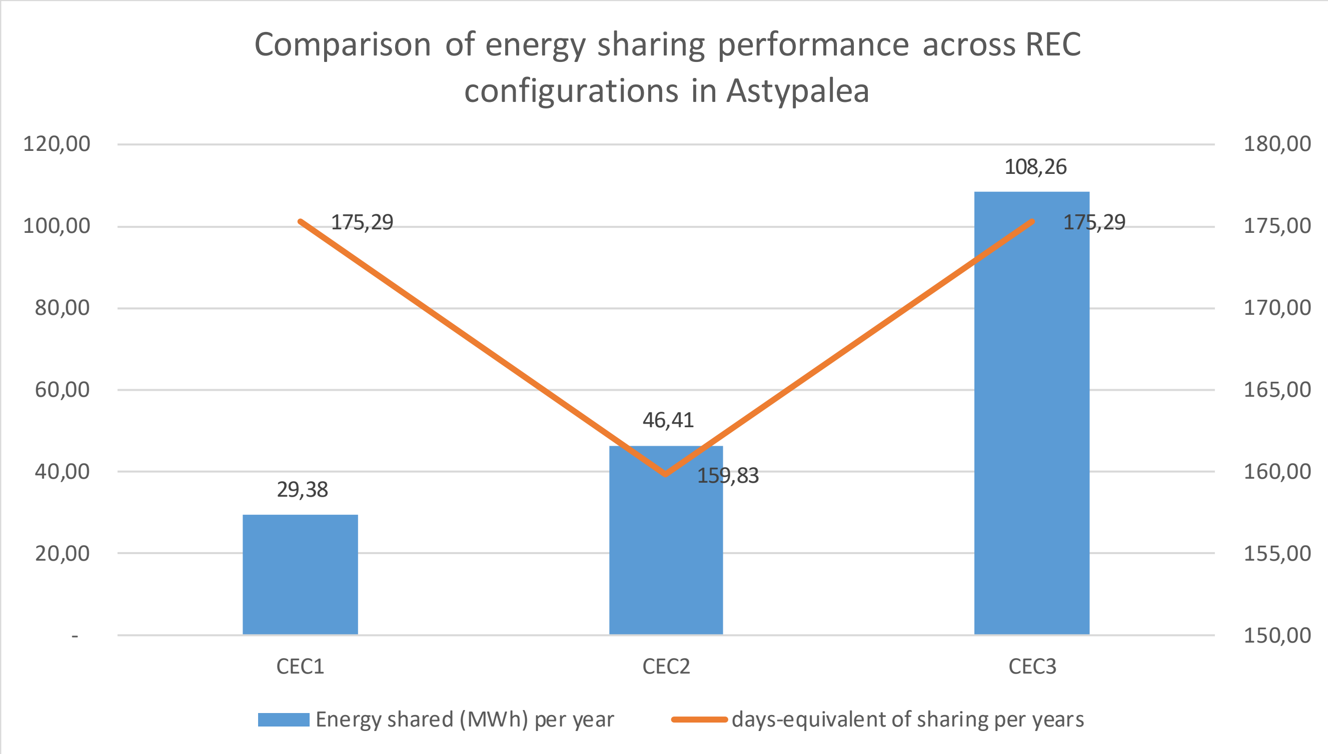


Figure 18 – Performance of the three different REC configurations in Astypalea

In Astypalea, the key finding in this simulation is that the third configuration, involving a shared solar installation, yields a much more effective result in terms of shared energy compared to installations spread across multiple owners, even though the difference in total power installed is minimal.

Further studies, in the very next period could include a desalination plant under construction in Astypalea islands, that can carry different performance in CEC efficiency if included in the CEC, both as consumer and as prosumer.

7.2 – CROATIA, Cres

Croatia has more than 1.200 registered islands but only 52 of them are inhabited and in the EU context, all islands are small islands with a total of 128508 inhabitants according to the latest official data from 2011.

Energy transition of Croatian islands started in 2017 on islands of Korčula, Hvar, Brač and Cres-Lošinj archipelago while in parallel European Commission signed the Valletta declaration and started the establishment of the Clean Energy for EU Islands secretariat. As described well in [35], Croatian islands developed their clean energy transition agendas in 2019, with the quadruple helix model of community development and special emphasis on the citizens and their role in the transition. The inhabited islands of the archipelago of Cres-Lošinj are interconnected through medium voltage subsea cables. Losinj and Cres are connected to the island of Krk with a high voltage (110 kV) and a medium voltage (35 kV) subsea cable. Krk is connected to the Croatian mainland with a 110 kV cable and a bridge. However, with the local population and visitors increasing, it has become a challenge for the islands in the archipelago to satisfy their energy demand via the current connections. The whole archipelago has a great, yet unused potential for renewable energy. Total solar photovoltaic capacity of 714 kW installed on the public buildings, private houses and business buildings with increasing interest in installing more. The islands' main challenge is the large difference in energy consumption between the summer and winter season due to tourism, which is its main economic sector. The energy consumption in summer is almost twice the island's consumption in winter.

In December 2021, the National Plan for Island development 2021-2027 and the Action plan 2021-2023 are entered into force: that defines the implementation of objectives from the National Development Strategy of the Republic of Croatia until 2030 in the administrative area of island development. With this document, 6 billion Kuna of funds (about 800.000.000 Euros) will be addressed to the island's priorities.

In October 2021, Law on electricity market (NN 111/21) was brought. This law claims a high degree of security of supply and a smooth transition to a sustainable low carbon energy system, supporting the integration of energy from renewable sources. Moreover, it introduces new institutes such as the active customer (prosumers) and the Citizens Energy Community, enabling all customers to directly take part in production, consumption and sharing of electricity. For the first time in Croatia, the final consumer can participate equally or through aggregation in the electricity markets. This is why one of the most significant novelties of the new Law is the introduction of the concept of the Energy Community.

Croatia's National Energy and Climate Plan (NECP) aims at increasing the share of renewable energy in gross final energy consumption to 36.4% by 2030 and reduce greenhouse gas emissions by 7% compared to 2005 levels for non-ETS sectors. The Low-Carbon Development Strategy targets a reduction of emissions by 33.5% by 2030 and up to 80% by 2050 compared to 1990 levels. Croatia cooperates with the European Investment Bank (EIB) to develop and finance energy sustainability and climate projects, reflecting its commitment to energy transition and climate change mitigation.

The national regulatory framework in Croatia regarding Renewable Energy and Energy Communities includes several key laws and regulations [44].

- The Energy Acts (NN 120/12, 14/14, 95/15, 102/15, 68/18) in Croatia defines activities related to energy generation, transfer, storage, distribution, and other energy activities, requiring valid permits for legal and natural persons to perform these activities. The Electricity Market Act (NN 111/21, 83/23) regulates the production, transmission, distribution, and storage of electricity, ensuring consumer protection and market transparency. It also specifies that energy approvals are now awarded through public tenders for project development, promoting electromobility and integrating electric vehicles into the national energy system.
- The Act on Renewable Energy Sources and High-Efficiency Cogeneration (NN 100/15, 123/16, 131/17, 111/18) defines conditions for installing RES facilities such as solar panels and wind turbines. This act also prescribes conditions for obtaining energy permits and construction rights and regulates the electricity market for renewable sources.

- The Regulation on the Use of Renewable Energy Sources and Cogeneration (NN 88/12, 148/13) provides technical conditions and connection procedures for the power grid, along with criteria for privileged producer status.
- Additionally, the Regulation on the Promotion of Electricity Production from RES and High-Efficiency Cogeneration (NN 116/18, 60/20) sets quotas and incentives, including financial support and preferential tariffs.
- The Electricity Market Act (NN 22/13, 95/15, 102/15, 68/18, 52/19, 111/21, 79/22) further regulates the electricity market, outlining the obligations of distribution system operators and defining the rights and obligations of electricity producers and suppliers.

Net-metering regulations in Croatia are covered under the Electricity Market Act, which sets rules for the electricity market, including net-metering provisions. The Regulation on the Use of Renewable Energy Sources and Cogeneration details the technical conditions and connection procedures necessary for implementing net-metering. The Croatian Energy Regulatory Agency (HERA) issues methodologies and rules on tariff rates, billing methods, and other technical aspects relevant to net-metering, ensuring proper integration into the national grid.

RES installations on Croatian islands are subject to specific regulations, particularly regarding wind farms. Spatial Planning Act (OG 153/13, 65/17, 114/18, 39/19, 98/19, 67/23) prohibits building wind farms on 1000 metres distance from the coastline to protect their environmental, cultural, and historical values, balancing economic development with environmental preservation. Outside this line, in theory, it is allowed to build a wind power plant, however due to the moratorium on the construction of wind power plants on all islands, which until recently was in force in Croatia, a certain aversion to this technology and projects was created. The second part of the medal is that the Croatian islands do not have a port infrastructure for receiving vehicles and equipment for wind farms, which are becoming larger due to economic profitability. In addition, the power network on the islands does not support such large investments without a thorough renovation and increase in the quality of the infrastructure. Furthermore, it is certain that all renewable energy projects that will be carried out on the Croatian islands will remain relatively small scale and possibly initiated by the community. The National Island Development Plan 2021-2027 provides a framework for sustainable development on islands, including guidelines on permissible projects, emphasizing the protection of natural and cultural resources [35].

Energy communities:

The Law on Renewable Energy Sources and High-Efficiency Cogeneration outlines the structure and rights of renewable energy communities. These communities are legal entities established with open and voluntary participation, focusing on providing environmental, economic, or social benefits rather than profit. Members can include individuals, SMEs, and local or regional government units. Renewable energy communities have the right to produce, consume, store, and sell renewable energy, and they can access energy markets directly or through aggregation. The law aims to remove regulatory and administrative barriers, ensure non-discriminatory treatment, and facilitate the participation of all consumers, including vulnerable groups. The distribution system operator is required to cooperate with these communities to support energy transfer within the community [44]. Interested stakeholders can use several forms if they want to be part of the energy community:

- Citizen energy communities (abbreviated as EZG in Croatian)
- Communities of renewable energy sources (ZOIE)
- Consumers acting together (at level of same building, Aktivni Kupci)

The laws in Croatia relevant for energy communities are:

- Law on the Electricity Market (Official Gazette 111/2021, 83/2023)
- Law on renewable energy sources and high-efficiency cogeneration (OG 138/21, 83/2023)
- Rulebook on general conditions for the use of the network and electricity supply (Official Gazette 100/2022)
- Rulebook on permits for the performance of energy activities and keeping a register of issued and revoked permits for the performance of energy activities (Official Gazette 44/2022).

Citizen energy communities (EZG in Croatian law)

CEC is a legal entity established in the territory of the Republic of Croatia, whose shareowners or members voluntarily join together in order to achieve the benefits of exchanging energy produced and consumed in a certain area of the local community. A legal entity has to be registered in the EC register through HERA (Croatian Regulatory Agency). Furthermore, a CEC:

- must be under the control of members or share owners (1 member equals 1 vote). Members can be LGUs, natural persons, micro and small businesses
- must have as primary purpose of providing environmental, economic or social benefit, not the creation of financial profit, which operates on the basis of the law regulating the financial operations and accounting of non-profit organizations
- may participate in the production, supply, consumption, aggregation, storage of energy, charging services for electric vehicles or provide other energy services to its members or shareholders. In order for the Citizen Energy Community to function fully, it is necessary to register the activity according to the National Nomenclature called "organizing energy communities" and obtain a decision on registration license from the Croatian Energy Regulatory Agency (HERA).

Communities of renewable energy sources (ZOIE in Croatian)

RECs are legal entities:

- which, based on open and voluntary participation, are independent and under the actual supervision of shareholders or members located near renewable energy projects owned or developed by that legal entity,
- whose shareholders or members are natural persons, small and medium-sized enterprises,
- with the primary purpose providing an environmental, economic or social benefit to the community for its shareholders or members or for the local areas in which it operates, rather than financial gain

RECs have the right:

- created to produce, consume, store and sell renewable energy, among other things through contracts on the purchase of renewable energy
- sharing, within its members, the renewable energy that is produced in the production units owned by that renewable energy community
- that can access all appropriate energy markets directly or through aggregation in a non-discriminatory manner.

Consumers acting together (Aktivni kupci in Croatian)

This form of energy community does not require a specific legal entity. Consumers of their own renewable energy may act jointly as:

- a group consisting of at least two self-consuming renewable-energy users who act together and are located in the same building or residential complex;
- provided that they are connected to the low-voltage line of the same medium-voltage (MV) distribution substation [35].

The establishment of energy communities in Croatia still faces several challenges, despite the potential of these communities to promote sustainable energy and energy democracy. As for now, according to a report by the Institute for Political Ecology and Green Energy Cooperative (ZEZ) in the framework of the "Fast Forward Action for Energy Communities in Croatia" project, only four citizen-led actions in the form of energy communities have taken place in Croatia [45].

Legal and regulatory uncertainty:

The Croatian legal framework for the energy community is relatively new and is still developing. The lack of clear guidelines and procedures can discourage citizens and organizations from launching such initiatives. Existing legislation is often not adapted to the specific needs of energy communities, which can lead to bureaucratic obstacles.

Firstly, establishing and managing energy communities requires specific technical knowledge about renewable energy sources, energy systems and project management. Many potential Energy communities' participants do not have the necessary knowledge or access to experts who could help in planning and implementing projects. Which in itself is not a problem if energy communities would be allowed to share resources in the sense of employing the same person in several energy communities or using these services as an external service. Unfortunately, for now, according to Croatian regulatory rules, each energy community must have at least one full-time employee who possesses technical and professional knowledge and skills, which represents a financial cost that newly formed energy communities cannot bear while they are in the beginning of the operation.

The process of establishing an energy community can be administratively complex and require the fulfilment of numerous conditions and procedures. The lack of coordination between different state bodies and institutions can further complicate and slow down the process. Furthermore, the fulfilment of all requirements constitutes a large financial cost for the communities themselves. Citizens and local communities are often not sufficiently informed about the advantages of energy communities and the possibilities available to them. Existing energy networks and infrastructure may not be sufficiently developed or adapted to the integration of smaller, decentralized energy sources that would be used by energy communities. Additional investments are needed in the modernization and adaptation of the energy infrastructure.

CRES ISLAND [35]

Geography

The Island of Cres is located in the Cres- Lošinj archipelago, and it is one of the northern islands in the in the Kvarner Gulf of Croatia. Cres is the largest island in the Adriatic Sea, among Lošinj, Unije, Ilovik, Susak, Vele Srakane and Male Srakane, covering approximately 405 km2. The total length of the coastal line of the island is approximately 268 km. In the past, Cres and the neighbouring island of Lošinj used to be one island, but now they are divided by a channel and connected by a bridge.

The municipalities of Cres and Lošinj share the authority over the archipelago. Municipality of Cres manages the islands of Cres and the uninhabited islands of Zeča, Visoki, Mišar and Pregaznik.

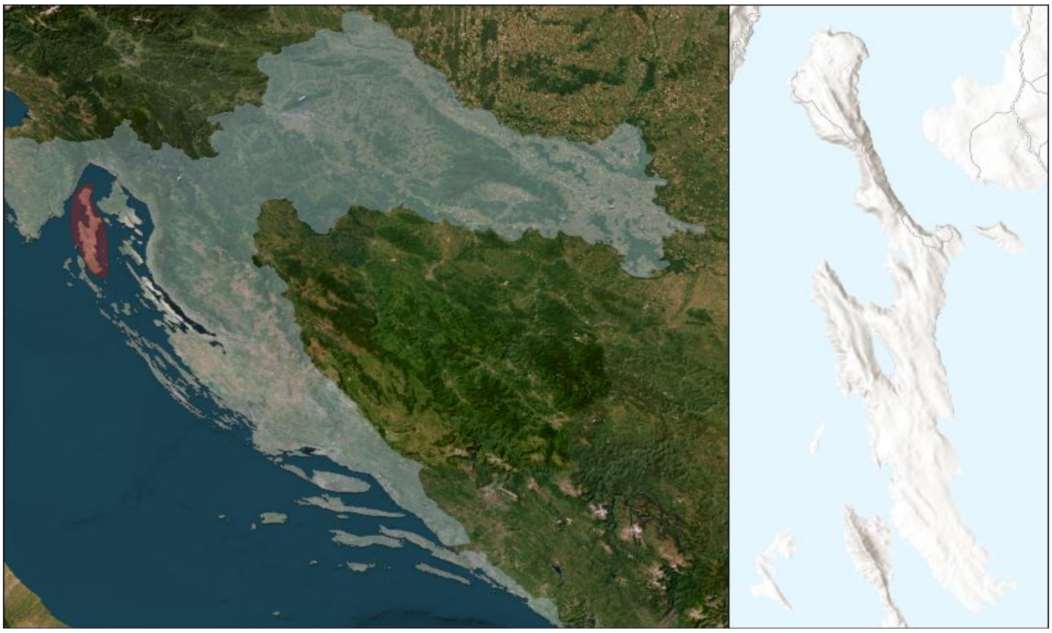


Figure 19 – Cres Island

Cres includes 26 settlements, with a total of 2,716 inhabitants. The main towns of the island are shown in the Figure 20.

Figure 20 – Map of towns of Cres Island

The nearest mainland port from Cres is Rijeka with a distance of 30 NM (56 km), while from Porozina is Brestova with a distance of 3 NM (6 km). The distance from the nearest larger island Valbiska is 6 NM (11 km), from Merag.

Climate, natural resources and special zones

The main part of Cres features a mid-latitude humid subtropical climate. Winters are cool and humid, interrupted by the Bora wind and summers are hot and quite dry. More specifically, the north part of the island is within Kvarner Bay and more exposed to bora (northeast wind) so winter is more intense. The south part of the island, belongs to the Mediterranean zone and thanks to the beneficial effect of the sea, has a mild climate with hot dry summers and rainy winters. Measured data for temperature and precipitation in Cres, are drown from Mali Lošinj. Table 17 shows the average monthly clear, rainy, hot and cold days from 1961 to 2022, whereas average monthly temperature and precipitation are in table 18.

Table 17 – Average monthly number of days between 1961 and 2022, with the different weather conditions, in Cres Island.

	Clear	**Foggy**	**Rainy**	**Frost-Snow**	**Ice-Cold** (Daily maximum temperature less than 0 ^oC)	**Warm** (Daily maximum temperature less than 25 ^oC)	**Hot** (Daily maximum temperature less than 30 ^oC)
January	5	0	10	1	1	0	0
February	6	1	9	0	1	0	0
March	6	1	9	0	0	0	0
April	6	1	10	0	0	0	0
May	6	0	10	0	0	5	0
June	8	0	8	0	0	19	5
July	13	0	6	0	0	28	12
August	13	0	6	0	0	28	12
September	10	0	8	0	0	14	1
October	8	1	9	0	0	1	0
November	4	0	12	0	0	0	0

December	5	0	12	0	0	0	0

Table 18 – Average monthly temperature and precipitation data between 1961 and 2022, in Cres Island

	Average air temperature (°C)	**Max. air temperature (°C)**	**Min. air temperature (°C)**	**Total precipitation (mm)**
January	7.8	17.4	-6.7	87.5
February	8.1	20.4	-4.4	74.7
March	10.1	24.1	-3.8	65.5
April	13.4	26.1	2.9	64.8
May	17.8	34.5	6.3	62.1
June	22.0	35.6	9.7	55.3
July	24.6	37.2	12.7	38.8
August	24.4	39.0	10.0	60.4
September	20.6	32.5	9.7	100.0
October	16.7	29.2	5.0	113.4
November	12.6	23.1	1.1	131.8
December	9.3	18.9	-5.2	104.0

The island of Cres reaches a maximum elevation of 650 m at Mount Gorice. Together with the island of Lošinj, Cres is structurally part of the limestone plateau of Istria. The island is largely composed of Cretaceous carbonate rocks with dolomite as the prevalent lithology. In the northeastern part of Cres, the Lake Vrana is located, which supplies Cres and Lošinj islands with freshwater. It is the largest lake in Croatia by volume and one of the deepest fresh water lakes in Eastern Europe, going down 61.3 m at its deepest point.

Cres Island is part of the European Ecological Network Natura 2000. Table 19 shows the codes of each protection zone, the site name, its area and the type of zone, which are depicted in Figure 21.

Table 19 – Network of Natura 2000 sites in Cres Island

Code	Site name	Area (km²)	Type of Zone
HR3000161	Cres - Lošinj	525.74	Sites of Community Importance (SCI)
HR3000004	Cres - rt Grota - Merag	3.24	SCI
HR3000005	Cres - rt Pernat - uvala Tiha	6,62	SCI
HR3000007	Cres - rt Suha - rt Meli	75.01	SCI
HR3000027	Podmorje Trstenika	4.87	SCI
HR4000031	Otok Zeča	5.25	SCI
HR1000033	Kvarnerski otoci	1,141.47	Special Protection Areas (SPA)
HR2001358	Otok Cres	401.99	SCI

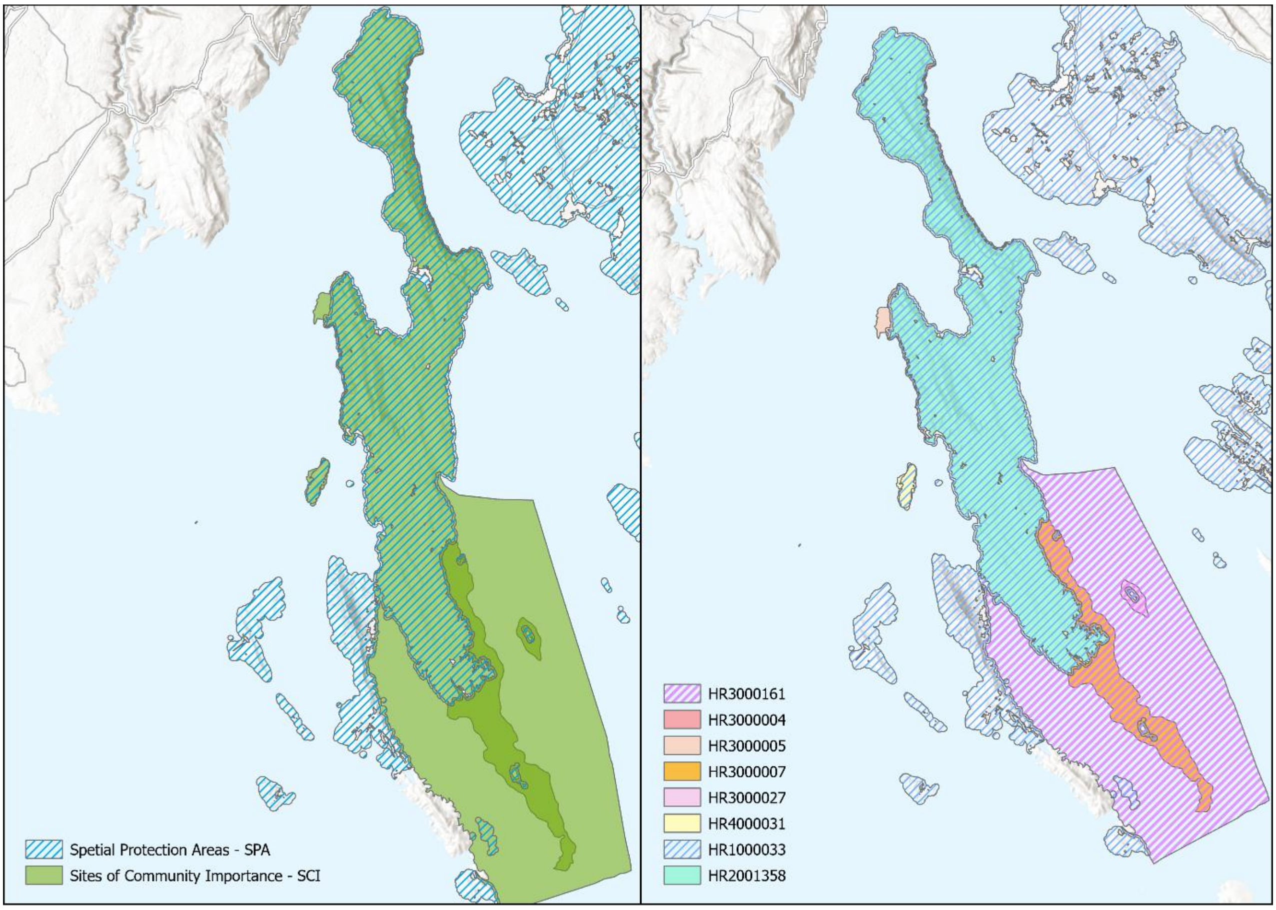


Figure 21 – Network of Natura 2000 sites in Cres Island

Land cover maps in Cres Island, realised thanks to the CORINE EU project show that in the northern part of the island, there is mainly a mix of a broad-leaved forest, with transitional woodland-shrub and sclerophyllous vegetation. Around the town of Cres, there is a quite big area of olive groves, which is surrounded by a mix of natural vegetation land, pastures, broad-leaved forest. At the centre of the island, there are small discontinuous areas of coniferous forests. In the southern part, again there are pastures, broad-leaved forest areas and sclerophyllous vegetation. Cres has a freshwater lake, Vrana, which serves as the main water source for both islands. This large natural reservoir holds more than 200 million m^3 of water and provides the islands with fresh drinking water.

Demography [46].

The total number of people living in Cres Island in 2023 is 2,716, with a population density of 6.6 people/km2. Around the 80% of residents live in the Town of Cres, while the other 20% are almost equally distributed in the other villages. Total number of households is 1,173. During the summer population increases by 200%, with a peak of 33,500 people in summer months.

Table 20 – Permanent residents per settlement in Cres Island

Town	Number of residents
Cres	2,185
Martinšćica	103
Orlec	88
Valun	64
Beli	54
Loznati	36
Miholašćica	31
Porozina	28
Stivan	24
Merag	22
Total	**2,716**

As regards the age structure of the population, the 12.96% of the population is aged less than 14 years old, the 62.08% is aged between 15 and 54 years old, while the other 24.93% is aged more than 65 years old. Gender breakdown of the population it is roughly balanced (50.18% male and 49.82% female).

Table 21 shows the population change in Cres Island over the last four decades. The population is in constant decline, with the largest decrease for the reporting period occurring in the last census.

Table 21 – Population change of Cres Island over the last 40 years

	1981	1991	2001	2011	2021
Cres	2,895	2,971 (+2.6%)	2,959 (-0.4%)	2,879 (-2.7%)	2,738 (-4.9%)

The level of education of permanent population of Cres Island is the following: 16.5% has primary education level, 58.7% has secondary education level and 24.8% has either tertiary or post tertiary education level.

Around 50% of the residents are economically active, from whom the 1.6% are unemployed. Around 90% of households in Croatia have access to the internet. In Cres, the situation is similar: there are 3,292 connections to the network overall in Cres Island, corresponding to a percentage of 86%.

<u>Economic activities</u>

The island's main economic sectors are tertiary and primary. The more developed sector in tertiary is tourism. More specifically, leading sectors of tourism are accommodation and food services. Following are the sectors of wholesale retail, transportation and storage and construction. From the primary sector, the main economic activities are agriculture, forestry, fishing and sheep breeding. All the above leading sectors are dynamic and growing over the past 5 years.

Table 22 – Number of Businesses per main employment sector in the City of Cres

Employment Sector	**Percentage of Businesses**
Manufacturing Industry	7.75%
Wholesale and Retail, Repair of Motor Vehicles	21.03%
Construction	14.76%
Agriculture, Forestry, and Fishing	4.8%

Accommodation, Food Preparation and Services	17.71%
Scientific and Technical Activities	4.06%
Transportation and Storage	6.27%
Administration	8.49%
Real Estate	5.54%
Sport, Art and Recreation	2.58%
Other	7.01%

Table 23 shows number of units and number of beds per type of touristic accommodation.

Table 23 – Data on touristic accommodation on Cres Island

Type of touristic accommodation	No. of units	No. of beds/*places*
Hotels	3	463
Camps	4	5,182
Private accommodation	810	5,339
Total		10,983

Transports

The Island of Cres has four main ports in Porozina, Merag, Cres and Martinšćica. The Island is interconnected with the mainland through the ports of Rijeka, Brestova, Rabac, Mali, Lošinj and Valbiska. The Lošinj Island, connected with a bridge to Cres, has one international airport, which also serves the transport of Cres.

There are 161 ferry routes (84 routes – Merag and 77 routes – Porozina) and 14 catamaran routes per week in low demand period and 182 ferry routes (91 routes – Merag and 91 routes – Porozina) and 14 catamaran routes per week in peak demand period from Cres to the mainland.

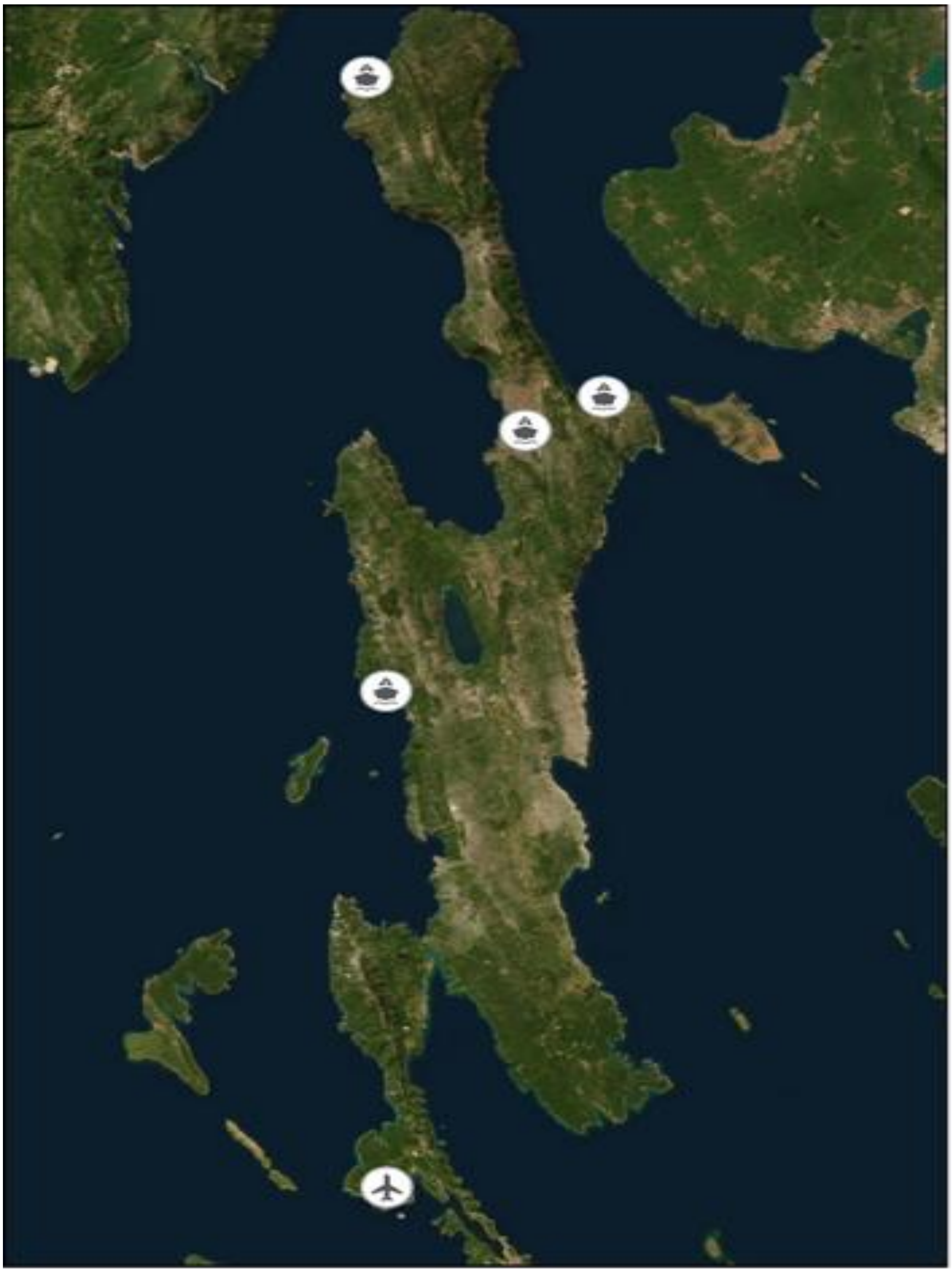


Figure 22 – Ports and airport infrastructures in Cres

Table 24 shows the total number of arrivals and departures in Cres, per means of transport and route:

Table 24 – Arrivals and departures on Cres Island

Routes	Passengers	Vehicles
Valbiska – Merag (Ferry)	1,244,576	528,634
Brestova – Porozina (Ferry)	520,008	217,645
Mali Lošinj – Cres - Rijeka	77,264	N / A
Airport Mali Lošinj	1,761	-

In addition to the main ports already described, Cres has two marinas, one significantly large and a smaller one:

Table 25 – Details about the marinas of Cres

	Berths	Dry Berths	Coordinates
ACI Marina Cres	440	70	44.949373, 14.415299
Marina Lošinj	175	80	44.544076, 14.461272

On the island, there are 47.8 km of main roads, 38 km secondary road network and 114 km rural roads. For the refuelling of vehicles, there are two gas stations in the island and two public electric vehicle charging (EV) stations. In addition to that, there are three private EV charging stations.

Table 26 – EV charging stations in Cres

Name	Type of charging station	No. of ports	Charging power
ACI Marina	Public	3	22 kW
Melin HEP-Elen	Public	2	50 kW DC and 40 kW AC
Hotel Kimen – T-Com	Private	3	15.4 kW AC
Camp Kovačine – T-Com	Private	2	22 kW AC
Miholašćica	Private	1	11 kW AC

According to the SECAP of the municipality of Cres, on the island there are 1,300 private cars, meaning that one in two residents owns a car, excluding commercial or work vehicles. Among them, there are no full electric car or commercial vehicles in Cres, and only five private hybrid cars.

Table 27 – Number of vehicles per category and type of fuel consumption in Cres

Personal and Commercial vehicles	Diesel	Petrol	EV	Hybrid	Total
M1 – personal vehicles (up to 8 passengers)	568	703	0	5	**1,300**
M2 – busses (8+ passengers up to 5t)	15	0	0	0	**15**

M3 – busses (8+ passengers above 5t)	176	1	0	0	**177**
L – motorcycles and mopeds	0	218	7	0	**225**
N1 – commercial (up to 3,5t)	154	12	0	0	**166**
N2 – commercial (3,5 – 12t)	28	0	0	0	**28**
N3 – commercial (above 12t)	31	0	0	0	**31**
Work machines	13	0	0	0	**13**
Total	**985**	**934**	**7**	**5**	**1,931**

Energy system

Cres is interconnected with Lošinj through medium-voltage subsea cables. Cres and Lošinj are interconnected with the mainland's electricity network through the island of Krk. More specifically, the islands are connected to the island of Krk with a high voltage (110 kV) and a medium voltage (20 kV) subsea cable. Krk is connected to the Croatian mainland with a 110 kV cable and a bridge. The operators of the island's electrical system are Hrvatska elektroprivreda - (HOPS - Croatian transmission system operator) and HEP ODS - Distribution system operator), which is a national energy company dealing with generation, distribution and supply of electricity. Table 28 and Figure 23 show the annual electricity consumption and the distribution per sector [47].

Table 28 – Annual electricity consumption per sector in Cres Island

<table>
<tr><th colspan="2">Overall consumption per sector</th><th colspan="3">Total consumption [GWh]</th></tr>
<tr><td rowspan="3">Buildings</td><td>Public buildings</td><td>0.76</td><td rowspan="3">26.25</td><td rowspan="6">38.71</td></tr>
<tr><td>Commercial and public sector</td><td>10.21</td></tr>
<tr><td>Households</td><td>15.29</td></tr>
<tr><td>Public lighting</td><td>Public lighting</td><td colspan="2">0.37</td></tr>
<tr><td rowspan="2">Transport</td><td>Public transport</td><td>0.73</td><td rowspan="2">12.09</td></tr>
<tr><td>Domestic transport</td><td>8.16</td></tr>
</table>

	Other transport (tourism mainly)	3.20		

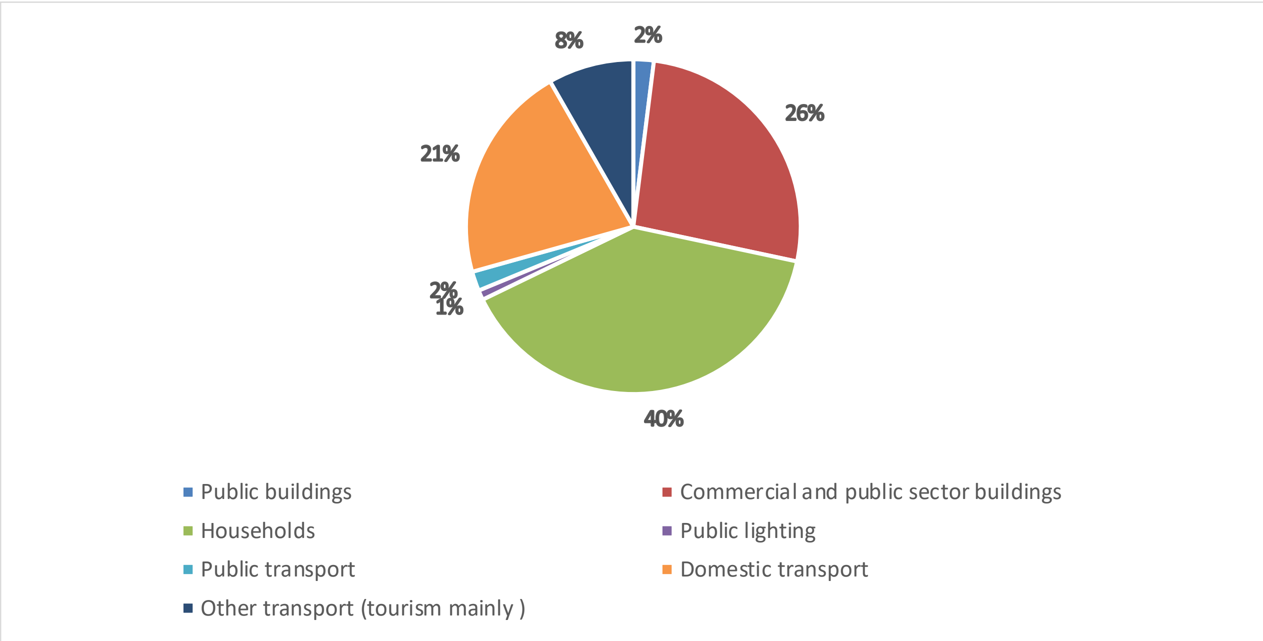


Figure 23 – Distribution of electricity consumption in Cres Island

The peak load demand is around 25.99 MW, and it occurs in August. There are 15 photovoltaic stations with 207.8 kW total installed power. The RES electricity production in 2023 was 0.15 GWh, giving a penetration of around 0.3% [35]. According the Clean Energy Transition Agenda (CETA) of Cres and Lošinj, drafted in November 2019 [48], the overall consumption will increase of around 15% in the next 10 years.

Table 29 – Projection of Cres energy load in the next 10 years.

Overall consumption per sector		**Total consumption [GWh]**		
Buildings	Public buildings	0.73	25.59	**44.86**
	Commercial and public sector	9.75		
	Households	15.11		
Public lighting	Public lighting		0.35	
Transport	Public transport	0.39	18.92	
	Domestic transport	5.77		

	Other transport (tourism mainly)	2.76		

The heating sources from buildings, secondary and tertiary sectors are indicated in Tables 30 and 31, as well as the heating consumption of the island.

Table 30 - Sources of heating used in private and public buildings

Source	Private buildings	Public buildings
Electricity	39.73%	66%
Heavy oil	5.18%	13%
Pellets	6.69%	3%
Natural gas (LPG)	-	18%
Wood	48.4%	-

Table 31 - Heating consumption of Cres per sector and fuel (MWh)

	Buildings	Secondary	Tertiary
Electricity	21,539	15,752	22,374
Heavy oil	2,012	506	1,814
Pellets	1,618	-	-
Natural gas	-	-	6,723
Wood	31,69	-	-

Other infrastructures

Water management:

Cres has a lake named Vransko or Vrana, which has a capacity of 220 million m^3 of drinking water, thus it has no desalination infrastructures or any drilling boreholes. It has also an operator for wastewater management and this is the Vodoopskrba i odvodnja Cres Mali Lošinj [35].

Waste management:

Regarding waste management, since 2018, all municipal waste is transported to the mainland (to the Mariščina facility, near Rijeka). The landfill that used to exist on the island has been remediated and has been out of service ever since. At the Pržić - Merag location, where a transfer station and recycling yard have been operating, fractions of sorted waste (paper, plastic, glass, and others) are collected.

Cres has also a system for waste separated collection. The quantities of waste collected at the island in 2023 are 2392 tonnes, meaning 880 Kg per person per year, and 375 tonnes of bulky waste. Moreover, we should consider about 100 tonnes generated from agri-food industry, mostly the olive husks. For the whole waste collection process a distance of 125.000 km is covered per year [35].

Table 32 – Quantities of waste per type of waste

Local municipality	Mixed communal waste (t)	Quantity of separated waste types (t)	Total amount of bulky waste (t)
Cres	1.527	865	375

Regional and local regulation on decarbonisation

In the 2019, a Clean Energy Transition Agenda (CETA) has been developed for the islands Cres and Lošinj [48, in Croatian]. A development plan for the islands emphasizes renewable energies as the key to future sustainability and development, targeting specifically public lighting and solar hot water systems. The plan sets strategic goals and foresees monitoring. It further takes into account measures to protect the local environment, including citizen education on renewable energy generation and the reduction of greenhouse gases.

The municipality of Cres has also designed a Sustainable Energy and Climate Action Plan (SECAP) in 2021. Moreover, Cres and Lošinj are part of the 30 islands for 2030 initiative promoted by the Clean Energy for EU islands Secretariat. In that framework, activities will:

- study the optimisation of the investment for the energy production with a 0.5 MW PV plant,
- investigate various applications for the hydrogen generated on the island,
- develop a business model for collective self-consumption, investigate how jointly owned PV systems can facilitate self-consumption,
- analyse the options for a battery energy storage system for the archipelago [49].

Energy Community of Cres

Considering the actual legislative framework in Croatia that prevents the actual success of any citizens-led energy initiative that foresees energy sharing, the pilot in this Country is formed by an Energy Community including as members three organisations and not citizens and households.

The initiative has been promoted by the Municipality of Cres, who invite the local Museum and the Kindergarten to be part of this initiative. Then, founding members of the EC are:

- Town of Cres,
- the Kindergarten "Girice", and
- the Cres Museum.

Following the founding assembly of the Cres Energy Community on 19 December 2024, the team initiated the formal registration process with the County Administrative Office for General Affairs and Legal Property Relations in Primorje-Gorski Kotar County. The submitted documentation included the association's statute, founding resolution, and supporting declarations.

The Statute of the Energy Community Cres (EZC) defines the association as a non-profit, non-governmental and non-political legal entity registered in Croatia. Its goals are to promote renewable energy production, enable energy sharing, and support collective self-consumption models. The community's objectives include increasing local energy independence, contributing to CO_2 reduction targets, fostering sustainable local development, and raising awareness and education about renewable energy and energy efficiency.

Membership is open to both natural and legal persons, with categories of regular and honorary members. Regular members have full rights, including participation in decision-making and the ability to share energy within the community. The governance structure consists of a General Assembly, composed of all regular members, and a Board of three elected representatives. The General Assembly adopts the Statute, annual and multi-annual plans, financial reports, and elects the Board, while the Board manages operations between assemblies, represents the community, and ensures statutory compliance. The Statute also specifies that any surplus revenues are to be reinvested in the community's objectives, prohibits profit distribution, and foresees the possibility to establish subsidiaries or companies aligned with the community's mission. It further regulates transparency, conflict of interest provisions, dispute resolution, and liquidation rules, ensuring that assets are transferred to organizations with similar goals in case of dissolution.

After a difficult exchange with relevant Croatian offices in charge of Energy Community registration, the initiative in Cres, initially started as CEC, was registered as REC under the Renewable Energy Sources and High-Efficiency Cogeneration Act (ZOIEVuK), adopted with amendments by the Croatian Government on 10 April 2025.

The Town of Cres and Cres Museum are located within the urban core of Cres, a protected cultural heritage zone, which presents significant limitations for installing rooftop photovoltaic (PV) systems. This restriction, however, positioned the kindergarten as a key asset, as it offered the only technically feasible roof for a solar PV installation among the group. The initial concept of the REC was based on a sort of "virtual net-billing energy-sharing scheme", where electricity produced at the kindergarten could be shared with the other public institutions through a legally recognized renewable energy community (REC) Being institutional organisations open to the general public, their energy demand is mainly during the day, in the hourly office.

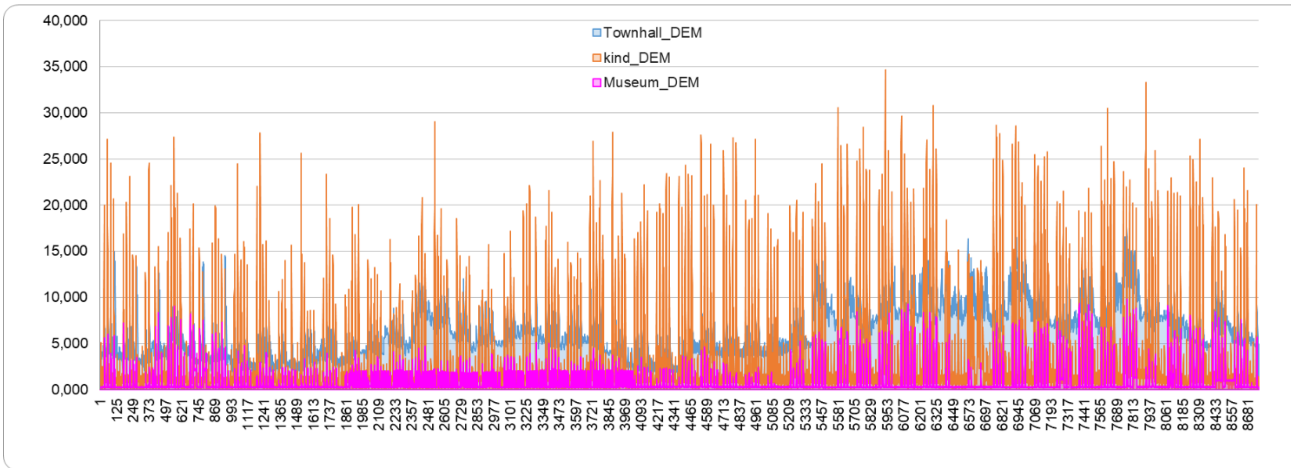


Figure 24 – Hourly energy demand of the three members of Cres Energy Community from April 1st, 2024 to March, 31st 2025

Among the three founding institutions, only Kindergarten "Girice" has a rooftop suitable for photovoltaic installation and is therefore the only one with the potential to produce electricity on-site. In fact, it is the only that, at the moment of the REC Foundation, has PV panels installed.

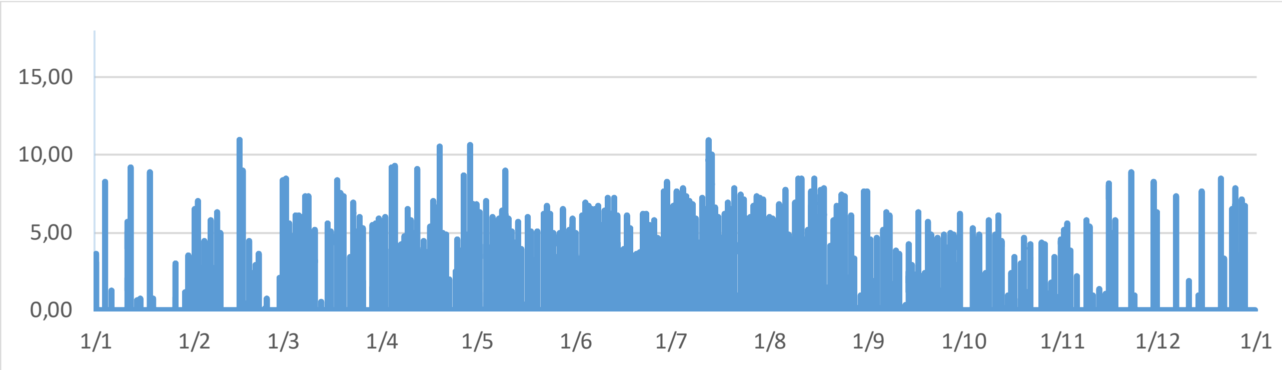


Figure 25 – Hourly shared energy (kWh) in Cres REC

The potential energy shared in the initial configuration is described in the Fig. 25, where the hourly energy sharing from April 1st to March 31st is shown. The result is that in the framework of REC, 6430,56 kWh are shared in a year, with a total of 1679 hours with some sharing active.

The available roof area also allows for the system's capacity to be doubled in future phases, depending on regulatory conditions and community needs. The rooftop of the kindergarten has a technical potential of 40 kWp for photovoltaic installation. In 2024, a 20-kW system was commissioned, primarily covering the kindergarten's daytime electricity demand.

Virtual net-billing energy sharing allows electricity from one PV plant to be virtually apportioned to multiple meters within the REC using predefined allocation keys; each beneficiary receives bill credits for their share of exported energy, while network charges are paid per meter as usual. In Croatia, this model is recognized in primary law but is not yet operable because DSO settlement rules, tariff methodology and data-exchange procedures for energy sharing are still pending. A new net-billing self-consumption system for individual prosumers will start on 1st January 2026.

An additional 20 kW is planned to supply energy for the needs of the museum and town hall, which also have peak consumption during daytime hours.

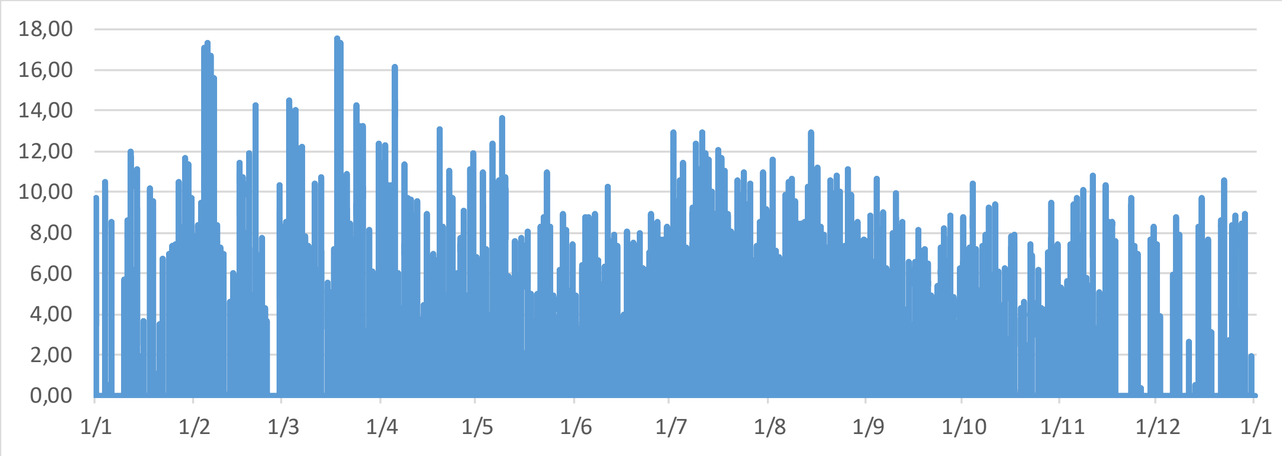


Figure 26 – Estimation of hourly energy sharing of energy community of Cres with installation of additional 20 kW PV panel on Kindergarten's roof

Adding new 20 kW PV panels in the Kindergarten's roof, even considering its self-consumption, improve the REC performance in terms of energy sharing. Members share energy for a total of 2558 hours per year, 13955 kWh shared.

It is possible to imagine, only for study purposes, to install the new 20 kW power plant in the Museum roof instead of the kindergarten one. This is not an actual option today, because of architectonical and landscape rules, that prevent to install PV panel in historical old towns. Anyway, if the new PV panels were placed at the Museum premises, the prosumers of the REC become two, the kindergarten and the museum, and the performance of the EC in term of energy sharing increase again: energy is shared for 3646 hours, with 18,714,98 kWh shared.

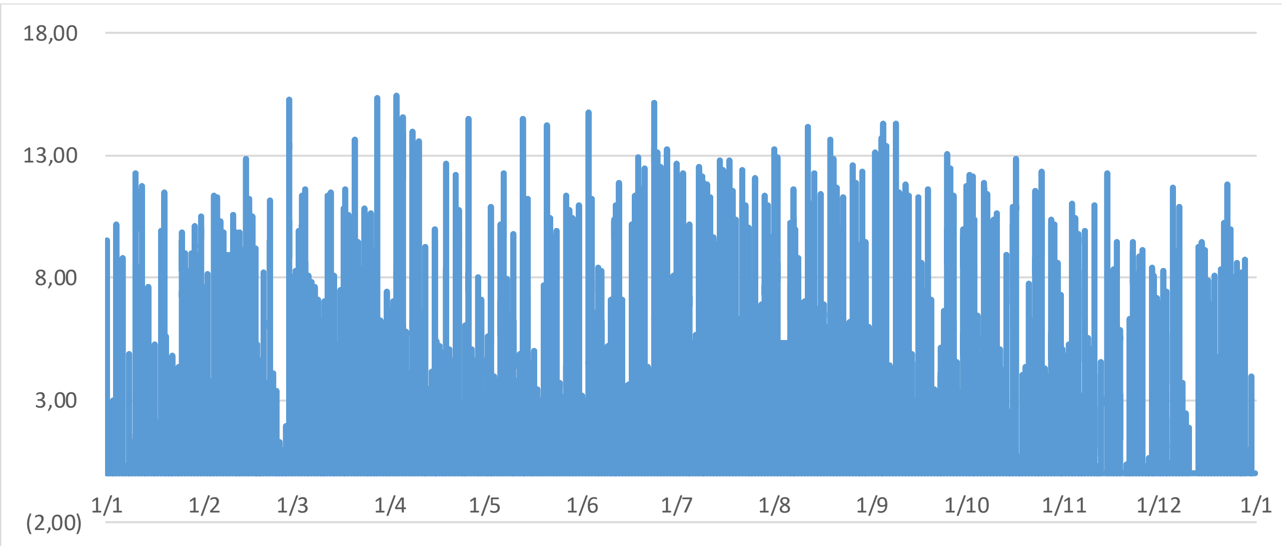


Figure 27 – Estimation of hourly energy shared (kWh) in energy community of Cres with installation of an additional 20 kW PV panel on Museum's roof

If we focus on specific period, as for example in spring and summer, the maximisation of energy sharing is in the REC with the option of new instalment in the kindergarten (REC-2) instead of at Museum (REC-3):

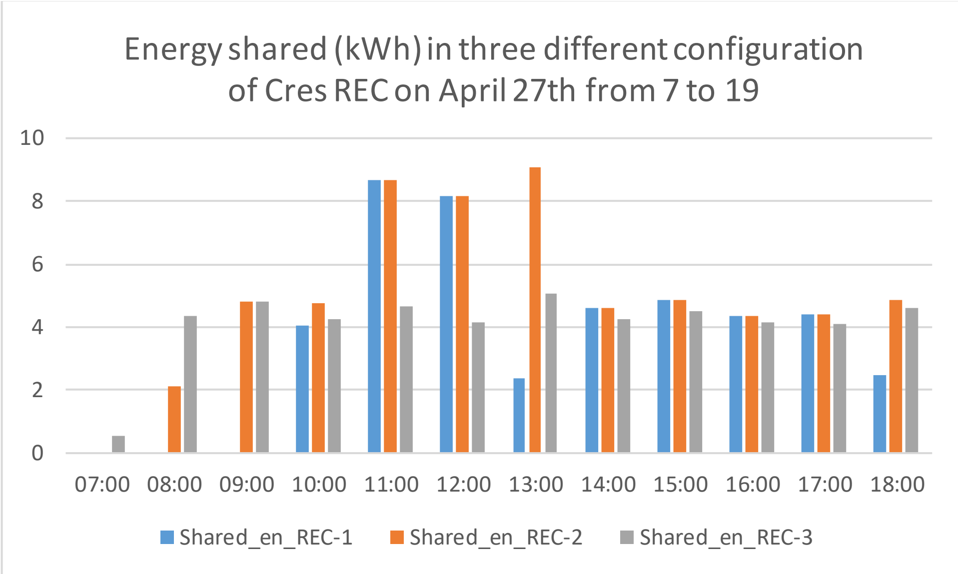


Figure 28 – Estimation of energy shared (kWh) in energy community of Cres in different configurations in a spring day (April 27th)

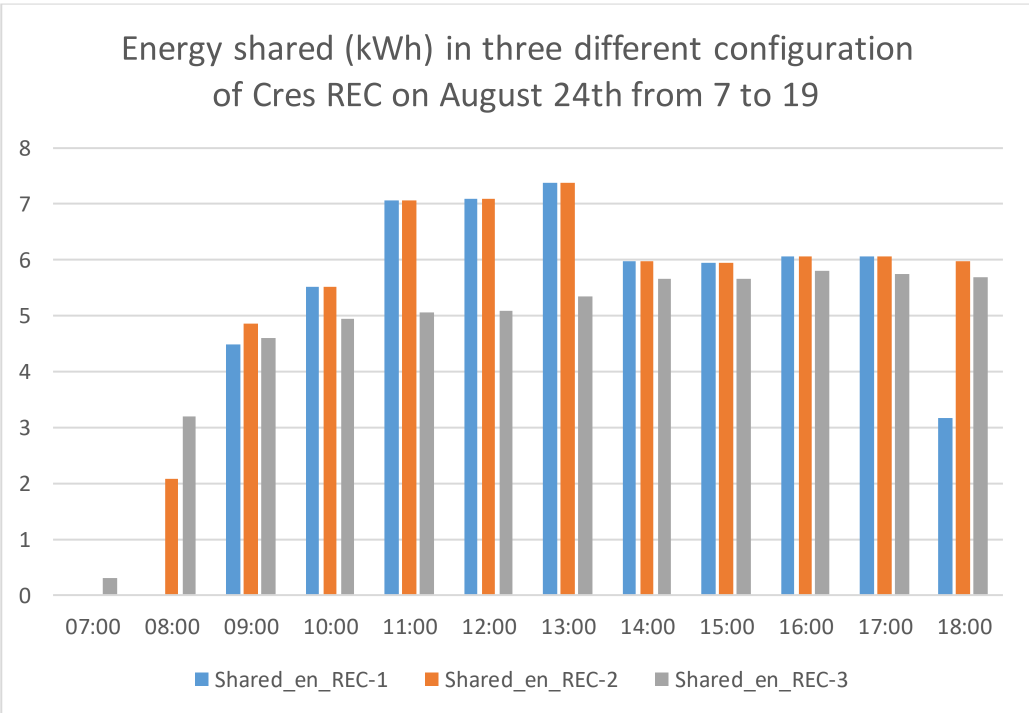


Figure 29 – Estimation of energy shared in energy community of Cres in different configurations in a summer day (August 24th)

This happens, because the kindergarten in spring has a lower energy demand and in summer is close, as the production is completely shared with the REC members. This aspect is very relevant in the islands, as the small islands have a peak load in July and August and having a school in a REC with households or touristic SMEs among members could improve the energy performance.

Summarizing the three different configurations' performance we have:

Table 33 – CRES Energy Community configurations studied

	Power installed (kW)					
	Town hall	**Kindergarden**	**Museum**	**Energy shared (kWh) per year**	**hours of sharing per years**	**surplus energy into the grid**
REC1 - 20kW tot	0	20	0	6.430,56	1.679,00	3.112,94
REC2 - 40 kW tot	0	40	0	13.955,00	2.558,00	13.704,97
REC3 - 40 kW tot	0	20	20	18.714,98	3.646,00	13.704,97

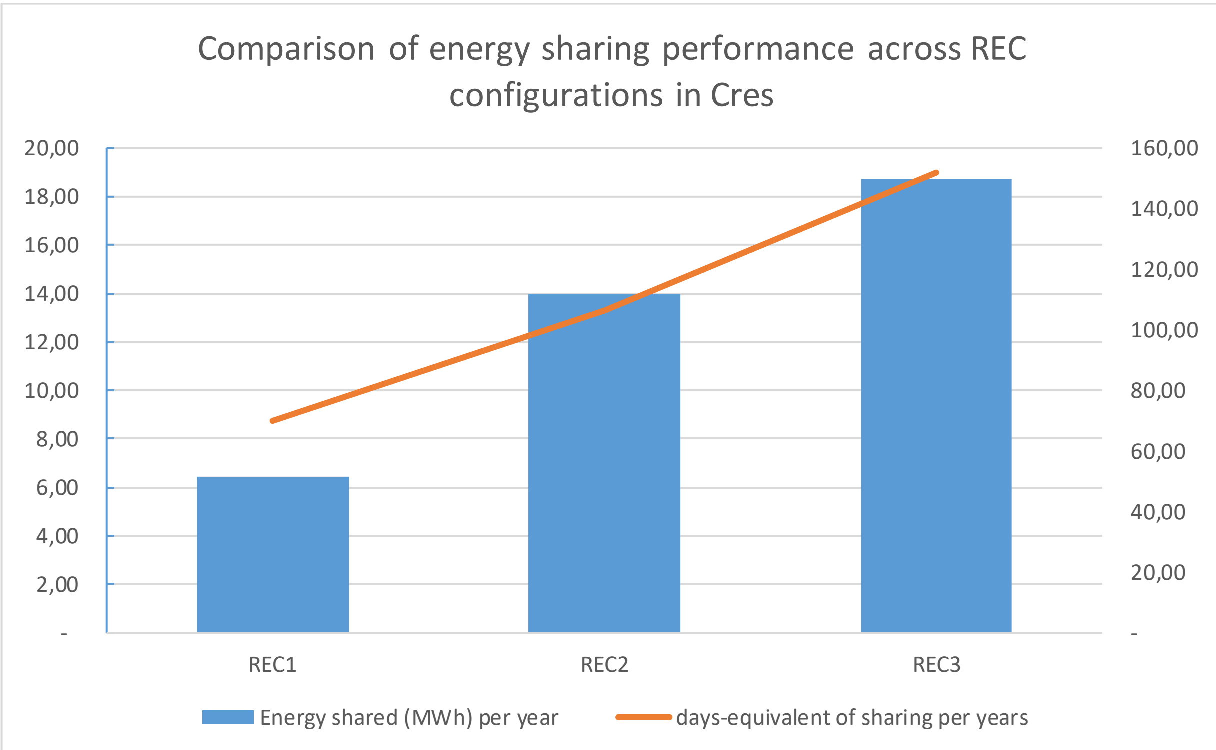


Figure 30 – Performance of the three different REC configurations in Cres

This happens considering all the yearlong, starting from the April 1st to March 31st. The amount of energy fed into the grid is the same for both systems installing a total of 40kWh and is quite high. The system could profit of involving members with different demand profile, in order to maximise the energy produced, considering that a change in energy source is more difficult to happen.

7.3 – ITALY, Procida

In Italy there are 30 inhabited islands considered as small islands, distributed in 36 municipalities where about 200.000 inhabitants reside. Among the 26 inhabited islands with more than 200 inhabitants, 19 are still non-interconnected to the electricity national grid. Although on some islands, there is one of the highest potentials for solar and wind energy in Italy, actually the number of plants of renewable sources are among the lowest nationwide. The coverage of electricity needs in non-interconnected islands is still guaranteed by oil-fired thermoelectric plants, with companies that – thanks to a regulatory exception allowed by European directives - control both production and distribution. Renewable energy installations are growing, but still too slowly compared to the targets Italy committed to in the Paris Climate Agreement. The installation of solar photovoltaic is growing, especially in islands that are non-interconnected with the mainland, but it corresponds to about 7,11% of the non-interconnected small islands' energy consumption (compared to the 40,65% at national level). Photovoltaic is present on all islands, as well as micro-wind power.

The lack of information about the opportunities and benefits, including economic ones, of the shift towards renewable energies for both citizens and companies, together with a difficult access to credit, the complexity of the procedures, landscape and environmental constraints seem to be the main existing barriers.

In Italy, energy communities and collective self-consumption configurations, after a first experimental transposition within the article 42-bis of the Decree Milleproroghe of 2020, are active at their maximum potential from November 2021, thanks to the stable transposition of RED II within the national legislative body (law decree n. 199/2021).

Italy's renewable energy framework comprises several key legislative measures.

- Law No. 220/2012 sets national targets for renewable energy growth and outlines incentive mechanisms to promote renewable technologies.
- Ministerial Decree DM 23/06/2016 establishes feed-in tariffs for electricity generated from renewable sources like solar, wind, hydro, and biomass.
- DM 28/12/2012 regulates incentives for renewable heating and cooling systems.

- Legislative Decree 28/2011 (Energy Code) governs access to grids for renewable energy facilities and promotes energy efficiency.
- Ministerial Decree DM 29/04/1999 oversees experimentation with new renewable energy technologies in the environmental sector.

The Ministerial Decree of 23 June 2016 establishes incentive tariffs for electricity from renewable sources and allows self-production and self-consumption, with excess energy fed into the grid and compensated through credits. The Ministerial Decree of 11 April 2018 details the procedures and conditions for implementing this on-site trading system, including access to the net metering system and methods for measuring and compensating energy exchanged with the grid.

The Legislative Decree 257/2016, known as the "Mobility Package," includes tax incentives for purchasing low-impact vehicles, support for installing charging infrastructure, and incentives for electric commercial vehicles.

The Legislative Decree 101/2019, the "Climate Decree," aims to reduce greenhouse gas emissions with provisions for tax incentives on electric and plug-in hybrid vehicles, tax relief for charging infrastructure, and subsidies for electric company vehicles.

Additionally, the Legislative Decree 103/2020, the "Simplification Decree," simplifies administrative procedures to boost electromobility, including easier installation of charging infrastructure and facilitating zero-emission vehicle purchases and access to restricted traffic zones. The 2022 Budget Law further supports zero-emission vehicles with tax incentives for electric vehicle purchases, installation of charging infrastructure, and tax relief for companies adopting zero-emission fleets.

As part of the System Research programme, during the 2022-2024 period, the tool 'Map of Energy Communities in Italy' has been developed By the Ricerca sul Sistema Energetico (RSE), offering qualitative guidance on the establishment of energy communities across the country, then the success of related legal framework [50]. The map is not up-to-dated constantly, and, after 2024, it is based on volunteer communication by interested Energy Communities.

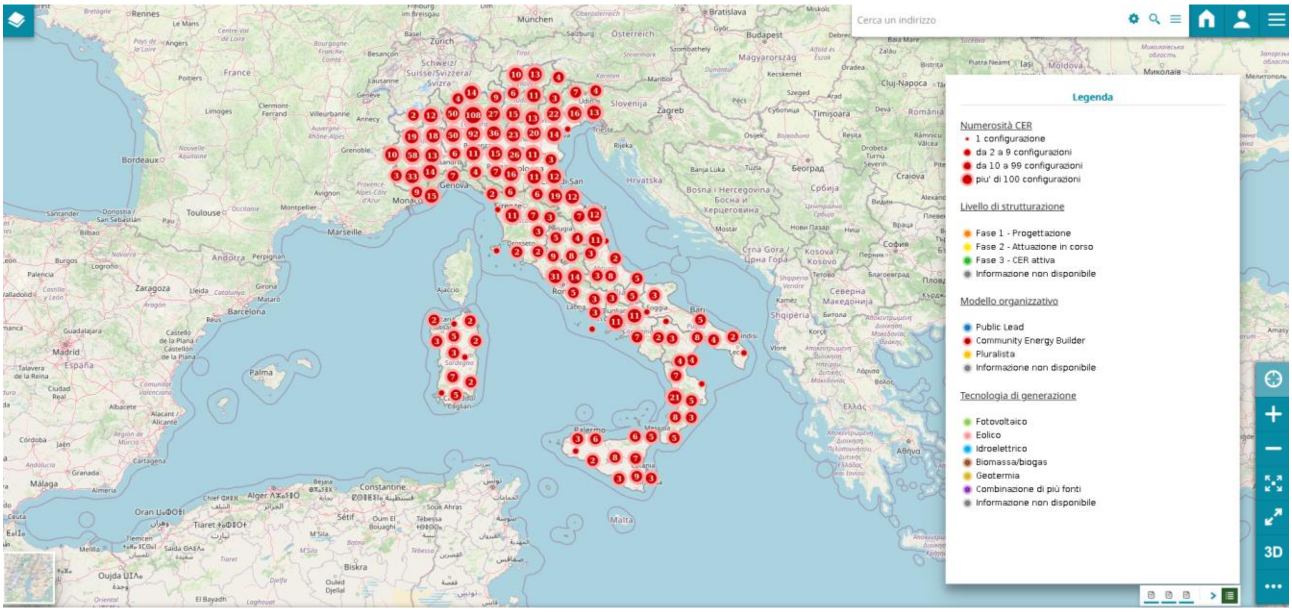


Figure 31 – Interactive MAP of Italian Energy Communities in the Geoportal of RSE.

Nevertheless, it shows as among the Italian small islands only Elba and Ventotene have a local Energy Community. Meanwhile, the Island of San Pietro, Ischia and – within the ISLET Project – Procida developed an Energy Community.

National laws regarding renewable energy (RES) installations on islands may vary slightly from those on mainland, taking into account specific challenges and opportunities related to geography and the resources available on the islands. In Italy, there are some laws and regulations that apply to islands to promote the development of renewable energy and decarbonisation. The most relevant source on this topic is the Ministerial Decree of Ministry of Economic Development of the 14 February 2017 "Coverage of the needs of the smaller islands not interconnected through energy from renewable sources" [51]. The decree aims to progressively cover the energy demand of Italy's small islands that are non-interconnected to the national electricity grid, by increasing the use of renewable energy sources. For each island, the decree defines minimum renewable energy targets to be reached by 31 December 2020, including thermal solar systems for domestic and non-domestic use, heat pumps for hot water and electricity generation from locally available renewable sources.

In order to implement it, regulatory and regulatory-support tasks were entrusted to the national energy regulator, ARERA — to define remuneration mechanisms for renewable electricity/thermal energy produced on the islands.

In the 19 non-interconnected islands, energy production and distribution companies operate — by special exemption — and are able to keep energy costs for citizens in line with national levels only thanks to state subsidies. The aforementioned Decree set the first major milestone at 31 December 2020. Nevertheless, the target for small islands are far from be reached, as indicated in the Table 34 (Capri was not interconnected in 2017, so it has an objective value, whereas now it is connected to the national grid) [52].

Table 34 – Energy production from PV plant and RES targets in Italian small islands in 2023

Island	PV power (2023) kW	Target MD 2017 (kW)	% DM 2017 reached		Main non-renewable energy sources	Local energy provider
Capraia	38,01	180	21,12%	Non-interconnected	4 Generator sets with certified sustainable biodiesel	Enel Produzione
Capri*	461,85	1000	46,19%	interconnected	-	-
Ischia	7.815,93	-		interconnected	-	-
Isola del Giglio	62,58	700	8,94%	Non-interconnected	1 diesel generator set	Società Impianti Elettrici srl
Isola d'Elba	8.987,09	-		interconnected	-	-
Favignana	660,28	1060	62,29%	Non-interconnected	2 diesel generator sets	Società Elettrica di Favignana SpA

Marettimo					1 diesel generator set	S.EL.I.S. Marettimo spa
Levanzo					diesel generator set, bottled gas for domestic use	I.C.EL. Srl
Lipari	1.253,72	2860	43,84%	Non-interconnected	2 diesel generator sets	Società Eletrrica Liparese
Vulcano					diesel generator sets	Enel produzione
Stromboli						
Panarea						
Filicudi						
Alicudi						
Salina	292,59	580	50,45%	Non-interconnected	diesel generator sets	Enel Produzione
Lampedusa	617,58	2310	26,74%	Non-interconnected	diesel generator sets	S.EL.I.S. Lampedusa SpA
Linosa					1 diesel generator set	S.EL.I.S. Linosa spa
Isole Tremiti	67,36	240	28,07%	Non-interconnected	1 diesel generator set	Germano Industrie Elettriche
La Maddalena	1.512,20	-		interconnected		-
Pantelleria	2.175,30	2720	79,97%	Non-interconnected	8 diesel generator sets	S.MED.E Pantelleria SpA
Ponza	346,32	720	48,10%	Non-interconnected	4 diesel generator sets	S.E.P. SpA
Procida	832,71	-		interconnected		
San Pietro	1.848,77	-		interconnected		-
Sant'Antioco	3.338,63	-		interconnected	-	-
Ustica	429,99	280	153,57%	Non-interconnected	1 diesel generator set	Impresa Elettrica D'Anna Bonaccorsi

Ventotene	158,03	170	92,96%	Non-interconnected	1 diesel generator set	Enel Produzione

By the end of 2023, only Ustica had significantly exceeded the target set for 2020. The island of Ventotene is very close to achieving its target, with approximately 93% coverage. These data are in line with the RES penetration in electricity total consumption in non-interconnected islands, calculated by ANCIM and ENEA for 2019 [53].

Table 35 – RES coverage in 20 non-interconnected small Italian Islands in 2019 [53]

Island	**Archipelago**	**RES penetration**
Capri	Campanian	0.35%
Capraia	Tuscan	0.78%
Isola del Giglio		0.45%
Pantelleria	Pelagie	2.12%
Lampedusa		0.48%
Linosa		
Favignana	Egadi	2.24%
Marettimo		
Levanzo		
Ponza	Pontine	1.39%
Ventotene		5.11%
Ustica		4.46%
Tremiti Islands	Tremiti	0.64%
Lipari	Eolie	1.07%
Vulcano		
Stromboli		
Panarea		
Filicudi		
Alicudi		
Salina		0.00%
Average		**1.59%**

For what it concerns the plans for connection, in its 2023 development plan, Terna had presented a proposal to interconnect the island of Favignana and a similar one for the Island of Giglio. With opinion 335/2022/I/EEL, in point 3, the Regulatory Authority for Energy,

Grids and Environment (ARERA) expressed a negative opinion, contesting the cost-benefit advantage and calling for a more in-depth assessment of the costs for consumers and the impact on the environment. The other small islands do not appear attractive for this type of intervention in terms of cost-benefit analysis, due to a very small number of permanent inhabitants or an excessive distance from the mainland [54]. The islands already interconnected are in fact also those with the largest number of inhabitants and the ones closer to the continental Italy.
In 2023, the energy demand covered by PV in non-interconnected islands was only 7.1%, while is 43.8% in the mainland, according to TERNA [52].

<u>Energy Communities</u>
Italy has transposed the Renewable Energy Community (REC) definition with Legislative Decree 199/2021 and the Citizen Energy Community (CEC) definition with Legislative Decree 210/2021. The REC definition aligns with the criteria in RED II, emphasizing autonomy and effective control, and allows for collective self-consumption with a capacity cap of 1MW per plant. The new legislation defines geographical proximity as consumption points connected to the same medium voltage station.
The CEC definition includes open and voluntary membership, effective control, and the ability to undertake various activities, provided their main aim is to bring environmental, social, and economic benefits to the local community, not financial profit. Both REC and CEC provisions promote inclusiveness, ensuring participation is open to low-income or vulnerable households. Further specification of criteria like proximity and autonomy is expected in by-laws.
The minimum number for the creation of a REC is two members and a member can be:

- Natural person
- SME (participation not their main commercial/industrial activity)
- Association with legal personality under private law
- Territorial bodies (Regions, Provinces, Metropolitan Cities, and Municipalities)

- Local administrations in the ISTAT list, within the Municipalities of REC production plants
- Research and training bodies
- Third sector and environmental protection bodies
- Religious bodies

The Italian National Integrated Plan for Energy and Climate (Piano Nazionale Integrato Energia e Clima – PNIEC) of 2019, in line with EU Regulation No. 1999/2018, outlines strategies for decarbonization, energy efficiency, energy security, the internal market, and research and innovation. Key targets include reducing CO_2 emissions by 43.7% by 2030 (compared to 2005 levels) and achieving net zero by 2050, as well as reducing primary energy consumption by 43% and final energy consumption by 39.7% by 2030. The plan promotes various measures, including financing decarbonization projects through EU ETS revenue, encouraging green building practices, and advancing green transport [55].

In 2023, Italy proposed updates to the PNIEC to better align with the European Green Deal, with the European Commission suggesting further amendments. Complementing the PNIEC, the National Energy Strategy of 2017 focuses on diversifying energy sources, improving energy efficiency, reducing greenhouse gas emissions, ensuring energy supply security, and supporting technological innovation. Additionally, Legislative Decree 192/2005 mandates nearly zero-energy buildings from 2021, and Decree No. 383 of 2022, following the "Save Gas for a Safe Winter" resolution, sets new temperature and operational limits for natural gas-fuelled heating systems in buildings to reduce energy consumption [35].

PROCIDA ISLAND

Geography

Procida is one of the Flegrean Islands off the coast of Naples in southern Italy, in the region of Campania. Procida is located between Capo Miseno and the island of Ischia. The total area of the island is less than 4.2 square kilometres. The length of its coastlines is approximately 16 km. The Terra Murata hill is the highest point on the island (91 metres).

The island lies at a minimum distance from the mainland of about four nautical miles (Procida Channel) and is connected by a small bridge to the nearby island of Vivara, which is a natural and inhabited state reserve.

Figure 32 – Procida Island

The island's coastline—characterized in places by low, sandy shores and elsewhere by steep, precipitous cliffs—gives rise to a series of bays and promontories that provide natural protection for small vessels. These geomorphological features have enabled the establishment of three marinas located on the northern, eastern, and southern margins of the island.

From a geological perspective, Procida is the product of eruptive activity associated with four distinct volcanic edifices, all of which are presently dormant and submerged.

Procida has one main settlement, the City of Procida. The main town is divided into nine districts, known as "grancìe": Terra Murata, Corricella, Sent'cò, San Leonardo, Santissima Annunziata (also called Madonna della Libera), Sant'Antuono, Sant'Antonio, and Chiaiolella.

Climate, natural resources and special zones

Procida has a Mediterranean climate, with hot, dry summers and mild, rainy winters.

Procida is influenced by winds from the south-west (Sirocco) and west/north-west.

Table 36 – Monthly temperature data in °C in Procida [35]

Month	Max (C°)	Min (C°)
January	13	7
February	13	7
March	14	8
April	18	11
May	22	14
June	26	18
July	29	20
August	29	20
September	26	18
October	22	15
November	17	12
December	14	9

Table 37 – Monthly precipitation and wind speed data in Procida [35]

Month	Total Precipitation (mm)	Average Wind Speed (km/h)
January	69	17.1
February	57	17.0
March	57	15.6
April	39	13.9
May	34	12.0
June	16	11.4
July	24	11.4
August	38	11.3
September	48	12.4

October	70	14.1
November	102	16.7
December	87	17.8

Part of the municipal area of Procida is a special protection area: privately owned, Vivara Island is a state nature reserve since 2002, important as an example of conservation of Mediterranean flora and fauna. The remains of a Mycenaean village from the 15th century BC have been found on the islet, with excavation campaigns still under way by Suor Orsola Benincasa University. A hunting lodge was built there in the 17th century.

Another Protected area is the Marine Protected Area "Regno di Nettuno" including the marine ecosystem located between Procida, Vivara and Ischia [56].

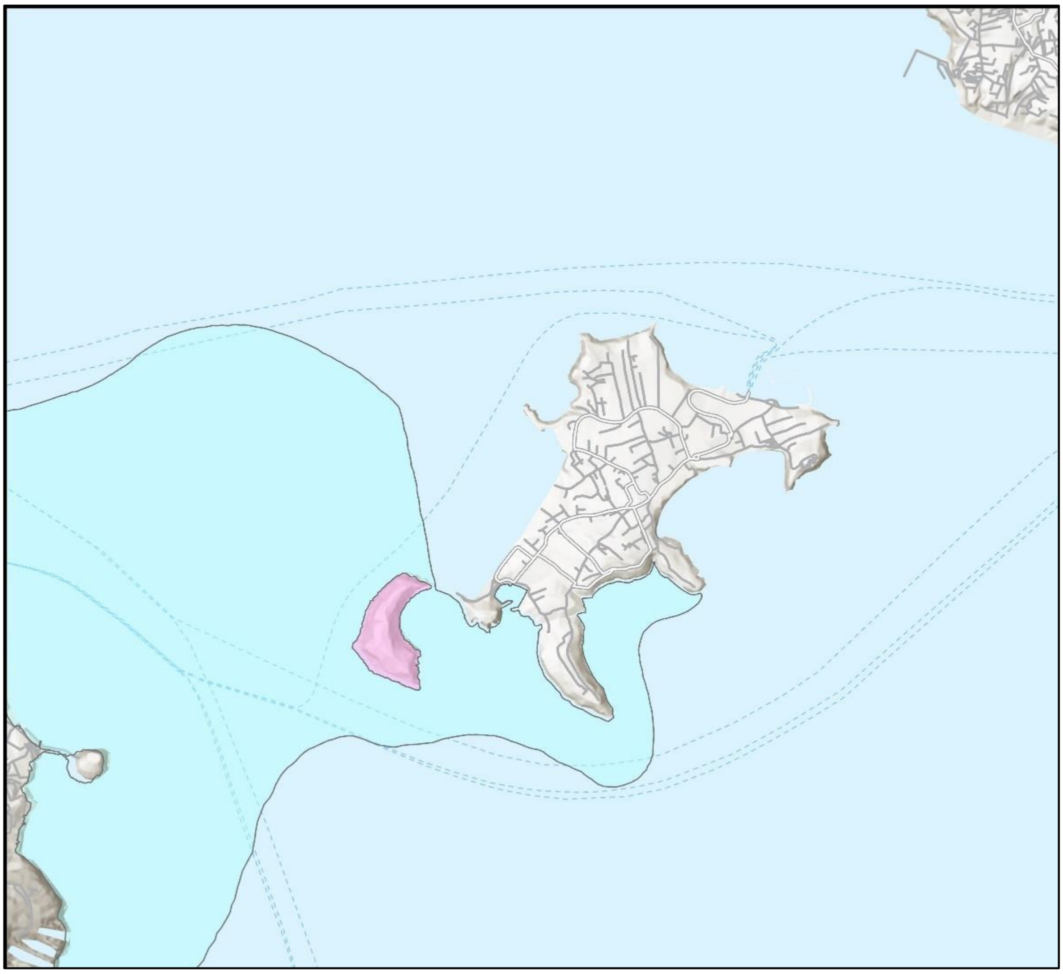


Figure 33 – Areas of nature conservation in Procida [56]

Demography.

The population of Procida, in 2023, was 10,118 habitants. With a total area of a 4.26 km2, the island is densely populated with 2,375 people/ km2. The annual visitors to the island are estimated around 440,000 people. The total number of households in the island is 4,585, and the 77% of the habitable residence is occupied all-year-round, with the remainder used only seasonally or not used [57].

The evolution of the population on the island can be seen in the Fig. 34. Data indicated a population slightly older than the national average and with genders more balanced in the islands (Table 38) compared to the Italian situation (F, 51.13%, M 48.87%) [58].

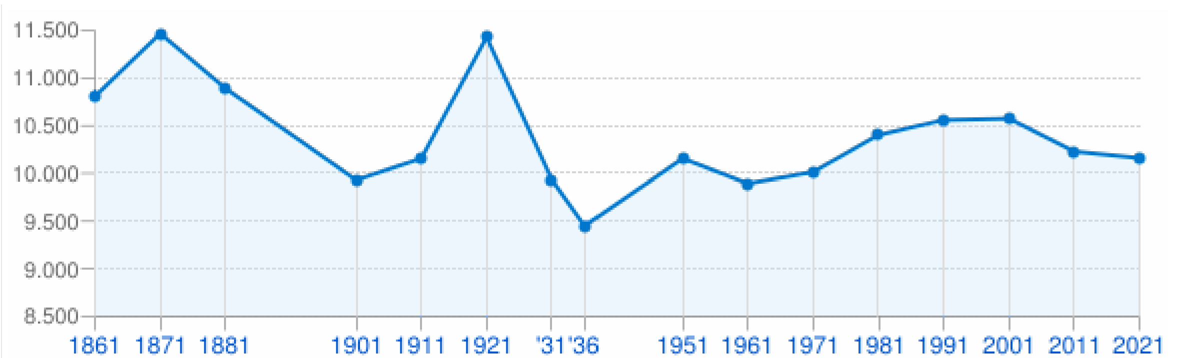


Figure 34 – Evolution of population (Procida)

Table 38 –Demographic statistics (Procida, 2023)

population 0-14 years old	**population 15-64 years old**	**population aged 65+ years old**
11.4%	62.7%	25.8%
Percentage of male population	**Percentage of female population**	
49.5%	50,5%	

Economic activity.

Tourism is one of the main pillars of Procida's economy, especially dynamic during the summer months due to the island's beaches, cultural heritage, and picturesque streets. Related industries such as hospitality with a total number of approximately 150 touristic accommodations, dining, boat rentals, and recreation thrive during this season. Local handicrafts, including pottery, paper products, and typical gastronomic items, are important for the economy, particularly through sales to tourists.

Fishing, with its long tradition, remains significant, though it faces challenges from fisheries management and regulations. Agriculture, while no longer predominant, still involves the cultivation of lemons and vegetables, though much agricultural land has been converted for residential or tourist purposes. The maritime sector continues to be crucial, supported by a maritime school that affects local employment. Additionally, sectors like retail, healthcare, education, public services, and other services provide stable employment for many residents.

Transports.

The island of Procida has one main commercial port, named Marina Grande, which is located on the northeast area of the island, on the islands side towards Naples. Furthermore, there are two marinas, Chiaiolella and Corricella, which only serve touristic boats. The island is interconnected via commercial ferries, with Napoli (Molo Beverello and Pozzuoli ports) and with the nearby island of Ischia (Casamicciola port), as shown in Fig. 35. Procida is also served via hydrofoils from Ischia and Molo Beverello ports.

Table 39 – Frequency of ferries during peak demand period

	From Molo Beverello (Naples)	From Pozzuoli (Naples)	From Casammicciola (Ischia)
Low season demand (Oct-Apr)	12	8	10
Peak demand period (Apr- Sept)	15	15	15

Figure 35 - Ferry routes from and to Procida

On the island of Procida, walking and bicycling are common modes of transportation due to the island's small size and narrow streets. Scooters and motorbikes are very popular too, offering a quick and convenient way to navigate the hilly terrain.

In terms of mobility, Procida is one of the most virtuous small Italian islands, with only 47 cars per 100 inhabitants [52].

Local buses connect the main points of interest, providing an affordable and efficient means of travel. Taxis are available for more comfortable and private transportation, while private cars and car rentals, though less common, offer another option for getting around the island. The length of the road network consists of approximately 4-5 km of main roads, 8-10 km of secondary roads and 2-3 km of rural roads.

On the island, there is one gas station and three public chargers for electric vehicles [35].

Energy System.

Procida is interconnected to the mainland via the island of Ischia, with an interconnection capacity of 30 kV. It is one of the few Italian islands connected to the national grid through a submarine cable. Electricity distribution is managed by E-Distribuzione, part of the Enel Group. Table 40 and Fig. 36 display the island’s electrical consumption data for 2021.

Table 40 – Electrical consumption per economic sector in Procida

Sector	Consumption (kWh)
Public buildings	430.630,00
Residential buildings	13.415.662,00
Agriculture	297.978,00
Industry	521.640,00
Tertiary	6.158.326,00
Public and street lighting	603.223,00
Total	**21.427.459,00**

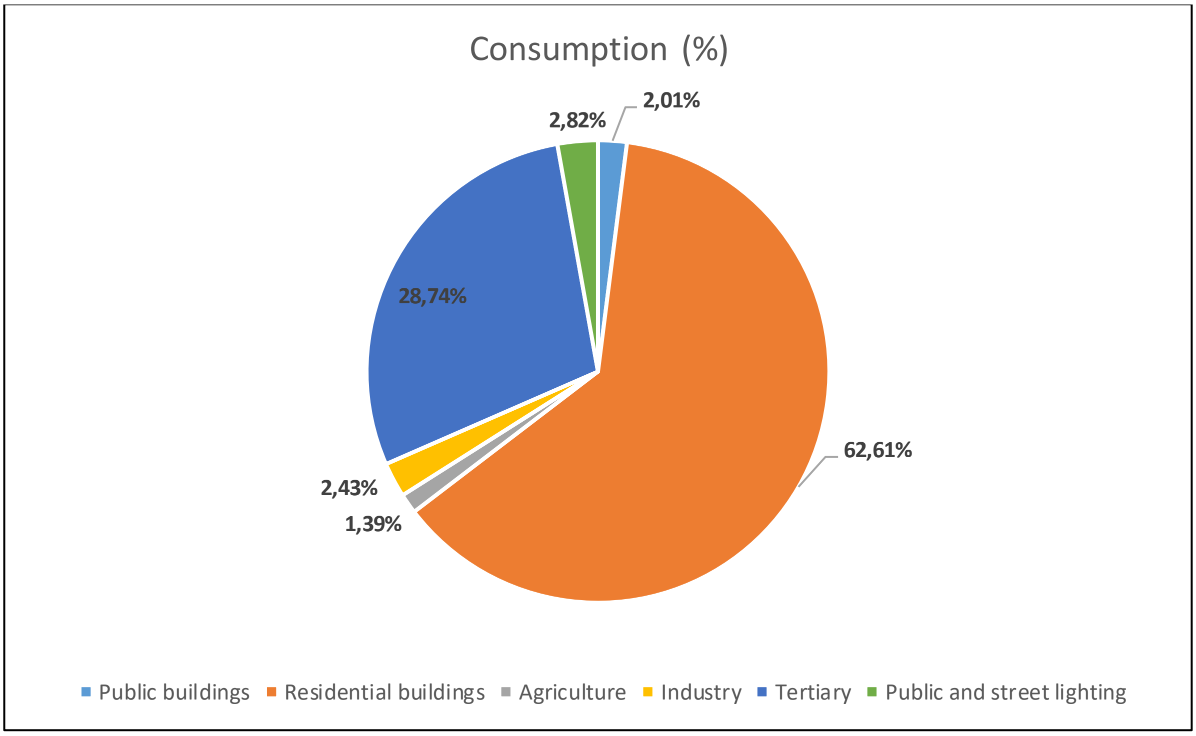


Figure 36 – Island's electrical consumption per sector

Procida is interconnected to the national electricity grid, but the renewable energy plants are few developed, with only 0.083 kWe per inhabitant. Photovoltaic panels are the only renewable source of energy available on Procida [59], with 832.71 Kw installed [52]. The use of natural gas for heating is not used, as only 30% of the dwellings are connected to the national gas network [57].

Other infrastructures.

Waste management on the island is being undertaken through a door-to door system, with 66% of waste being sorted for recycling [52]. The waste is collected throughout the island from residencies and businesses, is mechanically treated by a machinery and is then transported to the mainland for disposal.

There is no water management or related infrastructure on the island, as Procida is provided with clean water from the mainland through Naples.

For internet connection, a fibre-optic communication network is operating on the whole island.

Regional and local regulation on decarbonisation

The regional energy policy aims to shift the energy production-consumption paradigm in ways that support environmental protection, public health, safety, and hygiene. It focuses on reducing local greenhouse gas emissions in line with the targets of the Kyoto Protocol and national directives. This includes actions aimed at improving energy efficiency and promoting rational energy use across residential, commercial, public, transportation, and industrial sectors, ultimately working towards a more balanced and efficient regional energy system.

The Regional Energy-Environmental Plan (Piano Energia e Ambiente Regionale – PEAR) of the Campania Region is designed to create a foundational framework for implementing the Region's sustainable development policies in the energy sector. It outlines the strategic directions for energy policies, specifying targets, strategies, available resources, and actions needed to bring these plans to fruition. Key goals include promoting a development model centred on the efficient and sustainable use of resources, while ensuring competitiveness, security, and quality within energy and production systems. It set targets that will allow at regional level:

- To increase electricity production from renewable sources by over 900 GWh/year (+19% compared to 2015);

- To increase thermal energy production from renewable sources by over 1,000 GWh/year (+13% compared to 2015); and
- To save greenhouse gas emissions by over 0.5 million tonnes of CO_2 equivalent per year (3.5% compared to 2015).

The plan explicitly mentions the Energy communities as "High" priority and as means to promote decarbonisation, even that there is not mention of regional small islands [35].

More at local level, Procida's Sustainable Energy Action Plan (SEAP) was created in line with the European Commission's "Covenant of Mayors" initiative, with the municipality formally joining on 2015 [60]. Procida's SEAP has set ambitious goals, including a 27% reduction in CO_2 emissions by 2010 levels. To meet these objectives, the island is focusing on enhancing energy efficiency across urban sectors and launching an educational campaign to promote environmental best practices. These initiatives are crucial not only for meeting the Covenant of Mayors' targets but also for engaging the community in sustainable energy practices. The SEAP outlines both long-term strategies and immediate actions aimed at reducing fossil fuel dependence and cutting CO_2 emissions by 2020.

Finally, Procida is a "follower islands" for the Programme 30 islands for 2030 promoted by the Clean Energy for EU islands Secretariat [61].

<u>The energy community in Procida.</u>

A dedicated and motivated founding group of 11 citizens, together with the local administration, took the initiative in transforming widespread community interest into structured and formal participation, creating the "Prochyta" Renewable Energy Community.

The statute defines the governance arrangements, membership requirements, and participation rules, ensuring compliance with national legislation while remaining sensitive to Procida's specific social and institutional context.

The statute of the Prochyta Renewable Energy Community offers a representative example of how Renewable Energy Communities (CERs) have been legally organized in Italy in recent years, closely mirroring the "standard model" that is gradually consolidating at the national level. The community has been formally constituted as a non-profit association, and registered as a Third-Sector Entity (ETS) under Italian law. Founding members include both the Municipality of Procida and a group of private citizens, exemplifying the increasingly widespread public–civic partnership model that characterizes many of Italy's most innovative energy communities.

The statute clearly defines the community's objectives, which extend well beyond the mere sharing of renewable energy. These include the promotion of environmental sustainability, the generation of economic and social benefits for members and the local territory, and the encouragement of a rational and efficient use of natural resources. Any revenues or incentives required to be reinvested within the community or allocated to projects of social interest.

Membership is open to a broad range of actors, including private individuals, small and medium-sized enterprises (provided that energy production is not their primary activity), local authorities, religious institutions, Civil Society Organizations, and environmental associations.

The governance system follows a traditional associative structure. The General Assembly serves as the supreme decision-making body, granting all members voting rights and the ability to participate in collective decisions. Operational management is entrusted to a Board of Directors consisting of five members, including a President and a Vice-President, all of whom serve on a voluntary and unpaid basis. The statute also provides for the community's indefinite duration and defines members' rights and obligations. The community is required to prepare annual financial statements, maintain statutory records, and to comply with the reporting and social accounting requirements established under Italian Third-Sector legislation.

Finally, while the statute already recognizes the strategic importance of public incentives in achieving the community's objectives—such as reducing members' electricity costs or funding social initiatives—it intentionally leaves the detailed mechanisms for distributing these economic benefits undefined. This approach reflects a broader national trend in Italy, whereby the statutes of newly established RECs set out general principles for benefit-sharing while deferring specific allocation rules to subsequent operational decisions, once the community is fully functioning and incentive flows are concretely available.

Active members of the Prochyta REC are 11 citizens and the municipality. The Municipality of Procida, beneficiary of ISLET project, participates to the REC with the Town Hall Point of Distribution. One of the REC's members is in fact a furniture shop. The rest is formed by private households. Table 41 summarizes the bi-monthly energy consumption all long the year for each member:

Table 41 – bi-monthly energy consumption of Prochyta REC members (kWh) from their energy bills

	1st	2nd	3rd	4th	5th	6th	tot year
P1	608	384	313	146	541	270	2.262
P2	248	121	16	91	205	149	830
P3	107	84	100	123	564	103	1.081
P4	287	121	270	260	299	133	1.370
P5	465	406	84	33	361	130	1.479
P6	407	271	233	178	87	421	1.597
P7	601	380	309	144	535	267	2.236
P8	1.138	742	319	576	224	307	3.306
P9	482	431	424	340	845	901	3.423
SME	1.327	1.364	2.029	632	794	355	6.501
P10	1.555	1.598	2.377	685	1.118	416	7.749
Town Hall	8.380	6.439	6.524	7.968	7.007	7.920	44.238

There are three prosumers in the REC perimeter: the municipality, that installed 20 kW of PV panels in the rooftop of the Town Hall, and two households, P2 and P5, having respectively 3 kW and 6 kW of PV panels.

Considering average value of energy consumption provided by ARERA (see Chapter 4), the monthly consumption for each member, dividing day (52%) and night (48%) demand was estimate for the household (P1 to P10). For the shop (SME) and the Town Hall (Mun) we consider 70% demand for the day and 30% for the night. For the municipality, monthly data already were available.

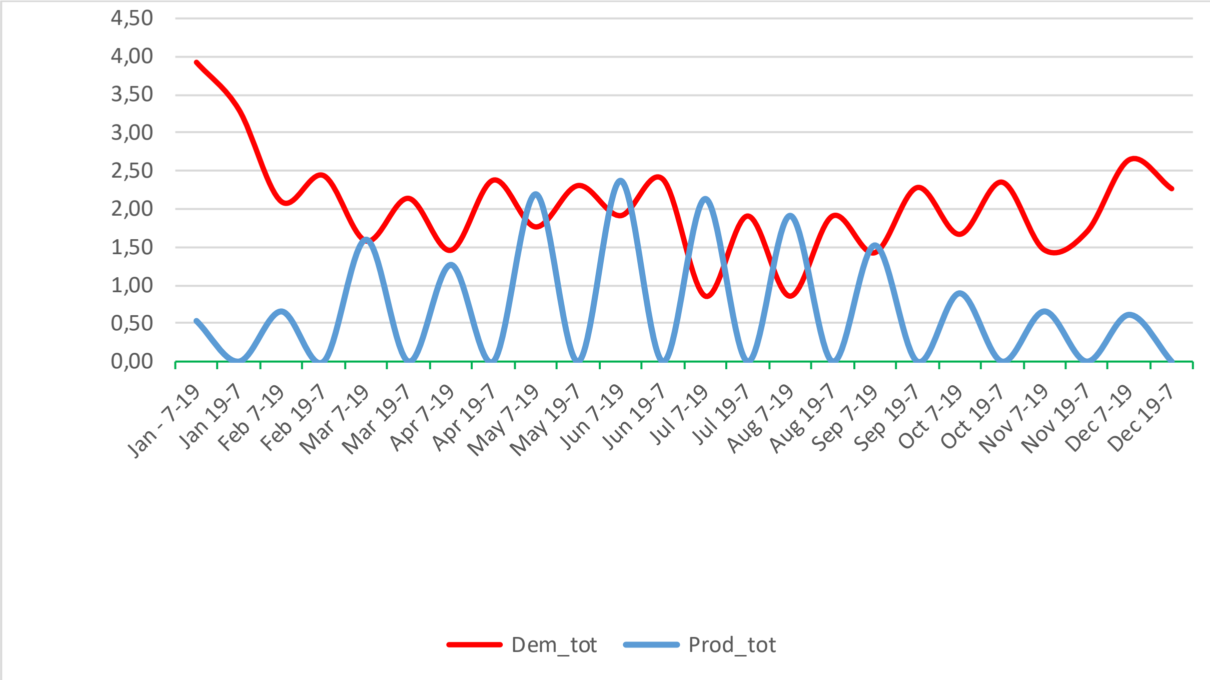


Figure 37 – Energy demand and consumption of REC Prochyta ETS at the moment of its founding

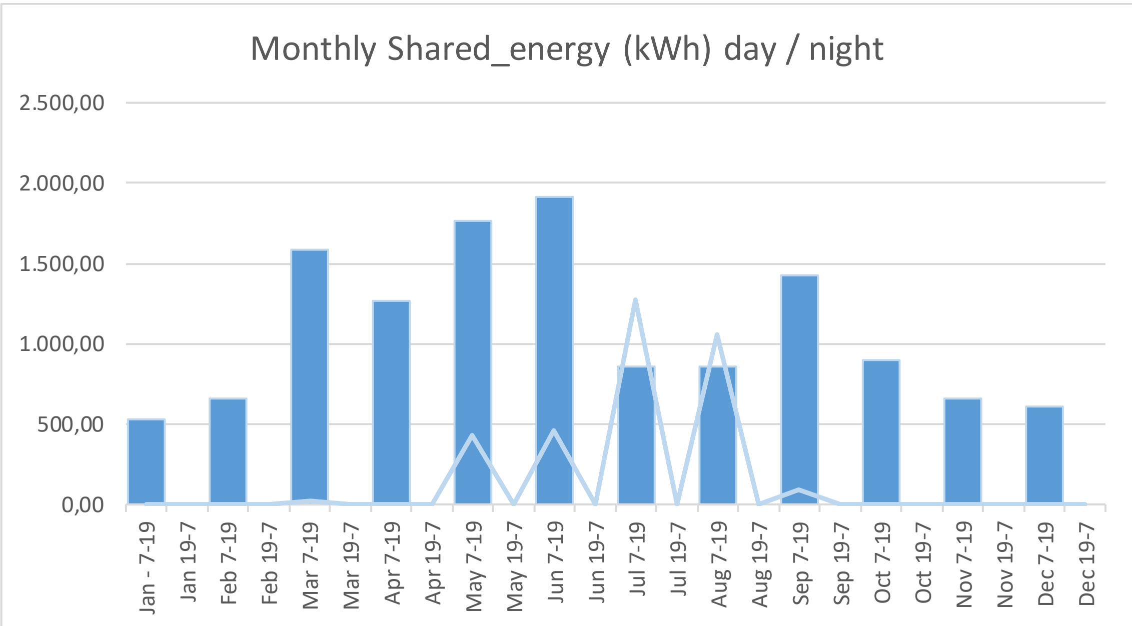


Figure 38 - Monthly Shared energy (kWh) day / night in REC Prochyta ETS at the moment of its founding

The future actual development of the CER in the near future involves several scenarios, which are not necessarily mutually exclusive, as described below.

The first and quickest upgrade is the installation of a 3-kW PV panel by a private resident on the island (P10). Considering the load profile of this member, the performance of the REC will get worst: even the total energy produced by REC with renewable energy sources grow, the total energy shared over the year falls by 1,887.20 kWh.

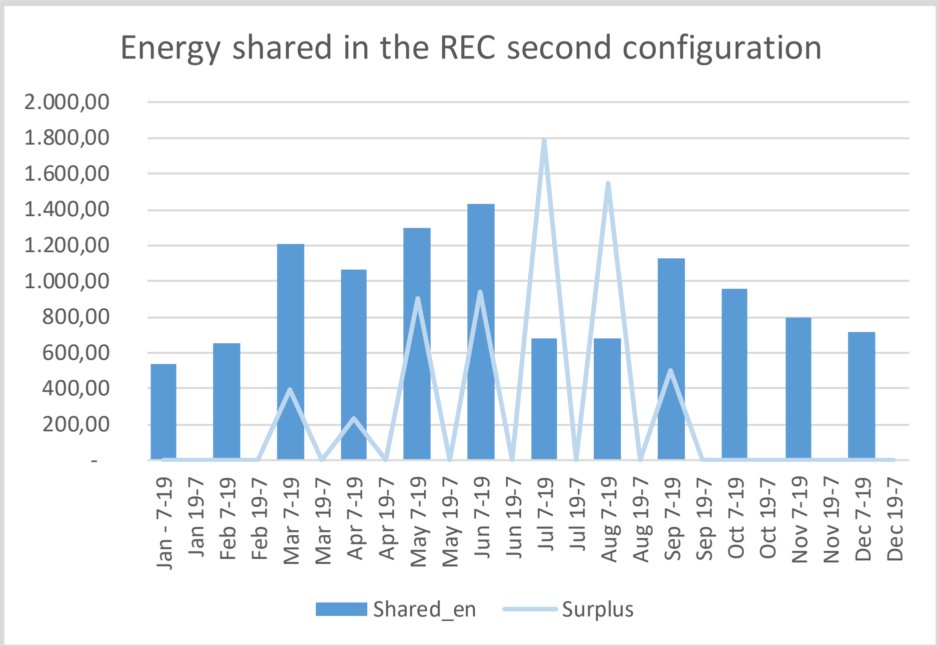


Figure 39 - Monthly Shared energy (kWh) day / night in REC Prochyta ETS with a new 3-kW PV panel owned by a private citizen

As we do not have hourly data, it does not make sense to consider during how many hours REC members are sharing energy, that indeed could be useful to calculate public incentives. Therefore, from the community point of view, this upgrade does not improve the REC performance.

The second possible expansion does not involve private operators increasing their output, but rather the inclusion of a new member in the CER: the I degree secondary school in Via Gioia, which is owned by the local municipality.

In that school, a PV plant with 20 kW of power is already planned. The municipality could include the school POD in the Prochyta REC. In this case, given that total energy production increases significantly, shared energy naturally increases as well, reaching 19,17 MWh.

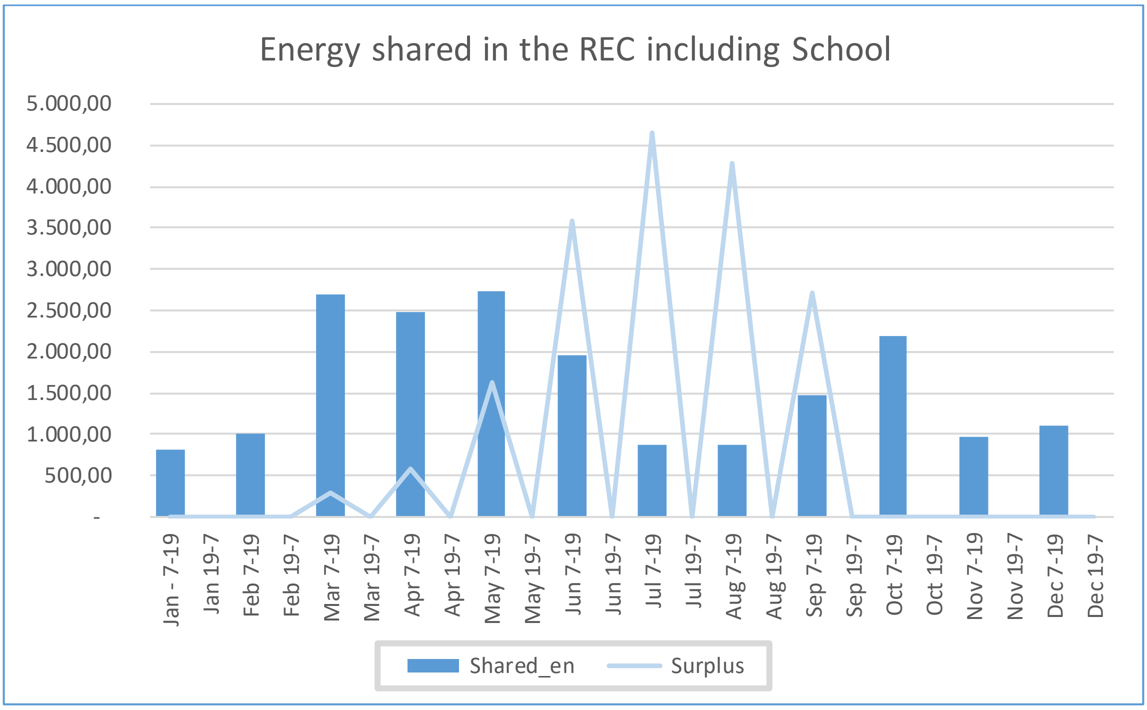


Figure 40 - Monthly Shared energy (kWh) day / night in REC Prochyta ETS, including school

Nevertheless, the municipality could decide to upgrade the PV panel already placed in its rooftop, without involving the school, getting a total power installed equal to 40 kW, all in the town hall premises. In that case, the performance of the REC would be even better: a total of 20,15 MWh will be shared each year.

If in the last simulation we add the private citizens previously considered for an installation of 3-kw PV plant (P10), the effect will be similar to the situation before explored: the general performance of REC in term of energy shared will deteriorates. The same will happen if this member (P10) become prosumer in the case of a REC including the school: compared to the option 3, the yearly result is worst.

Table and figure below are summarising the performance of the different options for the first upgrade of Prochyta REC:

Table 42 – Procida Energy Community configurations studied

	Power installed (kW)				
	Private	Town Hall	School	**Energy shared (kWh) per year**	surplus energy into the grid
REC	9	20	--	**13.031,14**	3.325,89

REC2	12	20	--	**11.143,94**	6.296,00
REC3	9	20	20	**19.167,41**	17.712,39
REC4	9	40	--	**20.148,39**	21.436,92
REC5	12	40	--	**17.727,56**	24.940,66
REC6	12	20	20	**17.089,05**	20.873,66

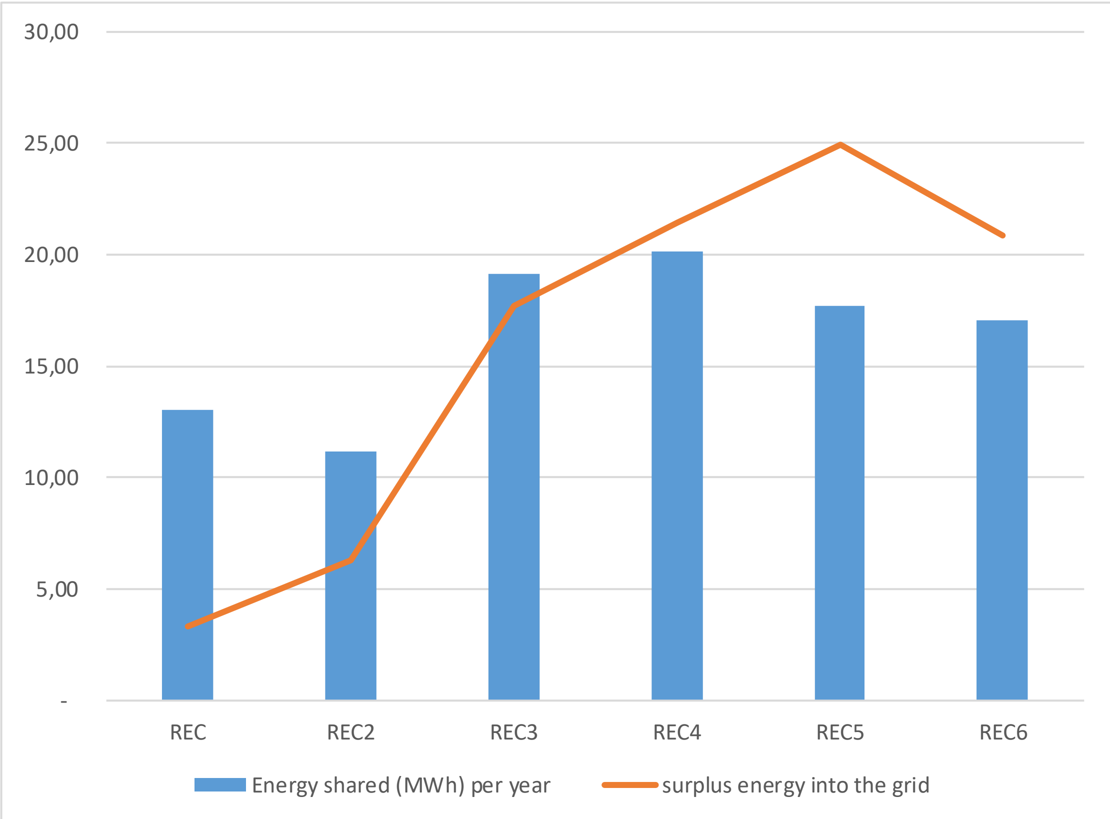


Figure 41 – Performance of the six different REC configurations in Procida

8 – Results and discussion

Across all three islands, several shared conclusions emerge concerning the Energy Community establishment. First, building local trust and facilitating engagement are essential—regardless of the specific regulatory framework, gaining community support hinges on continuous, inclusive outreach and the involvement of trusted local figures. Second, legal and administrative complexity presents a significant challenge, especially in systems where national REC laws are fragmented, newly implemented, or inconsistently enforced. Third, small-scale, symbolic initiatives (like installing solar panels on schools or public buildings) play an important role in making the abstract concept of RECs more tangible and relatable. These actions not only demonstrate institutional commitment but also foster public support. The pilots also highlighted that RECs could act as dynamic testing grounds for policy reform, particularly in island communities where energy independence isn't just a goal, but a necessity—due to factors like the absence of grid connections or dependence on fossil fuels.

Together, these lessons suggest that developing RECs in small Mediterranean islands requires a combination of grassroots social engagement and clear, supportive legal frameworks. This approach should not be seen merely as an infrastructure project, but as a process of community building that enhances local capacity and energy resilience.

Based on the experiences of the pilots, three key priorities emerge for speeding up EC development in Mediterranean islands:

i) simplifying and harmonizing national REC legislation with the legislation specifically address small islands and their decarbonisation, to reduce legal and administrative obstacles;

ii) establishing funding mechanisms for local facilitators and coordinators who can maintain trust and engagement, recognising the EC as a mean for local development and jobs;

iii) promoting small, visible pilot projects on public or community-owned buildings to build legitimacy and increase public awareness.

These steps would lower entry barriers and strengthen local ownership, particularly in island settings. Islands may represent extreme cases due to their isolation and energy dependence, but the same principles can guide REC development in other settings where communities face high energy costs, weak infrastructure, or limited institutional capacity. Concerning the point ii), although it is not the main focus of this work, the issue of the business model of the various energy communities is worth mentioning.

Reis et al. (2021) categorize energy community business models into distinct archetypes, such as energy cooperatives, community prosumerism, local energy markets, and third party-sponsored initiatives [62]. This classification helps to understand the funding option for each of them. One opportunity, especially in small municipalities and communities, as the islands ones, is the involvement of "indirect" stakeholders—actors who may not benefit personally from the energy output but are invested in the community's social and environmental goals. For instance, local authorities and Civil Society Organisations can serve as key intermediaries, providing technical expertise, policy advocacy, and infrastructure. This is the LIFE ISLET approach. Similarly, municipalities are uniquely positioned to ensure fair energy transitions, provided they possess the necessary political authority to facilitate such shifts [63].

Business plans in different ISLET pilot islands are obviously affected by the local and national framework and different rules for Energy Communities.

For the island of Astypalea in Greece, the financial analysis confirms the project's solid economic viability under a variety of financing scenarios, with all options yielding positive net present values. The most favourable structure combines member contributions with grant funding, maximizing both profitability and accessibility for participants. By means of this model, the community can achieve total energy cost savings between €259,000 and €376,000 over the project horizon (20 years), depending on the retail electricity price and level of self-consumption. These results also highlight that the project can be both environmentally sound and financially sustainable, offering tangible economic relief to its members, including vulnerable households. Nevertheless, members' contribution collection and grant funding strategy is still not defined.

For the island of Cres in Croatia, the economic viability is link with the partnership with the existing Energy Cooperative "Apsyrtides", that would like to become member of the REC in the near future, once the Croatian law will be finally improved, allowing to actually build RECs and CECs and sharing energy between their members. According to the local business plan, the Energy Cooperative "Apsyrtides" will launch a crowdfunding campaign to mobilize community members to raise capital through cooperative shares and/or donations. Most of the raised funds shall be deployed to complete the construction and commissioning of the 465 kWp PV plant in Filozići, a village located on the northern part of Cres Island.
In Procida (Italy), the financial analysis indicates that the REC can be implemented with a balanced combination of member contributions, national incentives, and public support schemes. Capital expenditure will be largely covered through the National Recovery and Resilience Plan (PNRR) funds and upfront contributions from households, businesses, and the municipality, while the residual financing needs can be managed by means of bank loans. Under certain assumption member contributions are estimated at around € 92,000, the PNRR grant at € 67,200, and the remaining funding gap is approximately €56,120. This amount is planned to be financed by means of a 20-year bank loan at an assumed fixed interest rate of 5%. Operating costs are expected to remain stable over the lifetime of the project, with incentives and avoided electricity costs ensuring long-term sustainability. While the precise financial figures will depend on the final system size and rooftop allocation, the community management will be ensured with volunteer work of some members, avoiding further operating costs.
Studies and outputs in different islands are also affected by the different legal frameworks of the Countries involved and by the different composition of ECs membership. Table 43 summarises the main framework for the three test beds.

Table 43 – summary of ECs framework for the three test islands

	Greece	Croatia	Italy
Relevant National/ regional laws for ECs and energy on Islands	Law 5037/2023 Subsidiary legislation 545.34 (Electricity Regulations) Subsidiary Legislation 545.35	Electricity Market Act (NN 111/21) for CECs Law on Renewable Energy Sources and High-Efficiency Cogeneration (NN 78/2025) for RECs	Legislative Decree No. 199/2021; Resolution 318/2020/R/eel; Ministerial Decree of 7 December 2023 ("decreto CER"); Ministerial Decree of 14 febbraio 2017 for non-interconnected islands (Decreto "Isole minori")
Date of Transposition of REDII	2018 pilot, 2023 transposition	14/10/2021 (Electricity Market) and 8/12/2021 (Law on RES)	2018 pilot, in 2021 transposition
share of energy from RES in electricity	51.24 % (EEA)	58.40 (EEA)	40.65% % (EEA), 10% covered by PV (Terna, 2023)
RES production share in small islands (average)	From 3.4% to 20% (Crete)	Not relevant, small islands are interconnected	Around 7,11% covered by PV in non-interconnected islands
Legal form(s) of ECs	A specific legal form called "Energy Community"	No specific legal form imposed, ECs must have non-profit character; (in Croatia Cooperatives are considered for profit entities.	No specific legal form imposed, ECs must have non-profit character or activity as main
Minimum number of members required	At least 30 members (20 in Islands with less than 3100 inh.) 15 if the members are SMEs, 3 mb if they are local authorities.	At least 2 users with a common metering point.	At least 2 members

	Greece	Croatia	Italy
Membership	Everybody could be a member. Big companies only in CECs.	All but big and medium companies. CECs allow only non-profit entities and cooperative are considered for profit. Another member cannot own members 100%. In RECs medium enterprises are allowed	All kind of organisation but energy companies, or large companies
Duration	20 years max but according to the statutes	undefined	20 years incentives
Geographic rules (constraints)	In the same "electricity system".		ECs have no geographical limits and could include more configuration. Each configuration must be in the same High-to-medium voltage substation.
Power limitation	Limits according to the energy system "dimension" (small, medium or bug). E.g. in Astypalea, limit of 100kW per energy project.		Max 1MW
Specific ECs incentives	no	no	yes
Possibility to sell energy to third parties	To the grid	yes	With some limits

	Greece	Croatia	Italy
EC working system	ECs members should have the same distributor, the EC negotiates the price	Virtual system	Virtual system, each member can keep the previous distributor

The three Energy Communities present different features, because of legal framework and local condition:

Table 44 –Legal form and membership of the three pilot ECs

	Maltezana's Energy CEC	Cres EC	Prochyta REC ETS
Legal form	CEC	REC	REC
Members	21	3	12
Prosumers	0	1	3

The municipality is involved in all the three configurations, but only in Cres a POD linked to a school is already involved. Touristic organisation or companies are present in Cres and in Astypalea, what is relevant because their energy demand increase in the summer. Also, the local administrators can enhance the trust in EC process, engaging people and promote the social impact of Energy Community.

Thanks to different simulations about energy sharing in Energy Communities is clear that the choice of the prosumers and the power of each for self-consumption can affect the EC performance.

Moreover, legislative constraint can prevent the EC success in term of maximisation of energy sharing toward the self-sufficiency at the community level, as in the case of Greek small islands.

So far, the key insights gained are related to EC projects on small Mediterranean islands. However, there is not a one-size-fits-all solution because of the varying legal frameworks, and the variety of islands, each facing its own unique challenges. In ISLET project lessons learnt include:

- Islanders tend to look at the experiences of other small islands rather than those on the mainland.
- Small islands could serve as ideal testing grounds for RECs, especially when it comes to social innovation.
- On small islands, addressing the water-energy connection in the design of energy communities could boost the efficiency and impact of RECs. For Mediterranean island RECs, involving local municipalities could be beneficial, as they may offer school rooftops during the summer, when energy demand typically peaks [64]. However, as demonstrated both in Cres and in Procida, having a school included in the configuration is a better option only if REC includes members that, for their demand profile can take profit of energy surplus in summer (e.g. touristic SMEs or summer houses).

9 – Conclusions

The decarbonisation of European small islands is a topic of increasing interest in academia and at policy level. Many studies work on specific small islands looking at technical issues to improve the energy self-sufficiency and the renewable share. [65]

Nevertheless, very few data are available both at islands level and at general one, nationally or EU-wide. Decarbonisation path is too often a solution provided by external entities, without any link, or living experience, in the small island targeted. Instead, the most sensible and fair approach is their exploitation from the local communities themselves. This is what islands have started to claim in different Countries. In this way, the conservation of the natural environment and the traditional island attitude can be ensured in the path toward decarbonisation. States should support these efforts of the insular communities with specific revisions – and harmonisation – of the national legislation [13].

The local dimension of renewable energies communities is a key feature for the EU legislator, that fix as explicit objective of a REC the environmental and social benefit supply in a specific area. Nevertheless, the insularity is a dimension strictly related to the geographical territory. Thus, the "local dimension" of ECs could find in the insularity its perfect dimension [37].

In interconnected islands, in principle, there are no major differences compared to the mainland, both on the technical and legislative sides. However, in all Mediterranean islands, an Energy Community could be a partial solution to the demand peaks that occur due to the increase in population during the summer months. What can be a problem for non-programmable energy sources, with an EC can be mitigated, especially by involving local authorities as prosumers, which manage school buildings that are closed in summer. Moreover, even interconnected islands suffer from other "ills" typical of small islands: depopulation, lack of skills, and economies based on tourism. The "determinants of citizens' involvement in ECs" [66] do not play in their favour.

In non-interconnected islands, Energy Communities could have a significant impact, both socially and environmentally (and economically for the State), considering how energy is currently produced [13]. However, the legislation on RECs places specific constraints on those in small islands (Greece) or is in competition and contradiction with the legislation promoting decarbonization of smaller islands (Italy).

Since renewable energy communities do not, at least for the time being, appear to pose a threat in themselves to local grids – given their minimal contribution to the transition to renewables – certain legislative restrictions or a failure to take account of the specific characteristics of islands are not justified.

Harmonisation of legislative frameworks among EU Member States seems essential for ensuring equal opportunities among citizens of different Countries, and considering the islands specificity is necessary to ensure the same possibilities to the islanders than the mainland inhabitants, ensuring fairness rather than mere equality of opportunities.

New research opportunities around energy communities in small islands comes from the social and environmental impact in interconnected and non-interconnected islands, as the starting hypothesis is that in this kind of areas the impact on social dimension and in environmental aspects is higher than in mainland. Another question to answer is if the EC business plans in small islands substantially differs from the funding opportuning in mainland's EC.

The scientific literature currently is expanding the knowledge about these topics and LIFE ISLET project, which will end in September 2026, will continue to investigate these aspects as well.

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