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Review

Greek Islands' Energy Transition: From Lighthouse Projects to the Emergence of Energy Communities

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Abstract: Energy transition in islands constitutes a major challenge. Apart from a necessity, it can also be a great opportunity for sustainable social and economic development. Toward this direction, a new, promising movement has emerged recently in Greek islands. Straight from the roots of the insular population, development of energy communities comes as the result of increased awareness of local people, raised also by the legacy of lighthouse projects and initiatives. Kythnos, Ikaria, Sifnos, Tilos, Agios Efstratios, Crete, and Chalki, are all islands that have embraced the implementation of successful, local-scale innovation projects and/or initiatives, generating meaningful results across different energy aspects and contributing to positive social change. Our study provides an overview of the broader energy transition aspects in Greek islands, discusses the impact of the aforementioned exemplary cases, and further elaborates on the model of energy communities. According to our analysis, leveraging on the experience of lighthouse projects and initiatives, and on the dynamics of the emerging energy community movement, could lead to increased social and economic benefits for the insular populations, to broad public acceptance, and to minimum environmental impacts for the islands' natural ecosystems.

Keywords: energy transition islands; renewable energy sources; energy communities; hybrid power plants; public acceptance; energy democracy independency

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1. Introduction

1.1. The Concept of "Energy Transition" in Europe

Energy transition is a term often used to describe the replacement of conventional, non-renewable fossil fuels for electricity, heat, and mechanical power production with the exploitation of the Renewable Energy Sources (RES) for the same reason, supported and strengthened with the so-called "Rational Use of Energy" (RUE) [1,2]. Yet, replacing fossil-fuel-based infrastructure with RES is consdierably more than a technological substitution. The social implications associated with this transition could be transforming the way we live [3–5]. In combination with energy savings through enhanced energy efficiency and conscious energy consumption, this transition could result in decentralized, locally based energy systems with a mix of locally available RES enough to satisfy 100% of society's energy needs. Nevertheless, factors, such as vested interests around assets of high investment costs and long lifespan, complex and unstable regulatory frameworks or people's low interest in energy, complicate this transition [6].

The energy transition has been officially recognized as an inevitable necessity from the European Union (EU) and its Member States, imposed by social, energy supply security and independency, environmental and economic reasons, through the two essential Directives on the promotion of the use of RES for energy production [7] and the RUE in buildings [8]. With its "Fit for 55 package", the EU proposed to revise and update EU legislation and to introduce new initiatives to ensure that EU policies are in line with the climate goals agreed by the Council and the European Parliament. The package aims at providing a coherent and balanced framework for reaching the EU climate objectives, which ensures a just and socially fair transition [9]. After the invasion of Putin's forces in Ukraine, the RepowerEU plan of the European Commission focuses on measures, such as energy savings, diversification of energy supplies, and the accelerated roll-out of RES to replace fossil fuels in homes, industry, and power generation, thereby ending the EU dependence on Russian fossil fuels and tackling the climate crisis [10]. The "green transformation" is expected to strengthen economic growth, security, and climate action for Europe and its partners.

Particularly for European islands, with the establishment of the "Clean Energy for EU Islands" Initiative in 2017 [11], the EU offers robust and multilevel support to insular communities to set-up and approach an effective, properly designed and, eventually, successful energy transition. Through its Secretariat, since 2018, the Initiative provides a variety of supportive actions for the insular communities, starting with the development of the Clean Energy Transition Agenda (CETA), a strategic roadmap for the transition toward clean energy and energy efficiency, covering the essential issue of capacity building and awareness raising, offering extensive opportunities for networking, and support through open calls for technical assistance for specific projects. It is worth mentioning that the process of developing a CETA helps the islands grow legitimacy and gain access to resources, as by articulating their vision, they can acquire the support of networks of (powerful) allies [12]. Therefore, it is an important first step in the islands transition process.

Islands in the world constitute vulnerable geographical and social entities, with regard to accessibility, health—social care, economy, environmental issues and biodiversity, and energy supply [13,14]. Particularly regarding energy supply, most islands in the world cover their energy needs with imported liquid fossil fuels (heavy fuel or diesel oil) burnt in small size; Autonomous Power Plants (APP) for electricity production. The high procurement prices of imported fossil fuels, burdened with the transportation cost from the mainland to the islands, lead often to the configuration of electricity levelized cost above EUR 300 MWh [15,16], as well remarkably high prices for the fuels used in the transportation sector and for indoor space heating. These costs have been further increased since the last months of 2021, as a consequence of the global economy's recovery from the COVID-19 effects and, mostly, of the war in Ukraine. It is indicatively mentioned that the maximum gasoline price in Greek islands on June 2022 approaches EUR 3 L, recording 65% increase since March 2022. The almost exclusive dependency of islands on imported fossil fuels imposes high vulnerability with regard to their energy supply security, as well as to the local economy [17,18]. On the other hand, islands typically possess excellent RES potential, most usually wind [19,20] and solar potential [21] or, in cases of bigger islands, biomass potential, as well [22–24]. The available RES potential in islands has been proved in technical feasibility studies and scientific articles to be several times adequate to fully cover all their energy needs (electricity, heat, transportations on the island), as it will be analyzed in the characteristic cases presented below.

1.2. Energy Transition Success Stories from the European Islands

Samsø, Denmark, constitutes certainly a success story regarding energy transition that started from and is undertaken by the local community [25]. The goal for 100% RES penetration in the island was set in 1997. The first project was an 11 MW onshore wind park, with 11 wind turbines installed in 1999–2000. Ten more offshore wind turbines of 2.3 MW nominal power each were installed in 2002. Additionally, a group of projects have been implemented focusing on the exploitation of the local biomass resources and the installation of solar collectors for the production of heat for indoor space heating and hot water production. All these efforts and projects were totally funded and implemented by the local islanders. The local community in Samsø has achieved 100% coverage of the electricity annual needs from the wind parks and 75% coverage of the heating annual needs in the island from biomass stations and solar collectors. However, it should be noted that Samsø is interconnected with the mainland Danish grid, a fact that eliminates the need for electricity storage plants installation together with the wind parks and makes the transition easier, faster, and cost-effective. Moreover, it is clear that, given the absence of storage facilities, the electricity demand is compensated aggregately on an annual basis and not on real-time.

Another success story comes from the northwestern Europe, the Orkney Islands, United Kingdom, located at the north cape of Scotland with a population of 22,000 inhabitants [26]. The initiative also started from the local community in 2000 with the formation of the Orkney Renewable Energy Forum (OREF). Only 13 years later, in 2013, the Orkney Islands produce more than 120% of their annual electricity needs from renewables, mainly from wind turbines with a total installed power of 70 MW. Apart from the large wind turbines, installed in most of the large islands of the Archipelago, more than 1000 small wind turbines and photovoltaic decentralized plants have been installed in islets and domestic facilities. This implies that one in ten of the islands' population produces his own power. Additionally, more than 200 Electric Vehicles (EVs) have been introduced and used on the islands, placing them in the first position with regard to the EVs density per inhabitant in the UK. Finally, a small number of decentralized storage devices (domestic electrochemical batteries) have been also introduced. All the introduced technologies are controlled by a smart grid, to ensure the matching between the RES production and the demand and the insular grid stability and dynamic security.

Another successful island, which nevertheless has not yet managed to sustainably cover its energy needs, is the island of La Palma in Spain. EU islands have traditionally been considered ideal for the development and adoption of renewable energy sources, also due to their strong and cohesive communities, which are somehow naturally generated due to their particular geographical context. La Palma is a volcanic island in the Atlantic Ocean, declared a biosphere reserve by UNESCO in 2002. The island has a permanent population of about 82,000 inhabitants and receives about 20,000–30,000 tourists each month [27,28]. La Palma Renovable is a project born from the citizens' movement Plataforma por un Nuevo Modelo Energético and financed by the Cabildo de La Palma, i.e., the local island government. The goal of the citizens' group is to reach a 100% renewable energy island, following a democratic, decentralized, and citizen-based model. In 2019, La Palma was selected as one of the six European pilot islands of the Clean Energy for EU Islands Secretariat. La Palma has emerged as one of the most successful initiatives in terms of the participation of the local stakeholders in the islands' sustainable energy planning. The emerged "Local Energy Community Energía Bonita y Renovable" focuses on solar power for shared self-consumption and aims to demonstrate the potential of energy communities to foster the energy transition. The local Energy Community has been awarded a grant of EUR 118,660 by the Spanish Institute for Energy Diversification and Saving (IDAE), ranking 5th among a total of 45 projects across the country, in the first call within the framework of the Recovery, Transformation, and Resilience Plan funded by the European Union—NextGenerationEU [29]. The first pioneering project of the Energy Community involves a shared self-consumption PV plant installed on one of the ponds of the local Irrigation Community; located above a pond, the installation prevents water evaporation and the appearance of algae, improving the quality of the water for the local community [30]. In addition, in December 2020, the New Energy Solutions Optimized for Islands (NESOI) project, granted La Palma's Energy Community EUR 60,000 worth of funding and technical advice for the Energy Community project presented jointly by the Cabildo de La Palma and La Palma Renovable [31]. It becomes clear that active citizen participation and good coordination between all involved stakeholders can yield successful results quickly, while ensuring that the energy transition generates socioeconomic and environmental benefits for the island communities.

Finally, regarding implementing outstanding energy transition projects in Europe, the hybrid power plant in El Hierro, Canary Islands, Spain, cannot be omitted. The construction of the plant was completed in 2016 and, at that time, it was the first and the unique hybrid power plant installed on an insular autonomous system worldwide, aiming at high RES electricity penetration. It consists of a 11.5 MW wind park and a hydro pumped storage system, operating with potable, desalinated water, with 11 MW nominal hydro turbines power and 6 MW nominal pumps power [32]. In February 2018, the hybrid power plant achieved the supply of 100% electricity demand in the island continuously for 18 days [32]. In 2020, 58% of the annual electricity demand on the island was covered by the hybrid power plant [33]. The plant's annual contribution on the electricity demand coverage is anticipated to gradually exceed 65% [32].

1.3. Scope of the Article

The present article focuses on the distance covered to date toward energy transition in Greek islands. Greece has more than 220 inhabited islands, with populations from some tens of inhabitants to more than 600,000 in Crete. All of them are endowed with remarkable wind and solar potential, some of them also with high enthalpy geothermal field, and the biggest ones, due to extensive agricultural and livestock activities, with considerable biomass resources. Currently, all of them are powered by imported fossil fuels and exhibit all these sensitivities and vulnerabilities mentioned previously. These facts, combined with the energy crisis since the end of 2021, make energy transition in Greek islands more urgent than ever. The article aims to present the overall situation of energy transition in Greek islands and provide some indicative and characteristic features. Additionally, it presents more analytically the progress achieved in some pioneering, highlighting all of the good lessons to learn, as well as examples to avoid.

2. Methodology

To provide a comprehensive analysis on the achieved steps of energy transition and, particularly, to explore the role of "Energy Communities" in the Greek islands, we adopted a Case Study Research methodology [34,35], whereby the unit of our analysis is the islands. The choice of islands as a unit of analysis was made for two main reasons. First, the islands comprise isolated territories demonstrating particular challenges, but also offering unique opportunities for study, as they comprise a well-defined boundary (eco)system. Second, our work has been carried out in relation to the Clean Energy for EU Islands Initiative, which targets the energy transition of islands in the European Union.

In our study, we focus on Greek islands. However, our results and recommendations can be applicable for islands in the Mediterranean basin. In Greece, there are 277 inhabited islands organized into three administrative regions: North Aegean, South Aegean, and Ionian Islands. The selected case studies (seven in total) comprise success stories and/or pioneering cases in the Greek islands of Sifnos, Crete, Chalki, Ikaria, Tilos, Agios Efstratios, and Kythnos. Out of the seven case studies, three have already formed an Energy Community, namely Sifnos, Crete, and Chalki. Following similar articles based on empirical findings from case studies [36,37], we used the criteria listed below for the selection of our case studies:

- Located on islands in Greece.
- Aim to achieve 100% energy self-sufficiency.
- Cases considered as pioneers/success stories.
- Islands of all typical and characteristic sizes.
- Islands with different technologies and energy transition plans.

- Balance between cases with the existence (or not) of Energy Communities.
- Islands with different origination of the energy transition efforts and alternative involved stakeholders.

Our case study research approach is based on data available from literature review, as well as interviews with experts and key stakeholders. With reference to the interviews, these were carried out in 2018 (Sifnos), 2020 (Chalki), and 2021 (Crete), including representatives from the established energy communities in Sifnos, Crete, and Chalki, these are the Sifnos Energy Community (SEC), the Minoan Energy Community (MEC), and the Energy Community of Chalki (ChalkiOn). For the rest of the cases (Ikaria, Tilos, Agios Efstratios, and Kythnos), where there is no energy community the researchers carried out a literature review.

Apart from collecting and analyzing data available in the public domain for these case studies, the authors have adopted an action research approach, participating in activities intended for bringing about a change at a group, organizational, and societal level [38], rather than being only an observer/detached outsider of the social system studied [39]. Action research, more than a method, is a philosophy of conducting research, that brings together action (i.e., real-world change), research (i.e., the generation of new scientific knowledge), and participation (i.e., the collaboration of scientists with practitioners) [40]. While all the authors of this paper wish to contribute to the acceleration of a sustainable and fair energy transition of the islands, this connection of action, research, and participation is particularly true in the case for Sifnos, Crete, and Chalki, where some of the authors had an active participation for the organization and formation of the Energy Communities and the design of the energy transition process and the first projects. Action research is particularly useful to accelerate research and joint action in pressing areas, such as sustainability challenges [41], thus being very relevant for the pressing issue of the energy transition, especially in island communities.

A case study includes:

- Background introduction including general information about the island, as well as information about the power production—both conventional and RES.
- Information about the energy cooperatives established (if applicable).
- Information about the Clean Energy Transition Agenda adopted (if applicable).
- Information about the energy transition activities implemented and the possible contribution of the energy cooperative in these activities.

3. The Existing Conditions in Greece

Greece has been blessed with remarkable RES potential. The yearly sum of global irradiation on the horizontal plane varies from 1500 kWh/m^2 in the northern Greece (Macedonia and Thrace) to more than 2000 kWh/m^2 in the central and southern Greece and the Aegean Sea islands [42,43]. In Figures 1 and 2, the yearly sum of global irradiation on the horizontal plane is shown for the islands of Crete (southern Greece, geographical latitude at 35° N) and the North Aegean Sea islands (northern Greece, geographical latitude at 40° N) [42].

Additionally, the availability of remarkably high wind potential has been documented by certified wind potential measurements executed in the whole country. In the mainland Greece, plenty of sites have been recorded with annual average wind velocity at the range of 7 m/s [44–46]. The available wind resources in the insular Greece are considerably more impressive. There are sites almost in all Aegean Sea islands with annual average wind velocity above 8.5 m/s, while, in the most favorable cases, annual average wind velocity above 11 m/s have been measured, leading to annual final capacity factors of a potentially installed wind park above 50% [47–49]. Indicatively, in Figures 3 and 4, wind potential maps are provided with the annual average wind velocity for the islands of Sifnos (western Aegean Sea, Cyclades complex) and Kassos (southeastern Aegean Sea, Dodecanese complex).

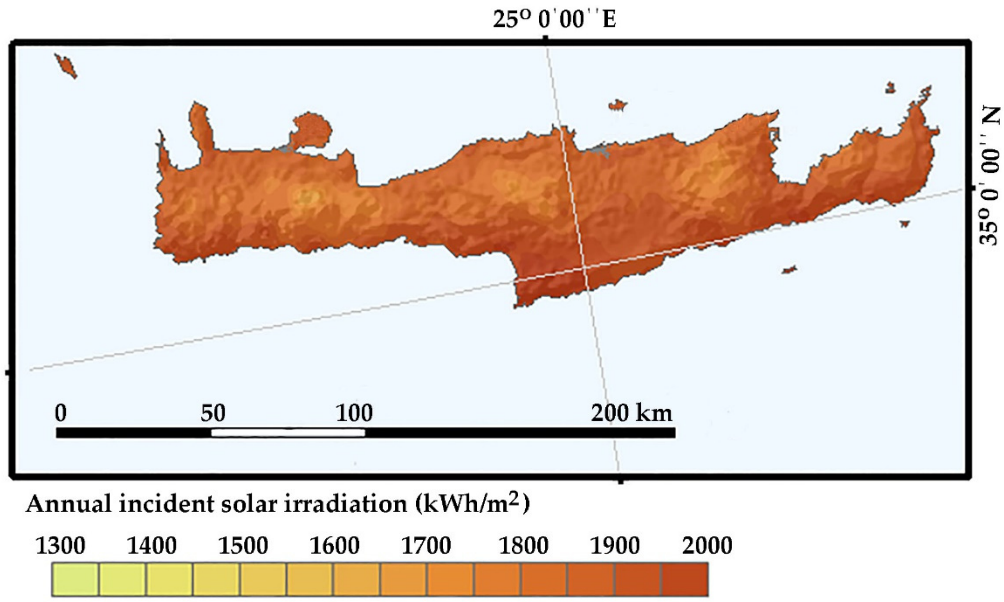

Figure 1. Yearly sum of global irradiation on the horizontal plane in Crete [42].

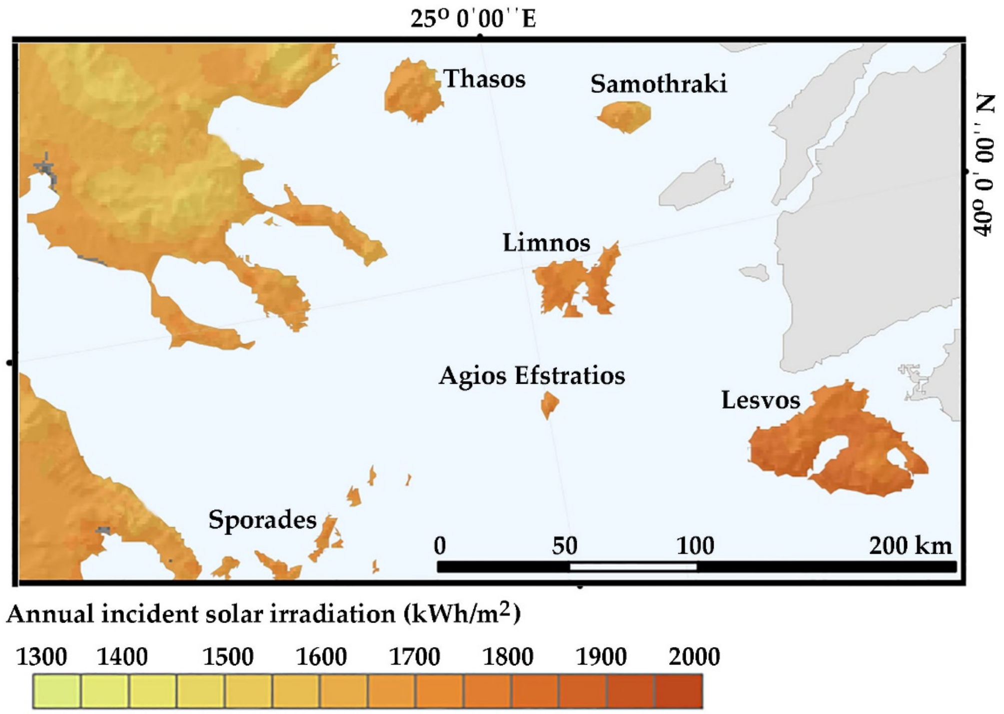

Figure 2. Yearly sum of global irradiation on the horizontal plane in the North Aegean Sea Greek islands [42].

Apart from wind and solar potential, in the biggest Greek islands (Crete, Rhodes, Lesvos, Chios, Kefallonia, Corfu, Samos, etc.) extensive biomass resources can be found, mainly from agricultural and livestock activities and secondary from organic urban waste. It has been proved, for example, that Crete can cover 2.4 times the annual heat currently produced by diesel oil for indoor space heating from the aforementioned resources [50]. Finally, some Greek islands possess also significant high enthalpy geothermal fields. Milos (Eastern Aegean Sea, Cyclades complex) has a certified, economically feasible geothermal potential that can provide 150 MW of electrical power output [51]. Similarly, the verified geothermal potential in Nisyros, a small volcanic island in the Eastern Aegean Sea, can provide 50 MW of electrical power output [52]. Finally, in Lesvos, the potential electrical power output from the available high enthalpy geothermal field is estimated at 10 MW [53].

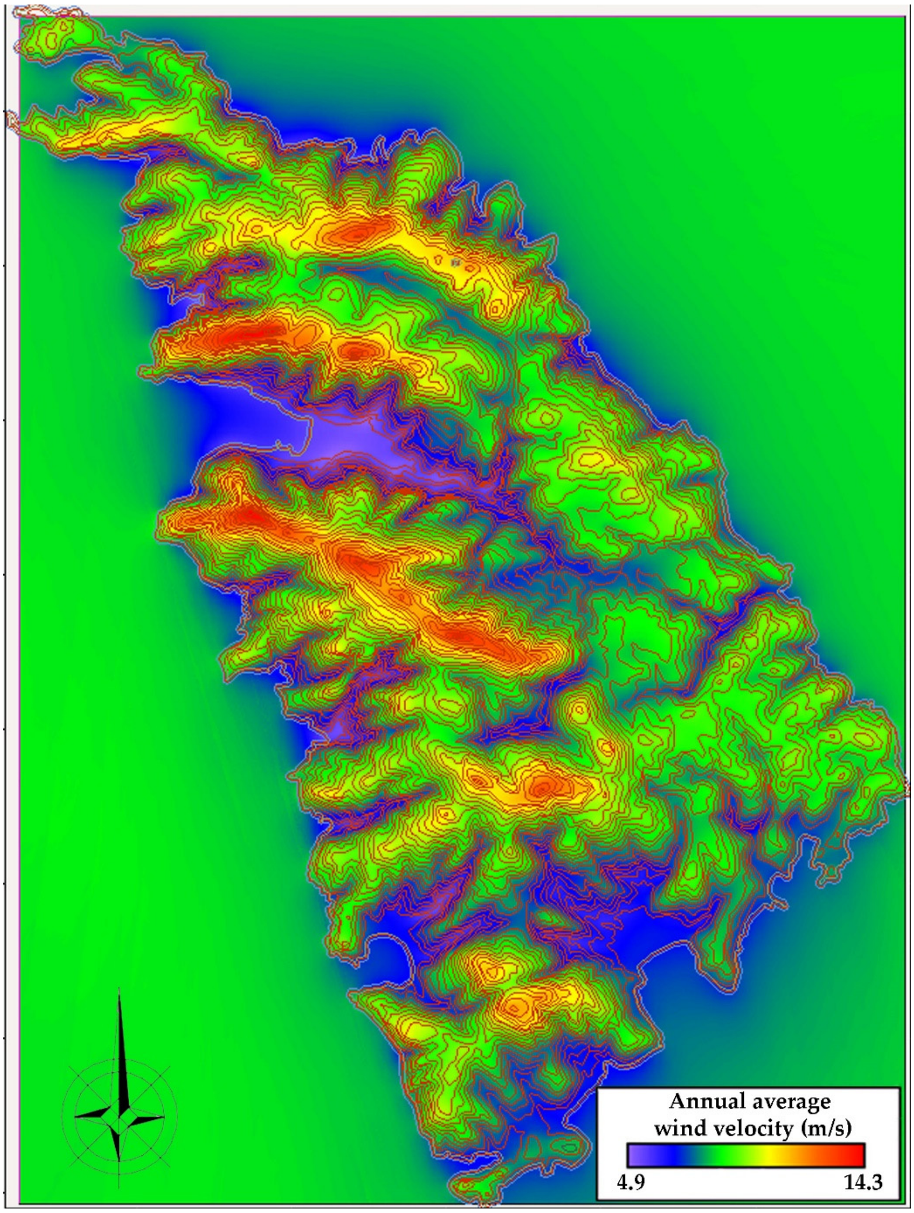

Figure 3. Annual average wind velocity map for the island of Sifnos.

The aforementioned potential of different types of RES can ensure a robust, secure, and cost-effective energy transition in the Greek islands, as it will be shown in the detailed analysis provided in the next section for some of them. On the other hand, as a sensible consequence, the availability of this plethora of energy resources in the insular Greece has triggered the interest of big investors for large size investments in the islands' territory, mainly wind parks and photovoltaics. According to the official registry of the Greek Regulatory Authority of Energy (RAE), the licensed projects to date for electricity production from RES and for energy storage are summarized in Table 1 [54].

As seen in Table 1, 89.5 GW of nominal power had been licensed in March 2022 for electricity production projects from RES and for energy storage projects, while at the same time, the annual peak demand in the whole mainland and insular system in Greece is estimated between 11 and 12 GW [55]. Specifically, the above facts reveal that, to date, licensed power is 7 to 8 times higher than the peak annual demand in Greece, revealing the extremely high interest from the potential investors in the development of electricity production from RES and energy storage projects. However, at the same time, given that all these projects cannot be implemented due to the considerably lower electricity demand, not taking into account their impacts and the violation of several licensing restrictions, this considerably high licensed power also reveals the lack of any centralized or local strategic plans for the construction of these projects and the smooth implementation of energy transition.

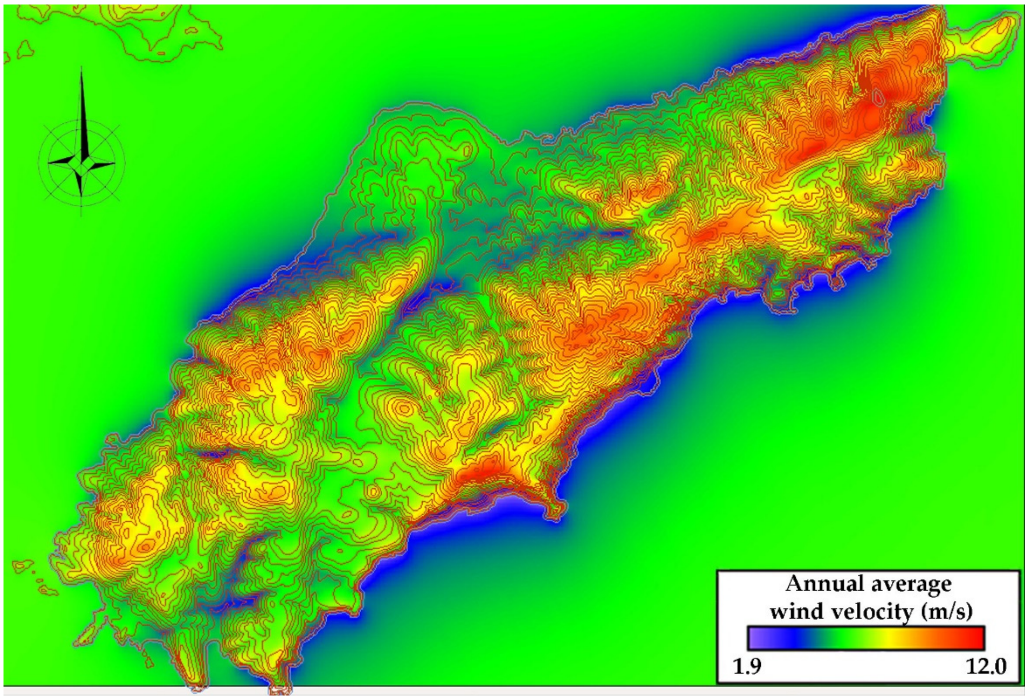

Figure 4. Annual average wind velocity map for the island of Kassos.

Table 1. Licensed projects for electricity production from RES and for energy storage on March 2022, according to the Greek Regulatory Authority of Energy (RAE) registry.

Technology	Licensed Nominal Power (MW)
Wind parks	24,777.8
Biogas plants	14.8
Solid biomass plants	371.2
Solar thermal power plants	101.3
Small hydroelectric power plants	1092.0
Photovoltaic plants	59,008.5
Combined heat and power plants	546.0
Storage plants	599.0
Total	89,510.5

As may be expected, most licensed projects are sited in the Greek islands since both the available wind and solar potential are maximum in their territories. Since 2009, big investors from Greece and abroad have been submitting a series of applications for the licensing of large size projects, mainly wind parks. In many cases, the geographical depiction of the captured sites provides a picture of islands almost fully covered with potential projects. In the case that these projects are implemented, they will certainly turn the existing traditional island attitude into an industrial landscape for the production of electricity by wind parks and photovoltaics. The maps presented in Figure 5, directly derived from the official Geographic Information System (GIS) of RAE, provide a typical picture of the currently configured situation [56].

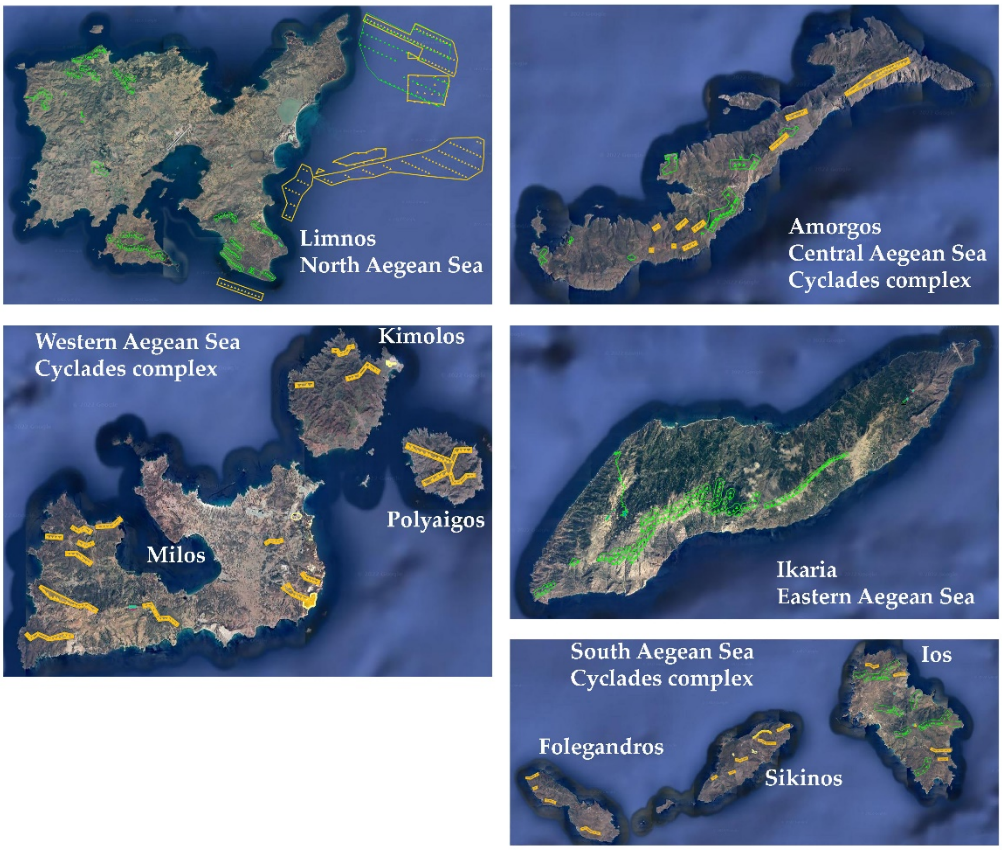

Figure 5. Typical maps from the GIS of RAE with the polygons of the captured land for the installation of wind parks [56].

Almost often, these applications and licenses were submitted and issued without any previous notification of or consultation with the local communities, thus, without their approval. The islanders were eventually informed of all these projects by the media or, in rare cases of individuals more capable of following the processes, by the RAE website. Additionally, several restrictions set in the national legislation, regarding environmental protection and existing human activities, are violated by most of these projects. As an absolutely logical consequence, a very definite and strong negative public opinion against the installation of any kind of RES projects has emerged since 2010 in the insular Greece, expressed via official documentation, participations in open-public events, and info-days and massive demonstrations. In many cases, these reactions oppose against the development of legitimate and rational small size RES projects, originating even by local stakeholders or initiatives. Conclusively, the implementation of energy transition in insular Greece seems to be a very difficult maze, accounting for the necessity to handle and, eventually reverse, this strong negative public opinion [57].

Given the above presented configured status, the only official planning regarding the energy future of the Greek islands is the scheduled interconnection with the mainland grid with underwater cables. The overall venture consists of four individual stages and is planned to be integrated by 2030 [58]. To date, the first interconnection of Crete has been completed, the second one has started, as well as the interconnection of the central islands of the Cyclades complex. A general map of what has been completed or started to date is depicted in Figure 6 [59].

The Greek State promotes these ambitious interconnection projects as the means which will enable the decarbonization of the Greek islands. Indeed, with the islands' interconnection, the small APPs can be shut down. In this way, no diesel oil or heavy fuel will be consumed in the insular territories for electricity production. However, the interconnection itself is not enough for the islands' decarbonization. This is revealed in Figure 7, which presents the total energy supply mixture in Greece from 1990 to 2020 [60].

Figure 6. Electrical interconnections already completed or started of the Greek islands with the mainland grid [59].

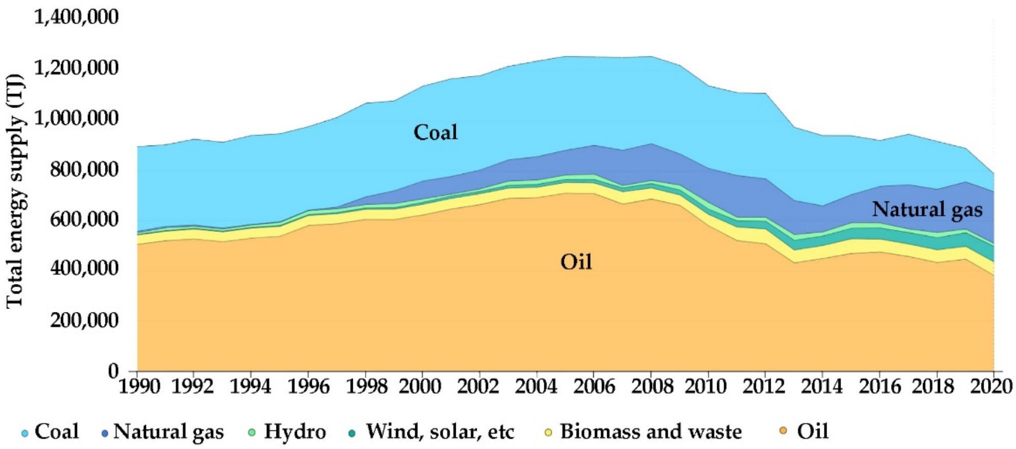

Figure 7. Evolution of total energy supply mixture in Greece from 1990 to 2020 [60].

As seen in this figure, the RES share (hydro, wind, solar, biomass, and waste) on the overall coverage of the energy demand remains rather low (16.2%), despite the fact that the total RES installed power in the mainland grid exceeded 9 GW in April 2022 [61]. The Greek State commitment to reduce the use of coal and oil was, practically, met through its shift from the consumption of the domestic and cheap coal and the imported oil to the import of natural gas. This shift certainly contributed positively toward a cleaner energy production process. However, on the other hand, it increased the country's dependency on imported and, still, non-renewable, energy resources. Indeed, the annual share of the imported oil and natural gas on the total energy resources consumption in Greece in 2020 was 48.5% and 26.2%, respectively, leading to a total 74.8% of national dependency on imported energy resources. From this, it follows that the simple interconnection of the Greek islands with the mainland grid, without any properly developed strategy for an effective, environmentally responsible, just and socially fair energy transition, will only further deteriorate this trend, namely the gradual increase in the national dependency on imported energy resources, exacerbating the living conditions of the island communities (and beyond).

The high dependency of Greece on imported energy resources imposes high vulnerability on the energy supply security and, of course, on the electricity production cost and, eventually, the electricity and heat pricing for the final consumers. These consequences had dramatically emerged as direct impacts of the war in Ukraine. Indicatively, while the average electricity price for households was at the range of EUR 0.17 per kWh until summer 2021, in June 2022 this figure was configured at EUR 0.24 per kWh, namely 41% higher [62]. The impacts on the electricity production cost and pricing in the Greek islands are considerably more intensive due to the additional transportation cost and the exclusive consumption of the expensive liquid fossil fuels for electricity production (heavy fuel only for the biggest islands of Crete, Rhodes, Chios, Lesvos, Karpathos, and Samos, and diesel oil for all the rest). In order to provide some typical figures, Table 2 presents the electricity production cost in the Greek islands in 2019 and 2020 [63]. As seen in this Table, in 2019 the average electricity production cost in the Greek islands was at a range of EUR 0.25–0.30 per kWh. For very small islands, this feature was above EUR 0.4 per kWh. Given the currently configured conditions, the average electricity production cost in the Greek islands should have become higher than EUR 0.50 per kWh.

Table 2. Electricity production levelized cost in Greek insular autonomous electrical systems in 2012 and 2013 [63].

	Electricity Production Levelized Cost (EUR/MWh)		
Group	**Island**	**2019**	**2020**
Very Small	Agathonisi	934.2	888.3
Very Small	Antikythera	1421.2	1412.3
Very Small	Donoussa	745.5	912.6
Ungroupped	Arki	1091.2	1160.4
Ungroupped	Gavdos	823.4	828.4
Very Small	Othoni	1165.3	1216.9
Very Small	Erikoussa	825.1	853.9
Very Small	Agios Efstratios	618.9	579.7
Very Small	Anafi	561.7	562.1
Very Small	Megisti	535.4	488.7
North Aegean	Ikaria	420.7	411.9
Small Scale—South Aegean	Astypalea	452.0	468.7
Small Scale—South Aegean	Symi	375.3	372.4
Small Scale—South Aegean	Amorgos	363.5	390.5
North Aegean	Skyros	442.3	378.2
Small Scale—South Aegean	Patmos	379.3	372.1
Small Scale—South Aegean	Kythnos	384.6	364.0
Small Scale—South Aegean	Sifnos	396.6	421.0
Small Scale—South Aegean	Serifos	384.9	417.9
Big Medium Scale—South Aegean	Karpathos	219.6	242.9
North Aegean	Limnos	218.6	210.4
Big Medium Scale—South Aegean	Thira	224.9	185.7
North Aegean	Samos	195.5	199.3
Big Medium Scale—South Aegean	Milos	169.1	164.4
North Aegean	Lesvos	175.0	158.7
North Aegean	Chios	153.1	148.7

Given the aforementioned configured conditions, namely:

- The high dependency of the electricity and heat production in Greece, and particularly in Greek islands, on imported fossil fuels.
- The remarkably high electricity production cost.
- The strong negative attitude against the installation of RES projects in the insular territories, especially from stakeholders with no bonds or origination with the insular communities.
- The high availability of RES potential.

The necessity for an efficient, socially fair, and effective energy transition in the Greek islands emerges as more urgent and imperative than ever. Some Greek islands seem to have realized this. The contribution of the "Clean Energy for EU Islands" Secretariat toward this objective was and remains very important [64]. Since September 2020, four workshops and info-days on the necessity, the objectives, the potential routes, and the anticipated benefits of energy transition have been implemented in Kassos, Symi, Chalki, and Crete. Additionally, following the repetitive calls for technical assistance announced by the Secretariat, technical studies and Clean Energy Transition Agendas (CETAs) have been implemented and delivered free of charge for the islands of Kassos, Crete, Symi, Chalki, Chios, Spetses, Kythira, Samos, Tilos, and Syros. The island of Sifnos was announced in 2018 as one of the six pilot islands of the initiative, while Crete and Samos were announced as pioneering islands. Finally, Kassos, Chalki, Samos, Sifnos, Symi, and Chios have developed and submitted their CETAs in the Secretariat, while Chios is currently continuing with a follow-up CE4EUIslands project focusing on shaping the energy transition strategy, taking also into account important topics on water security through desalination, as well as circular economy through the recovery of secondary raw materials through brine treatment [65–71].

However, the most important and hopeful token that the islanders in some Greek islands have realized is how crucial the energy transition is for the future of their regions. Therefore, they have decided to take the situation in their hands by founding energy communities of broad base, i.e., with the participation of a large number of individuals and the local authorities (municipalities or regional authorities). In this way, the insular communities not only oppose the transformation of their regions into industrial fields for the electricity production from RES by few large size investors, but they have planned and started to claim rational clusters of energy saving and production projects. These can ensure an environmentally sustainable and social fair energy transition, with public acceptance and minimum potential negative impacts on the natural environment and the existing human activities. In some cases, the first projects have been already integrated. These pioneering cases and success stories are presented in the next section.

4. Success Stories—Pioneering Cases in the Greek Islands

4.1. Sifnos

Sifnos is a small island, located in the Western Aegean Sea, in the Cyclades complex, with a population of 2625 and a total area of 73.9 km^2 [72]. Electricity production on the island is based on a small APP, with eight diesel generators installed with a nominal power of 1.1 MW each, a small wind park of 1.2 MW, installed in 2019, and 335 kW of small decentralized photovoltaic plants. The RES share on the annual electricity production balance is estimated at 8.4% through the computational simulation of the power production process. Transportations on the island and from and to the island are fully based on liquid fossil fuels (gasoline and diesel oil).

In December 2013, the Sifnos Energy Cooperative was founded, which at that time, was the unique energy cooperative in insular Greece [73]. Energy cooperatives refer to initiatives of citizens organized to jointly own and democratically control an enterprise that focuses on renewable energy, energy efficiency, e-mobility, and other energy related services. The legal statute is not always relevant [74]. What differentiates an energy cooperative from other organizational forms is the alignment with the seven cooperative principles as described by the International Cooperative Alliance [75]. In April 2021, it was transformed into the

Sifnos Energy Community (SEC), following the update of the relevant Greek and European legislation (Law 4513/2018 and Clean Energy for all Europeans Package, respectively).

Apart from the tangible contribution to the energy transition via the generation of RES, for instance, cooperatives may have a wider impact on the energy transition. While top-down policies and market forces push for a shift from a system based on large scale fossil to one based on large scale renewables, citizen-driven energy cooperatives envision an alternative for the current energy system with broader implications for society. Beyond their efforts to raise awareness and acceptance of renewable energy technologies, energy cooperatives are considered to represent a vehicle for the democratization of the energy system [76]. In fact, SEC assisted with the installation of two wind turbines of the national Power Production Corporation (PPC) on the island, addressing the concerns of the local community, and is now progressing with its own citizen-driven project that everyone can join, thereby helping advance the islands energy transition, while also directly benefiting from it.

SEC, as one of the six pilot islands of the Clean Energy for EU Islands Initiative, submitted its CETA in October 2019 [77]. An overall visual summary is depicted in Figure 8 [77].

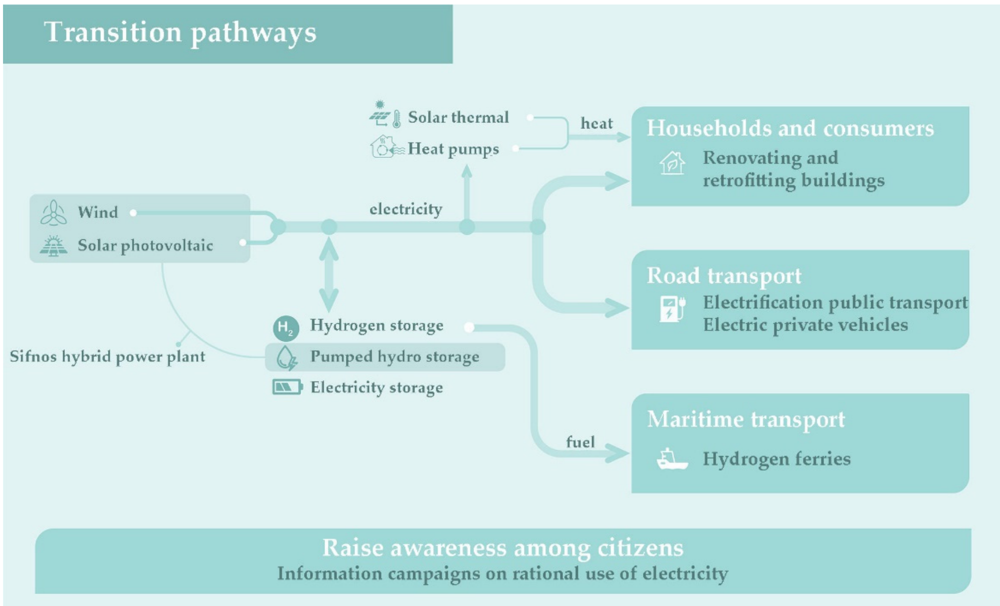

Figure 8. Visual summary of the Clean Energy Transition Agenda of Sifnos [77].

As seen in Figure 8, energy transition in Sifnos includes all final energy uses on the island: Transportations on the island, transportations from and to the island, indoor space heating, hot water production for domestic use, and all uses currently covered with electricity. The energy transition is based on the construction of an 11.5 MW wind park and a seawater Pumped Hydro Storage (PHS) plant with 8 MW guaranteed power, which will be the basis of the transition [78]. The achieved storage capacity of 860 MWh with the designed PHS offers an autonomy operation period of 16 days, accounted on versus the average daily electricity consumption. Due to the proper siting and the favorable land morphology, the PHS set-up levelized cost was calculated at EUR 30 per kWh of storage capacity [79]. With the designed hybrid power plant, 100% clear electricity demand real-time coverage is achieved, according to the executed computational simulations. The aforementioned achievements were possible thanks to the remarkable available wind potential (annual average wind velocity at 9 m/s) and the favorable land morphology at the PHS installation site, leading to the minimization of the corresponding set-up cost.

The project has been designed, sited at the northeast coastline of the islands, and was licensed by the RAE in September 2020. The project size, design, and siting satisfies all licensing restrictions, ensuring fast and unobstructed licensing. Moreover, the project has gained the acceptance of the vast majority of the local population. The sizing of the plant was selected to fully undertake the anticipated annual power demand, with the transition of the onshore transportation needs to the electrical grid. The power demand seasonality, expressed with considerably higher demand peaks during summer, imposed the over-dimensioning of the plant. This fact will, in turn, lead to significant electricity surplus during winter. In fact, this electricity surplus exceeds 15,000 MWh annually [78]. SEC plans to exploit this electricity surplus, increasing at the same time the selling electricity from the hybrid power plant and the corresponding income, for:

- The increase in the potable water production through reverse osmosis desalination plants, which will enable the development of additional professional activities on the island and reduce the high dependency of the local economy on tourism. Specifically, with the consumption of 5000 MWh of electricity, assuming a specific electricity consumption at reverse osmosis desalination plants of 4 kWh/m^3, 1,250,000 m^3 of potable water can be produced annually, an amount more than twice higher than the current potable water consumption in the island (600,000 m^3).
- The production of hydrogen through electrolysis units to power a small passenger vessel, with a capacity of 200 passengers, which will ensure, especially during winter, the regular and secure maritime connection of Sifnos, through a cycling maritime route of 110 nm in distance [78], with the neighboring administrative centers in the Cyclades complex, larger islands of Milos, Paros, and Syros, all equipped with their own airports. Given a specific hydrogen consumption of 3 kg/nm at the vessel, the annual electricity demand for the production of the required hydrogen amount with an electrolysis unit has been calculated at 6857 MWh, through the detailed computational simulation of the hydrogen production and storage plant [78]. An electrolysis unit of 5 MW nominal power and hydrogen storage tanks of total capacity of 500 m^3 at 300 bar will be required [78]. In this way, the major problem of insular isolation due to irregular accessibility, particularly during winter, will be treated.

The proposed project exhibits three essential innovative features:

- It is the first wind park—PHS plant operating with seawater.
- It is the first wind park—PHS plant licensed in an island for 100% electricity demand coverage.
- It is the first plan—initiative originating by an insular energy community, aiming at the 100% energy independency and democracy on the island.

The overall energy transition is integrated with the following small projects:

- Decentralized storage facilities, integrated within a smart grid layout, focusing on the reduction of the peak demand and the facilitation of the PHS operation, especially during summer [78]. For example, if 200 families in the island install a 3 kW photovoltaic plant and 100 families install a 10 kWh/10 kW battery operating through a 24-h cycling charge—discharge process (aiming to peak demand shaving), a 40% drop of the peak demand can be achieved during the winter period or 20% during the summer period. This will strongly facilitate the major task of the hybrid power plant to achieve 100% real-time power production all the time.
- Centralized solar collectors' fields for hot water production for domestic use and distribution to the final users through the district heating network. In this way, the visual deterioration of the traditional insular settlements in Sifnos due to the potential installation of solar collectors on buildings' roofs will be avoided.
- Open-loop geo-exchange plants, combined with district cooling networks, for the indoor space cooling of the coastal settlements, where the major power demand load appears during summer, due to the concentration of the main tourist facilities and the increasing needs for indoor space cooling.

To date, no studies have been accomplished for the solar collector and the geo-exchange plants.

Despite the relatively high set-up cost of the hybrid power plant (EUR 37.2 million), SEC managed to collect letters of interests from potential funders (banks and private capitals), more than 100% of the project's budget. The project's economic viability can be feasible with a selling price for the produced electricity of EUR 250 per MWh [78], which can be even lower than EUR 200 per MWh with the combined implementation of hydrogen and potable water production facilities, which will increase the absorption of the produced electricity.

The major problem to date for the implementation of the presented inspiring and innovative projects is the planning interconnection of the island with the mainland grid (scheduled to be completed by 2025), which, according to the Ministry of Energy, cancels the necessity of the hybrid power plant. Even in this case, the hybrid power plant can be implemented separately as a wind park and a large scale electricity storage plant. Therefore, given these new emerging facts, SEC is about to start the licensing process of the hybrid power plant from the beginning as two separate projects.

4.2. Crete

Crete is the biggest island in Greece and the 5th in size in the Mediterranean basin, with regard both to its population and size. It is located in the southernmost part of the Aegean Sea, with a population of 634,930 inhabitants and a total area of 8336 km^2 [80]. Electricity in Crete is produced by three thermal power plants, with a total installed nominal power of 843.3 MW, wind parks and photovoltaic plants with total nominal power of 200.3 and 107.4 MW, respectively, and a small hydro power plant with 0.6 kW nominal power [50]. The wind parks are owned by few private investors of medium and large size, while the total installed photovoltaic power is formulated by small projects, from 10 kW or even smaller, installed on buildings' roof, up to 80 kW, installed on the countryside. The RES projects in Crete produce 21% of the total electricity annual demand [50]. Additionally, it is estimated that 55–60% of the total heat demand for domestic hot water production comes from thermal solar collectors [50]. Very few EVs have been to date introduced by individuals.

Crete, although it has been selected as a pioneering island by the "Clean Energy for EU Islands" Secretariat, has not, to date, completed the development nor the implementation of its island-wide CETA. This is due to the large size of the island and, mainly, the different stakeholders involved in the overall process: Academics from three different Universities, local authorities (24 Municipalities and the Regional Authority of Crete), commercial and technical chambers, small and medium size local private firms, and the citizens. These stakeholders represent different and, in many cases, conflicting opinions and approaches or even interests, which is very difficult to be combined and conclude to a widely accepted CETA.

On the other hand, Crete might constitute one of the richest regions on the planet with regard to the available RES potential. Apart from the commonly available wind and solar potential in the insular Greece, what makes Crete different is its size, which enables the development of extensive livestock, agricultural, and urban activities, which, in turn, provide large amounts of organic waste, namely excellent biomass resources. The organic waste from livestock and urban activities can be used for the production of biogas in anaerobic digestion reactors, while solid biomass (from the olive trees pruning and greenhouses) can be burnt directly. It has been calculated that the available biomass resources in Crete can provide 2.4 times the annual heat currently produced from diesel oil for indoor space heating on the island [50]. Precisely due to the availability of this significant biomass resources, Crete constitutes an ideal field for the development of district heating networks supplied by Combined Heat and Power (CHP) plants, fired by solid biomass or biogas. It has been shown that the available biomass resources in Crete are enough to fully cover the indoor space heating demand of the twelve towns and cities on the island with population higher than 12,000 [50], through CHP plants and district heating networks [50]. The annual electricity production from the CHP plants will cover 11.4 % of the annual electricity demand, including the increased demand due to the full transition to onshore e-mobility.

Additionally, 14 wind parks, with total nominal power of 1.2 GW, supported with 14 PHS plants, with hydro turbines of total power of 600 MW and total storage capacity of 26.3 GWh have been thoroughly studied and sited [50]. The computational simulation of the annual operation of the aforementioned plants (wind parks, PHS, and CHP plants) proved that they can cover 89% of the expected annual electricity demand with the full transition to onshore e-mobility and 100% of the heat demand for indoor space heating [50]. If the considerable available margin for energy saving is also accounted [81–83], it is concluded that Crete can securely be a 100% clean energy island. Of course, due the large size of the island and the corresponding required projects, the overall investment is estimated at the range of some billions of euros and this, sensibly, constitutes a major issue to be handled toward the implementation of energy transition. The overall energy transition concept in Crete is graphically depicted in Figure 9.

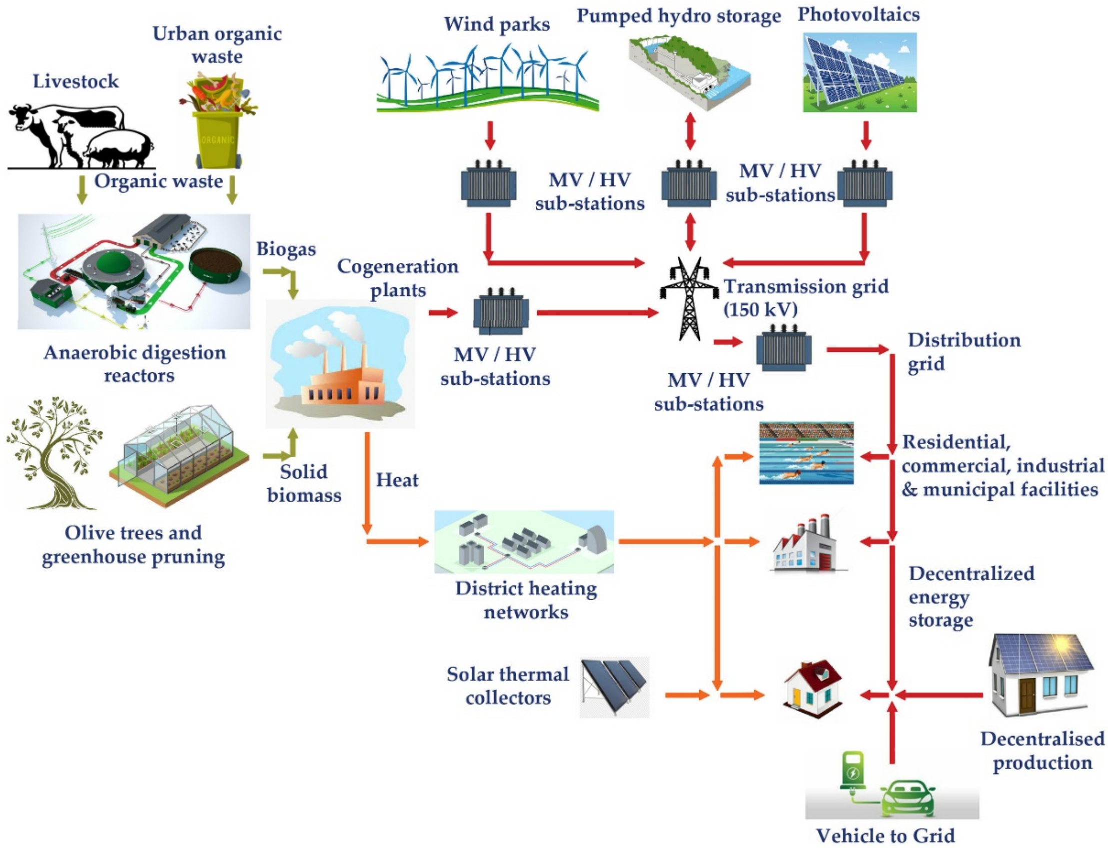

Figure 9. Overall energy transition concept in Crete.

In Crete, given its size, several energy communities have or are to be established. One of them, the Minoan Energy Community (MEC), founded in October 2019, seems to play a leading role on the overall energy transition [84]. With a constantly increasing number of, currently, 400 members (June 2022), among which three Municipalities and the Regional Authority of Crete, MEC is the biggest energy community in the insular Greece and, most probably, soon in the whole country. Its main objective is to undertake a regulatory and essential role on how energy transition is going to be implemented in Crete, claiming the maximum benefits for the local citizens, by combining energy independency and democracy, with equal rights and opportunities for all. MEC has already constructed two photovoltaic plants, of 405 kW and 1 MW nominal power, operating under the net-metering mode and compensating on an annual basis the electricity consumption of the roughly 350 involved members. Particularly in the 1 MW project, 100 families with low income, struck by the 6.3 Richter earthquake that occurred in the headquarters of the Community (the town of Arkalochori), will be offered free of charge the required power for their annual electricity compensation, on the cost of the Regional Authority of Crete. In this way, MEC makes the first practical step toward the handling of energy poverty in Crete. Both projects are exclusively funded by the equities of the involved members. It becomes clear that the cooperative principles reflected in the vision and action of MEC exhibit the potential for a deeper impact on the energy transition.

Apart from net-metering projects, MEC has also designed a series of other projects (three wind parks, a small wind turbines station, a large PHS, etc.). Moreover, it has completed two studies on the energy performance upgrade of two major sports facilities in Arkalochori, the municipal swimming pool center and the municipal indoor sports hall, funded by the H2020 NESOI project [85], proving that energy communities can successfully play the essential regulatory role, activated in all fields, for the implementation of fair, rational, and effective energy transition for all islanders. Finally, MEC, has supported other islands to establish their own energy communities and make their energy transition first steps (Kassos, Symi, Samos, Chalki, Sifnos).

Crete, due to its size, is blessed with remarkable RES potential and human resources for the design and the implementation of the energy transition. However, for the same reason, it also exhibits some very important pathogeneses and inadequacies. The first is the inability of the involved stakeholders to agree on some common strategies and actions. This is highlighted by the lack of the CETA to date. Second, as also mentioned previously, a major issue is the large amount of projects, the corresponding high set-up costs, the time-consuming licensing process, etc. However, probably the most important issue that the MEC and the rest of the Cretan stakeholders have to face is the big investing interest by a large size investor in developing RES projects uncontrollably on the island. This, on the one hand, has mainly contributed to the configuration of the existing negative reactions against RES projects in Crete. On the other hand, it creates important risks from the impacts on the natural environment, the landscape aesthetics, etc. and, eventually, threatens to deprive the Cretan community of the opportunities that have arisen from energy transition for the conservation and the development of the local society and economy. These important issues can be handled with the creation of an holistic action team on the island, with most stakeholders involved, and the configuration of a strongly supportive and protective legislation in favor of local energy communities and stakeholders.

4.3. Chalki

Chalki is a small island located at the Eastern Aegean Sea, at the Dodecanese complex, approximately 11.2 nautical miles to the west from the harbor of Kameiros in the nearby Rhodes island, with a total area of 26.988 km^2 and a population of 281 residents, according to the Greek national census of 2001 [86]. It is electrically interconnected with Rhodes, thus, until recently, all electricity needs on the island (and almost all final energy needs apart from transportations) were covered by the electricity produced in Rhodes.

In October 2020, Chalki was one of the first islands in Europe that completed and submitted its CETA in the "Clean Energy for EU Islands" Secretariat [87]. Chalki was selected by the Greek Government to be the first island of the initiative "GR-Eco" islands, a program funded by the EU and the Greek State for the implementation of energy transition projects in small Greek islands. In 2021, the first projects were implemented within this initiative. Specifically [88,89]:

- A photovoltaic plant of 1 MW nominal station, operating under net-metering mode for the annual compensation of the electricity consumption of households, commercial, tourist, and municipal facilities on the island. With the official interconnection of the project with the insular grid in April 2022, all 592 existing electricity consumptions on the island are powered by the electricity produced by the photovoltaic plant and Chalki has become the first Greek island with 100% electricity demand coverage from RES.

- The donation of six electrical vehicles for the local municipality and the installation of EVs charging stations.
- Upgrade of the public lighting with installation of low consumption lamps, floodlights and luminaires, and a centralized management system for remote control and optimized operation of the lighting infrastructure.
- The development of online, virtual services for public health, social care, and education.

The total project has a budget of EUR 1,500,000 and, since the GR-Eco program had not officially started yet in 2021, the budget was totally covered by donations and subsidies from private Greek and French companies [88,89].

For the implementation, the management and the operation of the already completed projects and the ones yet to come, the non-profit Energy Community of Chalki "ChalkiOn" was founded in 2021, with the initiative of the Municipality of Chalki. Despite the small size of the island, ChalkiOn already counts 155 members, namely more than 50% of the island's permanent population, a fact that proves the massive participation of the local citizens in the venture. After the integration of the aforementioned energy transition first projects, ChalkiOn plans for the approximate future:

- The implementation of district heating and cooling for the unique settlement on the island, based on open loop geo-exchange plants and the construction of the required district hydraulic network.
- The implementation of a centralized solar-combi system, consisting of solar collectors and thermal storage devices, for the production of hot water for domestic use, integrated with the construction of a district network for the hot water distribution to the final users.
- The installation of a commercial small wind turbines plant of 120 kW, following a relevant call from the Ministry, which will ensure a guarantee annual income for the Community to cover the projects' maintenance costs and to proceed to the development of the new ones.
- A cluster of projects focusing on the energy performance upgrade of the residential, commercial, and tourist facilities on the island.

In contrast to Crete, energy transition in Chalki seems to be a simpler and easier process, precisely due to its small size and, most importantly, the existing interconnection with the considerably larger insular grid in Rhodes (peak demand at 233 MW in 2021), which enabled the installation and the operation of the 1 MW photovoltaic plant as a net-metering project. The small, local community has been totally convinced on the necessity and the opportunities of energy transition and has been completely involved. The "ChalkiOn" Community enjoys a widely positive public opinion and a fertile ground for the next steps. The "ChalkiOn" Community proceeds in the approximate future with the implementation of the required studies for the design and the licensing of the aforementioned district heating projects and the small wind turbines station. Moreover, the small size of Chalki seems to be ideal for the implementation of pilot projects in the frame of national or EU projects (e.g., smart grids). Therefore, both the Municipality and the Community remain receptive to relevant proposals.

4.4. Ikaria

Ikaria is a medium-size island, located at the Eastern Aegean Sea, with a population of 8433 and a total area of 33.0 km^2. Ikaria has gained a position in this article thanks to the Hybrid Power Plant (HPP) constructed on the island, consisting of a wind park and a pumped storage system. The project's construction started in 2011 and was integrated in 2019 by the Power Production Corporation Renewables (PPC Renewables), the subsidiary of PPC S.A., the leading power generation and supply company in Greece.

The HPP in Ikaria consists of a 2.7 MW wind park (three wind turbines of 900 kW each), two hydro power plants in different altitudes (at 554 and 49 m), with 1.05 and 3.1 MW installed turbines' power each, and the pump station with 12 installed pumps of 250 kW nominal power each [90]. The project is based on the potable water surplus from an existing reservoir constructed for irrigation usage, located in the upmost altitude of 721 m. The water surplus is used during winter to be exploited in the upper hydro power plant, at 554 m, and to refill water losses from the two new reservoirs of the PHS plant during the previous summer, located at 554 and 49 m. During the summer period (irrigation period), the water in the upmost reservoir is used exclusively for irrigation uses, while the two new reservoirs, fully filled during winter, are used in a conventional cycle of the PHS plant. The project is estimated to produce 9.8 GWh of electricity on an annual basis, contributing 30–35% to the annual electricity demand coverage on the island. The plant's layout is depicted in Figure 10.

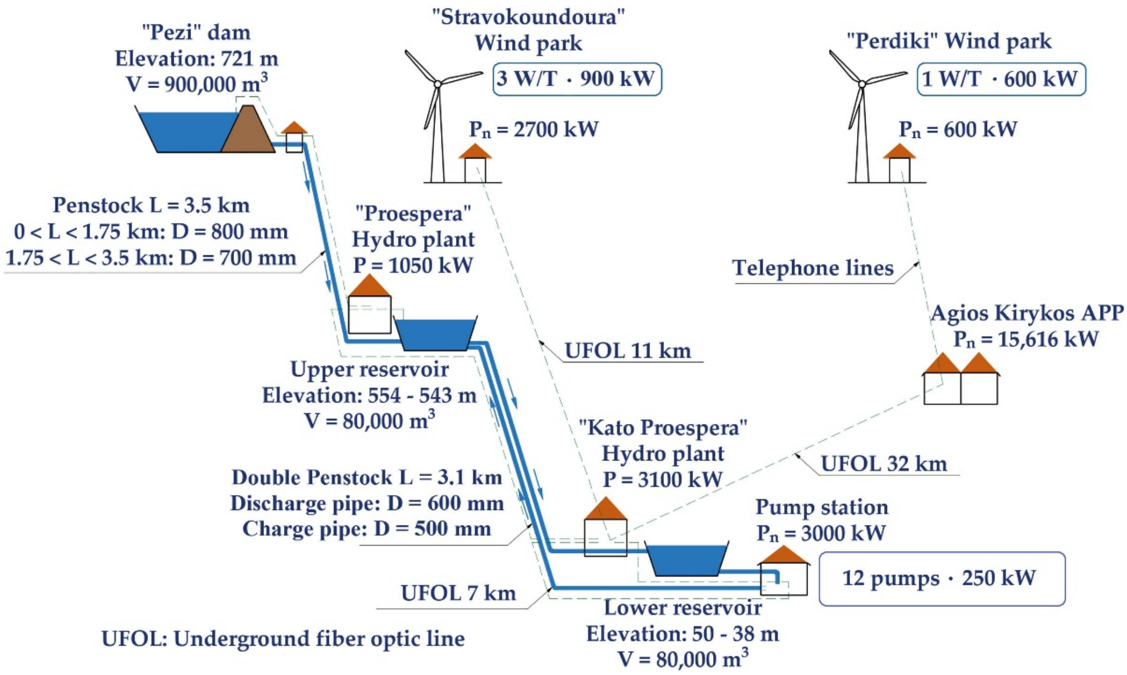

Figure 10. The layout of the hybrid power plant in Ikaria [91].

Although no other projects have been implemented in Ikaria (other smaller projects or at least any kind of motivation of the local community), the specific project itself makes the island a pioneer in energy transition. It should be mentioned that there is only one more similar project constructed worldwide in the island of El Hierro, Canary Islands, Spain [33]. Therefore, the HPP in Ikaria brings in Greece a global innovation and vanguard. Additionally, it offers important experience and technical knowledge to the local academic and engineering society, which can be invaluable for the successful energy transition in other islands, as well; given that the intensive land terrain in insular Greece provides excellent conditions for the construction of similar projects, with high storage capacities and low levelized set-up cost [92,93].

PPC Renewables, in co-operation with the Ministry of Energy, executes several experiments on the reaction of the HPP in Ikaria under different contingencies, introduced technically in the production system or in the transportation—distribution grid. The feedback from these experiments is used by the Ministry of Energy for the strategic planning of the energy transition in the other Greek islands. Finally, the implementation of the project constitutes a successful example of a private project installed on the island, without direct involvement of the local community. This proves that insular communities can be receptive to accept private RES projects, rationally designed, sited, and planned with regard to the energy needs on the island, with some essential compensatory works and the appropriate informative activities. Moreover, the project constitutes an excellent pilot case for the combined operation and exploitation of existing facilities (e.g., an irrigation reservoir) for both energy production and their existing use.

4.5. Tilos

Part of the Dodecanese group of islands, Tilos, lies in the mid sea between Kos and Rhodes. North-west to south-east, the island is ~14.5 km long, with a maximum stretch of 8 km and an overall area of approximately 64 km^2. Standing at a distance of 240 nautical miles from the Greek mainland (Piraeus, Attica), Tilos belongs to the special group of remote and small-scale European islands. According to the most recent census, Tilos has a total of ~830 registered inhabitants, with the winter period suggesting lower numbers, in the order of 500. On the other hand, the hosting capacity of the island during the summer months exceeds 30,000 visitors, with local tourism mainly oriented toward eco-touristic activities.

Over the recent years, Tilos island accelerated its clean energy transition in a remarkable pace, enabled by the strong commitment of the local Municipality, the pro-environmental culture and mindset of Tilos citizens and the implementation locally of innovative demonstration projects, such as the Horizon 2020 TILOS project [94,95]. By embracing community-scale wind and solar, battery energy storage, and advanced energy management and metering through Demand Side Management (DSM) strategies, Tilos achieves high shares of renewables in the local electricity sector. In more detail, the local Hybrid Power Plant comprises an 800 kW wind turbine, 160 kW of photovoltaic power, and a Zebra ($NaNiCl_2$) battery storage system of 800 kW/2.88 MWh, being the first of its kind in Greece and essentially introducing a new energy model for local-scale energy production of low environmental footprint. The overall layout of Tilos' microgrid is presented in Figure 11.

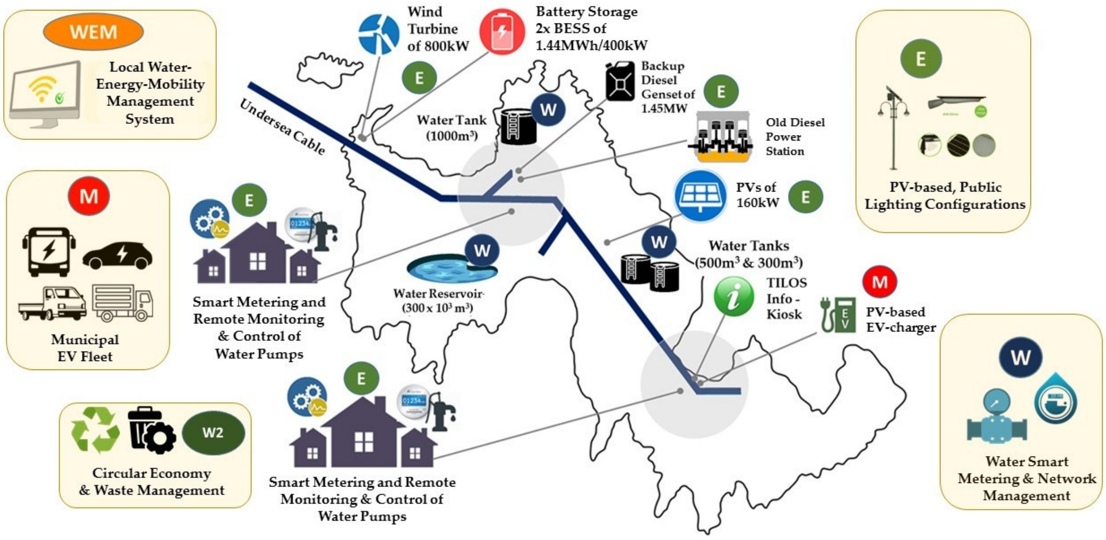

Figure 11. Tilos' microgrid layout.

At the same time, the island extends its efforts to the directions of e-mobility and renewable-driven EVs charging infrastructure, intelligent energy, and water management, and also energy efficiency for the local public lighting sector. A municipal EV-fleet including different types of EVs and a 52-seat electric bus, solar-powered EV charging infrastructure, introduction of solar-powered street lighting systems, a smart metering platform engaging different types of distributed loads, roll-out of smart water meters, and development of an intelligent water management system for the village of Livadia (main island settlement), all comprise components of a holistic approach and plan across different vectors, building on and also advancing the existing infrastructure of the island.

The latest achievement of the island concerns the ambitious Tilos-Just Go Zero project [96], aiming to zero local waste on the island. To that end, waste produced in Tilos is collected and managed in a fully circular way, which has essentially led to the decommissioning of the local landfill and to the emergence of a new management model that aspires to designate the hidden value of waste.

Throughout this process of transition, one may witness the empowerment of Tilos Municipality, leading the energy and also social transformation of the island with the support of the local population. By embracing innovation, Tilos Municipality initiated and sustained high awareness and positive social change locally, while attempting for a greater outreach and impact. Indicatively, and according to a national-scale survey organized from WWF Greece in 2018 [97], 75% of islanders across 15 Aegean islands welcomed Tilos energy solution as the alternative to the established oil-based power generation model. Leveraging on this type of broader impact has contributed to positive social change locally and has paved the way for further engagement of the local population in the form of a community-based scheme. In fact, this is currently identified as a main challenge and priority from the local Municipality, which, inspired also by the development of energy communities in other exemplary island cases, is already proceeding accordingly.

In that context, Tilos continues to work intensively toward the deeper integration of local renewables and a carbon-free island energy system, in an inclusive fashion and with the ambition to inspire other islands and local communities through the implementation of new innovation projects in the fields of clean energy, circular economy, and protection of the environment and biodiversity.

4.6. Agios Efstartios

Agios Efstartios is a 43.3 square kilometers island, in the North Aegean Sea, with 270 permanent inhabitants [98]. Its energy system is a typical insular not-interconnected system, with annual peak demand at 350 kW and annual electricity consumption at 1200 MWh, served by an APP, powered by five diesel generators, with 840 kW nominal power in total. The annual heat demand for indoor space heating and hot water production is estimated at 1000 MWh, served mainly by oil boilers and to a lesser extent by electrical heating devices.

"Agios Efstartios—Green Island" project is an innovative research-pilot project, funded by the European Regional Development Fund (ERDF) and the National Strategic Reference Framework (NSRF) 2014–2020 and implemented by the Centre of Renewable Energy Sources of Greece (CRES), in cooperation with the local Municipality. The project's goal is to reach 85% annual RES penetration over the annual electricity consumption coverage. For the first time, this high RES penetration target is set in an insular system, thus a considerable challenge has to be faced at a technical, economical, and institutional level. Simulations had shown that a mix of wind and solar energy combined with electrical storage could make the achievement of the target possible, leading, however, to annual RES rejection at the order of 65%.

This issue was addressed by introducing a "green" District Heating (DH) system, to produce hot water centrally in electric boilers, by exploiting the excess electricity. The produced hot water will be stored in thermal storage tanks and will, eventually, be distributed through the DH network to the final users. The goal is to reach 80% coverage of the annual heat demand in the island from the introduced HPP and leave only 20% to be supplied by fuel boilers. Through the combined operation of the introduced HPP and DH system, the ratios are reversed: 75% of the "green" electricity is used for the electricity and heat demand of the island and only 25% is rejected. The overall concept is graphically depicted in Figure 12.

The high RES potential in the island is revealed by the indicative data regarding solar and wind potential, presented below, as they result from the processing of the in situ measurements at the site of the project:

- Solar radiation intensity: 1000 W/m^2.
- Average annual wind speed at 41 m in height above ground level: 9.4 m/s.
- Weibull distribution factors: k = 1.86 and C = 10.5 m/s.
- Typical turbulent intensity: 9.9% (at wind speed 10.0 m/s).

The technical elements of the project are summarized below:

Hybrid power plant:

- RES plant: Wind turbine 900 kW, photovoltaic plant 225 kW.
- Batteries electricity storage system (BESS): 1.25 MW/2.5 MWh, site controller.
- Medium voltage line: 15 kV, 3.0 km in length.
- Interconnection works: Medium voltage grid, switchboards, and transformers.

District heating system:

- District heating building: 400 m^2 of covered area.
- Electric boilers: 1000 kW.
- Back up unit: 800 kW oil boiler.
- Thermal storage tanks: 4 × 125 = 500 m^3 individual hot water tanks, maximum temperature 120 °C.
- Hot water transmission and distribution network with a total length of 4 km.
- Consumers' supply units and substations (80 units).

The wind turbine and the photovoltaics will be installed in a 35-acre area off the settlement and connected to the HPP's medium voltage substation through an underground transmission line of approximately 3 kilometers in length. The medium voltage substation, the BESS, the thermal energy production equipment, the hot water storage tanks, and the control and monitoring unit will also be installed off the settlement, in a 4-acre area.

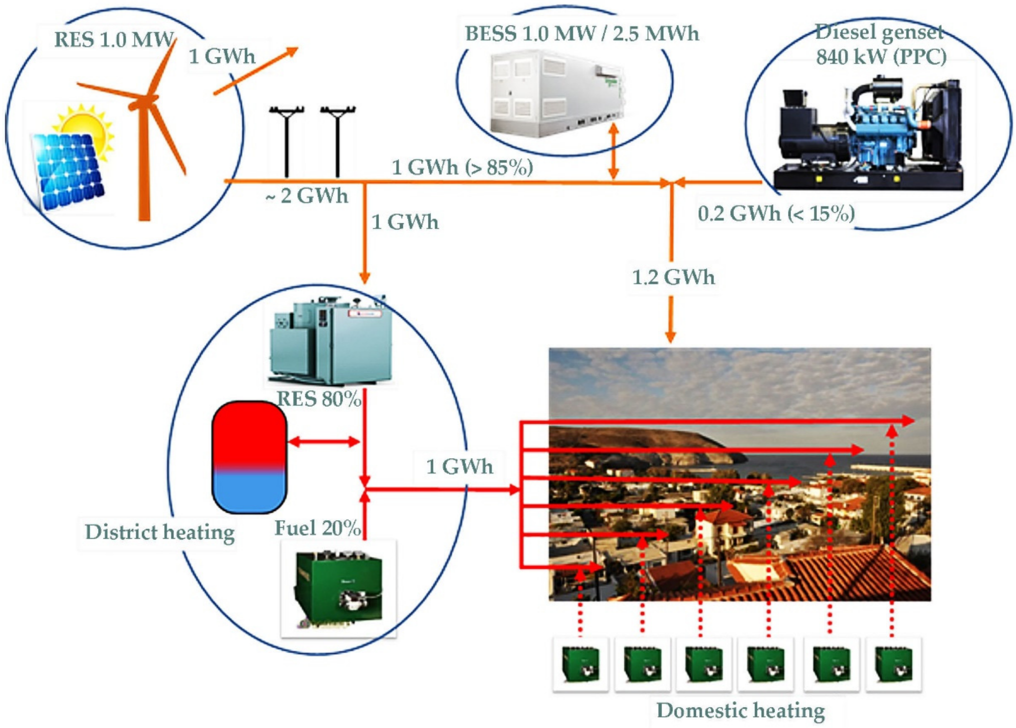

Figure 12. The layout of the overall energy transition project in Agios Efstratios.

On the demand side, the project includes the energy performance upgrade of five municipal buildings and the school complex, as well as the transition to e-mobility with the installation of RES charging stations, demonstrating the basic rule of energy transition: Rational use of energy should come first, before energy production from RES.

The project has an important research/innovative character; given that, for the first time, variable renewable energy generation participates with this high percentage in meeting the energy needs of an autonomous system. Today, the entire electricity demand of Agios Efstratios is covered by the five conventional generators of the island's APP, while, by law, the insular grid's operator is responsible for their operation management and dispatching.

After the installation of the HPP, by December 2023, the electrical system of the island will change drastically, since two RES plants, together with a BESS and the controlled load of district heating will be added. These additions will substantially change the energy/technological mix of the island's electrical system. The electrical components of the HPP, i.e., the RES units and the BESS, are expected to limit the operation of the conventional generators only to periods when energy generated by the HPP is not enough to satisfy the electricity demand of the island or the components of the HPP are unavailable due to scheduled maintenance or unexpected failure reasons.

The innovation character of the project is connected to the inception, development, and implementation of a new model for the management and control of the above-described electrical system in a way that allows the maximum renewable energy generation and storage with minimum conventional production costs and maintenance for the safe operation of the system. The new innovative energy management and control system has as its major element the monitoring operation of the HPP in real-time, thus enabling:

- Control in real-time of the operation of the HPP to meet the electricity demand of the island.
- BESS to monitor fluctuations in wind and PV production and electricity demand.
- Effective control of the district heating systems' load for maximum utilization of the RES production surplus.
- Issuing necessary orders for limiting the power output of RES units.

The energy management and control system under implementation will perform with its completion the following operations in successive stages, each one of which is under the responsibility of a respective operator:

- The dispatching of the conventional thermal generators is the sole responsibility of the insular operator (HEDNO). HEDNO plans the integration (or withdrawal) of the thermal generators to meet the electricity demand every 10–30 min, taking into consideration their availability, the BESS charge level, and forecasts about electricity demand and production from the HPP.
- The internal management of the HPP is performed in real-time and it is under the sole responsibility of the HPP operator. In the context of this management stage, the HPP operator coordinates the components of the HPP (RES plants and BESS) in order that their production covers at any time the part of the electrical demand that the APP units do not cover. This is performed by monitoring the fluctuations in electricity demand and RES production and after having scheduled the absorption level of the controlled load of the district heating to utilize any excess RES production. Due to the size of the RES units and taking into account the need for effective control of the district heating load, this stage contains the real-time issuing of orders limiting the RES output power. The issuing of these orders is repeated periodically at regular and short intervals (every 1 min).
- The internal management of the APP is under the responsibility of the APP operator (PPC). The APP receives from the insular operator (HEDNO) a total integration order as a result of the execution of the thermal generators dispatching. The automated APP management system then integrates the necessary generators to achieve the specified level of production, taking into account the technical characteristics of the APP generators, their availability, etc.

The new energy management system contains more control stages and new operators in relation to those foreseen by the existing regulatory framework. Therefore, it was necessary for the State to formulate a special regulatory framework to cover this completely new reality. As a first step the Ministry of Environment and Energy through the law 4495/2017 (art. 152) [99] characterized the project as a "research" one and excluded it from the existing licensing and operation procedures. Additional interventions through Ministerial or RAE's Decision were introduced regarding the establishment of a special regime for the operation of the island's electrical system, the responsibilities of the parties involved, namely the HPP's owner, the Power Production Corporation (PPC) and the Hellenic Electricity Distribution Network Operator SA (HEDNO), the licensing procedures of the project, the pricing principles, and the form of the operating aid.

The anticipated project's positive impacts, namely the reduction of the oil consumption, the CO_2 emissions, and the electricity production cost will result in a direct drop in electricity and heat procurement prices for the final users.

"Green" Agios Efstartios will be a "living lab", a place of energy innovation and scientific tourism. The evaluation of technologies in real conditions for high RES penetration in an autonomous network along with a controlled load will provide valuable conclusions regarding similar autonomous electrical systems (greenhouses, desalination, hydrogen production, etc.), microgrids and interconnected islands, as well.

In the long term, these new activities will increase the island's wealth and quality of life and improve the economic status of the inhabitants.

Finally, the institutional work performed to allow the coexistence of RES and the conventional plant will increase the expertise and the technical knowledge of the involved stakeholders (Ministry, CRES, RAE, HEDNO) regarding the adoption of simpler effective management models of similar systems.

4.7. Kythnos

Kythnos island belongs to Western Cyclades in the Aegean Sea. It has a surface of 100.2 km^2 and 1632 inhabitants. Kythnos has a long history in sustainable energy applications. It hosted the first wind farm in Europe, which was constructed in 1982 and consisted of five wind turbines of 20 kW. A hybrid power plant was installed in 1982, which included a 100 kW Photovoltaic (PV) plant and a 400 kWh battery storage system. A 500 kW wind turbine was installed in 1998, while, in 2000, a fully automated power system with 500 kW battery storage and 500 kW wind turbine was achieved.

The total yearly energy production and total yearly energy consumption of the Kythnos power system are 10,059 and 9167 MWh, respectively (year 2020). The peak load is 3.118 MW and the power system serves 3353 electricity customers (end consumers/producers–low voltage). The installed thermal generation (based on diesel) has a capacity of 5.2 MW, while there are three photovoltaic plants of 238 kW total capacity and 665 kW wind power installations. Moreover, Kythnos hosts a desalination plant of 75 kW, seven electric vehicles, and nine electric vehicle chargers (three phase, AC, dual socket). The heating system of a municipal building/school was recently restored with the installation of a heat pump (30 kW, operating during school days).

The first microgrid application in Europe was installed in 2001 in Gaidouromantra, a settlement built in a small valley next to the coast in the southern part of Kythnos [100]. The off-grid system electrifies 14 vacation houses with 100% renewable energy based on PVs (six PV arrays of 11 kW) and battery storage (Lead-Acid (FLA) 1000 Ah/48 V). The system was built in the framework of two projects, PV-MODE (JOR3-CT98-0244) and MORE (JOR3CT98-0215), supported by the European Commission. Project partners were the Centre for Renewable Energy Sources and Saving (CRES), SMA Solar Technology AG, and the Institut für Solare Energieversorgungstechnik (ISET eV) in Germany. The Kythnos Microgrid was upgraded in 2006 by the National Technical University of Athens (NTUA) in the framework of the MORE MICROGRIDS (SES6-PL019864) EU funded project. Intelligent load controllers were applied for load management using distributed control techniques forming a multi-agent system [101]. The intelligent load controllers (hosting agents) were installed outside the houses after the electric meter. This installation aims to minimize the operation of the diesel generator by controlling non-critical loads, such as water pumps and air conditioners. The intelligent load controllers communicate with each other and negotiate to determine which load will be disconnected, without the need for central coordination. In this way, the diesel generator switches on when there is a lack of power (low state of charge of the batteries, demand higher than the PV production) and the flexible loads have already been disconnected. Figure 13 presents the topology of the Gaidouromantra microgrid.

Currently, an upgrade of the existing infrastructure of Gaidouromantra microgrid is in progress in the framework of the national "Kythnos Smart Island" project. The upgrade is focusing on the increase in the power and energy capacity, the installation of a Microgrid Central Controller (MGCC) and protection/measurement devices. A new industrial backbone of hardware and communication protocols, such as the IEC 61850 and DNP3 is planned, among other activities.

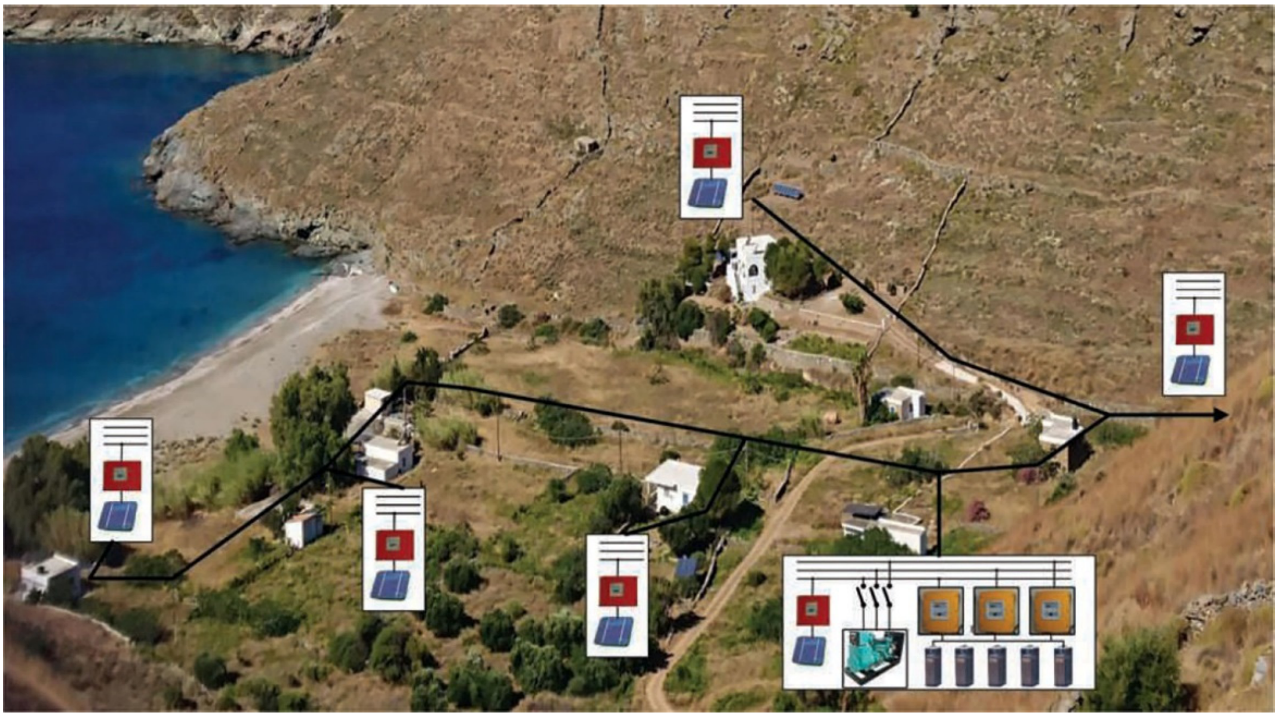

Figure 13. Overview of Gaidouromantra Microgrid in Kythnos island.

This work is further expanded in the framework of the new EU (H2020)-India funded project RE-EMPOWERED [102]. A complete set of tools for microgrid management is being developed that will be installed in Gaidouromantra microgrid and the Kythnos power system, among other demo-sites. Specifically, optimization of the Gaidouromantra microgrid operation will be achieved via an advanced energy management system (ecoMicrogrid) and smart meter/load controller (ecoDR) aiming to minimize the operation of the diesel generator. On a higher-level, citizen engagement will be promoted via a digital platform (ecoCommunity) that will communicate with the energy management system (ecoMicrogrid) through a cloud-based platform (ecoPlatform). Finally, a locally manufactured small wind turbine will complement the installations. Concerning the Kythnos power system, an energy management system for non-interconnected islands will be applied (ecoEMS), accompanied by a 7-year ahead energy planning tool (ecoPlanning) for assessing the deployment plan of new conventional production units and RES hosting capacity.

Kythnos island has a tradition in innovative renewable energy applications, starting from the 1980s. Nevertheless, it is still quite dependent on diesel generators and fuel oil, leading to the high variable cost of energy. As in other Greek non-interconnected islands, regulatory barriers are present, such as the need for a spatial planning framework for renewable energy sources and the margins imposed for their penetration in non-interconnected systems. Social acceptance of RES projects should be further promoted by providing incentives to the local community to participate in the energy transition through the creation of energy communities. An advanced energy management system can foster the higher penetration of renewable energy, as planned in ongoing research projects. Fortunately, electromobility has been embraced, but in a limited way until now.

On a smaller scale, the Gaidouromantra microgrid serves as a pilot living lab for the deployment of innovative technical solutions leveraging on several research projects in the last 20 years.

5. Comparative Analysis

The essential features of the seven cases are presented in Table 3.

Table 3. Comparative analysis of the seven presented insular case studies.

Island	Initiative	Main Projects To Date	Status	Funding	Next Projects
Sifnos	Local community	Wind park Pumped storage	Under licensing	Private funds Bank loans	District heating-cooling e-mobility Photovoltaics
Crete	Local community	Photovoltaics	Implemented	Equities	Wind parks Small wind turbines plant district heating pumped storage capacity building
Chalki	State Local community	Photovoltaics e-mobility	Implemented	Donations	District heating and cooling Small wind turbines plant Energy performance upgrade
Ikaria	Private sector	Wind park Pumped storage	Implemented	Private funds Bank loans State subsidy	-
Tilos	Academia Private sector Local community	Wind park photovoltaics battery storage e-mobility smart metering, circular economy, water-energy nexus	Implemented and ongoing	EU and national funding Private funds	Maturing of a community-based PV plant
Agios Efstratios	State	Wind park photovoltaics district heating	Under licensing	EU and national funding	-
Kythnos	Utility Academia Local community	Wind park photovoltaics battery storage microgrid	Implemented	EU funding, national funding, private funds	Energy management system, demand side management, small wind turbine

First, what is, perhaps, of major importance is that the initiatives in Sifnos and Crete have emerged and are driven by the local community, which is also reflected and expressed by the newly formed energy communities in these islands, without any stimulus or specific support of any exogenous actor (State, private sector, academia, etc.). SEC managed to design and license a highly innovative project, while, MEC has already constructed two photovoltaic plants, totally funded by their members, taking the first real step in helping to address energy poverty. SEC and MEC proceed with the design and the development of more projects of all feasible and necessary technologies, in the frame of an holistic energy transition plan. The examples of these two energy communities offer fertile ground and reasons for optimism for other Greek islands, as well.

The State contribution for the small island of Chalki was doubtlessly of major importance for the successful implementation of the first part of the energy transition projects in the island, in the frame of the "GR-eco islands" program. The activation of the local community through the foundation of the "ChalkiOn" energy community was also crucial. The small size of the island offers an excellent field for the application and implementation of a holistic energy transition plan and a crash test both on technical and economic levels for all the involved stakeholders (local community, State, academia, and private sector).

Then, when it comes to the project in Tilos, this is the result of the involvement of academia and the private sector in the energy transition project, with the support of the local Municipality and community. In Kythnos, the Public Power Corporation (Greek utility) developed the early installations, while, the subsequent activities were carried out in the framework of research projects. The local community was activated in both cases by the involved academics. Both projects were funded by EU, national, and private funds. The local community in Tilos has been successfully activated by the TILOS project and action remains through the implementation of new projects on the combined management of energy and water resources—demand, as well as on the investigation of a community-based PV plant. The involved stakeholders in Kythnos aim to engage the local community along with the deployment of innovative solutions in the framework of ongoing research projects.

Agios Efstratios is the first case in Greece where the energy transition is managed from the beginning, through the concurrent coverage of the power and the heat demand. Precisely due to this fact, Agios Efstratios exhibits considerable innovation features regarding the management and the automation of the project's components. Similarly with Chalki, due to its small size, it can be a pioneering pilot case for the implementation of a holistic energy transition plan.

Finally, the wind—PHS plant in Ikaria constitutes a great achievement for several reasons: Total acceptance of the local community, successful combined operation of a former single agricultural infrastructure both for water storage and power production, implementation of the first insular PHS plant in Greece, implementation of only the second wind—PHS plant in an island globally. Given the intensive land morphology in Greek islands, PHS plants can be the major energy storage technology, offering large storage capacities, low levelized installation cost, and long autonomy operation periods. For these reasons, the experience gathered by the wind-PHS plant in Ikaria can offer valuable lessons regarding its replication to other insular territories.

6. Lessons to Learn, Examples to Avoid, and Next Steps Forward

The distance covered since 2010 in the context of the energy transition of Greek islands offers some very important lessons to learn and examples to avoid to the scientific and technical community. The experience gained and the configured status also reveal clearly the forthcoming steps.

First, the configured situation can be outlined in the following essential facts:

- The insular territories are almost fully covered with applications from few large size investors, which leave rather no geographical or electricity space available for new RES projects siting.
- There is a strong and absolutely justified negative public opinion in all islands against the implementation of these large size projects connected mostly to the fact that there was no prior consultation or any other participatory/co-design process with the local communities, in order that their interests and concerns can be taken into account.
- In some islands the local communities have been organized in energy communities, ready and capable to undertake a governing and essential role on energy transition in their territories.
- There is also the will from the Greek State, to support with technical assistance and new funding mechanisms, the implementation of energy transition projects, at least in small islands, as revealed by the announcements for the "GR-eco Islands" program.

Given the above facts, the main example to avoid is certainly the inadequate legal framework that gave the opportunity to various opportunists to spread applications for new RES projects in the entire country of Greece. Particularly, two misplaced legal amendments led to the currently formulated inappropriate situation:

- The removal with a legislation revision in 2011 of the applicant's obligation to ensure the legal right to use the land property for the installation of the RES project at the very first stage of the submission of the application in the RAE for the issuance of the first required power production permit. Practically, with this amendment, any candidate investor could submit applications for new projects anywhere without having in advance informed the land owner, the local community nor the public authority in charge.
- The unclear requirements regarding the installation position of the wind potential measurements station with regard to the wind park's installation site. This enabled potential applicants to use any available wind potential measurements to justify the wind potential in the installation site, even if it was captured far away from this.

A potential remedy could be the recall of all these large size licenses or the rejection of any applications still under the evaluation process. This can be the first step from the Greek State to regain the confidence of the local communities and to create geographical space for a rational and fair spatial planning of the required energy transition projects in each island.

The second step should focus on the nurturing of the local communities and the reversal of the existing negative public opinion. This task can only be achieved with properly planned and performed capacity building campaigns. The first steps toward this goal have been already executed with the activities of the "Clean Energy for EU Islands" Secretariat, providing the results in Chalki, Kassos, Symi, and Crete. Capacity building campaigns can be organized with the support of academic institutes, the Secretariat, and the local energy communities. Islanders should be well aware of the necessity of the energy transition, the required projects with their potential negative impacts, as well as the means to avoid them and, most importantly, the anticipated benefits for the local community that can be claimed only with their active involvement in the projects' development, implementation, as well as management and operation.

The examples from Sifnos, Crete, and Chalki show that local islanders can be better informed than anyone else and obtain a clear plan in regard to the optimum projects for their territory. Moreover, they show that all needs for technical assistance can be covered by their own members or external partners and consultants. The Secretariat's support on this field with the technical assistance calls can also be very helpful. Finally, they proved that the funding of the projects cannot be an obstacle, on the condition of adequately designed projects, clear pricing policy, defined in a robust legal framework, and the acceptance of the public opinion. Furthermore, the cases illustrate how the operation of an Energy Community on an island can facilitate a wider distribution of the benefits of the energy transition in the local population.

The examples from Tilos and Ikaria show that local communities could be willing to accept RES projects that are introduced by actors not directly related to the insular society, which could also lead to the development of hybrid schemes and business models, with the participation also of the local communities. In the first case, the project was proposed by an academic institute and funded by the European Commission and the private sector. All the preliminary contacts with the Municipality and the local communities had been properly implemented beforehand. In the second case, the project was implemented practically by the State, again with a prior, proper info-campaign of the local community, and was accompanied with significant new parallel common-benefit projects for the local community. In both cases, the local communities were well aware about the projects and the public acceptance had been ensured before the beginning of the construction process. Ultimately, of course, both projects were sited in common with the local stakeholders and their size was adapted to the island's power demand scale.

The example of Chalki should be expanded to more small Greek islands, indicatively with a population lower than 3000. The pioneering islands presented in this article, apart from Crete due to its size, can constitute a guaranteed success recipe for the application of the "GR-eco Islands" program, given the existing activation of local communities in them and the creation of support mechanisms. The definition of clear and sensible eligibility criteria constitutes a prerequisite for the successful integration of the program.

However, above all, the advancement of a socially fair, environmentally sustainable, rational and effective energy transition in Greek islands requires a fair and supportive legislation framework, which will promote and strengthen the initiatives undertaken by the islanders in the form of energy communities, and/or potentially directly involving the insular Municipalities. To date, the existing legal framework does not provide any essential motives or facilitating processes for these local initiatives. These could be:

- Licensing priorities.
- Exemption of any rates, deadlines, and penalties during the licensing process.
- Introduction of new funding mechanisms, not only for the small islands.

In fact, according to EU legislation (recast Directive 2018/2001/ RED II), Member States ought to establish enabling frameworks for Energy Communities. Specifically, the Member States must lift all unjustified administrative and regulatory barriers, and provide tools in order that Energy Communities have access to finance and information. Furthermore, they ought to ensure that Energy Communities are able to access all electricity markets in a non-discriminatory manner [7].

Our analysis of the aforementioned cases shows that the insular communities in Greece have proved that they are capable of fully undertaking the design and the implementation of the required energy transition projects. The whole process can and should be undertaken by energy communities, as the examples from Sifnos, Crete, and Chalki show. Energy communities, representing the entire insular community, can ensure rational energy transition projects, properly sited and dimensioned, which can adequately address the energy needs of the islands and eliminate any potential impacts on the natural environment and the existing human activities. This is exactly the essential role of energy communities, which establishes their relationship with energy transition: To ensure a fair, effective, and rational energy transition in the islands, maximizing the social and economic benefits for the local communities, ensuring broad public acceptance of the required projects, facilitating fast and unobstructed implementation, and eliminating any potential impacts.

The aforementioned objectives should be approached with the following specific actions, undertaken, ideally, by energy communities:

- The development of the CETA, in which the energy needs in the island, the objectives of energy transition, and the optimum routes to approach them should be identified.
- The design of a spatial planning, which will set the regions that should be devoted for the installation of the required energy transition projects.
- The encouragement of the islanders and the local stakeholders to join forces forming an energy community to be actively involved in the projects' design and implementation.
- The coordinated and collaborative design, construction, and operation of the energy transition projects.
- The exploitation of the benefits brought by the energy transition to support and promote further economic and social development on the island.

7. Conclusions

The energy transition in Greek islands has started with rather an ineffective approach, based on an inadequate and unclear legislation framework, which enabled opportunists, stimulated by the high available wind and solar potential in the insular Greece, to cover almost all Greek islands with large scale applications, provoking the common sense and creating a very strong negative public opinion against RES projects.

During the last 5 years, with the support of the Clean Energy for EU Islands Secretariat and the examples of some pioneering initiatives, for instance, in Sifnos and Crete, islanders in Greece, apart from expressing their opposition to the large-scale projects, have started to formulate their fully justified and technically integrated proposals on how the energy transition should unfold in their territories. At the same time, they began to be organized in energy communities, through which they officially can claim a rational and tuned to the needs of the islands cluster of energy transition projects. The first implemented projects in Tilos and Ikaria have acted to date as the frontrunners for the other islands. The first projects implemented by the energy communities themselves in Crete and in Chalki proved that energy communities can move forward toward the implementation of projects, rather than remaining only in proposals and plans.

To date, the constructed or designed projects involve all different technologies: Wind parks and photovoltaics, pumped storage systems, smart grids with decentralized production, and storage, etc., proving the ability of the local communities, with the support of the consulting stakeholders, to select each time the optimum projects for each island, matching its needs and the existing conditions.

The results from the presented success stories should be popularized and disseminated, not only in other Greek islands, but also in the whole European continent and beyond. The goal is to spread the gained knowledge and awareness on crucial issues, these technical and technological topics, funding mechanisms, legal framework, and administrative processes, and make islanders believe that they can replicate these success stories for their territories. This can be performed with the interaction of insular communities between them, through the establishment of a strong and vivid networking, with the support of the Clean Energy for EU Islands Secretariat. This internal influence mechanism has been already activated in the Greek insular territory, through the already existing bonds between the insular stakeholders. More islands, such as Samos, Chios, Symi, and Kassos, inspired and stimulated by the presented pioneering cases, have started the process to create their own energy communities and take action on the implementation of energy transition in their territories. Hopefully, more similar cases should be expected in the approximate future.

Energy resources worldwide, as resources provided by nature, cannot be exploited only by a small number of investors. The most sensible and fair approach is their exploitation from the local communities themselves. This is what islands in Greece have started to claim. In this way, the conservation of the natural environment and the Aegean traditional island attitude can be ensured. The Greek State should support these efforts of the insular communities with specific revisions of the national legislation, in line with the guidance of the European Commission. In addition, these efforts can ensure an inclusive, smooth, and quick energy transition, without negative reactions and, eventually, they can lead to a sustainable development of the local economies, contributing, cumulatively, to the strengthening of the national economy.

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Abbreviations

APP	Autonomous Power Plant
BESS	Batteries Electricity Storage System
CETA	Clean Energy Transition Agenda
CHP	Combined Heat and Power plant

CRES	Centre of Renewable Energy Sources of Greece
DH	District Heating
DSM	Demand Side Management
ERDF	European Regional Development Fund
EU	European Union
EVs	Electric Vehicles
HEDNO	Hellenic Electricity Distribution Network Operator SA
HPP	Hybrid Power Plant
NTUA	National Technical University of Athens
IPTO	Independent Power Transmission Operator
MEC	Minoan Energy Community
NSRF	National Strategic Reference Framework
OREF	Orkney Renewable Energy Forum
PHS	Pumped Hydro Storage
PPC	Power Production Corporation
PPC Renewables	Power Production Corporation Renewables
RAE	Regulatory Authority of Energy
RES	Renewable Energy Sources
RUE	Rational Use of Energy
SEC	Sifnos Energy Community

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